RESEARCH TRIANGLE INSTITUTE

CONTROL OF AEROSOL (BIOLOGICAL AND NONBIOLOGICAL) AND CHEMICAL EXPOSURES AND SAFETY HAZARDS IN MEDICAL WASTE TREATMENT FACILITIES

YEAR 1 FINAL REPORT

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EXECUTIVE SUMMARY

Workers at MWTFs face many safety hazards, including cuts and puncture wounds from handling sharp medical instruments, noise, microwave radiation, heat stress, and ergonomic hazards. Thus, the study aimed to accumulate a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), and prevention and control. The overall objectives for the project were to identify currently available disinfection systems for infectious waste and to evaluate the worker environment with regards to safety, aerosol, chemical, blood and microorganism hazards and the use of engineering controls in controlling exposure. The secondary objectives of the project included identification of three MWTF (each of a different technology) based on criteria developed through a literature review; performing Phase 1 field evaluations with emphasis on sampling emissions, safety, and engineering control assessments; follow up with Phase 2 evaluation focussed on personal sampling; and writing reports based on the evaluations.

The medical waste treatment processes consist of untreated waste handling, treatment, and treated waste handling. The aspects of each of these three steps that influence the worker environment were examined. Untreated waste handling is not specific to any one treatment process; whereas the treatment and some of the treated waste handling aspects are process specific.

Site Descriptions

Three technologies at three different sites were included in the Phase 1 assessments: off-site steam autoclave, off-site microwave, and on-site pyrolysis. The first two facilities used technologies in place at many other facilities; whereas, the on-site hospital facility used a prototype method with treatment units that are regularly modified to improve their function and to test ideas for future models. All three facilities required some manual handling of prepackaged, regulated medical waste, and the three facilities had proactive, interested, and concerned management.

At the steam autoclave facility untreated medical waste is delivered by means of tractor trailers and trucks carrying either sealed cardboard boxes of varying sizes or plastic tubs of varying sizes. The containers are moved to a processing area either manually or with assistance of carts or forklifts. The processing involves filling large metal waste bins either manually or with assistance of a hydraulic dumper. The bins are weighed then mechanically moved by conveyor into an autoclave which treats the waste under steam heat (at approximately 160°C and 80-85 psig) designed to completely disinfect all materials. Following treatment, the bins are mechanically moved to a hydraulic dumper which deposits the treated waste into a hydraulic compactor and dumpster. When the dumpster is filled, the treated waste is hauled to an approved sanitary landfill. This facility treats up to 96 tons per day when running three shifts.

At the microwave facility, the "red-bag" untreated medical waste is received in 48 gallon rigid plastic, infectious waste containers. Sharps containers are normally segregated and handled separately from the other containers. The microwave facility's drivers manually load the containers into facility owned/operated trucks and bring them to the facility. The nominally 40 pound containers are manually pulled to a lift gate on the truck, off loaded, and manually stacked up to 3 high using no mechanical aids. After manifesting and weighing, the containers are manually opened and dumped into a large bin attached to one of the microwave units. The process cycle is machine controlled with limited worker action. The large cover on the hopper is automatically opened, the lift elevates the bin approximately 12 feet and, then, tips the bin. Once the waste has dropped, the lid closes over the hopper, and the bin is lowered to ground level. The waste is automatically shredded to material less than approximately 0.5 inch wide. During treatment, the waste is augured up a closed, inclined tube. The tube has six (6) microwave units mounted on top and several ports allow steam injection. The treated waste product is gravity-dropped into a dumpster located outside the building. This facility treats up to 6.6 tons per day when running 3 full shifts.

For the pyrolysis facility, most of the medical waste is delivered by hospital employees, while some is trucked in from local small-scale generators. The waste is contained in red bags in fiber boxes, of a uniform size and shape compatible with the unit, which were packaged and sealed prior to delivery. A conveyor that parallels the length of each unit is loaded with the boxes. At the pyrolysis chamber, each box is automatically weighed and the information sent to the controlling personal computer (PC). When the pyrolysis chamber is empty, the box is automatically lifted vertically, then moved horizontally over to the top of the unit where it falls into the pyrolysis chamber. Other than manually placing the boxes on the conveyor, no manual material handling is involved beyond nominal clean out of ash. This facility treats approximately 40 lb/hr for each unit and runs 2 shifts per day usually for 4 days per week.

While the three facilities all treated medical waste, there were significant differences in the process engineering. The two off-site, commercial facilities required extensive manual handling of the waste, resulting in frequent blood splashes, while the third facility had the waste prepackaged for ease of handling and smaller likelihood of leaks. The three facilities covered a large range of throughput. For these particular facilities, the higher the amount of waste treated the higher the risk of contact with untreated waste. This may not be true for medical waste treatment facilities overall as the packaging and handling methods are facility specific, not necessarily quantity specific.

In addition, the quantity of waste processed by each facility was facility specific as opposed to technology specific. Each technology could be set up to handle small or large quantities of waste depending on facility and equipment design. For all three technologies, the number and size of the treatment machines determines the amount of waste that can be treated. This amount is not pre-determined by the type of treatment. Smaller steam autoclaves are available, but the project team sampled at a large scale facility. The microwave facility would have been able to process less waste if it only had one machine. Conversely several more machines in the same facility would have allowed much more waste to be treated and, thus, increased the amount of waste handling and possibly the amount of risk of contamination or muscle injury to the worker - depending on whether the same handling tactics were still used. Again for the pyrolysis facility, a similar facility with more machines could handle a larger amount of waste. Also, as the pyrolysis manufacturers/developers pointed out, the currently used units are prototypes. The same treatment process could be used in machines built on a much larger scale and/or using different boxes. Thus the technology used was not the limiting factor on the amount of waste treated.

In addition, the technology is not the only factor leading to exposure risk. Another MWTF with different waste handling methods (as opposed to treatment method) could have different assessment results. For example a pyrolysis facility that allowed wet or unsealed boxes would be likely to have more blood exposure risk than the facility described in this report.

Safety

All of the facilities and their technologies had significant positives and negatives in their health and safety assessment. Based on this limited sample of medical waste treatment facilities, management was found to be very proactive and to provide extensive worker training and protective equipment. Many of the negatives were similar to those encountered at any industrial facility and point to the need for facilities to periodically conduct internal state and federal compliance audits. For example, required signs were missing, flammable chemicals were found in non-flammable cabinets, electrical hazards were present, and floors were wet, and potentially slippery, where liquid had spilled. Also, for two of the facilities, the large amount of manual labor led to ergonomic concerns over worker back and muscular strain. All workers had the potential for exposure to blood and other liquids, although the potential was greatly reduced in the on-site facility where the waste handling was minimized. Worker protection programs were generally in place but need to be followed carefully and upgraded to include, for example, specific glove use protocols. Most of the negatives that were found were facility issues that could be readily remedied.

Engineering Controls

Engineering control problems were not unique to medical waste. Example from the facilities included the following. There was equipment that let water drain across the floor resulting in a slipping hazard at the autoclave facility. At the microwave facility, the unit ventilation system's inspection found that a HEPA filter was installed backwards allowing bypass in the air cleanup system and that a worker had to climb into the hopper where the untreated waste was dumped to clean a screen to allow air flow through the system. At the pyrolysis facility, a sensor was positioned such that a worker had to enter an enclosed space to clean it. Most of the engineering control problems could be present at many types of industrial facilities and are readily amenable to improvement.

Industrial Hygiene

Other than risks posed by safety and blood-borne pathogen exposure issues, the assessed environmental conditions show little to be concerned about. The results for these areas include: noise was not shown to be above permissible limits; low microwave radiation levels when the units are maintained correctly; sufficient ventilation air entered at all facilities; no elevated, respirable particle concentrations were found; none of the sampled VOCs exceeded the OSHA permissible exposure limits (PELs) or ACGIH threshold limit values (TLVs); and formaldehyde concentrations were below the OSHA PEL and ACGIH TLV, but above the NIOSH Recommended Exposure Limit (REL). In both the autoclave and microwave facilities, acetaldehyde and acetone were detected, but at concentrations several orders of magnitude lower than their respective PELs. Short-term, high concentrations of ammonia, not associated with the medical waste, were found in the autoclave facility. The metals sampling for all three facilities indicated minimal levels, most lower than the detection limits. Also, no chlorine was detected in the air in the autoclave facility although a chlorine-based disinfectant was used to clean the empty tubs. The indoor air quality measurements for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO) showed acceptable levels during the sampling periods for all three facilities.

Blood Detection

The surface blood contamination evaluations consisted of visual inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection. The wipe samples were positive for hemoglobin in 44 to 64% of the samples. This test could not determine if the hemoglobin was pre- or post- treatment. For the on-site facility, it is possible that all or part of the positives were false due to use of a chlorine-based surface disinfectant that was not revealed to the project team until after the conclusion of the assessment. The recommendation was made that the Phase 2 sampling trips include blood splash assessments.

For Phase 2, at the autoclave facility, a splash assessment protocol was developed to monitor for hemoglobin on workers' upper torso area and on face shields. Seven workers were evaluated over the two test days, with blood detected visibly and confirmed by hemoglobin testing on 2 of 6 sample patches from two workers. Of seven workers' face shields monitored over the two days, two were positive for hemoglobin after the work shift. A moderate amount of hemoglobin was detected on one face shield, while a trace amount was detected on the other. Thus, the personal monitoring that was conducted to assess worker exposures to blood splashes confirmed that workers in the facility who are responsible for the direct handling of the untreated medical waste containers are at risk for bloodborne pathogen exposures. The test results also confirmed visual observations of the waste loading or dumping operation that was conducted during the Phase 1 evaluation, where environmental splashes of blood and other fluids were noted.

Microbes

The surface microbial contamination assessments for the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*, showed no *S. aureus* from any sample. One autoclave, three microwave, and one pyrolysis samples were positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but are inconsequential relative to assessing potential worker exposures to recognized human pathogens. The results in general show little waste contamination of facility surfaces. The implication of not finding the *S. aureus* and only infrequently finding the *E. coli*, is that some human pathogens in medical waste may inactivate soon after waste generation due to adverse environmental conditions (such as temperature, moisture level, and lack of nutrients) encountered during storage and transport. While this situation is relevant for some vegetative bacterial pathogens, it may not hold true for the more environmentally resistant and virulent pathogens. The presence of some viable indicator bacteria suggests that some of the waste being processed was recently generated. Otherwise, the organisms might have had time to die during transport and storage.

In Phase 2, to assess the potential for infectious agents to be liberated from the steam autoclave treatment process, bioaerosol monitoring was conducted during the treatment of spiked and non-spiked medical waste. Indicator organisms used included specific strains of *Bacillus stearothermophilus* and *Bacillus subtilis globigii* var *niger*. The data from the two bioaerosol samplers were conflicting: results from the M/G samplers were negative and those for the AGI-30s were positive for both the non-spiked and spiked treatment cycles. The difference in results showed the importance of using two different types of bioaerosol samplers. The results are inconclusive as to whether microorganisms are emitted during the steam autoclave process and suggest that, within the facility, *Bacillus* indicator spores are present on various surfaces.

Recommendations

Based on the blood and microbial results, it is recommended that a uniform policy on the use of gloves be adopted at each facility. Adequate splash protection should be included in the personal protective equipment. Protective clothing that is worn in the facility should not be worn home. To reduce transfer of contamination from the waste treatment areas to other areas, shoes that have been worn in the waste processing area should be changed or covered before entering office areas. Attention should be given to daily routine cleaning and decontamination of treatment unit surfaces and other potentially contaminated facility surfaces. Every MWTF should perform regular health, safety, and engineering control checkups keeping the OSHA regulations in mind; reduce manual waste handling where possible; provide adequate protective clothing and equipment and enforce the protocols for using them, and, most importantly, take steps to significantly reduce exposure to blood and body fluids.

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1.0 INTRODUCTION

Workers at MWTFs face many potential safety hazards from handling and treating medical waste, including cuts and puncture wounds from handling sharp medical instruments, chemical and microbiological exposure, noise, microwave radiation, heat stress, and ergonomic hazards. Thus, the study aimed to accumulate a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), and prevention and control. The overall objectives for the project were to identify currently available disinfection systems for infectious waste and to evaluate the worker environment with regards to safety, aerosol, chemical, blood, and microorganism hazards and the use of engineering controls in controlling exposure. The secondary objectives of the project included identification of three MWTF (each of a different technology) based on criteria developed through a literature review; performing Phase 1 field evaluations with emphasis on sampling emissions, safety, and engineering control assessments; follow up with Phase 2 evaluation focussed on personal sampling; and writing reports based on the evaluations. The initial phase of the project resulted in the selection of a steam autoclave, a microwave, and a pyrolysis facility to evaluate. During the first year covered by this report, three Phase 1 trips and one Phase 2 visit were completed. This report covers the four field evaluations.

More than 500,000 tons of medical waste will be processed this year in the United States. Waste processing will be carried out at various "off-site" commercial treatment facilities, or "on-site" at the health care facilities, laboratories, or industrial operations where the waste is generated. The medical waste treatment processes consist of untreated waste handling, waste treatment, and treated waste handling. The aspects of each of these three steps that influence the worker environment were examined. Untreated waste handling is not specific to any one treatment process; whereas the treatment and some of the treated waste handling aspects are process specific. As the waste is transported, unloaded, treated, and disposed of, workers can be exposed to a variety of potentially hazardous medical waste components and treatment residues, to include infectious agents, toxic chemicals, and radioactive materials. They may also be at risk regarding a number of safety related concerns to include injuries, noise, and ergonomics. At the present time there is a significant lack of information on the identification, evaluation, and control of hazards associated with the treatment of medical waste.

There are at least 114 commercial medical waste treatment facilities throughout the 50 states (Malloy, 1995). On average, such facilities operate two to three work shifts and process up to 100 tons of medical waste each day. It is estimated that the total number of medical waste treatment workers in the United States, from both the off-site commercial treatment facilities and the on-site facilities (at thousands of hospitals), easily exceeds 10,000.

Concern for medical waste treatment workers comes from the unique character of the waste material and varying treatment technologies, with three types of health hazards of particular concern: infectious agents, hazardous chemicals, and non-ionizing radioactivity. Routes of exposure can include skin, mucous membranes, inhalation, and ingestion; with hazards present or generated during treatment as aerosols, particulates, fluids, and sharps. Other concerns include safety hazards and risks of injury related to lifting, moving, slips, falls, machine guarding, and electrical problems. While significant hazard information and statistics are available for "health care workers," medical waste handlers and treatment workers have not been included in the data gathering. It is prudent to assume that medical waste workers are at risk for similar occupational illnesses and injuries as health care workers.

The Occupational Safety and Health Administration (OSHA) standard under section 6(b) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 655 is to eliminate or minimize occupational exposure to Hepatitis B Virus (HBV), Human Immunodeficiency Virus (HIV) and other bloodborne pathogens. Bloodborne pathogen exposure can be minimized or eliminated in a wide range of occupational settings where the potential exposure to such bloodborne pathogens may exist. Workers who routinely handle the collection, transport, treatment, and disposal of regulated medical waste are at risk of exposure by direct contact with blood on contaminated surfaces from spills or ruptured containers directly onto open skin cuts, abrasions, eyes, or mucous membranes; or from accidental needle, scalpel, or glass puncture wounds, or by inhaling blood aerosols which may be generated from various handling and processing methods. OSHA has reported data from one medical waste company that the annual needle injury rate is 11 injuries per 1000 workers (OSHA, 1991). In a survey of occupational exposure of waste industry workers to infectious waste, fifty percent of the respondents reported having received cuts and scratches, and twenty-two percent reported direct contact with waste blood (Turnberg, 1990). This points to a definite need to characterize worker exposure to bloodborne pathogens in the medical waste treatment industry. Surface and airborne sampling methods were used in order to assess the potential for worker exposure to bloodborne pathogens in various medical waste treatment facilities. The information from surface and airborne blood sampling may help to determine which combination of engineering and work practice controls is most useful in reducing or eliminating exposures to bloodborne pathogens for each medical waste treatment technology. Controls may include personal protective clothing and equipment, training, medical surveillance, HBV vaccination, signs, labels, and other provisions.

The potential for infectious disease agents to be aerosolized from a medical waste treatment system was evaluated as part of this study. The demonstration of the release of airborne agents would indicate a potential risk for waste treatment operators. RTI previously conducted such a study for the US EPA's Office of Solid Waste (Cole et al, 1993). The results

showed that those points in a medical waste treatment system that were open to the ambient environment had the potential to release potentially infectious microbial aerosols.

Medical waste contains numerous chemicals that are themselves hazardous to worker health, and the MWTF technologies have the potential to generate others. Emissions from medical waste incineration and potential effects on the environment have been extensively studied and include particulate matter, metal fumes and dusts, volatile organic compounds, carbon monoxide, and acid gases such as hydrogen chloride, sulfur dioxide, and nitrous oxides (US EPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies, with the exception of a US EPA Office of Solid Waste study on biological emissions conducted by RTI (Cole et al, 1993); and no research to this time has focused specifically on the identification and assessment of hazardous exposures to the medical waste treatment workers. Such an evaluation is the focus of the proposed work.

Radioactive materials are used in a number of medical procedures. However, these wastes are supposed to be processed separately from the main medical waste stream. Most MWTF pre-screen the medical waste stream entering the facility with Geiger counters. Any radioactive wastes found are not processed, limiting the likelihood of MWTF worker exposure to radioactive chemicals. For this reason, exposure to radioactivity is considered a low probability exposure hazard at MWTF.

The potential for worker exposure to nonionizing radiation exists whenever microwaves or other electromagnetic energy-based technologies are used to treat medical waste. The U. S. Bureau of Radiological Health has set a standard of 5 mW/cm^2 leakage measured 5 cm from an oven to reduce the potential for exposure. OSHA has set a maximum of 10 mW/cm^2 (for frequencies from 10 MHz to 100 GHz, with microwaves in the range of 2450 MHz), averaged over a six minute period. A room survey for nonionizing radiation was required since a microwave-based process was chosen as one of the MWTF technologies for field study.

Workers at MWTFs face many safety hazards, including cuts and puncture wounds from handling sharp medical instruments, noise, microwave radiation, heat stress, and ergonomic hazards. Ergonomics issues associated with MWTFs includes injuries from the common practice of loading large treatment containers by hand, with the associated concern for back injuries, potential repetitive motion disorders, and overall work tolerance. It is not known if medical waste treatment facilities provide adequate worker training in the biomechanical area to address ergonomic concerns.

The Occupational Safety and Health Administration (OSHA) is a regulatory agency with responsibility to assure that all employees have a workplace that is free from hazards that are likely to cause death or serious harm or injury. Due to the potential chemical, biological, and physical health and safety hazards for workers at medical waste treatment facilities who handle, process, treat, and dispose of medical waste, a thorough investigation of hazard identification, evaluation, and control was warranted. This report details the results and conclusions from three Phase 1 and one Phase 2 assessments. The Phase 1 field studies assessed emissions, safety hazards, and engineering controls at three MWTF, while the Phase 2 field study completed the assessment of worker exposure and MWTF hazards at one facility. The technologies methodologies and results are discussed in the succeeding sections.

2.0 MWTF TECHNOLOGY

The Medical Waste Tracking Act (MWTA) of 1988 defined medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals...". It categorized potentially infectious or "regulated medical waste" into seven types: cultures and stocks; pathological wastes; human blood and blood products; sharps; animal waste; isolation wastes; and unused sharps. Treatment was defined as "any method, technique, or process designed to change the biological character or composition of any regulated medical waste so as to reduce or eliminate its potential for causing disease." The MWTA also had a destruction requirement that regulated medical waste be "ruined, torn apart, or mutilated," so as to be unrecognizable and non-reusable. Many of today's available technologies employ destruction as part of the treatment process.

Traditionally, incineration has been a method of treatment and destruction of hazardous chemical waste, municipal solid waste, and pathological waste. It was logical then that when concern regarding infectious disease agents such as the AIDS and hepatitis B viruses prompted the treatment of all medical waste, and hence a new industry, that incineration would be used. Over the past several years however, environmental pollution concerns have fostered the development of a variety of medical waste technologies that are presently regarded as viable alternatives to incineration. Such technologies include steam autoclave, microwave, and mechanical/chemical disinfection. Newer types of treatment include such facilities as pyrolysis, plasma, gasification, electro-thermal, and radiowave. The parameters that influence some of the types of technology, as well as advantages and disadvantages of each are shown in Table 1. Incineration is included as the traditional and more studied form; steam autoclave, microwave, and mechanical/chemical as established alternatives; and pyrolysis as the selected example of the newer technologies.

Incineration is a controlled air combustion process in which waste is reduced to ashes through a chemical reaction that involves rapid oxidation of the organic substances in the waste and auxiliary fuels, releasing energy and converting the organic materials to an oxidized form. At present, most medical waste incinerators normally operate with a temperature in the secondary combustion chamber that exceeds 1800°F. The smallest controlled air incinerators now available are rated at 1000 lb/hour.

Steam autoclave treatment combines moisture, heat, and pressure to inactivate microorganisms. The process has been used for sterilizing medical instruments in hospitals for decades, and the validation of autoclaving as a sterilization technique for medical equipment and supplies is well documented. Hospital autoclaves normally operate at a temperature of 121°C and a pressure of 15 psi for gravity displacement units. A typical laboratory autoclave normally can treat some 20 lbs of medical waste in one cycle. Prevacuum units, such as ones used for on-site medical waste treatment operate at 132-138°C and 30 psi, and can treat approximately

Table 1. Medical Waste Treatment Technologies

	Influential Parameters	Advantages	Disadvantages
Incineration[1]	Turbulence and mixing Moisture content of waste Filling of combustion chamber Temperature and residence time Maintenance and repair	Reduction of waste volume, weight Ability to make waste unrecognizable Acceptability for all waste types Heat recovery potential	Public opposition High investment, operation cost Formation of dioxins and furans High maintenance, testing, repair costs Vulnerability to future restrictive emissions laws
Steam Autoclave	Temperature and pressure Steam penetration Size of waste load Length of treatment cycle Chamber air removal	Low investment cost Low operating costs Ease of biological testing Creation of residue that is less hazardous than for incineration	Inability to change waste appearance Inability to change waste volume Lack of suitability for some waste types Production of uncharacterized air emissions Ergonomic concerns
Microwave	Waste characteristics Moisture content of waste Microwave source strength Duration of microwave exposure Extent of waste mixture	Ability to make waste unrecognizable Significant volume reduction Absence of liquid discharges	High investment cost Increased waste weight Lack of suitability for some waste types Production of uncharacterized air emission Ergonomic concerns
Mechanical/ Chemical[1]	Chemical concentration, temperature, pH Contact time with chemical Waste and chemical mixing Recirculation versus flow-through	Significant waste volume reduction Ability to make waste unrecognizable Rapid processing Waste deodorization	High investment cost Lack of suitability for some waste types Production of uncharacterized air emission Need for chemical storage and use
Pyrolysis	Waste characteristics Temperature Length of treatment cycle	Almost no waste remains Ability to make waste unrecognizable Heat recovery potential	Novel technology Air emissions must be treated

[1] Not assessed in this project.

100 lbs per cycle. The off-site commercial treatment autoclaves operate at 160°C and 80-85 psi, and can treat some 3,000 lbs per cycle.

Microwave treatment uses nonionizing radiation to heat medical waste to produce the thermal inactivation of infectious agents. Typically, waste is fed by continuous batch mode into a grinding chamber where it is sprayed with steam and mechanically shredded/destroyed to render it unrecognizable. The waste is then treated with additional steam as it slowly moves via a transport auger under a series of microwave units. The internal temperature of the waste is maintained at >95°C. Following microwave exposure, the treated waste is conveyed via an auger tube to a dumpster or compactor. The treated waste may then be hauled to an approved landfill. The individual units are designed to treat medical waste at rates ranging from approximately 220 to 900 lbs/hr.

Mechanical/chemical treatment usually involves a batch or continuous feed process that combines chemical treatment (and occasionally elevated temperature) with waste shredding at a capacity of some 2,000 lbs per hour for off-site facilities or as low a 20 lbs/hr for smaller facilities. Chlorine-based disinfectants, such as sodium hypochlorite and chlorine dioxide, are typically used as the inactivating agent. Following destruction and treatment, the solids are separated from the liquid chemical and are ready for landfill deposition.

Other medical waste treatment technologies exist including pyrolysis, plasma, gasification, electro-thermal, and radiowave. Of these newer technologies, the one chosen for inclusion in this study was pyrolysis. **Pyrolysis** units treat medical waste by pyrolizing waste in a controlled temperature and pressure environment. The units may operate up to 950 °F with a second oxidation chamber operating at over 1800 °F. Pyrolysis reduces most medical waste to gases leaving a small amount of dust and solid debris. Metals and ceramics will not be reduced in size but will be sanitized by the high temperature in the treatment unit. All remaining solid waste is collected in a dust bin and emptied as needed.

Emissions from medical waste incineration and potential effects on the environment have been extensively studied and include particulate matter, metal fumes and dusts, volatile organics, carbon monoxide, and acid gases such as hydrogen chloride, sulfur dioxide, and nitrous oxides (USEPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies.

In the original proposal and study plan, the project was projected to include assessments of steam autoclave, microwave, and mechanical/chemical facilities. These types of MWTF were felt to be the most representative of the waste treatment arena outside of the previously better characterized incineration facilities. However, at the time the study was underway, access to commercial off-site mechanical/chemical facilities was limited. Thus the decision process moved on to look at newer, more novel processes, including pyrolysis, that currently have low throughput but were thought to be increasing in importance to the industry. In discussions with the project officer on February 8th, 1996, the project team recommended and received approval for selection of a pyrolysis site as the third technology to be tested. Therefore, this report covers assessments of one steam autoclave and one microwave MWTF as examples of fully-developed technologies, and one pyrolysis facility as an example of smaller installations and of developing technology.

3.0 FIELD EVALUATION PROTOCOL OVERVIEW

This report covers results and conclusions from both the Phase 1 and Phase 2 evaluations. The methodologies varied between the Phases and the facilities. A description of the basic methodology for each Phase is presented below. Within the Phase 1 descriptions, types of testing for all three facilities are presented. However only those tests appropriate to each facility were performed. For example the non-ionizing radiation survey was only performed at the microwave facility. Details of the methodologies used are presented in Appendices E-P.

3.1 Phase 1 Evaluations: Safety, Emissions, Controls, Surface Biohazards

Phase 1 of the field study portion of the research focused primarily on emissions, safety, controls, and biohazards. It consisted of the following, as appropriate to the given facility:

- an industrial hygiene survey,
- a comprehensive safety assessment,
- identification of potential emission points from the treatment system or process,
- area sampling for identification of target volatile organic compounds (VOCs),
- noise and nonionizing radiation measurements,
- identification and assessment of existing engineering controls,
- preliminary respirable aerosol assessment,
- the assessment of blood on surfaces, and
- the assessment of microbial surface contamination.

Each of the three selected sites underwent a Phase 1 survey. It was carried out by a field team of five people: a certified industrial hygienist (CIH), a certified safety professional (CSP), an experienced microbiologist, an engineer, and an environmental field sampling specialist.

The industrial hygiene and safety assessment surveys observed the facility, the waste treatment workflow and process, initially identified the hazards and routes of exposure unique to the waste treatment technology; secure floor plans, engineering control diagrams, and written safety policy; defined work shifts and worker populations; examined policy related to health promotion (e.g. hepatitis B vaccine, TB testing); described potential routes of exposure relative to specific job assignments, identify chemical compounds used or stored in the facility; identified unsafe procedures, practices or conditions, addressing all safety concerns, including machine guarding, slips and falls, and ergonomics; and identified training and personal protection devices currently used.

In addition, a detailed job safety analysis for each of the three facilities was performed where possible. The assessments focused on identifying unsafe physical conditions and practices relative to the industrial waste treatment process, as well as areas of concern specific to the facility, such as fire protection, illumination, electrical safety, housekeeping, materials handling, and first aid. The facilities compliance with OSHA standards, to include bloodborne pathogens, confined space entry, personal protective equipment, respiratory protection, and hazardous waste operations and emergency response were informally assessed, including review of written programs and procedures for those areas. The safety assessment protocol is presented in Appendix E.

VOCs are expected to be components of medical waste, and may be formed and emitted during the treatment process. Emissions of gaseous and particulate contaminants from medical waste treatment technologies have not been well characterized. Thus, data were not available for selecting target chemicals to monitor at the waste facilities. To overcome this, Phase 1 screening measurements were performed to identify hazardous chemicals to better target the Phase 2 personal sampling.

Phase 1 included not only the identification of target chemicals for personal monitoring, but also the selection of monitoring locations that accurately represent chemical emissions from the facilities. Sampling was performed for VOCs, aldehydes, ketones, hydrochloric acid, chlorine, and metals.

VOC samples were collected over integrated time periods of approximately 4 to 6 hours during one day at each facility. Using this approach, samples were collected over periods during which the composition of the waste stream can be expected to vary. This is an alternative to collecting many short-term samples for multiple batches of waste or for short periods during continuous operations. Integrated samples over long time periods should contain representative contaminants throughout the day even if the waste composition is varying. For aldehydes and ketones sample volumes of 24 to 36 L were collected over a 4 to 6 hour period. Only those aldehydes/ketones that were measured during Phase 1 screening were target compounds for Phase 2.

Hydrochloric acid and chlorine are potential contaminants from systems that use sodium hypochlorite or other chlorine-based biocides. Length-of-stain detector tubes were used to screen for the presence of these chemicals in air.

Metals were sampled for 4-8 hours at 1-2 L/min using a series of midget impingers. All of the area chemical emissions measurement protocols are described in Appendix F.

Noise was measured at all facilities using a Quest Precision Sound Level Meter Model 155 containing a Quest Octave Band Filter Model OB-145 as described int Appendix G. Nonionizing radiation was measured in the microwave facility using a Narda Microline Microwave detector Model 8200 (see Appendix G).

For the engineering controls assessment, ventilation, HVAC, and other control devices were examined. For control devices that include airflow (including the building heating, ventilating, and air-conditioning (HVAC) and hoods), a hot-wire anemometer was used to perform flow measurements to determine airflows. The airflow measurements were used to determine if there was adequate ventilation based on the ASHRAE requirement of a minimum 15 cfm/person. Control devices that could create hazards of themselves were investigated in conjunction with the hazard identification. As with the ventilation control evaluation, the evaluation of other engineering controls such as machine guarding, handrails, lifting assistance, noise control, and workplace ergonomics was performed in conjunction with the safety assessment. The engineering controls assessment protocol is presented as Appendix H.

A Handheld Aerosol Dust Monitor and an Optical Particle Counter were used to screen for respirable aerosols as described in Appendix I. The aerosol monitors were used to measure concentrations near each identified potential emission point and in several locations throughout the room. Measurements were taken in the regions identified as worker breathing zones to begin to estimate worker exposure to aerosols.

Surface contamination is also an important consideration in medical waste treatment. Surfaces with which workers might come in contact were monitored each day for blood contamination by a wiping procedure followed by elution and testing for blood using the hemoglobin detection method described in Appendix J.

The risk of medical waste treatment workers to dermal contact with infectious disease agents was assessed by sampling and analysis of treatment system surfaces for human pathogen indicator organisms. Areas of treatment systems that might be expected to harbor surface contamination were evaluated by sampling and analysis for two strains of vegetative bacteria associated with human infection and/or contamination, *Staphylococcus aureus* and *Escherichia coli*. Appendix K details this method.

3.2 Phase 2 Survey - Personal Samples and Exposure

The Phase 2 survey at each of the three sites focused (or will focus) on worker personal exposure monitoring using primarily active personal samplers. Phase 2 sampling was planned to consist of:

- Personal monitoring for VOCs identified in Phase 1,
- Air quality monitoring (temperature, relative humidity, CO, CO_2),
- Personal monitoring for blood aerosol, and
- Area and emission point monitoring for microbial aerosols.

The actual sampling performed (or to be performed) was determined for each site based on the Phase 1 assessments. No area sampling for VOCs will be conducted during Phase 2, and no metals sampling of any kind is planned for Phase 2. The Phase 1 results showed low respirable particle counts, so no Phase 2 aerosol sampling was needed. Also a blood splash protocol was developed to replace the planned blood aerosol testing. Since medical waste can vary on a day to day basis, sampling was conducted over two days. One shift per day was monitored. The field team consisted of three people including a certified industrial hygienist, microbiologist, and environmental sampling specialist. One of the three trips was made in the first year of the project.

VOCs were monitored in Phase 2 using the same multisorbent cartridge method (Tenax TA, charcoal, and ambersorb) that was employed in Phase 1. The samples were collected at nominally 16 cc/min for 7-8 hours on 5 workers on each of 2 days. Formaldehyde samples were collected using 3M 3720 passive formaldehyde badges. Again 5 workers were sampled for 7-8 hours on each of 2 days. Ethanol was measured using a direct reading passive Dräger diffusion tube (part no. 81 01 151) with a detection range of 125-3100 ppm. Five workers were sampled for 7-8 hours on each of 2 days. Ammonia was sampled using a direct reading Dräger tube (part no. 67 33 231) with a detection range of 0.5 - 30 ppm. Samples were collected over nominally one minute using a hand held pump (n = 5 strokes). Five ammonia samples were collected on each of 2 days in the boiler room adjacent to the autoclave processing area. Methanol and n-propanol were sampled using a direct reading Dräger tube (part no. 26 112) with a detection range of 25-5000 ppm. Samples were collected over one minute using a hand held pump (n = 10 strokes). Five samples were collected on each of 2 days in the autoclave processing area and adjacent boiler room. The methods used for the personal exposure monitoring are described in Appendix L.

Area air quality measurements were made at every site using a Metrosonics AQ-501 Air Quality Monitor in a similar manner to that used in Phase 1. This instrument provides information on the temperature, relative humidity, carbon monoxide, and carbon dioxide concentrations. The monitoring protocol is described in Appendix M.

Results from the Phase 1 evaluation indicated a risk for blood and body fluid splashes to workers loading untreated regulated medical waste into the large treatment bins prior to steam autoclaving. A splash assessment protocol was developed to collect samples for residual hemoglobin from the upper torso area of the workers, in addition to residuals on face shields. Upper body splashes were assessed using cotton patches attached to the front and back of the workers' shirts. Following a work shift, the patches were assessed for visible blood and processed using the hemoglobin detection method as previously described. Worker face shields were wipe sampled prior to a work shift and then again at the end of the shift. Both methods for sampling and blood detection are described in Appendix N.

A single area, 6 hour air filter sample for blood aerosols was collected on each of the two days and processed for hemoglobin as previously described. The samples were collected in the waste handling area. This method is described in Appendix O.

4.0 GENERAL SAFETY HAZARDS

Three sites were included in the Phase 1 assessments: one steam autoclave, one microwave, and one pyrolysis. Of these, the steam autoclave and the microwave facility were off-site facilities, while the pyrolysis unit was on-site at a hospital. The first two facilities used standard methods used at many other facilities; whereas, the pyrolysis facility used a prototype treatment method with units that are regularly modified to improve their function and to test ideas for future models. All three facilities involved some manual handling of prepackaged waste. All three facilities had proactive, interested management.

This section includes a detailed listing of findings. This review was as "global" as possible to include reference to OSHA regulations as well as good practices. This review was limited by the time available for the facility inspection, the number of job tasks reviewed, and the limited specific record review. This examination focused on unsafe conditions, engineering controls, and compliance training materials. Limited review of unsafe acts and enforcement was done.

In the steam autoclave untreated medical waste is delivered to the facility by means of tractor trailers and trucks carrying either sealed cardboard boxes of varying sizes or plastic tubs of varying sizes. The containers are moved to a processing area either manually or with assistance of carts or forklift. The processing involves filling large waste bins either manually or with assistance of a hydraulic dumper. The bins are mechanically moved by conveyor into an autoclave which treats the waste under timed, pressurized, steam conditions designed to completely disinfect all materials. After completing the treatment cycle, the bins are mechanically moved to a hydraulic dumper which dumps the waste into a hydraulic compaction unit which is attached to a compaction trailer into which the waste is pushed. Upon filling, the treated waste is hauled to a private landfill. This facility treats up to about 96 tons per day when running three shifts.

At the microwave facility, the untreated medical waste is placed in "red" plastic bags or sharps containers by the customers and the bags are placed in 48 gallon rigid plastic containers. The sharps containers were normally segregated and handled separately from the plastic containers. The microwave facility drivers manually load the containers into facility owned/operated trucks and bring them to the facility. The nominally 40 pound containers are manually pulled to a lift gate on the truck, off loaded, and manually stacked up to 3 high using no mechanical aids. After manifesting and weighing, the containers are manually dumped into a large bin attached to one of the microwave units. The process cycle is machine controlled with limited worker action. Upon signal from the microwave unit, a worker manually initiates a control on the unit which activates a lift mechanism. The large cover on the hopper is automatically opened, the lift elevates the bin approximately 12 feet and, then, tips the bin. Once the medical waste has dropped into the hopper, the lid closes over the hopper, and the bin is lowered to ground level. Once the medical waste has dropped in the hopper, the lid closes over the hopper, and the bin is lowered to ground level.

An automatic grinding cycle commences in which the waste is shredded to material less than approximately 0.5 inch wide. During treatment, the waste is augured up a closed, inclined tube. The tube has six (6) microwave units mounted in series on top and several ports allow steam injection. The microwave units heat the steamed waste as it travels through the auger. The treated waste product is gravity-dropped into a dumpster located on the outside of the building. An attached hydraulic ram periodically compacts the waste into the dumpster. When full, a contractor hauls the dumpster to the city landfill to be emptied. This facility treats up to 6.6 tons per day when running 3 shifts. Some comments concerning the operation of the microwave units from a consultant to the microwave unit manufacturer that were made in response to the draft report are included as an addendum to Appendix B.

For the pyrolysis facility, most of the medical waste is delivered by hospital employees, while some is trucked in from local small-scale generators (e.g., doctor's offices). The waste is contained in red bags in fiber boxes which were packaged and sealed prior to delivery. A conveyor that parallels the length of each unit is loaded with the boxes. At the pyrolysis chamber end each box is automatically weighed and the information sent to the controlling personal computer (PC). When the pyrolysis chamber is empty, the box is lifted vertically, then moved horizontally through an outer door into an airlock. The outer door closes and then a second door, inside the airlock, opens and the box falls into the pyrolysis chamber. Other than manually placing the boxes on the conveyor, no other manual material handling is involved beyond nominal cleanout of residue. This facility treats approximately 40 lb/hr for each unit and runs 2 shifts per day usually for 4 days per week.

All of the facilities had significant positives and negatives in their safety assessment. Many of these were similar to those expected at any industrial facility. For example, required signs were missing, flammable chemicals were found in non-flammable cabinets, electrical safety hazards were present, and floors were wet, and potentially slippery, where liquid spilled. Also for two of the facilities the large amount of manual labor led to concerns over worker back and muscular strain and exposure to the waste. As far as hazards related directly to the medical waste, the most significant came from blood and liquid spills. Examples of the positives that were found are shown in Table 2. Examples of the types of deficiencies that were found are shown in Table 3. The pyrolysis vendor's response to the draft report on that facility included a list of improvements made since the Phase 1 assessment. The information is included as an addendum to Appendix C and discussed in this report where appropriate, especially to show the ease with which many of the project teams' comments could be rectified. However, since a list of improvements was not requested from the facilities, the absence of similar information from the other sites can not be taken to indicate that improvements have not been made at those sites.

Based on this sample of medical waste treatment plants, management was found to be proactive and to provide worker training and protective equipment. On the negative side however, all workers had the potential for exposure to blood, other liquids, and sharps, although the potential was greatly reduced in the plant where the waste handling was minimized. Also ergonomic problems due to the handling of the waste are a major area of concern. Worker

Table 2. Examples of Positives Found in the Facilities[1]
(x = found in Phase 1 assessment, + = reported as improved since Phase 1 assessment)

Area of Concern	Autoclave	Microwave	Pyrolysis
Concerned and Proactive Management	x	x	x
Worker Training	x	x	x
Limited worker/waste interaction			x
Separate "clean" and "dirty" sections	x		
Separate clothes worn in facility	x	shirt only	+
Required end-of-shift showers	x		
Comprehensive Manuals	x	x	limited
Protective clothing available	x	x	

[1] Details for each facility can be found in Appendices A, B, and C.

Table 3. Examples of Negatives Found in the Facilities[1]

Area of Concern	Autoclave	Microwave	Pyrolysis
Potential exposure to liquid from the waste	x	x	x[2]
Potential exposure to sharps	x	x	x[2]
Electric:	x	x	
Extension cords used as permanent wiring	x		x[3]
Needed ground fault circuit interrupt	x	unclear	
Lack of 3 ft clearance	x	x	x[3]
Lack of Fall Protection	x	x	
Extensive manual material handling	x	x	
Ergonomic hazards	x	x	
Need for glove use protocol	x	x	x
Worker got into waste hopper		x	
Combustibles stored incorrectly	x		x[3]
Broken ladder	x		
Needed posted egress maps	x	x	x[3]
Protective clothing not always used or unavailable	face shields not used	hard hats/face shields	
Drink machine and water fountain in waste handling area		x	
Blocked exit door		x	
Faulty Testing Equipment		radiation gauge	

1 Details for each facility can be found in Appendices A, B, and C.

2 If boxes leak or rupture. Most limited apparent risk of the three facilities due to prepackaging of waste.

3 Remedied since Phase 1 visit according to pyrolysis vendor/facility operator.

protection programs were generally in place but need to be followed carefully and upgraded to include, for example, specific glove use protocols. All facilities needed some improvements in the areas of electrical connections and fall protection was an area shown to need improvement. However most of the negatives that were found in the MWTFs area also found in general industry and can be easily remedied.

5.0 NOISE AND RADIATION

5.1 Noise

The noise surveys were conducted using a Quest Sound Level Meter (S/N DL8110002) calibrated with a Quest Calibrator (S/N J8100013). At the autoclave facility, the noise levels ranged from 69 to 100 dBA in the process area and from 44 to 53 dBA in the office area. The sources of the loudest noise in the process area include the mechanical shaking of the drums at the compactor, venting/ramping of the autoclave steam, rolling bins off of trucks, the entrance to the container washer, and the radio located near the loading dock. While the area noise survey demonstrated that the potential to exceed the OSHA PEL of 90 dBA exists, the data is inconclusive since it was only a survey and not a measurement of an 8 hour time weighted average noise exposure. The management has a hearing conservation program in place and has documented that the OSHA PEL is not exceeded doing routine work in the process area. The hearing conservation program mandates hearing protection whenever the noise TWA exceeds 85 dBA and when working between the autoclaves during the ramping segment and when removing debris from the waste bins.

The noise levels ranged from 59 to 75 dBA in the process area of the microwave facility and from 42 to 47 dBA in the office area. A Quest Noise Dosimeter (S/N HM 0010038A) was also used to collect an eight hour time weighted average noise exposure for the plant area. The results from the noise dosimeter indicated an average noise level of 59.5 dBA in the plant, lower than the OSHA PEL of 90 dBA.

The noise levels ranged from 66 - 81 dBA at the pyrolysis facility. The source of the loudest noise (81 dBA) was a compressor located in the shop support area. The noise levels next to the pyrolysis units reached a maximum of 75 dBA near the pump/motor area attached to the unit.

During the phase 2 trip to the autoclave facility three integrated noise surveys were conducted at the control panel using the Quest Noise Dosimeter. All three surveys had average noise levels less than the OSHA PEL of 90 dBA (the average noise levels were 77.8, 81.3 and 73.9 dBA). The area noise surveys showed noise levels ranging from 70 to 100 dBA within the boiler room. The loudest noise in the boiler room was from a reportedly faulty motor that was coming on intermittently. Noise levels ranged from 69 to 97 dBA in the process area where the loudest noise was the venting/blowdown of the autoclaves which lasted nominally 2-3 minutes and occurred once every 50 minute cycle on each of two autoclaves.

Based on these data, exceedence of the OSHA PEL for noise does not appear to be a problem for these facilities. However, the noise was loud enough in some locations to warrant regular noise level checking.

5.2 Microwave Radiation

A survey of the microwave units was conducted using a Narda Microlien Electromagnetic Leakage Monitor, Model 8210 (S/N 03012), calibrated by the manufacturer on 7/95. The survey demonstrate a leak around the microwave closest to the shredder in unit number 2. The levels exceeded 10 mW/cm^2, and pegged the survey meter offscale. This was brought to the attention of the operator who immediately tightened the unit and reduced the leakage to <0.1 mW/cm^2 The facility is supposed to check the microwave units daily. Two microwave survey meters were observed; however, the meter located at unit no. 1 was out of calibration (due 10/92) and had dead batteries while the meter at unit no. 2 was usable but the calibration was past due 12/95. Thus based on this one sample, the radiation levels can be very low, but regular maintenance with operational, calibrated instruments is extremely important.

Non-ionizing radiation was not measured at the two facilities with no microwave sources.

5.3 Ionizing Radiation

The autoclave facility used fixed ionization survey detectors where waste was off-loaded from incoming trucks. Also, workers wore film badges. A record review found no badges exceeding background detection levels.

The microwave facility had an ionization survey meter on-site but it was not operational. Workers did not wear detection devices.

The pyrolysis facility had no ionization survey meters or worker detection devices.

All facilities relied on their customers to segregate any radioactive waste from the waste sent for treatment.

6.0 VENTILATION AND AEROSOLS

6.1 Ventilation

During the Phase 1 trip to both the autoclave and the microwave facilities, the outdoor weather was extremely windy, so that the airflow in the facilities was quite gusty, basically unpredictable. The air velocities, as measured with a hot-wire anemometer, were so variable that most of the readings consisted of determining a low and high velocity for the range over which the meter needle swung. For those cases where the readings were mainly at one level with brief gusts or calm spells, an average wind velocity was estimated by watching the gauge for several minutes. Both of these facilities had many openings to the outdoors.

In the autoclave facility, the airflows in the workers areas varied from 10 to 75 fpm while the center velocity near the fan next to the compactor averaged about 250 fpm. Airflows in the microwave facility varied from about 10 to 550 fpm depending on the direction the nearest opening faced (wind blowing in or sheltered from the wind), while outdoors in the direction of the wind gusts of up to 1500 fpm were measured. These measurements show sufficient air movement to easily exceed 20 cfm per person. However, it is impossible to tell with this data set if this would be true on a still outdoors day. In addition to the velocity values, an air exchange rate of approximately 2.9 was determined based on the height and width of the room and the fan ratings.

The inside of the pyrolysis facility was breezy. On the days of the Phase 1 assessment, this facility brought in most of its air by fans, as opposed to wind through building openings. During warmer times of year, the roll up doors may be open to allow more airflow. Indoors the airflows varied from 10 to 70 fpm in the worker areas; while the approximately 46 in. diameter fans pushed up to 950 fpm into the room. The measurements below show the ventilation to be sufficient for control of pollutants in the work space during our sampling visits.

Thus based on the data from this study, sufficient airflow is not a problem for these facilities.

6.2 Respirable Aerosols

Aerosol measurements were taken with the hand held aerosol monitor (HAM) that measures mass concentration and with the Laser Particle Counter (LPC) that measures the number of particles in various size ranges. A conservative assumption of an average density of 1.5 g/cm^3 was made and the mass concentration below 5 μm and the total mass up to 15 μm were calculated based on the LPC data. None of the measurements exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified. At the autoclave facility, all the measurements were below 1 mg/m^3, except the measurement taken immediately after the autoclave was opened, possibly due to the steam. That measurement peaked at 2.1 mg/m^3 but was down to 0.73 within 5 minutes. Many of the concentrations were below 0.1 mg/m^3 indicating that respirable particles were not dangerously elevated. The LPC data showed even lower concentrations.

At the microwave facility, none of the indoor respirable measurements exceed the outdoor air National Ambient Air Quality Standard of 0.075 mg/m^3, as the highest value was 0.025 mg/m^3. The pyrolysis facility had even lower concentrations with the highest value at 0.018 mg/m^3 when the photoelectric eye was cleaned and the average concentration was around 0.006 mg/m^3.

Thus the particle concentrations at all three facilities were low on the days tested.

6.3 Engineering Controls

Many of the items that could be considered in this category, such as fall protection, are covered in the safety section. This section covers such controls that have not been previously covered. The items in this category varied greatly between the plants so that generalized conclusions are difficult.

For the autoclave facility one important engineering control issue was the lack of drains for the tub washers. Both tub washers leaked a solution of contaminant, disinfectant, and water on to the floor during runs. The small tub washer leaked from a main overflow pipe, located in the back, during cleaning out. This water mix pooled on the floor and had to be swept down a drain. However, the floor, even though wet, did not appear to be slippery when walked on. It was recommended that a drain be installed to serve these two washers.

Another issue is the pole used to prod sticking waste from the tubs into the bins and to maximize loading of the bins. The pole is used then stored in the worker area, bringing fresh, untreated liquid waste into contact with the worker station. In addition, liquids may run down the pole to contact the workers. The use of the pole to remove waste from the bin loader should be rethought. It should not be used, then stored near the workers where unprotected contact could occur. A stand for the pole could be set up outside the worker shield. Also, redesigning the pole to prevent liquid from reaching the worker as suggested by the corporate toxicologist and engineer would be helpful.

At the microwave facility one important engineering control issue is the use of "swamp coolers" in the roof that can blow into the facility. These coolers are used and intended solely for temperature control, not for ventilation. The ducting for the fans is located over the bins near the loading dock, over the 2 units, and over the washer area. Thus the fans blow whatever gases or aerosol vents upward from the units back into the breathing zone of the workers and into the plant in general. There are tentative plans to convert two of the vents to exhaust or to add exhaust ventilation to the existing facility. If the two vents over the units are converted, this would reduce this problem greatly; however, the temperature control aspects of the swamp coolers may not be met and that incoming air may need to be positioned elsewhere to meet that need.

Also at the microwave facility, a number of problems with the exhaust air cleaners on the treatment units were found including leaky seals, a filter put in place backwards, and clogged air inlet. Upgrading the older air cleaner, sealing the unit, and adding a check point in the exhaust duct to determine the air velocity were recommended to improve these problems. Since this particular set of problems occurred in the purchased microwave units but were easily solved, other facilities should check their similar air cleaner systems perhaps including additions to the daily maintenance routine.

The pyrolysis facility serves in part as a research facility for the manufacturer of the units. Employees of the manufacturer also run the facility. One day a week the units are not run in order to allow for routine maintenance, upgrades, and testing. Information gained from this facility is being used to design future models of the pyrolysis units to reduce or eliminate current problems and to increase efficiency. It also needs to be noted that this facility processes much less waste that the other facilities which is one of the reasons why there is less manual labor involved, along with the generator-performed, prepackaging of the waste into treatable units. Much of the unit operation was set up to be run and monitored both manually and by computer allowing the operators to monitor, for example, the temperature in the units by checking a number on a computer schematic.

In this facility, the heat generated by the units is partially reused in the hospital boiler room as water pipes circulate water heated by the pyrolysis units to heat exchangers in the boiler room. All heat sources appear to be well shielded not presenting danger to visitors or operators.

The solid waste collector bins are located below floor level and create a dust cloud when emptied. Although the air levels of particles remained low during this study, there is a strong possibility that the operator dumping the bin could be exposed to high particle levels for short periods. Thus the newer models are being design with higher level bins and consideration is being given to an automated dumping process that would eliminated most of this potential exposure.

Also at the pyrolysis facility, the pH of the exhaust gas scrubber liquid is neutralized with NaOH that runs in lines across the ceiling. This potential source of caustic exposure needs to be reduced possibly be relocating the lines.

Overall each of the three treatment processes appeared to have good engineering for the process itself. However, each facility needed improvement in the design interfacing of the treatment unit within its facility and the worker protection between the unit and the facility. The concerns outlined here are mainly ones that are not specific to the medical waste treatment industry but are found in general industry as well.

7.0 CHEMICAL EXPOSURE

The medical waste as received is not chemically treated. The waste itself may contain any number of chemicals, most probably volatile metals such as mercury, VOCs, or aldehydes such as formaldehyde. The most abundant chemicals used at the autoclave facility include hypochlorite solution (bleach) for washing of the containers and ZEP Asphalt Release Agent (sodium dodecylbenzene sulfonate) sprayed into the large autoclave bins. The boiler in an adjacent room to the process area of the facility uses ammonia as a rust inhibitor. A 55 gallon drum of ZEP Dyna 143 cleaning solvent (aliphatic naptha) was observed near the mechanical workshop. The microwave facility uses miscellaneous chemicals including mineral spirits, 2-butoxyethanol, Betco disinfectant, Zeposcetor (pyrethin/pipernyl butoxide insecticide), phosphoric acid, aliphatic naptha, ZEP-Amine A (ethanol and ammonium chlorides), acetylene, oxygen and nitrous oxide. The most abundant chemical used at the pyrolysis facility is a 50% solution of sodium hydroxide (NaOH). There were also miscellaneous chemicals such as muriatic acid, lacquer thinner, motor oil, and acetylene located in the shop area adjacent to the pyrolysis units. Thus a wide variety of chemicals could reasonably be expected to be found in the air samples.

7.1 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) were collected by passing air through multisorbent cartridges containing Tenax TA, charcoal, and ambersorb (200 mm x 6 mm o.d., Envirochem, Kimblesville, PA). For Phase 1, sample volumes of approximately 5.0 L were collected over a nominal 5 hour monitoring period. For analysis, VOCs on exposed cartridges were thermally desorbed then analyzed by gas chromatography/mass spectrometry (GC/MS). Identification of unknown sample constituents was performed using an electronic search of the NIH/EPA/MSDC Mass Spectral Data Base (NIST library) and the Registry of Mass Spectral Library (Wiley Library). Manual review of the data was performed to verify computer identifications and to identify compounds not found using the computer literature search. A semiquantitative estimate of the identified compounds was made using the total ion peak area for each compound and the total ion response factor measured for toluene. A concentration estimate for total VOCs was made using the same approach. Example VOCs that are detectable by the multisorbent method are shown in Table 4. The compounds found in the test samples must be a subset of these.

VOCs were collected at a flow rate of nominally 15 cc/min for 5 hours, in the process area near the control panel, over autoclave number 1 and at the compactor in the autoclave facility; over both microwave units; and between the pyrolysis units 1 and 2 and in the shop area for the pyrolysis facility. The concentrations determined are based upon the formula weight of toluene, and only those VOCs in excess of 0.05 mg/m^3 are reported. The total VOC content consists of both those from the waste stream and from truck exhaust from the trucks unloading at the facility or driving in the parking lots.

Table 4. Example VOCs That Are Detectable by the Multisorbent Method

1,2-Dichloropropane	C_3-Benzenes	Bromoform
1,1,2,2-Tetrachloroethane	C_4-Benzene	Isopropanol
Dibromochloromethane	Methylene Chloride	Propanol
Bromodichloromethane	Bromethane	Butanol
cis-1,3-Dichloropropene	Chloroethane	Pentanol
1,1,2-Trichloroethane	Chloromethane	Benzene
1,1-Dichloroethane	Chloroform	Toluene
1,2-Dichloroethene (Total)	Trichloroethene	Acrolein
trans-1,3-Dichloropropene	Chlorobenzene	Acrylonitrile
1,2-Dichloroethane	Ethyl Benzene	Styrene
1,1,1-Trichloroethane	Dichlorobenzenes	Vinyl Chloride
Carbon Tetrachloride	1,1-Dichloroethene	Xylenes
	Tetrachloroethene	

Several VOCs were observed in each facility, but no OSHA PELs or ACGIH TLVs were exceeded. The highest concentration VOC for the three locations within the autoclave facility was 2-propanol at 643, 556, and 589 $\mu g/m^3$. The compound with the highest concentrations for all three sampling sites at the microwave facility was 2-propanol at 2318, 495, and 986 $\mu g/m^3$. For the pyrolysis facility, the highest concentration VOC found between the units was phenol at 1.7 $\mu g/m^3$ and in the shop area was decanal at 16 $\mu g/m^3$.

7.2 Aldehydes and Ketones

Formaldehyde is a contaminant that may be emitted during the treatment of medical waste. Formaldehyde and other volatile aldehydes and ketones were screened for using a silica gel/DNPH-(2,4-dinitrophenylhydrazine) method (US EPA, 1988). During air sampling, aldehydes/ketones instantaneously react on the cartridge to form the DNPH derivative. For analysis, the DNPH/aldehyde/ ketone derivatives were eluted from the cartridge with acetonitrile. This extract was then analyzed by high performance liquid chromatography (HPLC). Aldehyde/ketones were identified by comparison of their chromatographic retention times with those of purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range 0.02 to 15 ng/μL of the DNPH/aldehyde derivatives. Standards were analyzed and a calibration curve calculated by linear regression of the concentration and chromatographic data. A list of aldehydes/ketones analyzed during Phase 1 screening is shown in Table 5.

In the autoclave facility, aldehydes were collected at a flow rate of nominally 120 cc/min for 7 ½ hours at the process area near the control panel, over autoclave number 1, and at the compactor. In the microwave facility, aldehydes were collected at a flow rate of nominally 120 cc/min for 7 hours near the bin wash area workbench and over both microwaves. In the pyrolysis facility, aldehydes were collected at a flow rate of nominally 120 cc/min for 6 hours, next to pyrolysis unit no. 1, between the pyrolysis units, and in the shop area.

Table 5. Example Aldehyde/ketones to Be Analyzed During Phase 1 Screening

Formaldehyde	Acetaldehyde	Acetone	Acrolein
n-Propanal	Crotonaldehyde	n-Butanone	n-Butanal
Benzaldehyde	n-Pentanal	n-Tolualdehyde	n-Hexanal

The aldehyde results for the autoclave and pyrolysis facilities indicated concentrations of formaldehyde in the range of 0.08 to 0.18 mg/m^3 while the microwave showed similar results with a range of 0.007 mg/m^3 to 0.2 mg/m^3. All of these values are much lower than the OSHA PEL of 0.94 mg/m^3 and the ACGIH TLV of 0.37 mg/m^3 (ceiling limit). In both the autoclave and microwave facilities, acetaldehyde and acetone were also observed but at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs of 360 and 2400 mg/m^3.

7.3 Metals

The methodology for metals sampling used the EPA draft method 29 sampling train for combustion source emissions (US EPA, 1986). The sample system incorporates a glass fiber filter followed by two (2) impingers containing acidified peroxide solution for collection of aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), labile mercury (Hg^{+2}), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl) and zinc (Zn). Following the peroxide impingers were two impingers containing acidified potassium permanganate for the collection of elemental mercury (Hg°). The draft method has been evaluated extensively at RTI and other laboratories, particularly for mercury species. In addition, the method has been used in the field by a large number of industrial stack testing contractors. A miniaturized version of the sampling train that incorporates midget impingers (1 - 2 L/min sampling rates) instead of the Greenburg/Smith impingers (approximately 20 L/min) was used.

Metals were collected at a flow rate of nominally 1 L/min for 8 ½ hours at the area over autoclave number 1 and at the compactor in the autoclave facility. Metals were collected at a flow rate of nominally 1 L/min in the areas over both microwaves. In the pyrolysis facility, metals were collected at a flow rate of nominally 1 L/min for 6 ½ hours, next to pyrolysis unit no.1 and between the pyrolysis units.

The measurement of these resulting samples included graphite furnace atomic absorption (GFAA) for As, Sb, and Se, cold vapor atomic absorption (CVAA) for Hg and inductively coupled plasma (ICP) emission spectrometry for the remaining elements. These methods are described in both in the NIOSH Manual of Analytical Methods (NIOSH, 1994) and in EPA "Methods for Chemical Analyses of Water and Wastes" (EPA 600/4-79-020).

The results of the metals sampling for all three facilities indicated minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co, Ni, Zn, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg. The pyrolysis facility also showed minimum levels of P.

7.4 Chlorine

Hydrochloric acid and chlorine are potential contaminants from the bin washing systems that use sodium hypochlorite based biocides. To screen for the presence of these chemicals in air, length-of-stain detector tubes (Drager part no's 24301 and 01681) for chlorine and hydrochloric acid were used (ASTM D4490, 1992). During screening, a known volume of air is drawn through the tube using a hand pump. As air is drawn through the tube, a colorimetric reaction occurs; the concentration is read from the demarcations on the tube. The chlorine detector tube has a range of 0.2 to 3.0 ppm. The hydrochloric detector tube has a range of 1.0 to 10.0 ppm. Air samples for hydrochloric acid and chlorine were collected in the vicinity of the bin washers.

In the autoclave facility, no chlorine was detected at either side of the small bin washer or at either side of the large container washer. No hydrochloric acid was detected at the small bin washer or at the large container washer. Since the project team was unaware of any sources for these chemicals at the other sites, these tests were not performed at either the microwave or the pyrolysis facilities. After the assessment, the team was informed that a chlorine-based cleaning product is in use in the pyrolysis facility.

7.5 Phase 2 Monitoring for Chemical Exposure

The Phase 2 industrial hygiene survey conducted at the autoclave facility included personal monitoring for VOCs, ethanol, and formaldehyde. Area samples were collected for methanol, n-propanol, and ammonia. It was originally planned to collect 5 personal samples on 5 workers over each of 2 days, however, the facility had modified the work schedule to accommodate a reduction in the volume of medical waste received. Some employees were working 12 hour shifts from 11 a.m. to 11 p.m. or 12 p.m. to 12 a.m. To accomplish obtaining 5 complete shifts, it was necessary to change the personal samplers from one employee to another when the shift changed. Two job titles, Supervisor and one Laborer, required two employees from two shifts to share (trade-off) the chemical sampling equipment. One job (Maintenance) was performed from 0500-1330, so the first day of sampling only a 5 hour sample was collected. For the second day of sampling the maintenance employee was outfitted with sampling pumps, badges and collection media by 0500 to enable collection of an 8 hour sample.

VOCs, monitored using the same multisorbent cartridge method employed in Phase 1, collected samples at nominally 16 cc/min for 7-8 hours on 5 workers on each of 2 days. Several VOCs were identified and quantified with the highest concentration of 104 $\mu g/m_3$ for one worker's dichlorodifluoromethane concentration. All of the VOC results were less than OSHA PELs, NIOSH RELs, and ACGIH TLVs.

Formaldehyde samples were collected using 3M 3720 passive formaldehyde badges. Again 5 workers were sampled for 7-8 hours on each of 2 days. Formaldehyde concentrations on the workers ranged from 0.021 to 0.086 ppm. The control sample taken on an office worker was 0.04 ppm, higher than any plant workers on 6/26/96. The OSHA PEL is 0.75 ppm and the NIOSH REL is 0.016 ppm.

Ethanol was measured using a direct reading passive Dräger diffusion tube (part no. 81 01 151) with a detection range of 125-3100 ppm. Five workers were sampled for 7-8 hours on each of 2 days. No ethanol was detected on any of the personal direct reading Dräger tubes.

Ammonia was sampled using a direct reading Dräger tube (part no. 67 33 231) with a detection range of 0.5 - 30 ppm. Samples were collected over nominally one minute using a hand held pump (n = 5 strokes). Five samples were collected on each of 2 days in the boiler room adjacent to the autoclave processing area. Concentrations of ammonia above the maximum detection limit of 30 ppm were observed in the boiler room during the transfer operation of ammonia from the drum to the vat. The ammonia transfer procedure takes about 1 minute to complete. The OSHA short term exposure limit (STEL) is 50 ppm and the vacated 1989 OSHA STEL is 35 ppm. The NIOSH REL and the ACGIH TLV is 25 ppm with a STEL of 35 ppm.

Methanol and n-propanol were sampled using a direct reading Dräger tube (part no. 26 112) with a detection range of 25-5000 ppm. Samples were collected over one minute using a hand held pump (n = 10 strokes). Five samples were collected on each of 2 days in the autoclave processing area and adjacent boiler room. No methanol or propanol were detected on the Dräger tubes used for area samples.

The results of the study demonstrate that the medical waste treatment workers at the autoclave system have minimal exposure to most chemicals with the exception of formaldehyde, where concentrations of 0.021 to 0.086 ppm were observed and a very short exposure to ammonia above the detection limit of the test method.

7.6 Indoor Air Quality

The indoor air quality was evaluated from using a Metrosonics Air Quality Monitor AQ-501 (S/N 1613). The air was evaluated for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO). Average values for the sampling sites at each facility are shown in Table 6. The indoor air quality evaluation for all three facilities indicated adequate indoor air during the sampling periods.

Table 6. Metrosonic Values for the Three Facilities

	Autoclave	Microwave	Pyrolysis
CO_2 averages (ppm)	466, 388, 532, 345[1]	412, 490, 469, 354, 342	358, 378
CO averages (ppm)	0, 0, 0, 0[1]	1, 0, 0, 0, 1	0, 0
Temperature average (°F)	65.1, 58.7, 75.9, 79.4[1]	70.8, 74.6, 77.8, 64.2, 73.4	68.0, 75.7
Relative Humidity average (%)	41.7, 57.1, 31.5, 53.5[1]	25.6, 23.3, 18.5, 31.4, 23.9	61.8, 43.5

1 Phase 2 values.

8.0 BLOODBORNE PATHOGEN EXPOSURE

The Phase 1 environmental sampling and analysis assessed the extent of blood contamination on a variety of surfaces and materials in the three medical waste treatment facilities. Evaluation of blood and/or blood containing body fluids on surfaces in the processing area could provide important information relative to identifying the most potentially hazardous steps in the treatment process, which through modifications in engineering and/or work practice controls, could minimize worker exposures. The blood contamination examinations consisted of visual inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection. The samples were collected and processed immediately for the presence of hemoglobin, using collection and analysis methods described in Appendix J.

In the steam autoclave facility, sampling was carried out throughout the processing area, but focused primarily in the tub dumping and washing areas. Sampling was carried out throughout the processing area of the microwave facility, but focused primarily in the waste loading and tub washing areas. Sampling for blood contamination was carried out on a variety of surfaces and materials in the processing area of the pyrolysis facility.

Forty five (45) wipe samples were collected at the autoclave facility. Twenty (44%) of the samples were positive, primarily those associated with pre-treated waste dumping and the waste dumping area, including the concrete floor and liquid waste spills, tub dumper and railing, waste conveyor rollers, and a long stick used to reposition waste bags in the treatment bins. Most samples collected from the control panel area were negative, presumably because that area is protected by splash shields, and those workers operating the controls and touching various buttons and switches usually removed their gloves prior to touching them. Four samples were collected at the post-treatment waste compactor, of which three were positive for residual hemoglobin. Those three surfaces were very soiled and undoubtedly contained settled residues from hundreds of post-treatment compactions. This is consistent with the knowledge that not all hemoglobin is broken down in the autoclave process, and that non-infectious blood residues can be expected to accumulate in the compaction area. For control purposes, three samples were collected from surfaces in the maintenance area adjacent to autoclave #2 and were found to be negative as expected. No samples were collected from surfaces in the tub washing area, since most surfaces in that area are usually wet with hypochlorite solution, which gives a false positive hemoglobin result. The entire outer surfaces of two of the workers' face shields were tested and found to be negative.

At the microwave facility, fifty (50) wipe samples were collected and processed immediately for the presence of hemoglobin. Thirty two (64%) of the samples were positive, primarily those associated with manual waste dumping including liquids on the concrete floor, the waste dumper surfaces, the microwave unit control panel, worker gloves, and sink surfaces. Worker goggles, telephone, scanning gun, computer keyboard, and drink machine were all negative.

At the pyrolysis facility, twenty (20) wipe samples were collected from various locations on the floor near the two pyrolysis units, where spots or stains were suspected of being from blood contamination, and also from conveyor belts, lifters, and associated conveyor framework for both units. Although a visibly cleaner facility with no blood or fluid splashes occurring during the evaluation, twelve (60%) of the samples were positive, indicating a possible presence of residual blood contamination, most likely from occasional leaking waste boxes and indicating the need for greater attention to routine cleaning and decontamination. It must be pointed out however, that the surfaces sampled were periodically treated with chlorine-based cleansers/disinfectants, and chlorine residuals may give false-positive results in the rapid hemoglobin test.

Visual assessment of the process used in the autoclave facility, along with hemoglobin test results, shows that the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Both automatic and manual tub dumping result in the splatter and splash of liquids from untreated, regulated medical waste. Similarly, assessment at the microwave facility shows that the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Both automatic and manual waste dumping results in the splatter and splash of blood and liquids from untreated medical waste. Also, blood residuals detected at the sink used for washing hands suggests the need for routine decontamination and cleaning of the area. One specific hazard in the microwave plant was the fine droplet spatter of blood-laced liquid when the tubs were dumped as shown by the splatters from floor level up to about 12 ft on the wall near unit 2.

Based on the Phase 1 observations and test results, it was recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes be conducted in the steam autoclave and microwave facilities using personal sampling techniques.

On several occasions workers at the pyrolysis facility were observed loading the boxes onto the conveyors with latex gloves for hand protection, but without protection of their street clothes. Without a protective gown or coat, a leaking box can easily contaminate clothing, perhaps unknowingly to the worker.

In Phase 2, a splash assessment protocol was developed to collect samples for residual hemoglobin from the upper torso area of the workers, in addition to residuals on face shields. Upper body splashes were assessed using cotton patches in cardboard holders pinned to the front and back of the workers' shirts. Following a work shift, the patches were assessed for visible blood and processed using the hemoglobin detection method as previously described. Worker face shields were wipe sampled prior to a work shift and then again at the end of the shift. Seven workers were evaluated over two days, with blood detected visibly and confirmed by hemoglobin testing on 2 of 6 sample patches from each of two workers. Of seven workers' face shields monitored over the two days, two were positive for hemoglobin after the work shift. A moderate amount of hemoglobin was detected on one face shield, while a trace amount was detected on another.

The personal monitoring that was conducted to assess worker exposures to blood splashes confirmed that workers in the facility who are responsible for the direct handling of the untreated medical waste are at risk for bloodborne pathogen exposures. The test results also confirmed visual observations of the waste loading or dumping operation that was conducted during the Phase 1 evaluation where environmental splashes of blood and other fluids were noted. Based on the combined results, it is recommended that, in the absence of engineering controls that fully automate the waste dumping procedures, management enforce the wearing and proper use of personal protective clothing and equipment, particularly face shields.

The single area, 6 hour air filter sample for blood aerosols collected on each of the two days and processed for hemoglobin were both negative, indicating that the waste handling process does not generate significant small airborne blood particles. Rather, the greatest blood exposure risk is from blood splashes as discussed above.

9.0 INFECTIOUS AGENT EXPOSURE

The Phase 1 survey assessed the extent of microbial contamination on a variety of surfaces and materials in the processing area of each facility. Detection of the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*, could assist in determining the extent of microbial contamination from untreated medical waste throughout the facility and the potential for worker contact exposures. Fifty surface samples, including three controls, were collected and processed at each facility using a surface wipe and direct plate technique as described in Appendix K.

Sampling at the autoclave facility was conducted primarily in the tub dumping area where splatters and splashes were common, the control panel area where workers sometimes touched buttons, switches, a telephone, and scanner with potentially contaminated gloves, and personal protective equipment such as face shields and gloves. Knobs on doors exiting the process area were also sampled, as were control surfaces from a rest room located in the administrative section of the building. Sampling at the microwave facility was conducted primarily in the waste dumping area where splatters and splashes are common, the unit control panel where workers touched buttons, worker gloves, and door handles and doorknobs. Office area restroom samples were collected and processed as controls. Sampling was conducted on various surfaces of the two pyrolysis units including the conveyor framework and belts, in addition to control panels and handles that the operators would touch in the performance of their duties. Various surfaces in and around a toilet in the main hospital building away from the treatment facility were sampled as environmental controls.

No *S. aureus* was isolated from any sample at any faculty. One autoclave, three microwave, and one pyrolysis sample were positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but they are common environmental contaminants and are inconsequential relative to assessing potential worker exposures to recognized human pathogens. While the results in general show little microbial contamination of facility surfaces, the *E. coli* isolate does indicate that surface contamination may be present at any time possibly with waste that could contain more virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses.

In Phase 2, in order to assess the potential for infectious agents to be liberated from the steam autoclave treatment process, bioaerosol monitoring was conducted during the treatment of indicator spiked and non-spiked medical waste, at previously identified potential emission points. Indicator organisms used included specific strains of *Bacillus stearothermophilus* and *Bacillus subtilis globigii* var *niger*. Three potential emission points were identified: 1) above the autoclave doors as they were opened at the end of the treatment cycle, 2) between the autoclaves as steam was liberated from a condensate drain, and 3) at the top of the compactor as the treated waste was dumped and compacted. Results from the M/G impactor samplers were negative for the recovery of any indicator spores from both the non-spiked and spiked treatment cycles. The AGI-30 impactors however, recovered indicator spores from both the non-spiked and spiked treatment cycles at all three locations. The difference in results shows the value of utilizing two different types of volumetric aerosol samplers. Overall the monitoring was inconclusive as to definitively confirming or rejecting the potential for microorganisms to be emitted during the steam autoclave process. The greatest potential for emissions is during the evacuation of air and steam from the chamber during pressurization. Effective engineering controls, however, exhaust the evacuation air through an enclosed dust system that culminates in passage through a carbon filter before exiting the building. These results most likely indicate that within the facility are residuals of *Bacillus* indicator spores on various surfaces, particularly as monitoring was conducted very close to soiled surfaces such as near the floor between the autoclaves and at the waste compactor. It is recognized that medical waste will contain these indicator spores from positive controls that are run in hospitals to assess sterilization procedures.

10.0 DISCUSSION

Three sites were included in the Phase 1 assessments: an off-site steam autoclave, an off-site microwave, and an on-site pyrolysis. The autoclave site was revisited for the one Phase 2 trip that was accomplished during year one of this contract. The first two facilities used standard methods used at many other facilities; whereas, the pyrolysis facility used a prototype treatment method with units that are regularly modified to improve their function and to test ideas for future models.

While the three facilities all treated medical waste, there was a wide range of approaches to the processing of the waste. Two of the facilities had a great deal of manual handling of the waste. Two of the facilities had frequent blood splashes, while the third facility had the waste prepackaged for ease of handling and smaller likelihood of leaks. The three facilities covered a large range of throughput from approximately 5000 lb/week to 1.3 million lb/week. Each facility was set up to allow processing of a set amount of waste with variation possible by changing the number of loads per shift or the number of hours of operation. The amount of waste processed is a function of the size and number of treatment machines in operation not of the type of treatment. For example, the microwave facility originally had one machine but added a second, thus doubling the possible throughput. Also the same technology with a smaller sized unit, such as those autoclaves present on-site at hospitals, would process less waste.

The three facilities handled the incoming and outgoing waste is different ways. Both of the off-site facilities accepted red bagged waste in large reusable tubs. These bags frequently leaked liquids into the tubs leading to spills onto the floors and workers. Although sharps were generally packaged in plastic sharps containers, when the bags were manually transferred, the workers were in danger from sharp edges of waste that might poke through the plastic as well as the bloody liquid dripping from the bags. The on-site facility and the off-site autoclave both accepted boxed and sealed waste. These containers served as an extra layer of protection for the workers. However, only at the on-site facility were the boxes required to be dry. The methods of handling and transporting the waste are facility specific as opposed to technology specific as treatment units are available or could easily be designed to treat waste either in bags or boxes. Thus the dangers inherent in handling the waste are connected to the specific facility.

The safety assessments showed significant positives and negatives for each site. Management at each site was proactive and provided worker training and protective equipment. Each facility showed problems similar to those of many industrial facilities and problems related directly to medical waste. Regular inspections of the facilities with respect to OSHA regulations and other applicable codes could easily spot the electrical, storage, spill, and ergonomic problems and result in safer workplace environments. Additional problems would be reduced if worker protection programs were regularly upgraded and were carefully followed including a prohibition on entering the waste treatment units.

The large amounts of manual labor that lead to ergonomic concerns could be reduced by stream lining the waste handling flow patterns, by increasing the use of manual aids, and by decreasing the height of the stacks of the tubs of waste if possible. Obviously, potential changes must be considered in light of what is possible in a specific facility. For it to be possible that the tubs could be stacked two high instead of three, there must be enough storage space available so that the incoming trucks can still be unloaded. All of these concerns should be considered in plans for new facilities.

While the first area noise survey of the autoclave facility demonstrated that the potential to exceed the OSHA PEL exists since the noise levels ranged up to 100 dBA in the process area, the data was inconclusive since it was only a survey and not a measurement of an 8 hour time weighted average noise exposure. The autoclave management has documented that the OSHA PEL is not exceeded doing routine work in the process area. The Phase 2 integrated noise surveys confirmed this with all three values falling into acceptable ranges.

Based on the integrated noise surveys, exceedence of the OSHA PEL for noise does not appear to be a problem for any of these facilities. The noise surveys did show some high levels at some locations for short periods. These high levels usually occurred where machinery was malfunctioning. So, noise levels in each facility should be monitored periodically to avoid excessive noise levels that could develop as changes are made to processes or as equipment ages or malfunctions. Hearing protection should be worn in areas where high noise levels are found and in areas specified in the hearing protection programs.

The survey of the microwave units demonstrated a leak around one of the microwave units. The leak was readily reduced once the operator was apprised of the situation. The microwave radiation exposure would be controlled by regular maintenance with operating equipment. This finding serves mainly to point out that, in addition to regular checks of the treatment equipment, all testing equipment must be regularly checked, calibrated as needed, and maintained.

During the Phase 1 trip to both the autoclave and the microwave facilities, the outdoor weather was extremely windy, so that the airflow in the facilities was quite gusty and more than sufficient to meet ASHRAE recommendations for fresh air, easily exceeding 20 cfm per person. However, it is impossible to tell whether this would be true on a still outdoors day. Inside the pyrolysis facility was breezy with plenty of air brought in by fans, as opposed to wind through building openings. During warmer times of year the roll up doors may be open to allow even more airflow. Thus all three facilities showed sufficient ventilation.

Aerosol measurements showed that none of the facilities had high aerosol burdens. At the autoclave facility almost all of the measurements were below 1 mg/m^3. Many of the concentrations were below 0.1 mg/m^3 indicating that respirable particles were not dangerously elevated. The microwave facility's highest value was 0.025 mg/m^3 with the pyrolysis facility even lower with the highest value at 0.018 mg/m^3 when the photoelectric eye was cleaned and the average concentration was around 0.006 mg/m^3. The technologies used either do not produce significant levels of particles, the air cleaners work well, or the ventilation air is diluting the particles to reasonable levels.

Most of the engineering control problems were not specific to medical waste. The examples that were encountered included the following. The autoclave had equipment that let water drain across the floor resulting in a slipping hazard. The microwave facility had a cooling system that could blow gases and particles from the waste into the worker's breathing zone. The pyrolysis facility had a sensor located so that worker was required to enter an enclosed space to clean it. Both of the off-site facilities had a great deal of manual handling of the waste, some of which could be reduced by appropriate engineering solutions. All of these problems could be present at many types of industrial facilities and are readily amenable to improvement, although the pyrolysis facility's problem will require a redesign of the unit. The feasibility of engineering controls to reduce manual labor and safety hazards should be investigated. Specifically, adding a floor drain or ducting the runoff water to a drain at the autoclave site would eliminate the slipping hazard. The microwave facility's cooling system could be reversed to pull air contaminants away from the workers. The newer model of the pyrolysis machine could, and is planned to, be designed with an easily accessible sensor. And waste handling could be reduced by using conveyor belts or allowing the mechanical lifts to do more of the waste container moving.

However, some of the engineering control problems were medical waste specific. For example, the pole used at the autoclave facility to prod the waste increased the likelihood that the worker would be exposed to liquids from the waste. Also, the ventilation screen of the air cleaner system in the microwave unit had to be cleaned by a worker who entered the waste hopper, thus potentially exposing the worker to the medical waste. These types of problems need to be addressed to reduce the risk of exposure.

Airborne chemical concentrations were determined for various types of organics, metals, and chlorine. The medical waste as received is not chemically treated and could be expected to contain any number of chemicals, most probably volatile metals such as mercury, VOCs, or aldehydes such as formaldehyde. Several VOCs were observed in each facility, but no OSHA PELs or ACGIH TLVs were exceeded. The highest concentration VOC within the autoclave facility was 2-propanol at 643 $\mu g/m^3$. The compound with the highest concentrations at the microwave facility was 2-propanol at 2318 $\mu g/m^3$. For the pyrolysis facility, the highest concentration VOC found decanal at 16 $\mu g/m^3$. The aldehyde results for all three facilities indicated concentrations of formaldehyde in the range below 0.2 mg/m^3 much lower than the OSHA PEL, lower than the ACGIH TLV (ceiling limit), but above the NIOSH REL. In both the autoclave and microwave facilities, acetaldehyde and acetone were also observed at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs. In Phase 2 an autoclave maintenance worker was briefly exposed to ammonia at concentrations exceeding 30 ppm which is above the NIOSH REL and the ACGIH TLV. No chlorine was detected in the air in the autoclave facility, the only site tested. The metals sampling indicated minimal levels (most less than the detection limits).

These airborne chemical results show that levels of tested chemicals in the indoor air were all low compared to recognized standards on the days sampled except for the short-term ammonia exposure of Phase 2. These results indicate that either the chemicals are not liberated in the treatment of the waste, the venting procedures for the treatment units work well, or the dilution in the facilities due to the high levels of outdoor air keeps the concentrations low. Note that the testing was all indoors and is not necessarily indicative of concentrations that may be emitted to the outdoors.

The indoor air quality evaluations for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO) indicated adequate indoor air during all four of the sampling periods, reinforcing the ventilation results as acceptable CO_2 levels show that sufficient ventilation air is present.

The surface blood contamination evaluations consisted of visual inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection. Among the three facilities, 56% of the hemoglobin wipe samples were positive. The samples from the pyrolysis facility may have shown false positives due to the use of a chlorine-based cleaner that the project team was informed of after the site visit. For the autoclave, the positives were primarily those samples associated with waste dumping and the waste dumping area. The three samples (of four) collected at the post-treatment waste compactor that were positive for residual hemoglobin, came from surfaces that were very soiled and undoubtedly contained residues from post-treatment compactions. This is consistent with the knowledge that not all hemoglobin is broken down in the autoclave process, and that non-infectious blood residues can be expected to accumulate in the compaction area.

At the microwave facility, the positives were primarily those associated with manual waste dumping including liquids on the concrete floor. One specific hazard in the microwave plant was the fine spray of blood-laced liquid when the tubs were dumped as shown by the splatters from floor level up to about 12 ft on the wall near unit 2. This could be addressed by requiring the workers and other personnel in the vicinity to wear a shield protecting the head and face such as a hard hat with face shield or the installation of a canopy over the control station. Another option would be to require the workers to leave the immediate area when the tubs are dumping.

Thus the hemoglobin testing indicated that blood is contaminating surfaces in both facilities where wet red bags are handled. Due to the possible false positives for the pyrolysis, it is not possible to base conclusions about the effectiveness of the prepacking of the waste on this data set.

Based on the Phase 1 observations and test results, it was recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes using personal sampling techniques. A splash assessment protocol was developed to collect samples for residual hemoglobin from the upper torso area of the workers, in addition to residuals on face shields. Blood was detected visibly and confirmed by hemoglobin testing on 2 of 6 sample patches from two of the seven workers sampled. Of seven workers' face shields monitored over the two days, two were positive for hemoglobin after the work shift. A moderate amount of hemoglobin was detected on one face shield, while a trace amount was detected on another. Thus, the personal monitoring that was conducted to assess worker exposures to blood splashes confirmed that workers in the facility who are responsible for the direct handling of the untreated medical waste are at risk for bloodborne pathogen exposures. The test results also confirmed visual observations of the waste loading or dumping operations that were conducted during the Phase 1 evaluation where environmental splashes of blood and other fluids were noted.

These results lead to recommendations to the autoclave and microwave facilities to reduce exposure to blood and body fluid splashes include providing adequate splash protection especially personal protective equipment. Enforcement of the use of face shields is especially recommended for the autoclave facility. For the pyrolysis facility, the workers who load the waste boxes onto the conveyors should wear protective clothing such as gowns or lab coats. A uniform policy on the use of gloves should be adopted at each facility. Protective clothing that is not worn home should be worn in the plant. To reduce transfer from the waste treatment areas to other areas, shoes that have been worn in the plant should be changed or covered before entering the office area. The autoclave facility currently provides uniforms to be worn only in the plant, but other facilities may benefit from addressing these issues. At the microwave plant, a separate eating/break area would reduce the likelihood of contamination through intentional ingestion; this hazard is highlighted by the positive samples at the sink near the drink machines.

The waste handling area samples for blood aerosols, collected on each of the two days of the Phase 2 trip and processed for hemoglobin as previously described were both negative handling area. Both samples were negative, indicating that the waste handling process does not generate significant small particle blood aerosols.

During Phase 1, the surface microbial contamination assessments looked for the presence of the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*. Sampling at the autoclave facility was conducted primarily in the tub dumping area, the control panel area, and personal protective equipment. Knobs on doors exiting the process area were also sampled, as were control surfaces in the administrative section. Sampling at the microwave facility was conducted primarily in the waste dumping area, the unit control panel, worker gloves, and door handles and doorknobs. Sampling was conducted on various surfaces of the two pyrolysis units including the conveyor framework, belts, control panels, and handles. Various surfaces in and around a toilet in the main hospital building were sampled as environmental controls.

No *S. aureus* was isolated from any sample at any facility. One autoclave, three microwave, and one pyrolysis sample were positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but they are inconsequential relative to assessing potential worker exposures to recognized human pathogens. While the results in general show little waste contamination of facility surfaces, the *E. coli* isolate does indicate that surface contamination may be present at any time possibly with waste that could contain more virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses. Accordingly it is again recommended that attention be given to daily routine cleaning and decontamination of treatment unit and other facility surfaces. Also, a uniform policy should be established and enforced as regards the wearing of gloves to operate buttons and switches on the various control panels.

An implication of not finding the two potentially harmful bacteria, *S. aureus* and *E. coli*, is that the inactivation of some human pathogens in medical waste begins to occur rapidly after waste generation due to adverse environmental conditions relative to temperature, moisture, and nutrients that were encountered during storage and transport. While this can be the situation for some vegetative bacterial pathogens, such results are not necessarily indicative of the absence of more environmentally resistant and virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses. The presence of some viable indicator bacteria suggest that some of the waste was recently generated. Otherwise, the organisms should have had time to die during transport and storage as indicated in Appendix K.

In Phase 2, to assess the potential for infectious agents to be liberated from the steam autoclave treatment process, bioaerosol monitoring was conducted during the treatment of spiked and non-spiked medical waste, at previously identified potential emission points. Indicator organisms used included specific strains of *Bacillus stearothermophilus* and *Bacillus subtilis globigii* var *niger*. Three potential emission points were sampled: above the autoclave doors as they were opened, between the autoclaves as steam was liberated from a condensate drain, and at the top of the compactor. Results from the M/G samplers were all negative for both the non-spiked and spiked treatment cycles. The AGI-30s however, were positive for both the non-spiked and spiked treatment cycles at all three locations. The difference in results shows the value of utilizing two different types of volumetric aerosol samplers. It also shows that in regard to the monitoring conducted, the results are inconclusive as to the potential for microorganisms to be emitted during the steam autoclave process. The results suggest that within the facility there are residuals of *Bacillus* indicator spores on various surfaces, particularly as monitoring was conducted very close to soiled surfaces such as near the floor between the autoclaves and at the waste compactor. It is recognized that medical waste may contain these indicator spores from positive controls that are run in hospitals to assess sterilization procedures.

While the data are inconclusive, it must be recognized that parametric monitoring of the treatment autoclaves indicated proper functioning of each cycle relative to temperature, pressure, and time, and that internal routine monitoring of the treatment process by the facility, using biological indicators, routinely demonstrates sterilization conditions. Also, and perhaps most importantly, the greatest potential for emissions from an autoclave is during the initial exhaust of the chamber prior to pressurization. In the studied facility, that exhaust is ducted to and run through a carbon bed filter.

11.0 SUMMARY AND CONCLUSIONS

Three sites were included in the Phase 1 assessments: an off-site steam autoclave, an off-site microwave, and an on-site pyrolysis. The autoclave facility was also visited for a Phase 2 assessment. The first two facilities used standard methods used at many other facilities; whereas, the pyrolysis facility used a prototype treatment method with units that are regularly modified to improve their function and to test ideas for future models. The autoclave and the microwave facilities had a great deal of manual handling of the waste. These two facilities had frequent blood splashes, while the third facility had the waste prepackaged for ease of handling and smaller likelihood of leaks. The three facilities covered a large range of throughput, although the respective technologies could all process the range of waste quantities, with appropriate facility set up.

All of the facilities had significant positives and negatives in their safety assessment. Based on this sample of medical waste treatment plants, management was found to be proactive, interested and concerned. Many of the negatives were similar to those expected at any industrial facility. For example:

- Required signs were missing.
- Flammable chemicals were found in non-flammable cabinets.
- Electrical hazards were present.
- Floors were wet, and potentially slippery, where liquid spilled.
- Large amounts of manual labor led to concerns over worker back and muscular strain and exposure to the waste for two of the facilities.
- Workers were required to enter four of the six treatment units.

Most of the negatives that were found could be fairly easily fixed. Most of the safety issues were similar to those that might be found in other industrial, non-medical waste, facilities and point to the need for facilities to periodically internally access the OSHA regulations and other applicable codes.

As far as hazards related directly to the medical waste, the most significant came from blood and liquid spills and from exposure to sharps, although the potential was greatly reduced in the plant where the waste handling was minimized.

Engineering control problems were mostly not specific to medical waste and could be present at many types of industrial facilities. Most of the engineering control problems are readily amenable to improvement, although the pyrolysis units's sensor will need to be relocated in newer designs of the unit. Some examples of the problems that were found are:

- The autoclave had equipment that let water drain across the floor resulting in a slipping hazard.

- The microwave facility had a cooling system that could blow gases and particles into the workers' breathing zones.

- The pyrolysis facility had a sensor that required a worker to enter an enclosed space to clean it.

- Cleaning the microwave unit's ventilation screen required that a worker enter the waste hopper, thus potentially exposing the worker to the medical waste.

Outside of the safety and blood related issues, the assessed areas show little to be concerned about.

- Noise was not shown to be above permissible limits.

- Microwave radiation levels were low when the unit was maintained correctly.

- Sufficient ventilation air entered at all facilities.

- No high aerosol concentrations were found.

- Several VOCs were observed in each facility, but no OSHA PELs or ACGIH TLVs were exceeded.

- Formaldehyde concentrations were in below the OSHA PEL and lower than the ACGIH TLV mg/m^3 (ceiling limit), but above the NIOSH REL.

- In both the autoclave and microwave facilities, acetaldehyde and acetone were also observed, but at concentrations several orders of magnitude lower than their respective PELs.

- Short-term, high concentrations of ammonia, not emanating from the medical waste, were found in the autoclave facility.

- The metals sampling for all three facilities indicated minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co, Ni, Zn, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg. The pyrolysis facility also showed minimum levels of P.

- No chlorine was detected in the air in the autoclave facility. (The other sites were not tested as no sources of chlorine were known.)

- The indoor air quality evaluations for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO) indicated adequate indoor air during the sampling periods.

Blood and microbial sampling and medical waste specific observation showed several areas of concern, indicating that workers do have the potential risk of blood and microorganism exposure:

- Surface blood contamination sampling showed that blood is getting on surfaces at at least two of the facilities.

- Blood splash assessment of the workers confirmed that workers in the facility who are responsible for the direct handling of the untreated medical waste are at risk for bloodborne pathogen exposures.

- Blood splash assessment of the workers confirmed visual observations of the waste loading or dumping operation conducted during the Phase 1 evaluation where environmental splashes of blood and other fluids were noted.

- Area blood samples were negative, indicating that any airborne blood drops are sufficiently large to fall out of the air quickly.

- Surface microbial contamination assessments showed some *E. coli* and other non-pathogenic organisms, but no *S. aureus*, indicating that microbial contamination, especially from hardier species, is possible.

- The waste-spiking experiments were inconclusive as to the potential for microorganism emissions from the steam autoclave.

Recommendations for MWTF based on these assessments include the following. These recommendations include changes that needed to be made at one or all of the assessed facilities.

- Perform periodic general safety inspections including checks based on OSHA regulations and other applicable codes.

- Regularly calibrate and check functioning of testing equipment including battery checks.

- Continue providing regular worker training.

- Do not allow workers to enter the equipment unless absolutely necessary. Explore other options first such as the use of a long handled broom to clean the ventilation screen in the microwave unit. If necessary, make provision for sanitization of the waste before the worker enters and require the use of protective clothing, gloves, boots, and head protection.

- Provide protective equipment as appropriate to the facility including adequate splash protection.

- Require that protective clothing that is worn in the facility not be worn home. This stricture should include all outerwear.

- Reduce possible transfer of contamination from the waste treatment areas to other areas by having shoes that are worn in the plant changed or covered before the wearer enters the office area.

- Give careful attention to daily routine cleaning and decontamination of treatment units and other facility surfaces.

- Provide areas separate from the medical waste treatment for workers to use for taking breaks and eating lunch.

- Carefully follow and upgrade worker protection programs to include specific glove use protocols based on the situation in each facility and the NIOSH recommendations for glove usage. Suggestions to consider include double gloving where one glove is likely to rip, wearing work gloves over disposable gloves when needed, and consistent use of gloves when operating controls.

- Monitor noise levels periodically and require that hearing protection be worn in high noise areas and in any areas specified in hearing protection programs.

- Reconsider waste packaging and handling procedures to minimize worker exposure.

- For future installations or major upgrades, ensure that process design engineers consider the worker-facility-unit interfaces to design out hazards.

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APPENDIX A.

STEAM AUTOCLAVE MWTF SCREENING REPORT

A.1 INTRODUCTION

This report describes a single technology of a multiple technology, multiple phase study. The first phase assessment of a steam autoclave facility is presented. Discussion of other technologies are presented as separate reports that will be combined for a final, overall, contract report.

The Medical Waste Tracking Act (MWTA) of 1988 defined medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals in research pertaining thereto, or in the production or testing of biologicals...". It categorized potentially infectious or "regulated medical waste" into seven types: culture and stocks; pathological wastes; human blood and blood products; sharps; animal waste; isolation wastes; and unused sharps. Treatment was defined as "any method, technique, or process designed to change the biological character or composition of any regulated medical waste so as to reduce or eliminate its potential for causing disease." The MWTA also had a destruction requirement that regulated medical waste be "ruined, torn apart, or mutilated," so as to be unrecognizable and non-reusable. Many of today's available technologies employ destruction as part of the treatment process.

This year more than 500,000 tons of medical waste will be processed in the United States prior to its ultimate disposal. Waste processing will be carried out at various "off-site" commercial treatment facilities, or "on-site" at health care facilities, laboratories, or industrial operations where the waste is generated. As the waste is transported, unloaded, treated, and disposed of, workers can be exposed to a variety of potentially hazardous medical waste components and treatment residues, to include biological and nonbiological aerosols, infectious agents, toxic chemicals, and radioactive materials. They may also be at risk regarding a number of safety related concerns including: injuries, noise, nonionizing radiation exposure, and duties and equipment having poor ergonomics. At the present time there is a significant lack of information on the identification, evaluation, and control of hazards associated with the treatment of medical waste.

A recent survey identified 114 commercial medical waste treatment facilities throughout the 50 states (Malloy, 1995). On average, such facilities operate two to three work shifts and process up to 100 tons of medical waste each day. We estimate that the total number of medical waste treatment workers in the United States easily exceeds 10,000. Thus, the CDC determined that basic information on the current practices in MWTF should be collected.

A.1.1 Project Overview

The scope of the overall project encompasses all currently-available medical waste treatment technologies, with emphasis on the identification, evaluation, and control of all hazards associated with at least three different treatment systems. Hazards may include, but are not limited to: aerosols (biological and nonbiological), organic vapors, vapors and gases of biocidal agents, nonionizing radiation, materials handling, and safety issues (sharps, ergonomics, etc.).

The project tasks can be broken down into 4 categories: 1) conduct literature and field studies necessary to identify all currently-available disinfection systems for infectious waste; 2) recommend three technologies and associated sites for field evaluation; 3) conduct on-site field studies to assess worker exposures to the identified hazards using conventional and novel industrial hygiene methodologies, conduct an assessment of biological contaminants contained in the detailed study plan and experimental design, and evaluate facility engineering controls for worker protection; and 4) providing a detailed and comprehensive final report. The final report will contain descriptions of all investigated treatment technologies, sampling and analytical methods, facility health and safety evaluations, data analyses and risk assessments, evaluation of engineering controls, discussion of results, recommendations to reduce worker exposures, and conclusions.

This research has several purposes, all of which are related to a better understanding of the medical waste treatment occupation, and its potential health and safety hazards. The study will include the accumulation of a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), risk assessment, and prevention and control. The information collected was specific to the sites tested and the workers' environments; thus, the data reflect a combination of the facility practices and the technology used.

For the requisite field evaluations, two phases were planned. Each Phase 1 visit includes an industrial hygiene survey and safety assessment for identification of occupational hazards (chemical and physical), potential treatment system emission points, and engineering controls. The Phase 2 visit will evaluate hazard exposures by conducting comprehensive personnel and area sampling and analyses (as indicated by Phase 1 results) using conventional and novel industrial hygiene practices for organic vapors, mercury, metals, bioaerosols, biological surface contamination, non-ionizing radiation, noise, particles, air quality factors, and evaluate the effectiveness of engineering controls to protect the workers.

A.1.2 Technology Overview

Traditionally, incineration has been a method of treatment and destruction of hazardous chemical waste, municipal solid waste, and pathological waste. It was logical that incineration would be used when concern regarding infectious disease agents such as the AIDS and hepatitis B viruses prompted the treatment of all medical waste and hence a new industry. Over the past several years however, environmental pollution concerns have fostered the development of a variety of medical waste technologies that are presently regarded as viable alternatives to incineration. Such technologies include steam autoclave, microwave, pyrolysis and mechanical/chemical disinfection. This report focuses on a steam autoclave facility.

Steam autoclave treatment combines moisture, heat, and pressure to inactivate microorganisms. The process has been used for sterilizing medical instruments in hospitals for decades, and the validation of autoclaving as a sterilization technique for medical equipment and supplies is well documented. Off-site commercial treatment autoclaves typically operate at 160°C and 80-85 psi and can treat some 3,000 lbs per cycle.

Concern for medical waste treatment workers comes from the unique character of the waste material and varying treatment technologies. Medical waste contains numerous chemicals that are themselves hazardous to worker health, and the MWTF technologies have the potential to generate others. Emissions from incineration have been extensively studied (US EPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies. Several types of health hazards are of particular concern in this respect: infectious agents (blood-borne pathogens and others); hazardous drugs and chemicals; and non-ionizing radioactivity. Routes of exposure can include skin, mucous membranes, inhalation, and ingestion; with hazards present or generated during treatment as aerosols, particulates, fluids, and sharps. The nature of the MWTF technologies can generate special concerns, such as exposure to non-ionizing radiation. Other concerns include safety hazards and risks of injury related to lifting, moving, slips, falls, machine guarding, and electrical problems. While significant hazard information and statistics are available for "health care workers," medical waste handlers and treatment workers have not been included in the data gathering. It is prudent to assume that medical waste workers are at risk for the same occupational illnesses and injuries as health care workers.

A.1.3 Methodology Overview

Phase 1 of this project focused primarily on emissions, safety, controls, and biohazards. It consisted of the following:

- an industrial hygiene survey,
- a comprehensive safety assessment,
- identification of potential emission points from the treatment system or process,
- area sampling for identification of target volatile organic compounds (VOCs),
- area sampling for airborne metals,
- area sampling for aldehydes,
- noise and nonionizing radiation measurements,
- identification and assessment of existing engineering controls,
- preliminary respirable aerosol assessment,

- the assessment of blood on surfaces, and
- the assessment of microbial surface contamination.

Each of these areas are discussed in detail later in this report. Details of the specific methodologies used are addressed in Appendices E-P. This Phase 1 survey was carried out by a field team of five people: a certified industrial hygienist (CIH), a certified safety professional (CSP), an experienced microbiologist, an engineer, and an environmental field sampling specialist. Phase 1 survey did not attempt to determine if the technology was efficiently treating the waste. This assessment examined worker exposures due to the environment at the individual facility due to the technology, the work procedures including the handling of the waste, and the facility itself. It is important to note that the effect on the individual worker's environment of safety features and dangers inherent in each technology is dependent on the use of the equipment in a given facility, the care given to following the manufacturers established procedures, the design of the facility (especially as regards to waste handling and ventilation), and the individual worker's adherence to the procedures at the given facility (for example, use of provided personal protective equipment).

The industrial hygiene and safety assessment surveys observed the waste treatment workflow and process, identified the hazards and routes of exposure unique to the waste treatment technology/facilty; secured floor plans, engineering control diagrams, and written safety policy; defined work shifts and worker populations; examined policy related to health promotion (e.g. hepatitis B vaccine, TB testing); described potential routes of exposure relative to specific job assignments, identified chemical compounds used or stored in the facility; identified unsafe procedures, practices or conditions, addressing all safety concerns, including machine guarding, slips and falls, and ergonomics; and identified training and personal protection devices currently used.

The proposed samples for Phase 1 included for air emissions: VOCs, metals, mercury, aldehydes, ketones, and particles; and surface contamination from blood or microbial.

Potential chemical and biological emission points were identified to ensure that subsequent sampling was properly targeted. The identification was performed by visual inspection and facility usage determination, as appropriate. The results of this screening were used to identify areas and personnel on which to concentrate additional sampling.

Ventilation and HVAC control devices as applicable to the facilities air supply were investigated. Measurements of airflow were taken. The airflow measurements were used to determine if sufficient air is entering the facility based on the ASHRAE standard for indoor ventilation requirements. An attempt was made to determine if contaminated air from the disposal facility is being vented to any other indoor location (such as entering the return air to a main air distribution location). Control devices that could create hazards of themselves were investigated in conjunction with the hazard identification. The evaluation of other engineering controls such as machine guarding, handrails, lifting assistance, noise control, and workplace ergonomics were included.

Phase 1 included aerosol measurements to provide a concentration profile for the room. The aerosol monitor was used to measure concentrations near each identified potential emission point and in several locations throughout the room. The concentration in the incoming outdoor air and the office air were determined.

Surface blood contamination is also an important consideration in medical waste treatment. Up to 10 treatment system surfaces with which workers may come in contact were monitored each day for blood contamination by a wiping procedure using sterile gauze. The gauze was then eluted with sterile water and the eluate was tested for blood using the Hemastix detection method.

The risk of medical waste treatment workers of dermal contact with infectious disease agents were assessed by sampling and analysis of treatment system surfaces for human pathogen indicator organisms. Suspect surface areas were evaluated by sampling and analysis for two strains of vegetative bacteria associated with human infection and/or contamination, *Staphylococcus aureus* and *Escherichia coli.*

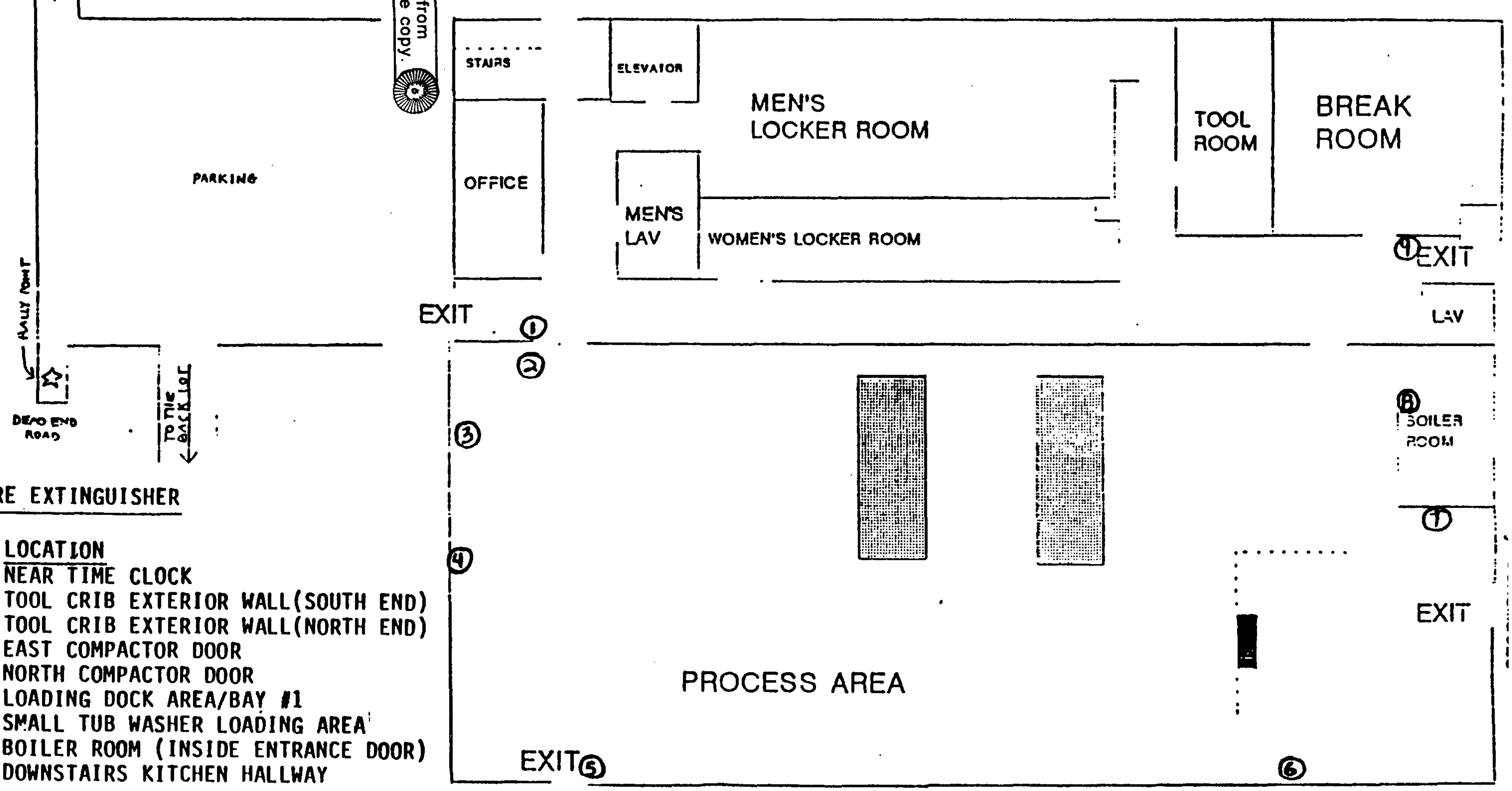
A.2 GENERAL SAFETY EVALUATION OF A STEAM AUTOCLAVE FACILITY

A.2.1 Summary

This steam autoclave facility occupies a light industrial building of approximately 16,000 square feet laid out as shown in Figures A-1 and A-1a . Untreated medical waste is delivered to the facility by means of tractor trailers and trucks carrying either sealed cardboard boxes of varying sizes or plastic tubs of varying sizes. The vehicles may be refrigerated or not depending on the source and travel time of the waste. The large tubs used weigh about 96 lb when empty and contain approximately 180 lb of medical waste; the samller tubs each contain approximately 50 lb of waste. The containers are moved to a processing area either manually or with assistance of carts or forklift. The processing involves filling large waste bins (approximately 5' x 5' x 5.5') either manually or with assistance of a hydraulic dumper. The bins are mechanically moved by conveyor into an autoclave which treats the waste under timed, steam conditions designed to completely disinfect all materials. After completing the treatment cycle, the bins are mechanically moved to a hydraulic dumper which dumps the waste into a hydraulic compaction unit which is attached to a compaction trailer into which the waste is pushed. Upon filling, the treated waste is hauled to a private landfill.

This facility used a combination of generally good engineering controls on equipment with heavy reliance on worker training and personal protective equipment for worker protection. Management is very proactive in their attempts to identify and train workers in proper techniques

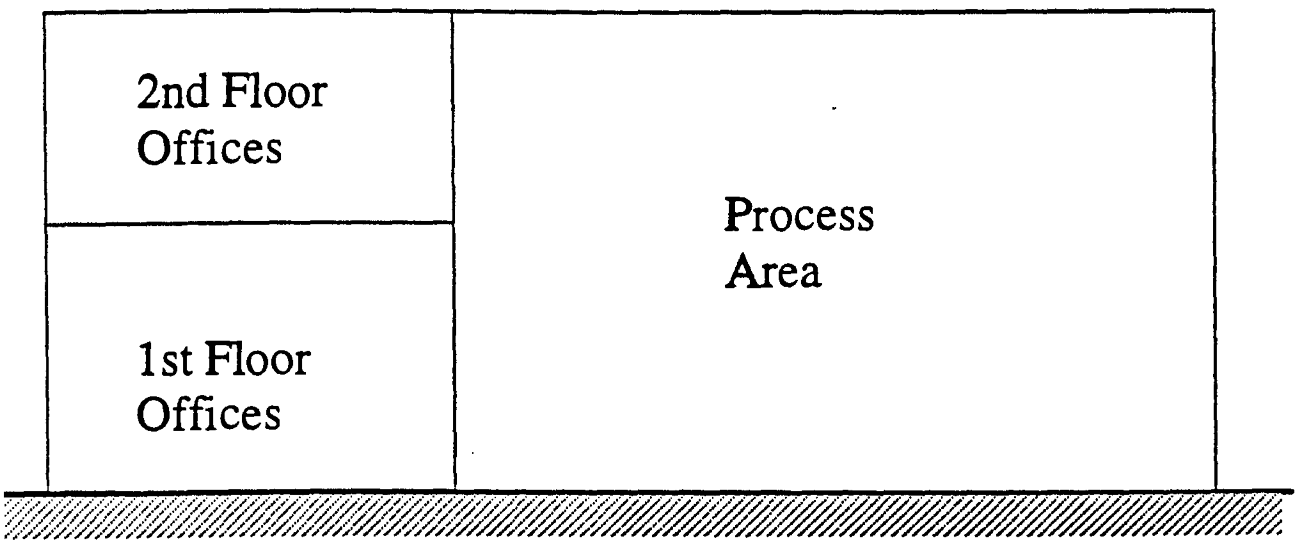
(1ST FLOOR)
EMERGENCY EXIT PLAN



O:FIRE EXTINGUISHER

ID#	LOCATION
1	NEAR TIME CLOCK
2	TOOL CRIB EXTERIOR WALL(SOUTH END)
3	TOOL CRIB EXTERIOR WALL(NORTH END)
4	EAST COMPACTOR DOOR
5	NORTH COMPACTOR DOOR
6	LOADING DOCK AREA/BAY #1
7	SMALL TUB WASHER LOADING AREA
8	BOILER ROOM (INSIDE ENTRANCE DOOR)
9	DOWNSTAIRS KITCHEN HALLWAY

Figure A-1a.
Schematic Sideview of Steam Autoclave Facility



for personal protection and had excellent training resources and manuals available. A strong emphasis on good housekeeping was noted throughout the facility. There were some structural deficiencies in parts of the facility and with equipment. The many intensive manual material handling steps combined with unsafe acts were the principal sources of worker exposure to hazards. The written compliance programs and program administration were excellent, but there are several areas recommended for improvement. The sequential job safety analysis of the primary jobs found the major personnel exposure hazards to be from the manual material handling found in virtually all tasks. The variability in job performance and variable use of personal protective equipment by different workers contributed to the overall worker exposure to hazards.

This section includes a detailed listing of findings. This review was as "global" as possible to include reference to OSHA regulations as well as good practices. This review was limited by the time available for the facility inspection, the number of job tasks reviewed, and the limited specific record review. Also, only management and corporate staff were approached for discussions to limit interference with the workers and their task performance. This examination focused on unsafe conditions, engineering controls, and compliance training materials. Limited review of unsafe acts and enforcement was done.

A.2.2 General Facility Review

Significant Positives

- A concerned and proactive management.
- The facility design with a "clean" side (offices, etc.), and "dirty" side (processing, shop, etc.) divided physically, operationally, and administratively.
- The operational requirement for all workers to shower out and change at the end of each shift.
- Overall workflow design minimized tasks interfering with each other.
- The exceptional attention to good housekeeping by workers and mechanics.

Significant Negatives

- The process design required extensive manual material handling/potential exposure to "contaminated" materials. This led to heavy reliance upon personal protective equipment and individual worker compliance to procedures.
- Exposure to unknown liquids, particularly at the tub dumping station. Walking surfaces were almost continuously wet from spillage, drainage, and cleaning. Direct discharge of water onto floor at plastic tub tunnel washer.

- Unguarded opening at the loading dock.

- Electrical safety hazards.

- Ergonomic hazards from manual lifting, twisting and pulling of boxes and tubs.

- General occurrence of unsafe acts such as: standing under elevated tubs without lockout protection, indiscriminate use and care of the "push stick" used at the tub dumper station, lifting/moving boxes over one's head, picking up unknown materials by hand, and entering "pit/horseshoe" area to retrieve material with conveyor system energized.

A.2.3 Specific Safety Concerns in the Plant

- Chocks unused at trailers.

- Change in elevation, home built skid, "ramp" for chemo-trailer did not allow use of chocks.

- Unguarded opening at loading dock.

- Lack of fall protection above autoclaves.

- Use of two non-plumbed eyewash stations not capable of 15 minutes of continuous drenching.

- Combustible oils/hydraulic fluid/greases in barrels in unprotected storage and subject to spillage on floor. 9 x 1 gallon of flammable liquid (methanol) stored unprotected on a high shelf in the parts area.

- Boiler room door (plant side) not labeled "*NOT AN EXIT*."

- Limited labeling of pipes - within boiler room and connecting to autoclaves.
  Note: Pipes were color coded.

- Electrical safety hazards:

  - Electric panel HL/B missing two blanks.

  - Electric forklift at tub washing station had frayed/taped cord at forklift housing entrance.

- Extension cords used as permanent wiring:

  Behind control panel leading to portable fan.

  Connecting tub washer unit to additive drum at lower level.

  Above loading dock leading to radiation detectors.

- Missing coverplate on electrical junction/control box on top of autoclave.

- Lack of emergency "kill" buttons/cable on primary conveyor loop; only disconnect boxes within the horseshoe area.

- Ground fault circuit interrupt receptacles needed at the tub washer/additive drum location.

- A full, unobstructed three foot clearance was not maintained in front of the primary electrical switchgear.

- Lack of preventive battery maintenance on ceiling mounted emergency lights.

● Miscellaneous

  - Two wooden stepladders with hazards: broken step on one; broken rail duct taped on the other.

  - Improper storage of oil in Pepsi bottles (i.e. mislabeled and improper container).

  - No labeling, NFPA diamond or other, on outside #2 diesel fuel oil tank.

  - Ends of forks on forklift used in tub handling area have sharp ends and extend beyond tub.

  - Confined space signs on each autoclave have small, faded lettering.

  - Work rest on grinder was >1/8 inch [correction made while at site].

A.2.4 Specific Safety Concerns in the Office Area

- No lighted EXIT sign above first floor, glass door adjacent to worker break/lunch room.

- Elevator was used as storage location for a handcart.

Recommendation

- The individual orientation of visitors to the plant noting the floor layout and exits meets the emergency plan condition. However, to cover anyone inadvertently missed, it is recommended that a office/plant diagram noting the exits be posted on each floor of the clean (office) side in an easily visible location.

A.2.5 Training Materials, Compliance Documentation, and Program Administration

Significant Positives

- The company Risk Management Manual was excellent in both form (utility) and function (complex detail presented succinctly and accurately).

- The "Bloodborne Pathogens Exposure Control Program" contained within the manual was comprehensive and current.

- Management was able to readily provide their copies of the OSHA required written programs (Figure A-2) for almost all areas requiring them (see recommendation below).

- A detailed "1996 Environmental, Health and Safety Calendar" covering training, reviews, inspections, record keeping, permits, monitoring, calibrations, reporting, and goals was available. A spot check of several items found the training being met.

- Both corporate representatives and plant management were proactive with training.

- The following is a list of written manuals:

  New Employee Hiring, Training and Orientation Policies and Procedures
  Occupational Medicine Procedural Manual
  Hazard Communication/Right-to-Know
  Confined Space Entry Program

Figure A-2 Status of Written OSHA Programs

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WRITTEN OSHA PROGRAMS

☑ Emergency Action Plans (Means of Egress) – Handout } Employees get a cc. of plan.	29 CFR 1910.35(i)
☑ Employee Emergency Plans & Fire Prevention Plans	29 CFR 1910.38(a)(1)
☑ Hazard Communication – Detailed program & MSDS's	29 CFR 1910.1200
☑ Lockout/Tagout – Detailed writeup & employees signed.	29 CFR 1910.147
☑ Access to Exposure and Medical Records – each employee – 1 year file – signed by each employee – Extensive occup. med. procedures manual	29 CFR 1910.20
☑ Hearing Conservation Programs – N/A – Annual audiograms – Written program – Survey done	29 CFR 1910.95
☑ Medical Services and First Aid – CPR & 1st Aid – Done offsite by Amer. Red Cross	
☑ Personal Protective Equipment – 3 ring binder	29 CFR 1910.Subpart I
☑ Respiratory Protection – Written * 1 full face SCBA in boiler room.	29 CFR 1910.134
☑ Injury and Illness Recordkeeping – cc. of 200 Log provided	(200 Log: Hazard Specific Standards)
☑ Electrical Safety-Related Work Practices – Contracted out.	29 CFR 1910.
☐ Fall Protection Program – NO	29 CFR 1926.Subpart M. Appendix E
☑ Confined Space Entry Program – Written – Access by contractors.	29 CFR 1910.146
☑ Fire Brigades – Do not have a fire brigade – Incipient only	29 CFR 1910.156
☑ Hot Work Permits – In process of writing; forms are in office.	29 CFR 1910.252(a)(iv)

Figure A-2. (Cont'd)

Written OSHA Programs (continued)

☑	Ground Fault/Assured Equipment Grounding Program - No written program	29 CFR 1910.304(b)(1)(ii)A
☑	Electrical ~~Hazardous~~ Locations (Missing) - Done via walkaround	29 CFR 1910.304(b)(1)(ii)A
☑	Emergency Response	
☑	Laboratories N/A	29 CFR 1910.1450
☑	Bloodborne Pathogens	29 CFR 1910.1030
☑	Cotton Dust Program N/A	29 CFR 1910.1043
☑	Air Contaminants IH monitoring shows no need for plan	29 CFR 1910.Subpart Z
☑	Process Safety Management - N/A	29 CFR 1910.106
☑	Radiation Program ____________ - Written	

Respirator Program
Bloodborne Pathogen Exposure Control Plan
Radiation Program
Lockout/Tagout Program
Personal Protective Equipment
Hearing Conservation Program

Significant Negatives

- None.

Areas Recommended for Review by Management

- Ground Fault/Assured Equipment Grounding Program [see 29 CFR 1910.304(b)(1)(ii)A] While this site is not a construction site in the context that the cited standard was written, the use of extension cords within the plant both in the material processing area and in the maintenance repair area, coupled with the presence of liquids and workers performing numerous tasks, suggests that a deliberate review of the shock hazard potential be examined. A written program, added to the EH&S calendar may be of value.

- Fall Protection Program [see 29 CFR 1926. Subpart M, Appendix E]. Although a construction safety standard, the basic premise of preventing falls more than 6 feet is applicable. A written fall protection program should not be necessary if the fall hazard that exists while climbing onto the top of the autoclaves for maintenance activities can be engineered out. If guardrails, nets, or a personal fall arrest system are infeasible, a written program should be prepared.

- A review of the list of hazardous materials on-site found numerous chemical names misspelled. This could hinder attempts to find the appropriate Material Safety Data Sheet (MSDS) in an emergency. [Note: A marked up copy was left on-site. A second review of the list with additional markups is included (Figure A-3). Only the chemical name column was reviewed. A more thorough and accurate list could be compiled using the MSDS book.]

A.2.6 Job Safety Analysis

A total of four processing tasks were observed in detail to identify the separate steps, hazards in each step and personal protective equipment (PPE) and/or safety aids used. Suggested changes to the steps were made. A summary, by task, is given below.

Figure A-3. Misspellings in Hazardous Materials Listing

CHEM_NM	TRADE_NM	MFG	CUR_QTY	QTY_PER	UNIT	LOCATION	MSD
AMMONIUM HYDROXIDE	AQUA AMMONIUM	MID-STATE CHEMICAL	110	1640	GAL	BOILER ROOM	YES
SODIUM SULFATE	BETZ 733	BETZ	20	470	LBS	BOILER ROOM	YES
BROMCRESOL GREEN INDICATOR	BROMCRESOL GREEN INDIC	BETZ	4	8	OZ	BOILER ROOM	YES
GALIC ACID	GALIC ACID	BETZ	1	8	OZ	BOILER ROOM	YES
HARDNESS BUFFER AGENT	HARDNESS BUFFER REAGEN	BETZ	1	2	OZ	BOILER ROOM	YES
HARDNESS INDICATOR	HARDNESS INDICATOR	BETZ	3	1	LB	BOILER ROOM	YES
HARDNESS TITRATING SOLUTION	HARDNESS TITRATING SOL	BETZ	1	1	GAL	BOILER ROOM	YES
ORANGE INDICATOR	METHYL ORANGE	BETZ	14	8	OZ	BOILER ROOM	YES
NITRILOTRIACETIC ACID L	OPTI-SPERSE 25	BETZ ENTEC	85	240	GAL	BOILER ROOM	YES
PHENOLPHTHALEIN	PHENOLPHTHALEIN	BETZ	14	5	OZ	BOILER ROOM	YES
VARIOUS	POTASSIUM IODIDE-IODAT	BETZ	2	1	GAL	BOILER ROOM	YES
PURPLE INDICATOR	PURPLE INDICATOR	BETZ	12	2	OZ	BOILER ROOM	YES
SODIUM IODIDE	SOLAR-SALT	AKZO INC	50	4000	LB	BOILER ROOM	YES
SULFAMIC ACID	SULFITE INDICATOR	BETZ	1	1	LB	BOILER ROOM	YES
SULFURIC ACID	SULFURIC ACID N/50	BETZ	1	1	GAL	BOILER ROOM	YES
POTASSIUM IODIDE	BLEACH REAGENT#1 R0644	TAYLOR TECHNOLOGIES	150	60	ML	LAB ROOM	YES
SODIUM BISULFATE	BLEACH REAGENT#2 R0458	TAYLOR TECHNOLOGIES	100	10	GR	LAB ROOM	YES
SODIUM THIOSULFATE	BLEACH REAGENT#3 R0646	TAYLOR TECHNOLOGIES	40	60	ML	LAB ROOM	YES
HYDROCARBON	DE-SOLV-IT	ORANGE-SOL INDUSTRIES	1	2	GAL	LAB ROOM	YES
CHLORINE	DPD SOLUTION (CHORINE)	BETZ	12	8	OZ	LAB ROOM	YES
ALKYL DIMETHYL BENZYL	ERESALINE	FENDALL'CO.	1	4	GAL	LAB ROOM	YES
HNO3-NITRIC ACID	HNO3	BETZ	5	8	OZ	LAB ROOM	YES
PH 10 BLUE BUFFER SOLUTION	PH 10.0 BLUE BUFFER	BDH INC	3	8	OZ	LAB ROOM	YES
PH4 RED BUFFER SOLUTION	PH 4.00 RED BUFFER	BDH INC	2	8	OZ	LAB ROOM	YES
PH 7.00 YELLOW BUFFER SOLUTION	PH 7.00 YELLOW BUFFER	BDH INC	2	8	OZ	LAB ROOM	YES
PHOSPHATE	PHOSPHATE BUFFER	BETZ	12	8	OZ	LAB ROOM	YES
POTASIUM IODINE	POTASIUM IODINE	BETZ	1	8	OZ	LAB ROOM	YES
SODIUM THIRSULFATE	SODIUM THISULFAT N0700	BETZ	8	8	OZ	LAB ROOM	YES
HYDROCHLORIC ACID	STARCH INDICATOR SOLUT	TAYLOR TECHNOLOGIES	40	40	ML	LAB ROOM	YES
SURFURIC ACID	SURFURIC ACID	BETZ	10	8	OZ	LAB ROOM	YES
SODIUM THIOSULFATE	THIOSULFATE REAGENT	TAYLOR TECHNOLOGIES	50	40	ML	LAB ROOM	YES
STODDARD SOLVENT	ALUMINIUM PAINT - 1200	UNITED GILSONITE LABS	2	1	GAL	PAINT CABINET	YES
ACETONE/NAPTHA	BATTERY TERM PROTECTOR	PLASTI-KOTE	12	8	OZ	PAINT CABINET	YES
PETROLLIUM DISTILLANT	BRAKE FLUID	NAPA	2	1	GAL	PAINT CABINET	YES
TOLUENE	CARBURATOR CHOKE CL.	MAC'S OIL	52	24	OZ	PAINT CABINET	YES
DICHLORO DIFLUOROETHANE	CONTACT CLEANER	CRC	75	50	OZ	PAINT CABINET	YES
PETROLEUM DISTILLATES	CUTTING OIL	RIDGID	1	15	GAL	PAINT CABINET	YES
PETROLEUM DISTILLATES	CWF	FLOOD CO	2	1	GAL	PAINT CABINET	YES
SILICON DIOXIDE	DRYLOK ANCHORING CEMEN	UNITED GILSONITE LABS	1	1	GAL	PAINT CABINET	YES
CALCIUM SULFATE	DURABOND PLASTER WALL	DAP	4	4	LBS	PAINT CABINET	YES
PETROLEUM DISTILLATES	EASY SURFACE PREP.	THE FLOOD COMPANY	1	1	OT	PAINT CABINET	YES
VARIOUS	HANDI FOAM	FOMO PRODUCTS	24	24	OT	PAINT CABINET	YES
METHLY ETHYL KETONE	LACQUER THINNER	E.E.ZIMMERMAN	1	1	GAL	PAINT CABINET	YES
ZINC METAL	LPS COLD GALVANIZE	LPS LABORATORIES, INC	14	8	OZ	PAINT CABINET	YES
1,1,1-TRICHLOROETHANE	MCLUB	MCGEE	3	1	OT	PAINT CABINET	YES
PETROLEUM DISTILLANT	NAUTICAL PAINT	NAUTICAL PAINT INC	1	1	GAL	PAINT CABINET	YES
DEASPHALTED RESIDUUM	WOCO WCP2 BRUSH ON COM	WOCO COMPANY	1	1	OT	PAINT CABINET	YES
DESPHALTED RESIDUUM DISTILLATE	WOCO TERMINAL PROTECT	WOCO COMPANY	12	24	OZ	PAINT CABINET	YES
ACETONE	SEYMOUR	SEYMOUR PAINT	4	20	OT	PAINT CABINET	YES
PETROLEUM NAPHTHA	SPRAY & GLUE	DAP INC.	30	10	OZ	PAINT CABINET	YES
MINERAL SPIRITS	TECH-GUARD BLUE ENAMEL	PRATT & LAMBERT	1	1	GAL	PAINT CABINET	YES
TITANIUM DIOXIDE	TECH-GUARD WHITE ENAME	PRATT & LAMBERT	4	1	GAL	PAINT CABINET	YES

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CHEM_NM	TRADE_NM	MFG	CUR_QTY	QTY_PER	UNIT	LOCATION	MSD
PETROLEUM DISTILLATES	THOMPSONS WOOD PRESERV	THE THOMPSON COMPANY	1	1	GAL	PAINT CABINET	YES
SULFURIC ACID	TRAILMOBILE CLEANER	NIAGARA NATIONAL CORP	1	1	GAL	PAINT CABINET	YES
SODIUM DODECYLBENZENE SULFONAT	ASPHALT RELEASE AGENT	ZEP	55	275	GAL	SUPPLY ROOM	YES
ANTI-BACTERIAL SOAP	BACTI-CREAM ANTISEPTIC	NATIONAL CHEMICAL LABS	0	4	GAL	SUPPLY ROOM	YES
N/A	BELT DRESSING	PERMATEX	12	0	OZ	SUPPLY ROOM	YES
SODIUM HYPOCHLORITE	BLEACH	MID STATE CHEMICALS	165	1650	GAL	SUPPLY ROOM	YES
SALT	BLUE FIRE	BENCH PROD. SALT LAKE	100	100	LBS	SUPPLY ROOM	YES
CALCIUM CARBONATE	BLUE PIPE JOINT COMPOU	PERMATEX	0	4	OZ	SUPPLY ROOM	YES
XYLENE	BRAKE CLEAN	VALVOLINE	102	75	OZ	SUPPLY ROOM	YES
PETROLEUM	CS-A ANTI-SEIZE	FEL-PRO	107	32	OZ	SUPPLY ROOM	YES
METHYL CYCLOHEXENE	CITROL DEGREASER CLEAN	LAKESIDE DISTRIBUTION	5	5	GAL	SUPPLY ROOM	YES
SODIUM METASILICATE	CLD DISHWASHER SOAP	NAMICO	50	50	LBS	SUPPLY ROOM	YES
ETHYLENE GLYCOL	CLEANER DEGREASER	ZEP	1	1	GAL	SUPPLY ROOM	YES
PROPANE/BUTANE BLEND	COUNTRY GARDEN MIST	ZEP	0	0	GAL	SUPPLY ROOM	YES
PETROLEUM DISTILLATE	CRC 2-26	CRC	132	20	OZ	SUPPLY ROOM	YES
PETROLEUM DISTILLATES	CRC 3-36	CRC IND.	132	20	OZ	SUPPLY ROOM	YES
AMONIUM OXALATE	CREAM-IT	NATIONAL CHEMICAL LAB	9	4	GAL	SUPPLY ROOM	YES
TRIETHANOLAMINE	CREAMY FOAM METAL CLEA	LAKESIDE DISTRIBUTION	102	0	OZ	SUPPLY ROOM	YES
SODIUM CARBONATE	DISH CLEANER/DEGREASER	WALTON-MARCH INC	3	3	LBS	SUPPLY ROOM	YES
SULFURIC ACID	DRAIN-A-GO-GO	SKASOL	7	0	QT	SUPPLY ROOM	YES
CRYSTALLINE SILICA	FLOOR ABSORBENT	OIL-DRI CORPORATION	400	1200	LBS	SUPPLY ROOM	YES
PHOSPHORIC ACID	FOAMING ACID CLEANER	ZEP	6	2	GAL	SUPPLY ROOM	YES
VARIOUS	FORMULA 777 WEED KILLE	ZEP	2	1	GAL	SUPPLY ROOM	YES
N/A	FRAGRANCE PACK	STATE CHEMICAL	20	0	EACH	SUPPLY ROOM	YES
METHYLENE CHLORIDE	GASKET REMOVER	PERMATEX	10	0	OZ	SUPPLY ROOM	YES
N/A	GROOVY-PASTE	ZEP	96		OZ	SUPPLY ROOM	YES
BISPHENOL A FUMARATE RESIN	H TEMP ANT-GALLING PIP	LOCTITE	0	0	EA	SUPPLY ROOM	YES
TOLUENE	HARD HAT STRIPING PAIN	RUST OLEUM	18		OZ	SUPPLY ROOM	YES
	LIQUID TIRE BUFFER	CAMEL PRODUCTS	32	0	OZ	SUPPLY ROOM	YES
METHACRYLIC ESTER	LOCKS NUTS	PERMATEX	50	200	ML	SUPPLY ROOM	YES
HEXAMETHYL DISILOXANE	LUBRI-OIL	FEL-PRO	4		OZ	SUPPLY ROOM	YES
ISOPROPYL ALCOHOL	MAGIC LENSE CLEANER	SILICONE STIRLING PAPE	100		WIPES	SUPPLY ROOM	YES
TRIETHANOLAMINE	METAL CLEANER CREAMY	CHEMICAL PACKAGING	9	12	OZ	SUPPLY ROOM	YES
PROPANE/BUTANE BLEND	METER MIST/NO ODOR	ZEP	0	0	EACH	SUPPLY ROOM	YES
PROPANE/BUTANE BLEND	METER MIST/ODOR NEUTRA	ZEP	0	0	EACH	SUPPLY ROOM	YES
PROPANE/BUTANE BLEND	METER MIST/SMOKESCREEN	ZEP	0	0	EACH	SUPPLY ROOM	YES
MINERAL SEAL OIL	MISTY LEMON OIL POLISH	AMREP, INC	1	1	GAL	SUPPLY ROOM	YES
N/A	MURPHY OIL SOAP	COLGATE-PALMOLIVE CO.	1	4	GAL	SUPPLY ROOM	YES
POLYSTYRENE EMULSION	NATURES SOLUTION	NATIONAL CHEMICAL CO.	1	25	GAL	SUPPLY ROOM	YES
PETROLEUM	NEVER-SEEZ	BOSTIK	1	1	LB	SUPPLY ROOM	YES
ISOPROPLY ALCOHOL	NO MORE LEAKS	PERMATEX	16	16	OZ	SUPPLY ROOM	YES
N/A	NOCO BATTERY BATH	NOCO COMPANY	16	32	OZ	SUPPLY ROOM	YES
SODIUM LAUREL SULFATE	PINK ANTISEPTIC SOAP	BOJO INDUSTRIES, INC	0	9	OZ	SUPPLY ROOM	YES
POLYGLYCOL DIOCTANOATE	PNEUM/HYD SEAL	LOCTITE	1		OZ	SUPPLY ROOM	YES
BUTOXYETHANOL	POLYSLIP	DIVERSITY CORP	55	100	GAL	SUPPLY ROOM	YES
SODIUM TALLATE	POWER PUNCH	NATIONAL CHEMICAL CO	3	110	GAL	SUPPLY ROOM	YES
LIVE BACTERIA	PRO.LINK LIQ. ENZYMES	PREFERRED DISTRIBUTORS	4	20	QT	SUPPLY ROOM	YES
HYDROCARBON	PROPANE FUEL	COLEMAN	0	5	LBS	SUPPLY ROOM	YES
SILICONE	RTV BLUE SILICONE	BALKAMP INC	0	4	OZ	SUPPLY ROOM	YES
SANOR SERIES	SANORSERIES SPRINGTIME	ROCHESTER MIDLAND	11	20	GAL	SUPPLY ROOM	YES
VARIOUS	SOLOPOL EF	STOCKHAUSEN	6000	12	L	SUPPLY ROOM	YES
NONYLPHENOXYPOLY	SOLVENT DEGREASER	ZEP	7	7	GAL	SUPPLY ROOM	YES

Figure A-3 (Cont'd)

CHEM_NM	TRADE_NM	MFG	CUR_QTY	QTY_PER	UNIT	LOCATION	MSD
PETROLEUM DISTILLATES	SOLVO RUST	PERMATEX	78	150	OZ	SUPPLY ROOM	YES
AMINO (ETHANOL) ETHANOL	WIPER PURGE	NAT. CHEM. LAB.	1	1	GAL	SUPPLY ROOM	YES
SALT	TRIPLE MELT	OSSIAN INC	150	200	LBS	SUPPLY ROOM	YES
ETHYLENE GLYCOL — Ammonium	TRUE BLUE GLASS CLEANE	WALTON-MARCH	60	150	OZ	SUPPLY ROOM	YES
AMMONIUM CHLORIDE	ULTRA 0128	ULTRA CHEM INDUSTRIES	2	2	GAL	SUPPLY ROOM	YES
ACRIDIETHOL	ULTRA-CLEANER	ULTRA CHEM IND	1	4	L	SUPPLY ROOM	YES
N/A — 5 ?	ULTRA-FLEX (FLOORCOAT)	ULTRA CHEM IND.	1	8	L	SUPPLY ROOM	YES
PROPYLENE ISOMER	ULTRA-STRIP	ULTRA CHEM IND	1	4	L	SUPPLY ROOM	YES
ETHYLENE GLYCOL	WHITE PEARL	NATIONAL CHEM LAB	2	20	GAL	SUPPLY ROOM	YES
NONIONIC SURFACTANT	WISE MOVE	WALTON-MARCH	64	8	OZ	SUPPLY ROOM	YES
ETHYL ALCOHOL	WOOD PLUS	NATIONAL BRANDS	1	0	GAL	SUPPLY ROOM	YES
HEXANE O.K.	ZEP AID HC	ZEP	2	6	LB	SUPPLY ROOM	YES
ISOPARAFFINIC SOLVENT	ZEP GROOVY	ZEP	180		OZ	SUPPLY ROOM	YES
ALIPHATIC NAPHTHA (ODORLESS)	ZEP SLIDE	ZEP	1	2	GAL	SUPPLY ROOM	YES
TRICHLOROETHANE	ZEPRIDE	ZEP	1	8	GAL	SUPPLY ROOM	YES
TRICHLOROETHANE	ZEPTOX II	ZEP	180	216	OZ	SUPPLY ROOM	YES
PETROLEUM DISTILLATE	#2 DIESLE	ROCO ENERGY	250	2800	GAL	TOOL ROOM	YES
VARIOUS	6011	HOBART	75	100	LBS	TOOL ROOM	YES
VARIOUS	7018	UNITED ALLOYS	100	200	LBS	TOOL ROOM	YES
(ACETYLENE) (ETHYNE) ? METHYLENE OR ETHYNE, NOT BOTH	ACETYLENE	LIQUID AIR CORP	138	520	CF	TOOL ROOM	YES
METHANOL	AIR BRAKE DEICER	MIDLAND	10	4	GAL	TOOL ROOM	YES
(METAL) CHLORIDE ! METHYL !	AIRFLOW INDICATOR TUBE	SENSIDYNE, INC	12	36	TUBE	TOOL ROOM	YES
SODIUM HYDROXIDE	ALKI FOAM	VIRGINA REFRIGERATION	3	8	GAL	TOOL ROOM	YES
(METHYL) ALCOHOL — METHYL	ANTI-FREEZE	NAPA	5	4	GAL	TOOL ROOM	YES
ARGON	ARGON	LIQUID AIR CORP	100	144	CU	TOOL ROOM	YES
HYDROCARBONS	CSA ANTISEIZE LUBRICAN	FELPRO	1	1	LB	TOOL ROOM	YES
LIGHT ALIPHATIC NAPHTHA	DYNA 143	ZEP	30	30	TOOL	TOOL ROOM	YES
ISOPROPYL ALCOHOL	FORM-A-GASKET	LOCTITE CO.	6	6	OZ	TOOL ROOM	YES
PETROLEUM DISTILLANTS	GEAR LUBRICANT	KENDALL	30	90	GAL	TOOL ROOM	YES
PETROLEUM HYDROCARBONS	HIGH TEMP GREASE	KENDAL	410	5760	LB	TOOL ROOM	YES
PETROLEUM HYDROCARBONS ?	HYDRAULIC OIL	KENDAL	55	270	GAL	TOOL ROOM	YES
POLYGLYCOL DIMETHACRYLATE	HYDRAULIC SEALANT	PERMATEX INDUSTRIAL	50	100	ML	TOOL ROOM	YES
PETROLEUM HYDROCARBONS	MOTOR OIL	KENDAL	55	40	GAL	TOOL ROOM	YES
PETROLEUM DISTILLATES	MYSTERY OIL	MARVIL	2	16	OZ	TOOL ROOM	YES
O2	OXYGEN	AIRCO	310	1152	CU	TOOL ROOM	YES
HYDROCARBON	PROPANE	KANN	92	96	OZ	TOOL ROOM	YES
(METHYL) ETHYL (KETONE) ACETONE	PVC CEMENT	OATEY	16	8	OZ	TOOL ROOM	YES
(METHYL) ETHYL (KETONE) KETONE	PVC PRIMER	OATEY	64	73	OZ	TOOL ROOM	YES
OHIO STATE CHEMICAL	SODIUM HYPOCHLORITE	OCCIDENTAL CHEMICAL	220	5000	GAL	TOOL ROOM	YES
HEPTANE	STARTING FLUID	MAC'S OIL & CHEMICAL	110	48	OZ	TOOL ROOM	YES
VARIOUS	SUPERCAST	UNITED METALS	2	5	LBS	TOOL ROOM	YES
PETROLEUM DISTILLANTS	TRANSMISSION FLUID	KENDALL	5	5	GAL	TOOL ROOM	YES
			=======	=======			
			11093	30092			

KETONE

! -- METHYL

DIMETHACRYLATE

PROBABLY BOTH ARE METHYL ETHYL KETONE

Task: Unloading Tubs from Trailer

Primary hazards: Fall, strains, pinches, cuts, slipping.

PPE Used: Work clothes, steel toed shoes, hard hat, leather gloves.

Safety Aids: Forklift.

Suggested Changes:

1) Guard, install floor, or otherwise protect workers from falling into the opening between the main floor and trailer. At a minimum, paint a 2" wide, bright yellow stripe along the perimeter of the hole (along both horizontal and vertical planes) and use wider dock plates.

2) Workers should always push tubs when moved manually.

3) Leather work gloves should always be worn.

4) Immediately remove from service any tub container with cracked/broken plastic.

Task: Manual Unloading of Boxes and Plastic Containers from Trailer

Primary Hazards: Fall, strains, needle sticks, cuts, slipping, direct fluid exposure.

PPE Used: Work clothes, steel toed shoes, hard hat, leather gloves.

Safety Aids: Cart

Suggested Changes:

1) Guard, install floor, or otherwise protect workers from falling into the opening between the main floor and trailer. At a minimum, paint a 2" wide, bright yellow stripe along the perimeter of the hole (along both horizontal and vertical planes) and use wider dock plates.

2) Wear latex gloves under leather gloves.

3) Wear leather apron or heavy rubber apron.

4) Wear oversleeves/protective sleeves to protect skin area between glove and shirt.

5) Always wear face shield down.

6) Lift and place one cardboard box at a time into bin.

7) Dump directly from plastic containers into bins (preferably using a mechanical aid) versus direct handling/lifting of waste bags.

Task: Loading Bins Using Tub Dumpers and Direct Loading

Primary Hazards: Splashing/direct fluid contact, puncture, strains, slipping.

PPE Used: Work clothes, steel toed shoes, hard hat with shield, leather gloves.

Safety Aids: Moveable rollers, "push stick."

Suggested Changes:

1) Always wear face shield down.

2) Wear latex gloves under leather gloves.

3) Wear leather apron or heavy rubber apron.

4) Wear oversleeves/protective sleeves to protect skin area between glove and shirt.

5) Dump directly from plastic containers into bins versus direct handling/lifting of waste bags.

6) The "push stick" should remain on the dirty side of the control system shield and be routinely disinfected after fluid contact.

7) Tub dumper operator should have a blocking pin/bar to place under raised tubs prior to entry in area under raised tubs, i.e. lockout procedures. Always have face shield down and minimize exposure to fluids.

8) Lockout procedures to be used if entry is made onto conveyor system to retrieve overflow material.

9) Always push carts.

Task: Washing Tubs and Plastic Containers

Primary Hazards: Slipping, pinches, burns, electrical shock, puncture.

PPE Used: Work clothes, steel toed shoes/rubber boots, hard hat with shield, rubber apron.

Safety Aids: Forklift

Suggested Changes:

1) Eliminate tripping hazard at tub washer by hard wiring and removing extension/electrical cord.

2) Install GFCI receptacle; repair cord to forklift.

3) Direct drain water from tunnel washer to sewer.
[Note: Management stated this project was to be done.]

4) Use forklift to stack tubs and eliminate manual lifting/stacking.

5) Replace/shorten the forks of the forklift to eliminate protrusion beyond tub.

Other - Miscellaneous

1) It has been confirmed that an EPA Identification Number was NOT needed at this facility.

2) The signage on the aluminum trailers hauling the treated waste should read: "MUNICIPAL" versus "MUNICIPLE."

A.3 EMISSION POINT IDENTIFICATION

During the initial visit to the autoclave facility potential chemical and biological emission points within the facility were identified to allow for subsequent, properly targeted, sampling. The identified potential emission sites for the facility included the autoclaves especially when venting, the exhaust stream from the air cleanup system, the truck unloading area, the bin loading area, the tub transfer and cleanup areas, and the compactor loading area. These emission points were the basis for the choices of sample sites.

A.4 CHEMICAL MEASUREMENT RESULTS

The medical waste as received is not chemically treated. The waste itself may contain any number of chemicals, potentially including volatile metals such as mercury, volatile organic compounds, or aldehydes such as formaldehyde. The most abundant chemicals used at the facility include hypochlorite solution (bleach) for washing of the containers and ZEP Asphalt Release Agent (sodium dodecylbenzene sulfonate) sprayed into the large autoclave bins. The boiler in an adjacent room to the process area of the facility uses ammonia as a rust inhibitor. A 55 gallon drum of ZEP Dyna 143 cleaning solvent (aliphatic naptha) was observed near the mechanical workshop area.

A.4.1 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) were collected by passing air through multisorbent cartridges containing Tenax TA, charcoal, and ambersorb (200 mm x 6 mm o.d., Envirochem, Kimblesville, PA). For analysis, VOCs on exposed cartridges were thermally desorbed then analyzed by gas chromatography/mass spectrometry (GC/MS). Identification of unknown sample constituents was performed using an electronic search of the NIH/EPA/MSDC Mass Spectral Data Base (NIST library) and the Registry of Mass Spectral Library (Wiley Library). Manual review of the data was performed to verify computer identifications and to identify compounds not found using the computer literature search. A semiquantitative estimate of the identified compounds was made using the total ion peak area for each compound and the total ion response factor measured for toluene. A concentration estimate for total VOCs was made using the same approach. Example VOCs that are amenable to analysis by the multisorbent method are shown in Table A-1. The VOCs found in the assessment were a subset of those that could be found by this method.

VOCs were collected at a flow rate of nominally 15 cc/min for 5 hours, in the process area near the control panel, over autoclave number 1 and at the compactor.

Several VOCs were observed at the facility and are listed in Tables A-2 through A-5 and Figures A-4 through A-7. The concentrations given are based on the formula weight of toluene, and only those individual VOCs found in excess of 0.05 mg/m^3 are reported. The total VOC content will comprise both those from the waste stream and from truck exhaust from the trucks unloading at the facility. No OSHA permissible exposure limits (PELs) or ACGIH threshold limit values (TLVs) were exceeded. The VOC field control recovery percentages are shown in Table A-6.

A.4.2 Hydrochloric Acid and Chlorine

Hydrochloric acid and chlorine are potential contaminants from the bin washing systems that use sodium hypochlorite based biocides. To screen for the presence of these chemicals in air, length-of-stain detector tubes (Drager part no's 24301 and 01681) for chlorine and hydrochloric acid were used (ASTM D4490, 1992). During screening, a known volume of air is drawn through the tube using a hand pump. As air is drawn through the tube, a calorimetric reaction occurs; the concentration is read from the demarcations on the tube. Air samples for hydrochloric acid and chlorine were collected in the vicinity of the bin washers.

The chlorine detector tube has a range of 0.2 to 3.0 ppm. No chlorine was detected at either side of the small bin washer or at either side of the large container washer.

The hydrochloric acid detector tube has a range of 1.0 to 10.0 ppm. No hydrochloric acid was detected at the small bin washer or at the large container washer.

Table A-1.
Example VOCs That Are Amenable to Analysis by the Multisorbent Method

1,2-Dichloropropane	C_3-Benzenes	Bromoform
1,1,2,2-Tetrachloroethane	C_4-Benzene	Isopropanol
Dibromochloromethane	Methylene Chloride	Propanol
Bromodichloromethane	Bromethane	Butanol
cis-1,3-Dichloropropene	Chloroethane	Pentanol
1,1,2-Trichloroethane	Chloromethane	Benzene
1,1-Dichloroethane	Chloroform	Toluene
1,2-Dichloroethene (Total)	Trichloroethene	Acrolein
trans-1,3-Dichloropropene	Chlorobenzene	Acrylonitrile
1,2-Dichloroethane	Ethyl Benzene	Styrene
1,1,1-Trichloroethane	Dichlorobenzenes	Vinyl Chloride
Carbon Tetrachloride	1,1-Dichloroethene	Xylenes
	Tetrachloroethene	

Site 1 Autoclave No. 1 4.87L

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4257

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ng/m3)
4.11	Methane, dichlorodifluoro-	84	250
4.63	Propane, 2-methyl-	70	362
6.39	Methane, oxybis-	52	119
6.86	Acetone	(c)	112
7.07	Methane, trichlorofluoro-	83	42
7.67	2-Propanol	60	643
8.23	Methane, dichloro-	87	25
8.52	Carbon disulfide	76	168
11.50	Chloroform	(c)	41
12.15	Ethanol, 2-methoxy-	76	2.5
13.63	1-Butanol	30	7.5
15.09	Ethene, trichloro-	89	1.9
15.48	Methyl methacrylate	58	11
16.77	Disulfide, dimethyl	96	2.0
18.00	Benzene, methyl-	93	34
19.69	Pyrazine, methyl-	79	4.7
19.88	2-Furancarboxaldehyde	95	47
21.88	Benzene, ethyl-	89	72
22.30	m,p-Xylene	96	329
22.47	Cyclohexanone	87	22
22.90	Styrene	95	24
23.14	o-Xylene	96	99
23.27	Ethanol, 2-butoxy-	83	8.3
24.69	2-Propanol, 1-butoxy-	89	12
25.69	Phenol	94	20
27.63	Benzenemethanol	89	3.6
27.84	1-Hexanol, 2-ethyl-	86	50
28.39	Limonene	96	155
32.76	Ethanol, 2-(2-butoxyethoxy)-	64	9.9
	Total Volatile Organic Hydrocarbons		3308

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure A-4. VOC Results
Site 1 Autoclave No. 1

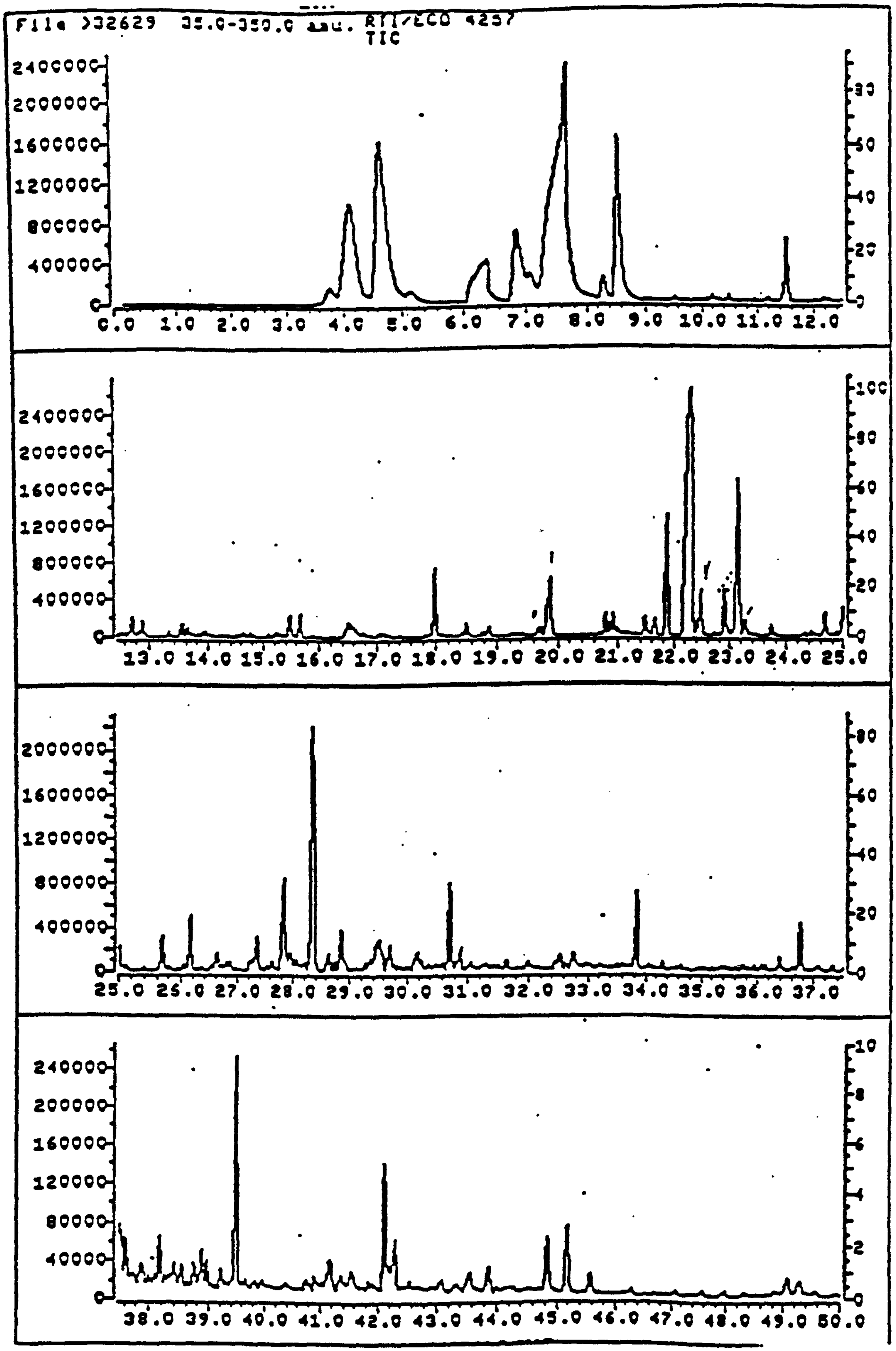


Table A-3. VOC Results
Site 1 Compactor 4.67L

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4259

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
4.10	Methane, dichlorodifluoro-	87	215
4.64	Propane, 2-methyl-	60	239
6.41	Methane, oxybis-	52	137
6.86	Acetone	59	104
7.08	Methane, trichlorofluoro-	83	9.3
7.65	2-Propanol	76	556
8.29	Methane, dichloro-	87	11
8.52	Carbon disulfide	76	95
11.50	Acetic acid, ethyl ester	11	15
12.16	Ethanol, 2-methoxy-	76	5.1
12.74	2-Propanone, 1-hydroxy-	60	10
15.48	Methyl methacrylate	58	7.2
17.99	Benzene, methyl-	93	23
19.69	Pyrazine, methyl-	86	5.3
19.89	2-Furancarboxaldehyde	95	51
21.88	Benzene, ethyl-	87	71
22.29	m,p-Xylene	96	330
22.48	Cyclohexanone	87	31
22.91	Styrene	96	26
23.14	o-Xylene	96	102
23.26	Ethanol, 2-butoxy-	83	9.9
24.68	2-Propanol, 1-butoxy-	89	14
25.12	Terpene isomer	(c)	3.4
25.71	Phenol	94	29
27.64	Benzenemethanol	89	6.0
27.86	1-Hexanol, 2-ethyl-	86	79
28.40	Limonene	96	203
32.75	Ethanol, 2-(2-butoxyethoxy)-	53	8.6
37.86	Phenol, 2,6-bis(1-methylethyl)-	86	2.1
	Total Volatile Organic Hydrocarbons		3011

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure A-5. VOC Results
Site 1 Compactor

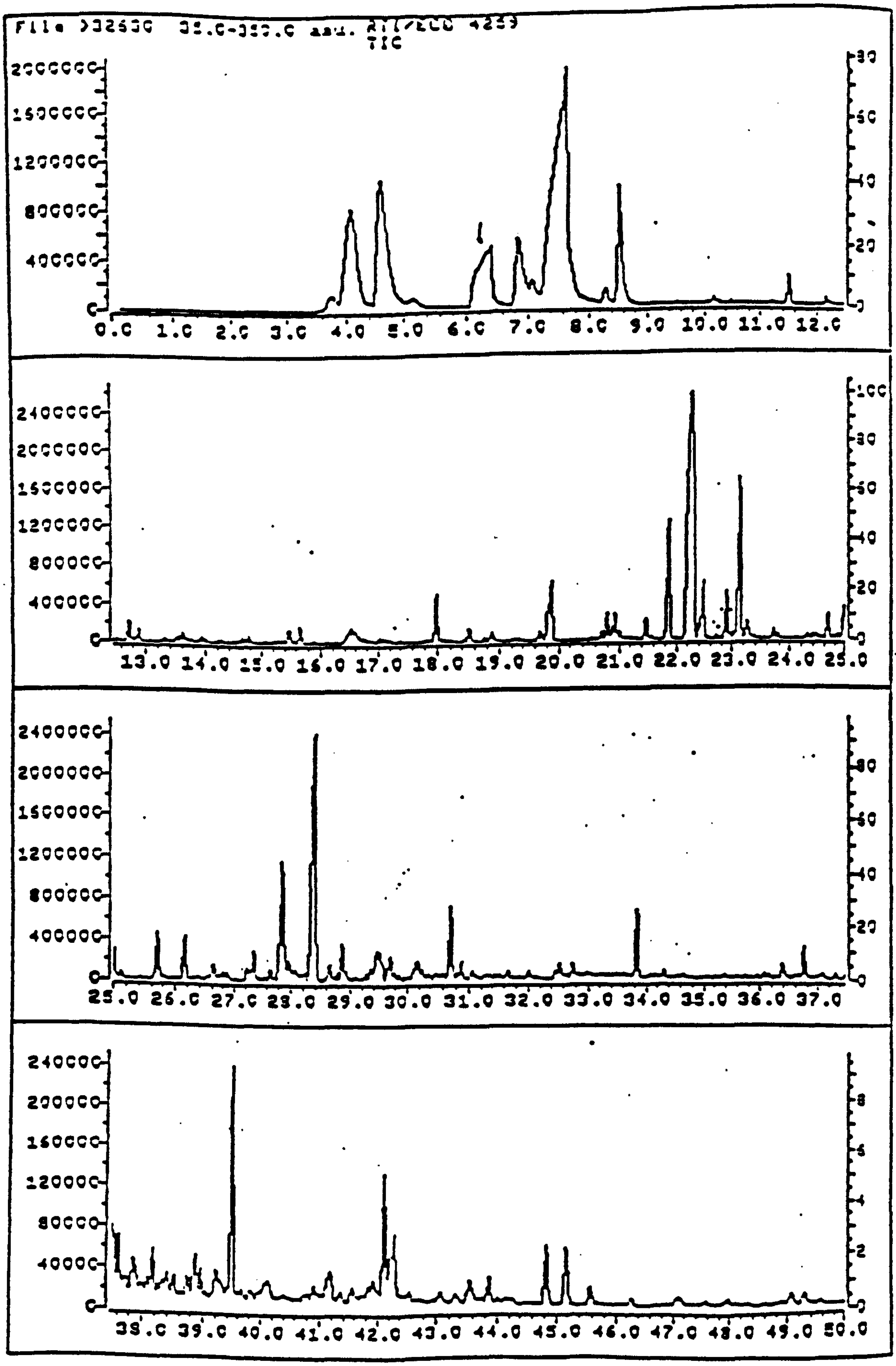


Table A-4. VOC Results
Site 1 Operator Area 4.35L

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4260

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
4.10	Methane, dichlorodifluoro-	87	218
4.62	Propane, 2-methyl-	70	324
6.41	Methane, oxybis-	31	149
6.57	Acetonitrile	76	251
6.86	Acetone	50	133
7.63	2-Propanol	78	589
8.28	Methylene chloride	87	15
8.52	Carbon disulfide	76	148
11.51	Chloroform	70	35
12.15	Ethanol, 2-methoxy-	76	5.8
12.73	2-Propanone, 1-hydroxy-	60	12
13.53	Benzene	86	7.0
13.63	1-Butanol	78	10
15.48	Methyl methacrylate	58	9.8
17.99	Benzene, methyl-	93	32
19.69	Pyrazine, methyl-	84	4.4
19.87	2-Furancarboxaldehyde	95	44
21.88	Benzene, ethyl-	87	71
22.28	m,p-Xylene	96	330
22.47	Cyclohexanone	86	27
22.90	Styrene	95	21
23.13	o-Xylene	96	99
23.28	Ethanol, 2-butoxy-	83	22
24.68	2-Propanol, 1-butoxy-	89	11
25.69	Phenol	94	21
27.63	Benzenemethanol	89	3.7
27.83	1-Hexanol, 2-ethyl-	86	47
28.38	Limonene	96	156
32.75	Ethanol, 2-(2-butoxyethoxy)-	76	8.2
	Total Volatile Organic Hydrocarbons		3518

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure A-6. VOC Results
Site 1 Operator Area

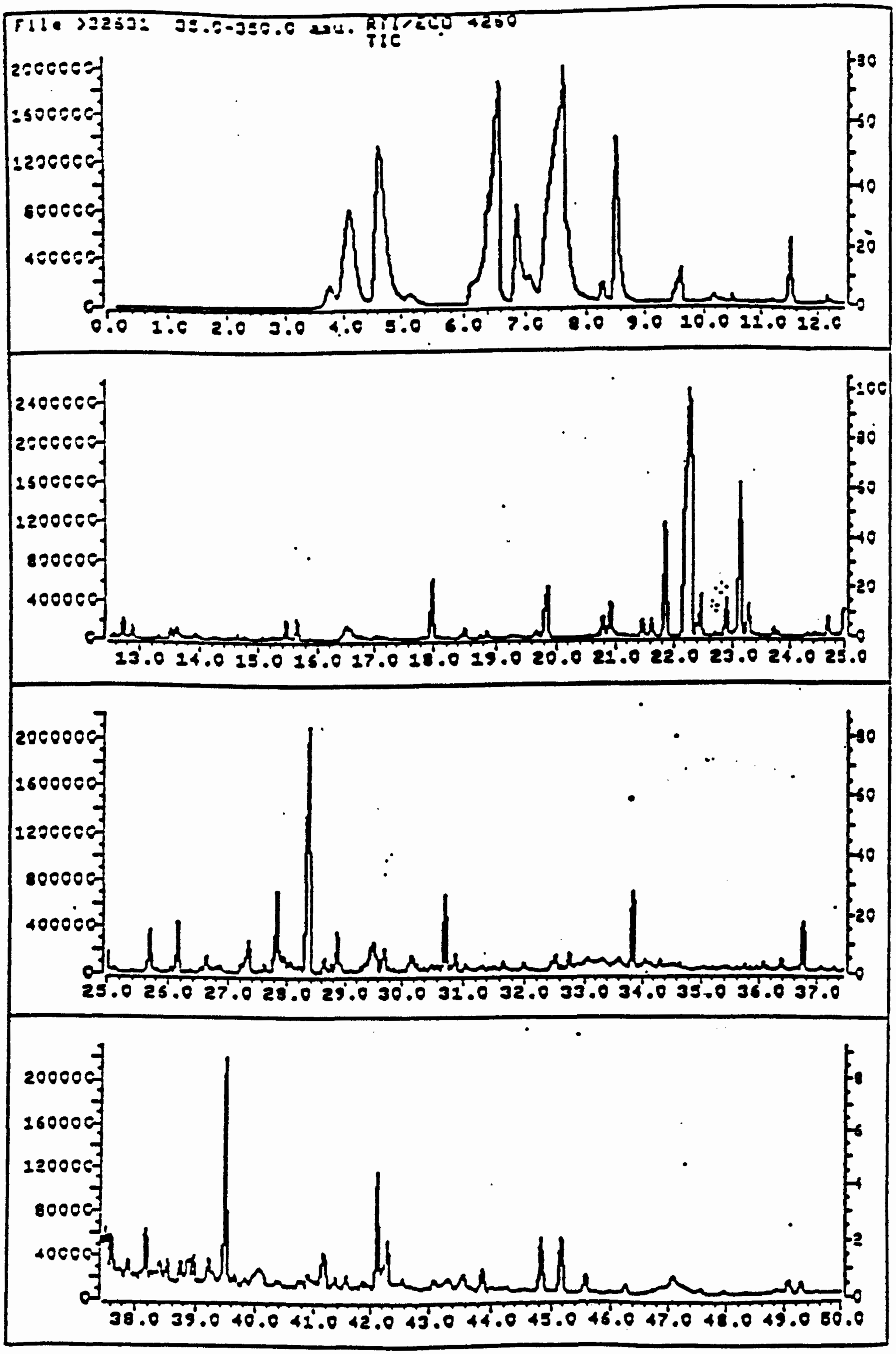


Table A-5. VOC Results
Site 1 Field Blank

QUALITATIVE IDENTIFICATION REPORT

FB-1 Site 1

Retention Time (min.)	Peak Identification(a)	Fit(b)
12.57	Internal standard	
21.54	Internal standard	

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure A-7. VOC Results

Site 1 Field Blank

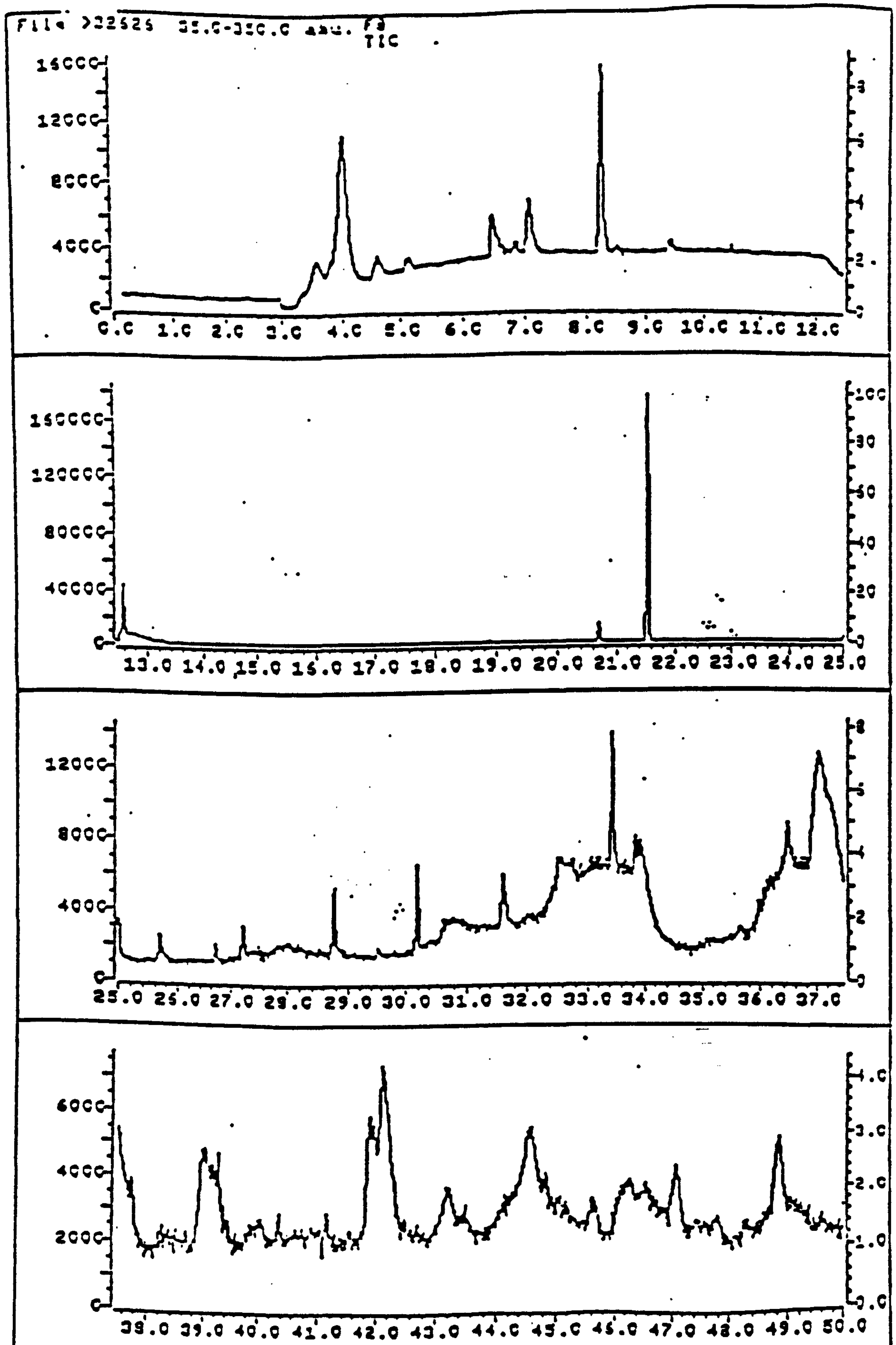


Table A-6.
Medical Waste
Field Control Recoveries VOCs

	Site 1 % Recovery FC vs. LC[a]
Chloroform	148.0
Toluene	153.6
o-Xylene	97.7
Vinyl chloride	19.3
Benzene	97.2
trichloroethylene	96.5

[a] Field control versus lab control

A.4.3 Aldehydes and Ketones

Formaldehyde is a contaminant that may be emitted during the treatment of medical waste. Formaldehyde and other volatile aldehydes and ketones were screened for using a silica gel/DNPH-(2,4-dinitrophenylhydrazine) method (US EPA, 1988). During air sampling, aldehydes/ketones instantaneously react on the cartridge to form the DNPH derivative. For analysis, the DNPH/aldehyde/ ketone derivatives were eluted from the cartridge with acetonitrile. This extract was then analyzed by high performance liquid chromatography (HPLC). Aldehyde/ketones were identified by comparison of their chromatographic retention times with those of purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range 0.02 to 15 ng/μL of the DNPH/aldehyde derivatives. Standards were analyzed and a calibration curve calculated by linear regression of the concentration and chromatographic data. A list of aldehydes/ketones analyzed during Phase 1 screening is shown in Table A-7.

Table A-7. Example Aldehyde/ketones Analyzed During Phase 1 Screening

Formaldehyde	Acetaldehyde	Acetone	Acrolein
n-Propanal	Crotonaldehyde	n-Butanone	n-Butanal
Benzaldehyde	n-Pentanal	n-Tolualdehyde	n-Hexanal

Aldehydes were collected at a flow rate of nominally 120 cc/min for 7 ½ hours at the process area near the control panel, over autoclave number 1, and at the compactor.

The aldehyde results (Table A-8) indicated concentrations of formaldehyde in the range of 0.08 to 0.18 mg/m^3 as compared to the OSHA PEL of 0.94 mg/m^3 and the ACGIH TLV of 0.37 mg/m^3 (ceiling limit). Acetaldehyde and acetone were also observed but at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs of 360 and 2400 mg/m^3.

A.4.4 Metals sampling and analysis

The methodology for metals sampling used the EPA draft method 29 sampling train for combustion source emissions (US EPA, 1986). The sample system incorporates a glass fiber filter followed by two (2) impingers containing acidified peroxide solution for collection of aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), labile mercury (Hg^{+2}), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl) and zinc (Zn). Following the

Table A-8.
Results of Aldehyde Analysis

Sample ID	Location	Air Volume
4262	Site 1 - autoclave No. 1	54.7 L
4263	Site 1 - compactor	55.1 L
4264	Site 1 - operator area	56.1 L
4265	Site 1 - operator area duplicate	60.0 L
FB-1	Site 1 - field blank	0.0 L

Concentrations expressed in ($\mu g/m^3$)							
Sample	Field Control	Solution Blank-B1	4262	4263	4264	4265	Field Blank-1
Compound	% Recovery						
Formaldehyde	86	<2.6	141	185	124	79	<2.6
Acetaldehyde	99	<2.6	73	73	67	35	<2.6
Acetone	98	<2.6	95	88	90	61	<2.6
Acrolein	0	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Propionaldehyde	91	<2.6	27	40	27	19	<2.6
Crotonaldehyde	4	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
2-Butanone	64	<2.6	7.4	5.4	5.6	<2.6	<2.6
Methacrolein	2.5	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Butyraldehyde	88	<2.6	12	13	11	4.9	<2.6
Benzaldehyde	99	<2.6	13	18	8.2	5.9	<2.6
Valeraldehyde	71	<2.6	<2.6	3.4	<2.6	<2.6	<2.6
m-Tolualdehyde	84	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Hexanal	76	<2.6	4.9	5.5	8.6	3.3	<2.6

peroxide impingers were two impingers containing acidified potassium permanganate for the collection of elemental mercury (Hg°). The draft method has been evaluated extensively at RTI and other laboratories, particularly for mercury species. In addition, the method has been used in the field by a large number of industrial stack testing contractors. A miniaturized version of the sampling train that incorporates midget impingers (1 - 2 L/min sampling rates) instead of the Greenburg/Smith impingers (approximately 20 L/min) was used.

Metals were collected at a flow rate of nominally 1 Lpm for 8 ½ hours at the area over autoclave number 1 and at the compactor.

The measurement of these resulting samples included graphite furnace atomic absorption (GFAA) for As, Sb, and Se; cold vapor atomic absorption (CVAA) for Hg°, inductively coupled plasma mass spectrometry (ICP/MS) (EPA Method 200.8) for Al, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Ni, Ag, Tl and Zn; and inductively coupled plasma emission spectrometry for Al, Fe, Zn and P. These methods are described in both the NIOSH Manual of Analytical Methods (NIOSH, 1994) and in EPA "Methods for Chemical Analyses of Water and Wastes" (EPA 600/4-79-020).

The results of the metals sampling (Tables A-9 through A-11) indicate minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co, Ni, Zn, P, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg. Quality control data for the metals testing is shown in Table A-12.

A.4.5 Indoor Air Quality

The indoor air quality was evaluated from 3/26/ 96 to 3/27/96, using a Metrosonics Air Quality Monitor AQ-501 (S/N 1613). The air was evaluated for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO). The results (Table A-13) indicate adequate indoor air during the sampling period.

A.5 NOISE

A noise survey was conducted on 3/26 - 3/27/96 using a Quest Sound Level Meter (S/N DL8110002) calibrated with a Quest Calibrator (S/N J8100013). The noise survey demonstrated that noise levels ranged from 69 to 100 dBA in the process area and from 44 to 53 dBA in the office area (Figures A-8 and A-9). The sources of the loudest noise in the process area include the mechanical shaking the drums at the compactor, venting/ramping of the autoclave steam, rolling bins off of trucks, the entrance to the container washer, and the radio located near the loading dock. While the area noise survey demonstrated that the potential to exceed the OSHA Permissible Exposure Limit (PEL) of 90 dBA exists, the data is inconclusive since it was only a survey and not a measurement of an 8 hour time weighted average noise exposure. Most of the noise is intermittent and scattered at various locations throughout the plant floor. Company management has a hearing conservation program in place and has documented that the OSHA PEL is not exceeded during routine work in the process area. There is a supply of foam ear plugs available at the entrance door to the process area but no employees were observed to be wearing any hearing protection. The hearing conservation program requires employees to wear hearing

Table A-9. Site 1
Metals Analysis ($\mu g/m^3$)
Blank Corrected

.ocation I/ECD No. Identifier Volume (m^3)	Autoclave 4272 Prefilter 0.522	4266 Impinger 1 0.522	4267 Impinger 2 0.522	4268 Impinger 3 0.522	4268 Impinger 4 0.522	4269 Impinger 5 0.522	4271 Impinger 6 0.522
als							
Be	<0.06	<0.06	<0.06	<0.06	a	a	a
Al	<6.0	<6.0	<6.0	<6.0	a	a	a
Cr	<1.0	<1.0	<1.0	<1.0	a	a	a
Mn	<0.06	<0.06	<0.06	<0.06	a	a	a
Fe	<1.0	<1.0	<1.0	<1.0	a	a	a
Co	<0.4	<0.4	<0.4	<0.4	a	a	a
Ni	<0.2	<0.2	<0.2	<0.2	a	a	a
Zn	<1.0	<1.0	<1.0	<1.0	a	a	a
Cu	<0.06	0.0785	0.0766	0.0632	a	a	a
Cd	<0.02	<0.02	<0.02	<0.02	a	a	a
Sb	<0.02	<0.02	<0.02	<0.02	a	a	a
Ba	1.0249	0.1820	0.0421	0.0364	a	a	a
Tl	<0.02	<0.02	<0.02	<0.02	a	a	a
Pb	<0.1	<0.1	<0.1	<0.1	a	a	a
Hg^{+2}	0.0050	0.0105	0.0305	b	a	a	a
Hg°	c	c	c	c	0.3801	b	0.8107
As	<0.1	<0.1	<0.1	<0.1	a	a	a
Se	<0.1	<0.1	<0.1	<0.1	a	a	a
Ag	<0.1	<0.1	<0.1	<0.1	a	a	a
P	<10.0	<10.0	<10.0	<10.0	a	a	a

a. Impingers 4-6 analyzed only for Hg°
b. Solution lost to analysis
c. Prefilter and impingers 1-3 analyzed for Hg^{+2}

Table A-10. Site 1
Metals Analysis ($\mu g/m^3$) Set 2
Blank Corrected

Location RTI/ECD No. Identifier Air Volume (m^3)	Compactor 4278 Prefilter 0.528	4273 Impinger 1 0.528	4274 Impinger 2 0.528	4275 Impinger 3 0.528	4276 Impinger 4 0.528	N/A Impinger 5 (broke)	4277 Impinger 6 (Rinse)
Metal Be	<0.06	<0.06	<0.06	a	n	N/A	b
Al	<6.0	<6.0	<6.0	a	b	N/A	b
Cr	<1.0	<1.0	<1.0	a	b	N/A	b
Mn	<0.03	<0.03	<0.03	a	b	N/A	b
Fe	1.3447	<1.0	<1.0	a	b	N/A	b
Co	<0.4	<0.4	<0.4	a	b	N/A	b
Ni	<0.2	<0.2	<0.2	a	b	N/A	b
Zn	1.0795	<1.0	<1.0	a	b	N/A	b
Cu	0.0720	0.1723	0.0758	a	b	N/A	b
Cd	<0.02	<0.02	<0.02	a	b	N/A	b
Sb	<0.02	<0.02	<0.02	a	b	N/A	b
Ba	1.8182	0.1515	0.1307	a	b	N/A	b
Tl	<0.02	<0.02	<0.02	a	b	N/A	b
Pb	<0.1	0.1591	0.1420	a	b	N/A	b
Hg^{+2}	0.0119	0.0265	0.0095	0.0044	b	N/A	b
Hg°	c	c	c	c	0.8420	N/A	0.0568
As	<0.1	<0.1	<0.1	a	b	N/A	b
Se	<0.1	<0.1	<0.1	a	b	N/A	b
Ag	<0.1	<0.1	<0.1	a	b	N/A	b
P	<10.0	<10.0	<10.0	a	b	N/A	b

a. Solution lost to analysis
b. Impingers 4-6 analyzed only for Hg°
c. Prefilter and impingers 1-3 analyzed for Hg^{+2}

Table A-11. Site 1
Metals Analysis (Total μg)
Blank Data

RTI/ECD No.	4284	4280	4282
Identifier	Filter Blank	Metals Impinger Blank	Mercury Impinger Blank
Metals			
Be	<0.03	<0.03	a
Al	<3.0	<3.0	a
Cr	<0.5	<0.5	a
Mn	0.060	<0.03	a
Fe	<0.5	<0.5	a
Co	<0.2	<0.2	a
Ni	<0.1	<0.1	a
Zn	<0.5	<0.5	a
Cu	<0.3	<0.03	a
Cd	<0.01	<0.01	a
Sb	<0.01	<0.01	a
Ba	<0.03	<0.03	a
Tl	<0.01	<0.01	a
Pb	0.080	<0.05	a
Hg^{+2}	<0.02	<0.02	a
Hg°	b	b	0.0057
As	<0.05	<0.05	a
Se	<0.05	<0.05	a
Ag	<0.05	<0.05	a
P	<5.0	<5.0	a

a. Mercury impinger blank analyzed for Hg°
b. Metals impinger blank analyzed for Hg^{+2}

Table A-12.
Quality Control for Metals
(Spike Recoveries)

	Solution		Filter	
Metal	**Total μg**	**% Recovery**	**Total μg**	**% Recovery**
Be	113	113	9.42	94.2
Al	1002	100	N/A	--
Cr	86.6	86.6	99.30	93.0
Mn	83.0	83.0	9.45	94.5
Fe	996	99.6	22.3	89.2
Co	69.6	69.6	8.84	88.4
Ni	938	85.6	9.52	95.2
Zn	98.7	98.7	43.4	86.8
Cu	99.5	99.5	23.1	92.4
Cd	97.4	97.4	8.75	87.5
Sb	4.66	93.2	N/A	--
Ba	98.0	98.0	9.00	90.0
Tl	4.50	90.0	8.80	88.0
Pb	336	67.2	22.4	89.6
Hg	N/A		N/A	
As	4.79	95.8	42.5	85.0
Se	4.90	98.0	23.2	92.8
Ag	N/A		4.45	89.0
P	471	94.2	N/A	--

N/A Solution was not spiked

Table A-13.
Indoor Air Quality

Sampling Dates	3/26/96	3/26 to 3/27/96	3/27/96
Location	Left Wall Near Bin Washer	Operator Area	1st Floor Break Room
CO_2 average	466 ppm	388 ppm	532 ppm
OSHA PEL[a]	10,000 ppm	10,000 ppm	10,000 ppm
RTI Suggested Limit	1,000 ppm[b]	1,000 ppm	1,000 ppm
CO average	0 ppm	0 ppm	0 ppm
OSHA PEL	35 ppm	35 ppm	35 ppm
Temp. average	65.1°F	58.7°F	75.9°F
minimum	56.4°F	52.9°F	63.6°F
maximum	69.6°F	63.3°F	78.9°F
Relative humidity			
average	41.7%	57.1%	31.5%
minimum	30.2%	33.8%	26.4%
maximum	51.6%	80.0%	58.7%

[a] OSHA PEL is the Occupational Safety and Health Administration Permissible Exposure Limit for an 8 hour workday.

[b] 1,000 ppm is the current limit adopted by the State of Washington.

Figure A-8. Noise Survey of Office Area

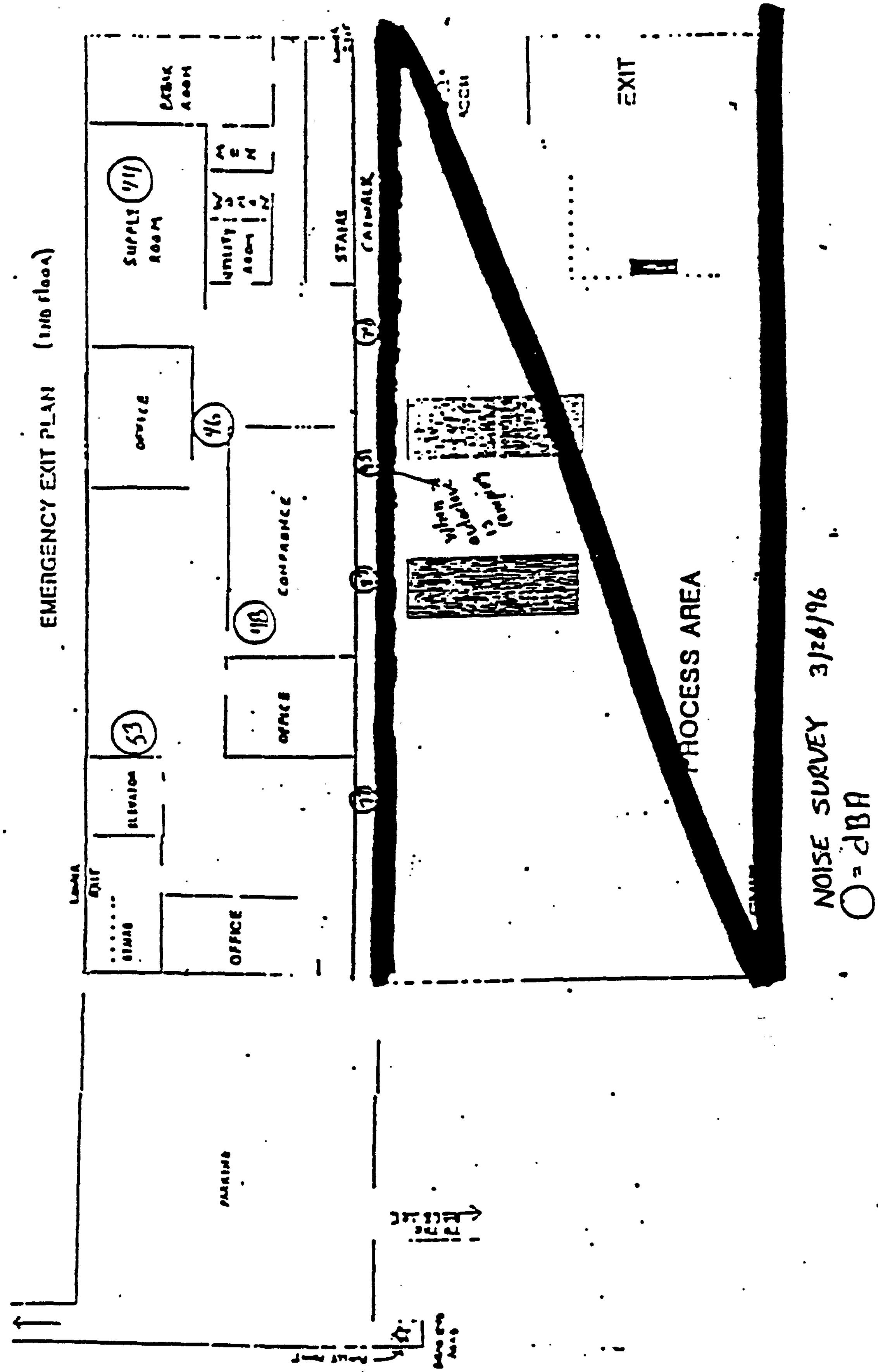
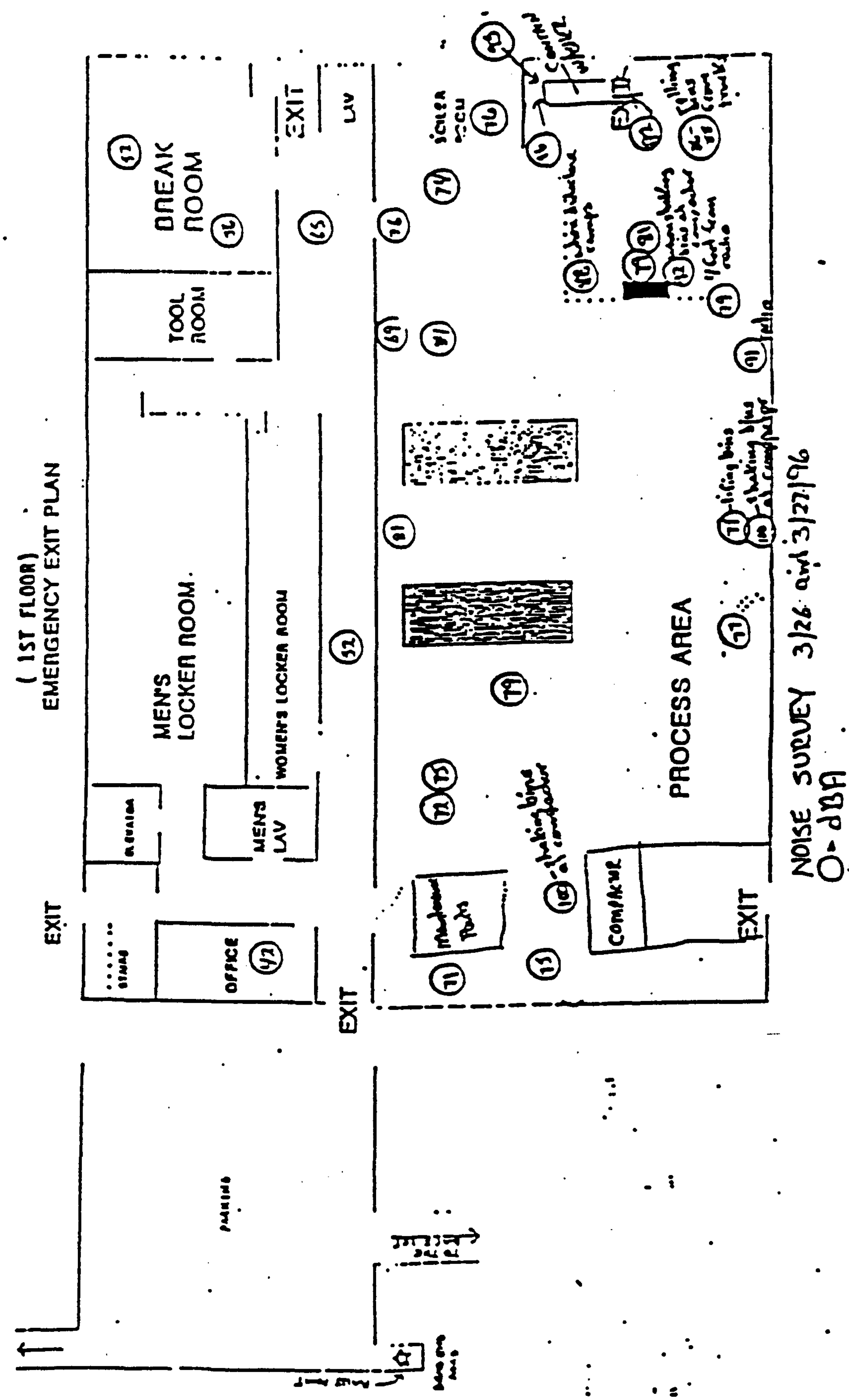


Figure A-9. Noise Survey of Plant Area



protection whenever working between the two autoclaves during the ramping segment, when cleaning inside of the autoclave, and when removing debris from the autoclave waste bins, and whenever operating the shredder. The shredder is no longer present in the plant.

A.6 ERGONOMIC ISSUES

The purpose of an ergonomic assessment is to prevent the occurrence of work related musculoskeletal disorders. Work related musculoskeletal disorders are usually attributable to the following work practice which was observed at this facility, "unassisted manual lifting and lowering of anything weighing more than 25 pounds more than once during the work shift." Workers were observed removing bins (weighing nominally 25 pounds) from the top of a stack of three, and dropping the bin down on the ground (to perform a sort of preliminary compaction and remove any material stuck in the bin lid). They then opened the lid and picked up the small bins and dumped them into a large waste bin. This process involved lifting, lowering and twisting of the torso. The potential for injury is strong in spite of the employees wearing back braces. This problem has been addressed by having workers change tasks every two hours.

A.7 ENGINEERING CONTROLS

The areas of emphasis of this section are ventilation and engineering controls. However, much of the engineering control aspects of this inspection are covered more in depth in the safety report. Relevant details about the plant are presented first followed by data, then recommendations.

A.7.1 Plant Description

A.7.1.1 Autoclave Venting

The autoclaves pull approximately 15 in. H_2O postrun vacuum before opening. This eliminates some of the steam from entering the room, but very clearly not all. When the autoclave opens much steam can be seen being released. Steam rises toward the ceiling but does not appear to head to the vent. However, the gas stream may be venting acceptably but becoming non-visible before the vent. Also, the opacity of the steam plume may decrease on warmer days. It is clear that the vents do not operate as hoods or the visible plumes would exit toward the vents.

A carbon bed is used to filter the effluent gas stream from the autoclaves (produced from the vacuum applied before opening) before discharging the air into the plant very near the ceiling vent. The bed is replaced every 6 months. This bed operates at high humidity. Assuming that the airflow out the vent entrains this treated air, this poses no problem for the interior. However, the airflow pattern needs to be examined more thoroughly.

A.7.1.2 Radiation Detection

A radiation detector is used as a control for gamma radiation exposure. The detector scans all incoming waste so that unacceptably radioactive waste is not unloaded into the facility. The facility limit for radioactive material was 50 microcuries.

A.7.1.3 Floor Drains

At several locations in the plant, floor drains covered by grating allow water to quickly drain from the floor eliminating much potential for slippery floors and water borne contamination spread to the workers. These drains are an effective control measure where they are present.

Both tub washers leak a solution of contaminant, disinfectant, and water to the floor during runs. The small tub washer leaks from a main overflow pipe, located in the back, during cleaning out. This water mix currently pools on the floor and must be swept down a drain. The plant personnel report plans to install a grate-covered floor drain near the bin washer to help with this problem. It is unclear whether the main drain from the small tub washer will actually be piped to the drain or whether the water will simply drain across the floor to the grate. Either way it will be an improvement, but direct ducting to the sewer or to the drain would be preferable. The floor, even though wet, did not appear to be slippery when walked on.

A.7.1.4 Ventilation

In the main room, there were definite gusts of cold air. Both days at the facility were quite windy with March 26 being exceptionally so. There are plastic guards around the truck entrances to prevent excess cold air from entering. In addition six gas radiation, heating fans, were stationed throughout. These heaters were often on. Two wall fans blow in about halfway up the walls at approximately halfway down the wall. The fans are rated at 8950 cfm. During the first day, one of the side fans was on continuously; the other was turned on for part of the day. The fan on the "dirty" side pulls air from outside at the back of the building not near anything. The other fan pulls air from above the parking lot. Neither fan blows air in from near the loading dock.

Another two 8950 cfm rated fans are pulling air out through the 2' square roof vents. The total floor space in the main room is approximately 13624 sq. ft. including the area covered by equipment. The total room volume, including the volume filled with the elevated "dirty" area, the equipment, people, and waste, was approximately 368,000 cu. ft, using an average ceiling height of 27 ft. Thus, based on the fan ratings, an air exchange rate for the room due to the fans would be approximately 2.9 ach. According to personnel the prevailing winds during the winter are from the north (which means wind blows into the facility bays) and from the south in the summer. Thus in the winter the air exchange will definitely be improved by the winds, as was seen with the gusting of the wind into the room during our visit. During the summer some air will enter through the boiler room when the large door is open, but the influence of outside breezes will probably be less, resulting in higher concentrations of indoor generated pollutants and a greater temperature elevation.

The room temperature as monitored at the worker station showed the room temperature at that location to be around 64°F on March 26 and 68°F on March 27. Thus the subfreezing outdoor temperatures were not cooling the room excessively. It was very windy outdoors on 3/26/96. Gusts of air were entering the main room through the boiler room when the outdoor "truck" width and height door was open. It was reported that sometimes the airflow is out through the boiler room from the autoclave area. The boiler room pulls 10,000 cfm for use by the boilers but not from the main room.

During the summer the plastic guards from around the trucks are removed to allow additional airflow. In the summer big floor level fans are employed to move air in the facility. According to the personnel the summer outdoor temperatures are usually in the 70-80°F range, while the indoor temperatures are higher (100° F was mentioned).

A.7.1.5 Waste Removal Pole

The pole used to prod recalcitrant waste from the tubs creates several problems. First the pole is used, then stored in the worker area. Thus the pole may bring fresh, untreated liquid waste into contact with the worker station. Second, liquids may run down the pole to contact the workers.

A.7.2 Air Velocities

As has been addressed earlier, the airflow in the building was gusty. The air velocities, as measured with a hot-wire anemometer, were so variable that most of the readings consisted of determining a low and high velocity for the range over which the meter needle swung. For those cases where the readings were mainly at one level with brief gusts or calm spells, an average wind velocity was estimated by watching the gauge for several minutes. On 3/26/96, a very windy day, the air velocity coming into the building at the then empty bay near the unloading trucks varied basically between 10 and 20 fpm with occasional gusts as high as 75 fpm. At the operator station the air velocities varied mainly from 0 to 30 fpm with occasional gusts up to 45 fpm. On 3/27/96, a day not quite as windy as the day before, the airflow coming into the builidng through the fan near the compactor was measured. The measurements were taken on the scaffolding in front of the fan about 4 feet out from the center of the fan. The air velocity at this point varied regularly between 125 and 475 fpm with an apparent average value of 250 fpm.

A.7.3 Recommendations

Reduction of the amount of hand labor would be desirable. Possible suggestions to this include extending the conveyor for the box unloading closer to the bins to eliminate the need to pick up and heave the boxes across the room and over the railing.

Floor drains should be installed in the areas near the tub washers. If possible the drainage from the washers should be directly ducted to the sewer or to the drain. The drains should be positioned to catch the draining water as close to the source as practical so that the water does not have to flow across traveled paths to reach the drain.

The use of the pole to remove waste from the bin loader should be rethought. It must not be used, then stored near the workers. A stand for the pole could be set up outside the worker shield. This stand and the pole could be disinfected at regular intervals and when the floor is cleaned to reduce contamination transfer to the worker. Also, redesigning the pole to prevent liquid from reaching the worker as suggested by the corporate toxicologist and engineer would be helpful. A "lip" to stop the liquid might prove useful if the workers are trained to carefully dump the entrained liquid into the bin and not onto themselves or the floor. Workers using the pole must be careful to have all skin covered: gloves should cover the edges of sleeves and gloves should be replaced if liquid waste runs onto them. It might be beneficial to double glove for this task so that the outer glove could be routinely removed.

Some kind of noise control for the compactor during dumping (especially the shaking) would lower noise exposure; however, the Phase 1 screening only showed possible accedence of the noise limit (see Section A.4.6).

A.8 RESPIRABLE AEROSOL SCREENING

Aerosol measurements were taken with the hand held aerosol monitor (HAM) that measures mass concentration in the 0.3 to 2 μm size range and with the Laser Particle Counter (LPC) that measures number of particles in various size ranges. An average density of 1.5 g/cm^3 was assumed as a conservative estimated for the particles counted by the LPC; the density of water is 1 g/cm^3 so the 1.5 assumption allows for any heavier particles. Thus the mass calculated should, if anything, err slighlty on the high side. The mass concentration below 5 μm and the total mass up to 15 μm were calculated. The HAM results are shown in Table A-14 and the LPC data are shown in Table A-15. None of the measurements exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified.

As treated waste bins exited the autoclave, particle concentrations at the worker station rapidly increased from approximately 0.04 to 2.1 mg/m^3, then reduced to 0.73 in less than 5 minutes. The air looked foggy toward the open autoclave. It is possible however, that the increase in particle concentration at this point is primarily due to the steam release.

In addition these numbers do reflect the concentrations for a very gusty day when the outdoor air was quite low in concentration. On a windless day the level may be much higher. However, strictly from the particle concentrations, no problem can be diagnosed that needs addressing.

Table A-14.
HAM Measurement for the Autoclave Facility

Location	Mass Concentration (mg/m^3)	Notes
Breakroom	0.006, 0.008	
Boiler Room	0.007	
At top of steps - (near boiler room)	0.100, 0.200	
At table - near operator station	0.050	
Next to operating tub washer	0.450	
Near loading bins when not loading	0.044	
At compactor trailer, while cleaning when backing	0.050 0.020	below dumping site for treated waste, lots of outdoor air
Worker station - peak value shortly after one autoclave opened	2.100	
Worker station as particle concentrations decay/vary	0.730	<5 min later
	0.085	15 min later
	0.070	3:02 pm, door opened at 3:03 pm
	0.068 to 0.073	3:05 pm
	0.032	3:07 pm
	0.600	3:09 pm
Loading area when bags are being loaded	0.085 to 0.109	
In steam plume from autoclave	1.800	--

Table A-15.
Mass Concentrations for the Autoclave Facility

Location	Mass <5 μm (mg/m^3)	Total Mass (mg/m^3)	Noted activity during sampling
Breakroom	0.0002	0.0056	
Table near operators	0.0103	0.0759	autoclave opened after 1st 10 μm reading
Table near operators	0.0391	0.0904	while bins exiting autoclave
Table near operators	0.0391	0.1150	while bins exiting autoclave
Plastic bag loading area	0.0142	0.1097	autoclave opening
Compactor dumping	0.0111	0.0237	
Compactor - not loading	0.0061	0.0232	
Near large tub washer	0.0105	0.0211	
Near compactor	0.0060	0.0250	autoclave opened in middle of series spraying of lower floor toward end tub dumping with liquids flying and asphalt release agent spraying
Near compactor	0.0052	0.0175	bins approaching from autoclave
Near venting autoclave and running tub washer	0.0043	0.0095	

* Based on LPC data and assumed density of 1.5 g/cm^3

A.9 ASSESSMENT OF BLOOD ON SURFACES

The March 26-27, 1996, Phase 1 environmental sampling and analysis assessed the extent of blood contamination on a variety of surfaces and materials in the processing area of a medical waste facility using the steam autoclave process for waste treatment. Evaluation of blood and/or blood containing body fluids on surfaces in the processing area could provide important information relative to identifying the most potentially hazardous steps in the treatment process, which through modifications in engineering and/or work practice controls, could minimize worker exposures. Visual inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection, was carried out throughout the processing area, but focused primarily in the tub dumping and washing areas. In the dumping area large tubs of waste are mechanically emptied into the large treatment bins that hold the waste during the autoclaving process. Also in that area, smaller tubs are emptied by the manual extraction of the red bag waste, which can often be seen dripping fluids. From the dumping area, all reusable tubs are moved to the washing area where they are decontaminated, deodorized, and cleaned in a semi-automated procedure.

Forty five (45) wipe samples were collected and processed immediately for the presence of hemoglobin, using collection and analysis methods described in Appendix J. Results are presented in Table A-16. Twenty (44%) of the samples were positive, primarily those associated with waste dumping and the waste dumping area, including the concrete floor and liquid waste spills, tub dumper and railing, waste conveyor rollers, and a long stick used to reposition waste bags in the treatment bins. Most samples collected from the control panel area were negative, presumably because that area is protected by splash shields, and those workers operating the controls and touching various buttons and switches usually removed their gloves prior to touching controls. Four samples were collected at the post-treatment waste compactor, of which three were positive for residual hemoglobin. Those three surfaces were very soiled and undoubtedly contained settled residues from hundreds of post-treatment compactions. This is consistent with the knowledge that not all hemoglobin is broken down in the autoclave process, and that non-infectious blood residues can be expected to accumulate in the compaction area. For control purposes, three samples were collected from surfaces in the maintenance area adjacent to autoclave #2 and were found to be negative as expected. No samples were collected from surfaces in the tub washing area, since most surfaces in that area are usually wet with hypochlorite solution, which gives a false positive hemoglobin result and was confirmed by testing. The entire outer surfaces of two of the workers' face shields were tested and found to be negative.

Recommendations to reduce exposure to blood and body fluid splashes include providing adequate splash protection especially personal protective equipment including enforcement of the use of face shields. A uniform policy on the use of gloves should be established and enforced especially in the control panel area. In this area some workers removed gloves to push buttons while others left used gloves on. One suggestions would be to have workers don clean gloves before touching the panel.

Table A-16.
Steam Autoclave Surface Blood Results

Sample #	Date	Location / Description	Area	Hemastix	Comment
Autoclave 1	03/26/96	Cntrl Pnl A to right of button	2"x 4"	Neg	
Autoclave 2	03/26/96	Cntrl Pnl B	2"x 4"	Neg	
Autoclave 3	03/26/96	Concrete floor spill behind Cntrl Pnl	3"x 5"	+++	
Autoclave 4	03/26/96	Cntrl Pnl below condenser knob	1"x 3"	Neg	
Autoclave 5	03/26/96	Cntrl Pnl below temp readout	3"x 4"	Neg	
Autoclave 6	03/26/96	Tub dump restraint bar - right	1.5"x 6"	Neg	
Autoclave 7	03/26/96	Tub dump restraint bar - left	1.5"x 10.5"	+++	
Autoclave 8	03/26/96	Plexiglass splash wall - waste side	4"x 5"	Neg	
Autoclave 9	03/26/96	Tub dumper (left) wet area	6"x 6"	Neg	
Autoclave 10	03/26/96	Tub dumper (right) wet area	6"x 6"	Neg	
Autoclave 11	03/26/96	Worker face shield entire sfc	15.5"x 8"	Neg	
Autoclave 12	03/26/96	Floor drips from bags in small tubs		+++	
Autoclave 13	03/26/96	Large tub wet top edge	6"x 3"	Neg	
Autoclave 14	03/26/96	Large tub top handle		Neg	
Autoclave 15	03/26/96	Waste conveyor roller		+Ht	
Autoclave 16	03/26/96	Railing next to tub dumpers	6"x 3"	+++	
Autoclave 17	03/26/96	Compactor clamp ratchet handle	2" circumf.	Neg	
Autoclave 18	03/26/96	Compactor top railing (very soiled)	1"x 12"	+Ht	Very soiled surface
Autoclave 19	03/26/96	Compactor edge	1"x 12"	++	Very soiled surface
Autoclave 20	03/26/96	Compactor, opposing top rail	1"x 12"	++	Very soiled surface
Autoclave 21	03/26/96	Asphalt release agent (test)		Neg	
Autoclave 22	03/26/96	Tub washer water		++	
Autoclave 23	03/26/96	Tub dumper end rail	1"x 12"	+Ht	
Autoclave 24	03/26/96	Tub dumper retainer bar right	24"	++	
Autoclave 25	03/26/96	Wood waste poking stick handle	12"	+++	Visible blood
Autoclave 26	03/26/96	Cntrl Pnl B	6"x 6"	Neg	
Autoclave 27	03/26/96	Cntrl Pnl metal shelf	12"x 24"	+Ht	
Autoclave 28	03/27/96	Concrete flr drips left of tub dump		+++	
Autoclave 29	03/27/96	Cntrl Pnl A left of button	6"x 6"	+Ht	
Autoclave 30	03/27/96	Cntrl Pnl B left of button	6"x 6"	Neg	
Autoclave 31	03/27/96	Plexiglass splash wall	6"x 6"	+	
Autoclave 32	03/27/96	Flr left tub dmp aft NaOCl clean, dry	4"x 5"	Neg	
Autoclave 33	03/27/96	Tub dumper left railing	6"x 3"	+++	
Autoclave 34	03/27/96	Worker face shield entire sfc	15.5"x 8"	Neg	
Autoclave 35	03/27/96	Cntrl Pnl below temp readout	3"x 4"	Neg	
Autoclave 36	03/27/96	Cntrl Pnl below condenser knob		Neg	
Autoclave 37	03/27/96	Cntrl Pnl shelf same area as 3/26/96	12"x 24"	Neg	
Autoclave 38	03/27/96	Cntrl Pnl shelf adjacent area	12"x 24"	+Ht	

Sample #	Date	Location / Description	Area	Hemastix	Comment
Autoclave 39	03/27/96	Waste conveyor, ½ of a roller		+Ht	
Autoclave 40	03/27/96	Large Tub handle		+Ht	
Autoclave 41	03/27/96	Hydralic lift handle		Neg	
Autoclave 42	03/27/96	Rail above Unit #2	12"	Neg	
Autoclave 43	03/27/96	Flammable cabinet top edge	6"x 4"	Neg	
Autoclave 44	03/27/96	Cabinet next to door maint. area	8"x 8"	Neg	Very soiled surface
Autoclave 45	03/27/96	Tool box top next to Unit #2	12"x 15"	Neg	

*Hemastix Key

Neg	Negative - No color change
+Nht	Positive non-hemolyzed trace
+Nhm	Positive non-hemolyzed moderate
+Ht	Positive hemolyzed trace
+	Positive small
++	Positive moderate
+++	Positive large

Detection limit = 5000 RBC/ml sample which corresponds to 0.000027 ml blood eluted from gauze wiped over a surface

Visual assessment of the process, along with hemoglobin test results, shows that the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Both automatic and manual tub dumping result in the splatter and splash of liquids from untreated, regulated medical waste. Based on the Phase 1 observations and test results, it was recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes using personal sampling techniques.

A.10 SURFACE MICROBIAL CONTAMINATION

The Phase 1 survey assessed the extent of microbial contamination on a variety of surfaces and materials in the processing area of a medical waste facility using the steam autoclave process for waste treatment. Detection of the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*, could assist in determining the extent of microbial contamination from untreated medical waste throughout the facility and the potential for worker contact exposures. Sampling was conducted primarily in the tub dumping area where splatters and splashes were common, the control panel area where workers sometimes touched buttons, switches, a telephone, and scanner with potentially contaminated gloves, and personal protective equipment such as face shields and gloves. Knobs on doors exiting the process area were also sampled, as were control surfaces from a rest room located in the administrative section of the building.

A total of 50 surface samples and three controls were collected and processed using a surface wipe and direct plate technique as described in Appendix K. Results are shown in Tables A-18 and A-19. Although samples were collected from many wet areas to include liquids from waste dumping and associated spills, no *S. aureus* was isolated from any sample, and only one sample was positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but they are inconsequential relative to assessing potential worker exposures to recognized human pathogens. The implication of not finding the two potentially harmful bacteria is that the inactivation of some human pathogens in medical waste begins to occur rapidly after waste generation due to adverse environmental conditions relative to temperature, moisture, and nutrients that were encountered during storage and transport, thus older waste would be expected to have fewer living organisms than recently generated waste as indicated in Appendix K. While this can be the situation for some vegetative bacterial pathogens, such results are not necessarily indicative of the absence of more environmentally resistant and virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses.

A.11 SUMMARY AND CONCLUSIONS

The steam autoclave facility occupies a light industrial building of approximately 16,000 square feet. Untreated medical waste is delivered to the facility by means of tractor trailers and trucks carrying either sealed cardboard boxes of varying sizes or plastic tubs of varying sizes. The containers are moved to a processing area either manually or with the assistance of carts or

Table A-17.
E. coli Test Results

Sample #	Date	Location	Area	Total CFU	Total E. coli
Autoclave 1	03/26/96	Cntrl Pnl A	2"x 2"	20	0
Autoclave 2	03/26/96	Cntrl Pnl B	2"x 2"	22	0
Autoclave 3	03/26/96	Condenser Switch ½		4	0
Autoclave 4	03/26/96	System start button ½		28	0
Autoclave 5	03/26/96	Floor spill by cntrl pnl	2"x 2"	114	0
Autoclave 6	03/26/96	Restraint bar right tub dumper	1"x 3"	300	0
Autoclave 7	03/26/96	Restraint bar left tub dumper	1"x 3"	TNTC	0
Autoclave 8	03/26/96	Toilet rim (Control)	2 in²	TNTC	0
Autoclave 9	03/26/96	Toilet seat (Control)	2 in²	62	0
Autoclave 10	03/26/96	Toilet handle ½ (Control)		13	0
Autoclave 11	03/26/96	Plexiglass splash wall - waste side	2"x 2"	4	0
Autoclave 12	03/26/96	Tub inside top edge - wet	2"x 2"	TNTC	0
Autoclave 13	03/26/96	Railing next to tub dumper	2"x 2"	TNTC	0
Autoclave 14	03/26/96	Railing near cntrl pnl		20	0
Autoclave 15	03/26/96	Keyboard cover space bar		50	0
Autoclave 16	03/26/96	Hand truck handle		46	0
Autoclave 17	03/26/96	Worker glove		50	0
Autoclave 18	03/26/96	Railing left of dumper		TNTC	0
Autoclave 19	03/26/96	Face shield - supervisor	2"x 2"	39	0
Autoclave 20	03/26/96	Face shield - worker	2"x 2"	52	0
Autoclave 21	03/26/96	Scan gun cntrl pnl/ handle, trigger		4	0
Autoclave 22	03/26/96	Telephone receiver handle		6	0
Autoclave 23	03/26/96	Small tub edge		25	0
Autoclave 24	03/26/96	Floor drips from bags in small bins		TNTC	0
Autoclave 25	03/26/96	Door knob exit to break room hall		194	0
Autoclave 26	03/27/96	Cntrl Pnl A	1"x 3"	40	0
Autoclave 27	03/27/96	Cntrl Pnl B	1"x 3"	27	0
Autoclave 28	03/27/96	Condenser Switch ½		1	0
Autoclave 29	03/27/96	System start button ½		2	0
Autoclave 30	03/27/96	Restraint bar right tub dumper	1.5"x 3.5"	75	0
Autoclave 31	03/27/96	Restraint bar left tub dumper	1.5"x 3.5"	TNTC	0
Autoclave 32	03/27/96	Floor to left of tub dumper - wet		TNTC	0
Autoclave 33	03/27/96	Tub dumper inside right - wet	2"x 2"	TNTC	0
Autoclave 34	03/27/96	Tub dumper inside left - wet	2"x 2"	TNTC	0
Autoclave 35	03/27/96	Railing near cntrl pnl	2"x 2"	5	0
Autoclave 36	03/27/96	Railing to left of tub dumper		TNTC	0
Autoclave 37	03/27/96	Keyboard cover spacebar		25	0
Autoclave 38	03/27/96	Small tubs - wet edge		TNTC	0
Autoclave 39	03/27/96	Telephone receiver handle		1	0

ample #	Date	Location	Area	Total CFU	Total E. coli
utoclave 40	03/27/96	Scanner		2	0
utoclave 41	03/27/96	Glove - supervisor		0	0
utoclave 42	03/27/96	Face shield - worker	2"x 2"	TNTC	0
utoclave 43	03/27/96	Large tub edge - wet	4"x 4"	TNTC	0
utoclave 44	03/27/96	Hand truck handle	1"x 8"	0	0
utoclave 45	03/27/96	Plexiglass splash shield - waste side	4"x 5"	0	0
utoclave 46	03/27/96	Door knob exit from maintnce to hall		0	0
utoclave 47	03/27/96	Door knob exit to break room hall		TNTC	1
utoclave 48	03/27/96	Toilet seat (upstrs office Men) Cntrl	2"x 2"	0	0
utoclave 49	03/27/96	Toilet handle		0	0
utoclave 50	03/27/96	Toilet rim		0	0
utoclave 51	03/27/96	Table top upstairs conf room	4"x 4"	0	0
utoclave 52	03/27/96	Handle, dr to dwnstrs near conf room	4"x 3"	0	0
utoclave 53	03/27/96	Computer space bar, office		0	0

Table A-18.
Staphylococous Aureus Test Results

Sample #	Date	Location	Area	Total CFU	Total S. aureus
Autoclave 1	03/26/96	Cntrl Pnl A	2"x 2"	61	0
Autoclave 2	03/26/96	Cntrl Pnl B	2"x 2"	36	0
Autoclave 3	03/26/96	Condenser Switch ½		0	0
Autoclave 4	03/26/96	System start button ½		7	0
Autoclave 5	03/26/96	Floor spill by cntrl pnl	2"x 2"	178	0
Autoclave 6	03/26/96	Restraint bar right tub dumper	1"x 3"	4	0
Autoclave 7	03/26/96	Restraint bar left tub dumper	1"x 3"	3	0
Autoclave 8	03/26/96	Toilet rim (Control)	2 in²	9	0
Autoclave 9	03/26/96	Toilet seat (Control)	2 in²	86	0
Autoclave 10	03/26/96	Toilet handle ½ (Control)		32	0
Autoclave 11	03/26/96	Plexiglass splash wall - waste side	2"x 2"	6	0
Autoclave 12	03/26/96	Tub inside top edge - wet	2"x 2"	23	0
Autoclave 13	03/26/96	Railing next to tub dumper	2"x 2"	18	0
Autoclave 14	03/26/96	Railing near cntrl pnl		16	0
Autoclave 15	03/26/96	Keyboard cover space bar		77	0
Autoclave 16	03/26/96	Hand truck handle		48	0
Autoclave 17	03/26/96	Worker glove		38	0
Autoclave 18	03/26/96	Railing left of dumper		5	0
Autoclave 19	03/26/96	Face shield - supervisor	2"x 2"	38	0
Autoclave 20	03/26/96	Face shield - worker	2"x 2"	56	0
Autoclave 21	03/26/96	Scan gun cntrl pnl/ handle, trigger		59	0
Autoclave 22	03/26/96	Telephone receiver handle		5	0
Autoclave 23	03/26/96	Small tub edge		37	0
Autoclave 24	03/26/96	Floor drips from bags in small bins		92	0
Autoclave 25	03/26/96	Door knob exit to break room hall		TNTC	0
Autoclave 26	03/27/96	Cntrl Pnl A	1"x 3"	85	0
Autoclave 27	03/27/96	Cntrl Pnl B	1"x 3"	99	0
Autoclave 28	03/27/96	Condenser Switch ½		7	0
Autoclave 29	03/27/96	System start button ½		4	0
Autoclave 30	03/27/96	Restraint bar right tub dumper	1.5"x 3.5"	45	0
Autoclave 31	03/27/96	Restraint bar left tub dumper	1.5"x 3.5"	34	0
Autoclave 32	03/27/96	Floor to left of tub dumper - wet		160	0
Autoclave 33	03/27/96	Tub dumper inside right - wet	2"x 2"	TNTC	0
Autoclave 34	03/27/96	Tub dumper inside left - wet	2"x 2"	TNTC	0
Autoclave 35	03/27/96	Railing near cntrl pnl	2"x 2"	35	0
Autoclave 36	03/27/96	Railing to left of tub dumper		35	0
Autoclave 37	03/27/96	Keyboard cover spacebar		42	0
Autoclave 38	03/27/96	Small tubs - wet edge		219	0
Autoclave 39	03/27/96	Telephone receiver handle		9	0

ample #	Date	Location	Area	Total CFU	Total S. aureus
utoclave 40	03/27/96	Scanner		23	0
utoclave 41	03/27/96	Glove - supervisor		43	0
utoclave 42	03/27/96	Face shield - worker	2"x 2"	7	0
utoclave 43	03/27/96	Large tub edge - wet	4"x 4"	246	0
utoclave 44	03/27/96	Hand truck handle	1"x 8"	9	0
utoclave 45	03/27/96	Plexiglass splash shield - waste side	4"x 5"	12	0
utoclave 46	03/27/96	Door knob exit from maintnce to hall		4	0
utoclave 47	03/27/96	Door knob exit to break room hall		TNTC	0
utoclave 48	03/27/96	Toilet seat (upstrs office Men) Cntrl	2"x 2"	9	0
utoclave 49	03/27/96	Toilet handle		60	0
utoclave 50	03/27/96	Toilet rim		2	0
utoclave 51	03/27/96	Table top upstairs conf room	4"x 4"	0	0
utoclave 52	03/27/96	Handle, dr to dwnstrs near conf room	4"x 3"	42	0
utoclave 53	03/27/96	Computer space bar, office		157	0

forklift. The processing involves filling large waste bins either manually or with the assistance of a hydraulic dumper. The bins are mechanically moved by conveyor into an autoclave which treats the waste under timed, steam conditions designed to completely disinfect all materials. After completing the treatment cycle, the bins are mechanically moved to a hydraulic dumper which dumps the waste into a hydraulic compaction unit which is attached to a compaction trailer into which the waste is pushed. Upon filling, the treated waste is hauled to a private landfill.

This facility used a combination of generally good engineering controls on equipment with heavy reliance on worker training and personal protective equipment for worker protection. Management is very proactive in their attempts to identify and train workers in proper techniques for personal protection and had excellent training resources and manuals available. A strong emphasis on good housekeeping was noted throughout the facility. There were some structural deficiencies in parts of the facility and with equipment. Electrical safety hazards included frayed cords and the use of extension cords as permanent wiring. The many intensive manual material handling steps combined with unsafe acts were the principal sources of worker exposure to hazards. Unsafe acts included standing under elevated tubs and picking up unknown materials by hand. The written compliance programs and program administration were excellent but there are several areas recommended for improvement. The sequential job safety analysis of the primary jobs found the major personnel exposure hazards to be from the manual material handling found in virtually all tasks. The variability in job performance and variable use of personal protective equipment by different workers contributed to the overall worker exposure to hazards.

Drains should be installed for the tub washers. The usage of the pole to remove waste from the bin loader should be rethought due to the potential for blood to run down the pole onto the worker or to contaminate the control area. It should not be used, then stored near the workers. A stand for the pole could be set up outside the worker shield. This stand and the pole could be disinfected at regular intervals such as when the floor is cleaned, to reduce contamination transfer to the worker. Also, redesigning the pole to prevent liquid from reaching the worker as suggested by the corporate toxicologist and engineer would be helpful.

Several VOCs were observed at the facility, but no OSHA permissible exposure limits (PELs) or ACGIH threshold limit values (TLVs) were exceeded. The highest concentration VOC for the three locations within the facility was 2-propanol at 643, 556, and 589 $\mu g/m^3$. No chlorine was detected at either side of the small bin washer or at either side of the large container washer. No hydrochloric acid was detected at the small bin washer or at the large container washer.

The aldehyde results indicated concentrations of formaldehyde in the range of 0.08 to 0.18 mg/m^3 as compared to the OSHA PEL of 0.94 mg/m^3 and the ACGIH TLV of 0.37 mg/m^3 (ceiling limit). Acetaldehyde and acetone were also observed but at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs of 360 and 2400 mg/m^3.

The results of the metals sampling indicate minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co, Ni, Zn, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg.

The indoor air quality evaluation for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO) indicated adequate indoor air during the sampling period.

The noise survey demonstrated that noise levels ranged from 69 to 100 dBA in the process area and from 44 to 53 dBA in the office area. The sources of the loudest noise in the process area include the mechanical shaking the drums at the compactor, venting/ramping of the autoclave steam, rolling bins off of trucks, the entrance to the container washer, and the radio located near the loading dock. While the area noise survey demonstrated that the potential to exceed the OSHA Permissable Exposure Limit (PEL) of 90 dBA exists, the data is inconclusive since it was only a survey and not a measurement of an 8 hour time weighted average noise exposure. Most of the noise is intermittent and scattered at various locations throughout the plant floor.

The ergonomics survey showed workers involved in lifting, lowering and twisting of the torso during the manipulation of the bins. The potential for injury is strong in spite of the employees wearing back braces. The company has addressed the potential musculoskeletal disorders problems by having workers change tasks every two hours.

The airflow measurements showed sufficient air circulating in the facility, but were extremely variable due to the wind gusts making air exchange rate calculation meaningless. None of the aerosol measurements exceeded the ACGIH TWA of 10 mg/m^3 for particulates not otherwise classified. All measurements were below 1.0 mg/m^3 except those attributable directly to the steam plume.

Assessment of the blood contamination of surfaces and materials in the processing area included visual inspection for visible blood on surfaces and the collection of wipe samples for hemoglobin detection. These were carried out throughout the processing area. Positive samples were primarily those associated with waste dumping and the waste dumping area. Most samples collected from the control panel area were negative, presumably because that area is protected by splash shields and workers usually removed their gloves prior to touching controls. Three of four samples collected at the waste compactor were positive for residual hemoglobin. This is consistent with the knowledge that not all hemoglobin is broken down in the autoclave process, and that non-infectious blood residues can be expected to accumulate in the compaction area. Control samples collected from surfaces in the maintenance area were negative as expected. Thus, the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Both automatic and manual tub dumping result in the splatter and splash of liquids from untreated, regulated medical waste. Recommendations to reduce this type of exposure include providing adequate splash protection especially personal protective equipment including enforcement of the use of face shields and establishment and enforcement of a uniform policy on the use of gloves especially when working on the control panel.

It was recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes using personal sampling techniques.

The assessment of surface microbial contamination with *Staphylococcus aureus* and *Escherichia coli* was conducted primarily in the tub dumping area, the control panel area, and on personal protective equipment. Control surfaces from a rest room in the administrative section were also sampled. No *S. aureus* was isolated from any sample, and only one sample was positive for *E. coli*. Not finding the two potentially harmful bacteria indicates that the inactivation of some human pathogens in medical waste begins to occur rapidly after waste generation due to adverse environmental conditions relative to temperature, moisture, and nutrients that were encountered during storage and transport. While this can be the situation for some vegetative bacterial pathogens, such results are not necessarily indicative of the absence of more environmentally resistant and virulent pathogens.

Thus the site was found to have proactive management in many areas. The major hazards found were safety and ergonomics issues and the potential for exposure to blood from the untreated waste.

APPENDIX B.

MICROWAVE MWTF SCREENING REPORT

B.1 INTRODUCTION

This report describes a single technology of a multiple technology multiple phase study. The first phase assessment of a microwave facility is presented. Discussion of other technologies are presented as separate reports that will be combined for a final, overall, contract report.

The Medical Waste Tracking Act (MWTA) of 1988 defined medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals in research pertaining thereto, or in the production or testing of biologicals...". It categorized potentially infectious or "regulated medical waste" into seven types: culture and stocks; pathological wastes; human blood and blood products; sharps; animal waste; isolation wastes; and unused sharps. Treatment was defined as "any method, technique, or process designed to change the biological character or composition of any regulated medical waste so as to reduce or eliminate its potential for causing disease." The MWTA also had a destruction requirement that regulated medical waste be "ruined, torn apart, or mutilated," so as to be unrecognizable and non-reusable. Many of today's available technologies employ destruction as part of the treatment process.

This year more than 500,000 tons of medical waste will be processed in the United States prior to its ultimate disposal. Waste processing will be carried out at various "off-site" commercial treatment facilities, or "on-site" at health care facilities, laboratories, or industrial operations where the waste is generated. As the waste is transported, unloaded, treated, and disposed of, workers can be exposed to a variety of potentially hazardous medical waste components and treatment residues, to include biological and nonbiological aerosols, infectious agents, toxic chemicals, and radioactive materials. They may also be at risk regarding a number of safety related concerns including: injuries, noise, nonionizing radiation exposure, and duties and equipment having poor ergonomics. At the present time there is a significant lack of information on the identification, evaluation, and control of hazards associated with the treatment of medical waste.

A recent survey identified 114 commercial medical waste treatment facilities throughout the 50 states (Malloy, 1995). On average, such facilities operate two to three work shifts and process up to 100 tons of medical waste each day. It is estimated that the total number of medical waste treatment workers in the United States easily exceeds 10,000. Thus, the CDC determined that basic information on the current practices in MWTF should be collected.

B.1.1 Project Overview

The scope of the overall project encompasses all currently-available medical waste treatment technologies, with emphasis on the identification, evaluation, and control of all hazards associated with at least three different treatment systems. Hazards may include, but are not limited to: aerosols (biological and nonbiological), organic vapors, vapors and gases of biocidal agents, nonionizing radiation, materials handling, and safety issues (sharps, ergonomics, etc.).

The project tasks can be broken down into 4 categories: 1) conducting literature and field studies necessary to identify all currently-available disinfection systems for infectious waste. 2) to recommend three technologies and associated sites for field evaluation; 3) conducting on-site field studies to assess worker exposures to the identified hazards using conventional and novel industrial hygiene methodologies, contained in the detailed study plan and experimental design, evaluate facility engineering controls for worker protection; and 4) providing a detailed and comprehensive final report. The final report will contain descriptions of all investigated treatment technologies, sampling and analytical methods, facility health and safety evaluations, data analyses and risk assessments, evaluation of engineering controls, discussion of results, recommendations to reduce worker exposures, and conclusions.

This research has several purposes, all of which are related to a better understanding of the medical waste treatment occupation, and its potential health and safety hazards. The study included the accumulation of a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), risk assessment, and prevention and control. The information collected was specific to the sites tested and the workers' environments; thus, the data reflect a combination of the facility practices and the technology used.

For the requisite field evaluations, two phases were planned. Each Phase 1 visit included an industrial hygiene survey and safety assessment for identification of occupational hazards (chemical and physical), potential treatment system emission points, and engineering controls; Phase 2 visits evaluate hazard exposures by conducting comprehensive personnel and area sampling and analyses (as indicated by Phase 1 results) using conventional and novel industrial hygiene practices for organic vapors, mercury, metals, bioaerosols, biological surface contamination, non-ionizing radiation, noise, particles, air quality factors, and evaluated the effectiveness of engineering controls to protect the workers.

B.1.2 Technology Overview

Traditionally, incineration has been a method of treatment and destruction of hazardous chemical waste, municipal solid waste, and pathological waste. It was logical that incineration would be used when concern regarding infectious disease agents such as the AIDS and hepatitis B viruses prompted the treatment of all medical waste and hence a new industry. Over the past several years however, environmental pollution concerns have fostered the development of a variety of medical waste technologies that are presently regarded as viable alternatives to incineration. Such technologies include steam autoclave, microwave, pyrolysis and mechanical/chemical disinfection. This report focuses on a microwave facility.

Microwave treatment uses nonionizing radiation to heat medical waste for the thermal inactivation of infectious agents. Typically, waste is fed by continuous batch mode into a grinding chamber where it is sprayed with steam and mechanically destroyed to render it unrecognizable. The waste is treated with additional steam as it slowly moves via a transport auger under a series of microwave units. The internal temperature of the waste is maintained at >95°C. Following microwave exposure, the treated waste is conveyed via an auger tube to a dumpster or compactor. The systems are designed to treat medical waste at rates ranging from about 220 to 900 lbs/hr.

Concern for medical waste treatment workers comes from the unique character of the waste material and varying treatment technologies. Medical waste contains numerous chemicals that are themselves hazardous to worker health, and the MWTF technologies have the potential to generate others. Emissions from incineration have been extensively studied (US EPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies. Several types of health hazards are of particular concern in this respect: infectious agents (blood-borne pathogens and others); hazardous drugs and chemicals; and non-ionizing radioactivity. Routes of exposure can include skin, mucous membranes, inhalation, and ingestion; with hazards present or generated during treatment as aerosols, particulates, fluids, and sharps. The nature of the MWTF technologies can generate concerns, such as exposure to non-ionizing radiation. Other concerns include safety hazards and risks of injury related to lifting, moving, slips, falls, machine guarding, and electrical problems. While significant hazard information and statistics are available for "health care workers," medical waste handlers and treatment workers have not been included in the data gathering. It is prudent to assume that medical waste workers are at risk for the same occupational illnesses and injuries as health care workers.

B.1.3 Methodology Overview

Phase 1 of this project focused primarily on emissions, safety, controls, and biohazards. It consisted of the following:

- an industrial hygiene survey,
- a comprehensive safety assessment,
- identification of potential emission points from the treatment system or process,
- area sampling for identification of target volatile organic compounds (VOCs),
- area sampling for airborne metals,
- area sampling for aldehydes,
- noise and nonionizing radiation measurements,
- identification and assessment of existing engineering controls,
- preliminary respirable aerosol assessment,

- the assessment of blood on surfaces, and
- the assessment of microbial surface contamination.

Each of these assessment areas are discussed in detail later in this report. Details of the specific methodologies used are addressed in Appendices E-P. This Phase 1 survey was carried out by a field team of five people: a certified industrial hygienist (CIH), a certified safety professional (CSP), an experienced microbiologist, an engineer, and an environmental field sampling specialist. Phase 1 survey did not attempt to determine if the technology was efficiently treating the waste. This assessment examined worker exposures due to the environment at the individual facility due to the technology, the work procedures including the handling of the waste, and the facility itself. It is important to note that the effect on the individual worker's environment of safety features and dangers inherent in each technology is dependent on the use of the equipment in a given facility, the care given to following the manufacturers established procedures, the design of the facility (especially as regards to waste handling and ventilation), and the individual worker's adherence to the procedures at the given facility (for example, use of provided personal protective equipment).

The industrial hygiene and safety assessment surveys observed the waste treatment workflow and process, initially identify the potential hazards and routes of exposure unique to the waste treatment technology/facility; secure floor plans, engineering control diagrams, and written safety policy; define work shifts and worker populations; examine policy related to health promotion (e.g. hepatitis B vaccine, TB testing); describe potential routes of exposure relative to specific job assignments, identify chemical compounds used or stored in the facility; identify potentially unsafe procedures, practices or conditions, addressing all safety concerns, including machine guarding, slips and falls, and ergonomics; and identify training and personal protection devices currently used.

The samples for Phase 1 included for air emissions: VOCs, metals, mercury, aldehydes, ketones, and particles; and surface contamination from blood or microbial. Noise and nonionizing radiation were also measured.

Potential chemical and biological emission points were identified to ensure that subsequent sampling was properly targeted. The identification was performed by visual inspection and facility usage, as appropriate. The results of this screening were be used to identify areas and personnel on which to concentrate additional sampling.

Ventilation and HVAC control devices as applicable to the facilities air supply were investigated. Measurements of airflow were taken. The airflow measurements were used to determine if sufficient air is entering the facility based on the ASHRAE standard for indoor ventilation requirements. An attempt was made to determine if contaminated air from the disposal facility is being vented to any other indoor location (such as entering the return air to a main air distribution location). Control devices that could create hazards of themselves were investigated in conjunction with the hazard identification. The evaluation of other engineering controls such as machine guarding, handrails, lifting assistance, noise control, and workplace ergonomics were included.

Phase 1 included aerosol measurements to provide a concentration profile for the room. The aerosol monitor was used to measure concentrations near each identified potential emission point and in several locations throughout the room. The concentration in the incoming outdoor air and the office air were determined.

Surface blood contamination is also an important consideration in medical waste treatment. Treatment system surfaces with which workers may come in contact were monitored each day for blood contamination by a wiping procedure using sterile gauze. The gauze was then eluted with sterile water and the eluate was tested for blood using the Hemastix detection method.

The risk of medical waste treatment workers to dermal contact with infectious disease agents were assessed by sampling and analysis of treatment system surfaces for human pathogen indicator organisms. Suspect surface areas were evaluated by sampling and analysis for two strains of vegetative bacteria associated with human infection and/or contamination, *Staphylococcus aureus* and *Escherichia coli.*

B.2 GENERAL SAFETY EVALUATION

B.2.1 Summary

The microwave facility, shown in Figure B-1, is located on flat terrain, in an area with many light industrial buildings. This facility is located in a light industrial building essentially built of concrete block with steel rafter/supports and a lightweight, corrugated roof. It is approximately 60 feet x 110 feet x 24 feet in height. Approximately 1/3 of the building was used for two floors of offices which were divided from the plant side by a floor to ceiling wall. The plant side had free space from floor to ceiling. One section approximately 24 feet x 24 feet had been created with permanent block walls and housed one microwave treatment unit. Another unit was in the larger, open section of the plant which served as the unloading/staging/cleaning area for the medical waste containers. A microwave unit is shown in Figure B-2. The plant side was protected by a charged water sprinkler system with sprinkler riser controls inside and Fire Department Connection (FDC) outside. The office side had no sprinklers. Occupancy was around 6 in the offices and 3-6 in the plant at any given time.

Untreated medical waste is placed in "red" plastic bags or sharps containers by the microwave facility customers and the bags are placed in 48 gallon rigid plastic containers that generally weigh between 25 and 47 pounds. Smaller, 28 gallon, containers weighing 16-20 pounds may also be used, but none were seen by the assessment team. The sharps containers were normally segregated and handled separately from the plastic containers. The microwave facility drivers manually load the containers into microwave facility owned/operated trucks and bring them to the facility. The containers are manually pulled to a lift gate on the truck, off

Figure B-1.
Microwave Facility Schematic

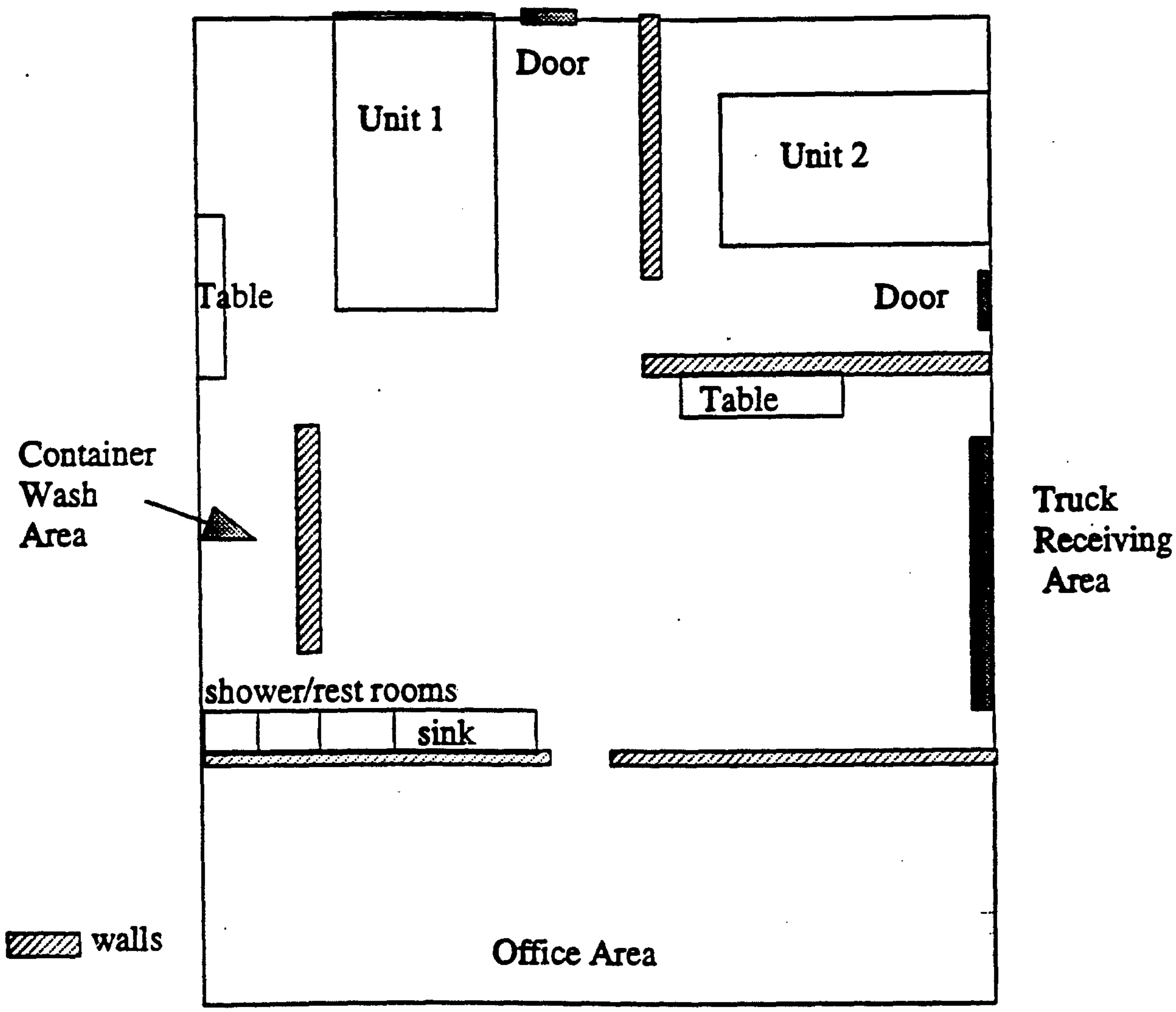
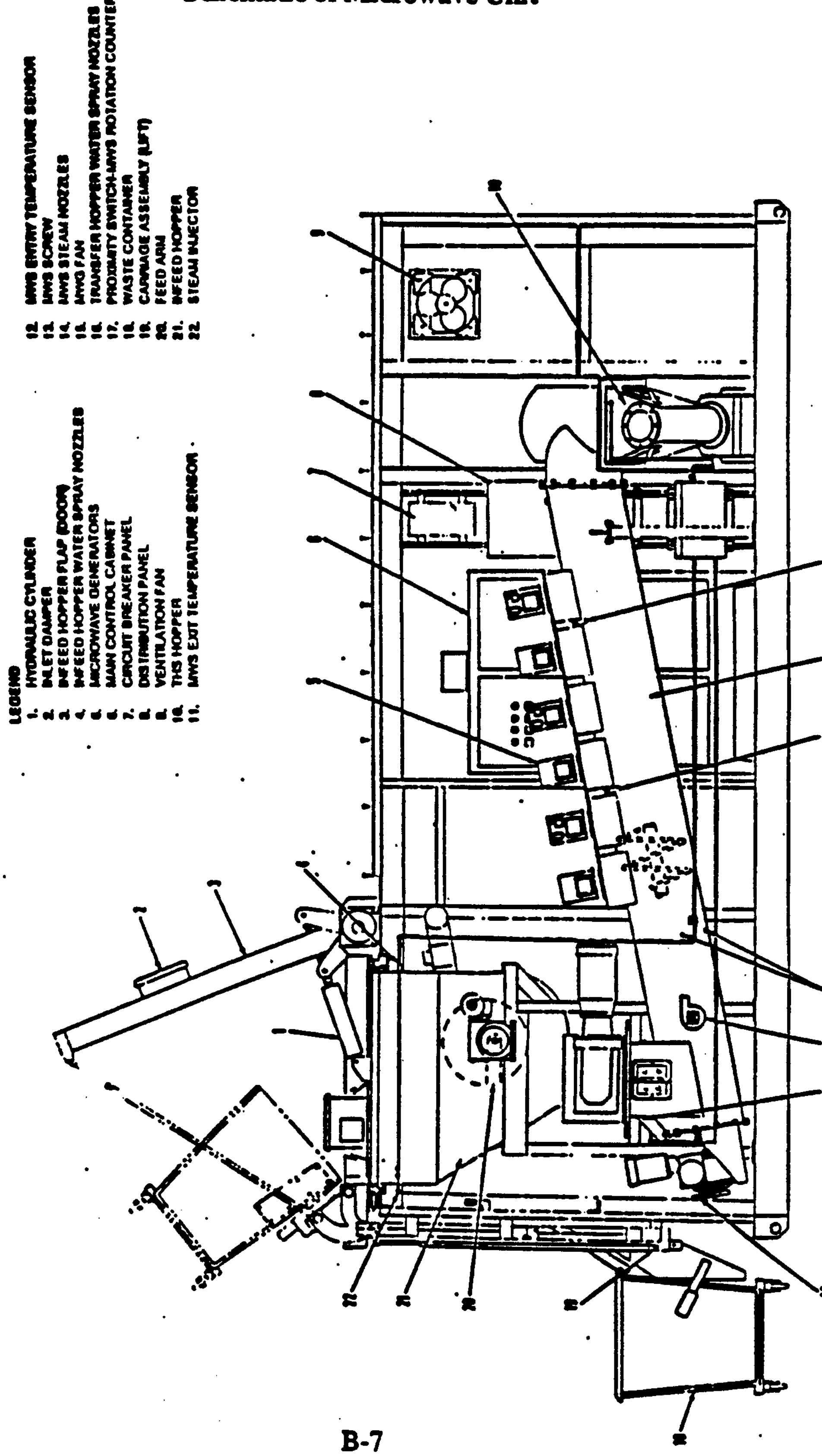


Figure B-2.
Schematic of Microwave Unit



loaded, and manually stacked up to 3 high using no mechanical aids. After weighing, the containers are manually dumped into a large bin attached to one of the microwave units. The process cycle is machine controlled with limited worker action. Upon signal from the microwave unit, a worker manually initiates a control on the unit which activates a lift mechanism. The large cover on the hopper is automatically opened, the lift elevates the bin approximately 12 feet and, then, tips the bin. Once the medical waste has dropped in the hopper, the lid closes over the hopper, and the bin is lowered to ground level.

An automatic grinding cycle commences in which the waste is ground up to material less than approximately 0.5 inch wide. During treatment, the waste is augured up a closed, inclined tube. The tube has six (6) microwave units mounted on top and several ports allow steam injection. The microwave units heat the steam and waste as it travels through the auger. The treated waste product is gravity-dropped into a dumpster located on the outside of the building. An attached hydraulic ram periodically compacts the waste into the dumpster. When full, a contractor hauls the dumpster to the city landfill to be emptied.

A general safety review of the facility was conducted, including material control and engineering controls for worker protection, review of the general safety training and compliance programs, and conducting a sequential job safety analysis of the primary jobs.

The microwave facility physical plant had some inherent hazards needing attention as well as the need for establishment of certain routine preventive procedures. The primary treatment units were commercially produced and had several inherent hazards needing attention. A large component of the material handling was manual, without aids. The primary worker exposure hazard was to liquid exposure during bin loading, bin dumping, and container cleaning. Back and muscle strain exposure hazards were noted during the truck loading/unloading, pulling, stacking, and dumping of the containers. Puncture hazards were found from waste dumped into the hopper rolling off the top of the unit to the worker standing at the unit control location and from workers pushing red bags in the bin to more efficiently load the bin.

Management was very interested and proactive in providing workers with training of many types and providing protective equipment. The microwave facility had an active safety committee. Written programs and documentation were good. A strong emphasis on good housekeeping in the active work area was evident, but needed improvement in several areas.

A detailed listing of findings is attached along with numbered photographs with corresponding narrative. This review was as "global" as possible to include items found in OSHA regulations, fire and electrical codes, and good practices. A separate ventilation engineering, industrial hygiene and blood/microorganism/environmental contamination review was conducted by others on the project team.

B.2.2 General Facility Review

Significant Positives

Proactive management.
Located in an industrial area, no residential, school, or other non-industrial neighbors within immediate vicinity.
Good fire protection.

- Sprinkler system in plant.
- City fire hydrant directly across the street.

Approved, fixed ladder access to roof.
Overall, plant and offices well maintained.

Significant Negatives

Electrical safety program needs attention:

- Electrical panel room (office side) is badly cluttered making panel access very difficult. A 36" clearance in front of all panels was not found.
- Circuits in several electrical panels in the office area were not identified. In the plant the panel near the safety station has worn/faded labeling.
- It was not clear that Ground Fault Circuit Interrupt (GFCI) protection is provided in some areas where needed e.g. receptacles - plant side - wash area; kitchen - office side - 2nd floor. If testing reveals lack of GFCI protection, it should be provided for all receptacles within six (6) feet of a water source and any exterior receptacle.
- Missing receptacle cover plate in Unit 1.
- Motor/grinder electrical box, Unit 1, protected by duct tape.
- Worn wiring on cord - housing entrance - portable air compressor.

Egress issues which need attention:

- No egress diagrams for the facility were found. They are typically posted in prominent locations easily found/seen by visitors.
- Proper designation of exits was needed. All EXIT doors must swing OUT when exiting the area.
- Exit doors may NOT be locked on the inside. All occupants must be able to exit using a SINGLE motion to unlock & open exit door. The main door (plant side) leading to the offices was designated as an exit. It pulled IN and it was capable of being key locked.

- Exit doors may never be blocked. A pallet jack blocked the opening of the door at the base of the stairwell. e.g. paint, on asphalt, yellow zone approximately 4 foot square outside the door discharging from stairwell and allow no placement of materials in this zone.
- No emergency egress lighting (in case of power failure) was found. Consider installation of hard wired EXIT lights above designated exits. Note - EXIT lights with battery backup will give emergency lighting; alternatively flashlights/lights that plug into receptacles and activate on power failure are available.
- Periodic (at least annual) emergency drills should be conducted.
- Clear, unobstructed, designated, aisleways in the plant were not observed. e.g. paint lines on plant floor 3 feet apart leading to EXIT door(s). Allow no placement of materials in these zones.

Fall Protection:

- Fall protection is needed above both Unit 1 and Unit 2 that meets 29 CFR 1926 Subpart M, Appendix E. Note: While 29 CFR 1926 Subpart M is a construction industry standard, it gives guidance on methods to prevent falls from >6 feet e.g. using guardrails (with toeboard - to prevent falling objects).

Cross-Contamination:

- The workers did not have a means to quickly remove potentially contaminated work/protective clothing and take food/water breaks i.e. move from a "potentially contaminated (dirty) area" to an "uncontaminated (clean) area."
- Drinking water and a soda machine were within the plant area adjacent to incoming waste and subject to cross-contamination. There was evidence of smoking/drinking in the active waste area (i.e. cigarette and bottle debris on top of Unit 2).
- The workers did not have easy access to the existing shower for emergency washdown due to material storage in front of the door.
- Workers wear potentially contaminated clothing home.

Fire Safety:

- A large rock was adjacent to the fire hydrant which could inhibit firefighters free and quick access to the hydrant. [Note: This is a city versus microwave facility issue but does affect the microwave facility.]
- The curbing 3 feet to either side of the fire hydrant was not painted yellow to visually remind drivers not to park near the hydrant. [See note above.]
- A 3 foot zone (painted or striped red) around the fire sprinkler riser, would remind staff to avoid placement of materials within this zone.

- A Sign reading "FDC" was not mounted above the Fire Department Connection on the outside of the building.
- The fire hose needs to be pressure tested; re-rolling into a coil will help prevent cracking at the folds. Hose testing is required every 2 years under some fire codes.
- The sprinkler head that is adjacent to the "swamp cooler" unit discharge in the loading/unloading ceiling area is partially blocked by duct work.
- The 10 pound fire extinguisher at the safety station is mounted very high and is not easy to procure.

Microwave Unit Safety

- Unit 1 and Unit 2
  - The location of the control panel does not allow workers to be away from the area most likely to have liquid spills or falling material. A small canopy above the control station could protect the operator from drips/splashes/falling materials. Also, a toeboard at the top of the unit would assist in controlling spills or falling material.
  - There were two unguarded shafts on each unit: one at the auger base and one by the grinder.
- Unit 1
  - The guard that covers a fan on microwave #2 (from base) was loose, exposing the fan.
  - The exhaust filtration and discharge system on Unit 1 was not working properly as discussed in B.6.2.
- Access to the top on Unit 1 and Unit 2 was by ladder. Carrying items while climbing the ladder is hazardous. Moveable stairs, with siderails, to gain access the top of each unit would eliminate this hazard e.g. one set of metal stairs, with siderails, on rollers, could serve both units and eliminate use of ladder and stepladder plus aide in carrying of tools and materials on and off the top of the unit.
- Radiation
  - The non-ionizing microwave meters/detectors and the ionizing meter/crystal detector needed calibration. All units were beyond calibrate date due; 2 units were inoperable.

Miscellaneous Safety Items:

- Signage
  - The existing informational signage is not consistent with practices observed. e.g. "*No food, beverages or smoking beyond this point,*" yet water and soda machine within the area and consumption allowed.
- Housekeeping
  - Access to the shower room was blocked.

- Eyewash stations
    - An established zone to be kept clear around each eyewash station was not present e.g. a 2 foot square (green) area on floor and with no allowed placement of materials in this area.
- Truck (Isuzu, License Plate 4PM-644)
    - An empty bottle of absorbent was in the safety supplies.

Environmental Safety Issues:

- It has been confirmed that the microwave facility does not produce hazardous wastes or radioactive wastes. Therefore, no EPA identification number or NRC license is required.
- The author confirmed that the microwave facility does not possess quantities of hazardous materials above the EPA Threshold Planning Quantity (TPQ)" [Note: No hazardous materials were found exceeding EPA "Release Quantities (RQ)" either.]. Therefore, no annual reporting or emergency release notification is needed.
- A neighbor industry located behind the microwave facility has placed a large (approximately 5000 gallon) diesel fuel tank about 30 feet from the fence behind the microwave facility plant. The fuel tank does <u>NOT</u> appear to have secondary containment, but does have concrete barricades surrounding it. Rupture of the fuel tank, fuel overflowing during re-fueling, or similar scenarios would be likely to cause environmental pollution to the microwave facility property.

B.2.3 Training Programs and Documentation

Note: These observations are based on review of the personal training records and other information provided by the plant manager.

<u>Significant Positives</u>

The company has an active company safety committee.
Excellent written programs are in place for:

- Bloodborne Pathogens
- Hazard Communication
- Contingency Planning

Excellent and active training is given for all workers in essentially all OSHA required areas.
Employee training records are also kept.
There is a strong emphasis on not touching the waste.

Significant Negatives

No written respirator protection program was available.

Other Issues

- It was not determined if plant workers routinely participate on the safety committee. Recommended practice is to have representative workers rotate onto the committee.

- The "Disposal Services Agreement, Section 2.1," did not specifically EXCLUDE RADIOACTIVE WASTE, AS DEFINED BY THE NUCLEAR REGULATORY COMMISSION. An audit program (e.g. semiannually) to check incoming waste for radioactive content was not in place.

- The job duties listed in the "task assessments" did not include specific reference to the actual weights a worker must be able to lift/manipulate.

- The emergency plan was not tabbed, by contingency, to assist rapid location of the sequence to follow.

- The emergency plan did not designate that all workers are to fight only incipient fires, not structural fires since microwave facility does not have a fire brigade, with equipment, training, and documentation.

B.2.4 Job Safety Analysis

Task: Unloading Truck

Primary Hazard - muscle pulls/strain

Personal Protective Equipment (PPE) Used - Long sleeve shirts, pants, steel toed shoes, latex and leather gloves, safety glasses

PPE Present, Use not observed - A Wilson half face respirator with cartridges for formaldehyde, chlorine, hydrochloric acid, sulfur dioxide and hydrogen sulfide; 3M 8500 Comfort Masks and Aseptex 1800 Fluid Resistant Molded Surgical Masks were observed in a cabinet.

Safety Aids - None

Suggested Changes - explore use of mechanical or other devices to assist workers.
- stack containers only 2 high
- move with cart/dolly to minimize pulling

Task: Loading Microwave Unit Bins/Loading Hopper

Primary Hazard - exposure to splashes/drips/falling material

Personal Protective Equipment (PPE) Used - Long sleeve shirts, pants, steel toed shoes, gloves, safety glasses

Safety Aids - None

Suggested Changes - Protect personal clothing from work clothing i.e. wearoveralls/disposable Tyvek®; leave workshoes at work or cover with booties.

NOTE: Worker exposure to falling debris and liquids during the bin dumping should be eliminated or further minimized. Potential actions:

(1) Move control panel to opposite end of unit to physically remove the worker from the hazard.

(2) Addition of a protective canopy installed over the control station.

(3) Install a toeboard along top of each unit (as part of Fall Protection Guardrails) to help prevent objects/liquids from falling onto worker.

(4) Wear protective headwear and faceshield e.g. hardhat with attached faceshield or a personal air purified respirator (PAPR).

- Strict adherence to non-handling/touching of the red bags/ medical waste.

Task: Washing Containers

Primary Hazard - Worker exposure to splashes of residual liquid from container onto face or other exposed parts of body while washing/rinsing containers and lids.

Personal Protective Equipment (PPE) Used - Long sleeve shirts, pants, steel toed shoes, gloves, safety glasses

Safety Aids - None

Suggested Changes - Personal protective outerwear.
- Hard hat with face shield or PAPR use.

B.2.5 Additional Concern

Transportation Safety

- A review of the container labeling found no use of the "Infectious Substance" or "Biohazard" labels on the containers. It appears that the exemption provision noted on p. 48787 of Federal Register, Volume 60, Number 182 [September 20, 1995] and U.S. Department of Transportation Exemption "DOT-E 11588 (First Revision)" [April 9, 1996], which specifically names microwave facility, are used to meet marking requirements. Per Item 10 of the DOT exemption, a copy of the exemption letter should be carried in each microwave facility vehicle.

B.3 EMISSION POINT IDENTIFICATION

During the initial visit to the microwave facility potential chemical and biological emission points within the facility were identified to allow for subsequent, properly targeted, sampling. The identified potential emission sites for the facility included the microwaves, the exhaust stream, the loading doors especially when venting, the tub washing areas, and the unloading areas. The emission points were the basis for the choices of sample sites.

B.4 CHEMICAL MEASUREMENT RESULTS

The medical waste as received is not chemically treated. The waste itself may contain any number of chemicals, most probably volatile metals such as mercury, volatile organic compounds, or aldehydes such as formaldehyde. The facility uses miscellaneous chemicals including mineral spirits, 2-butoxyethanol, Betco disinfectant, Zeposcetor (pyrethin/pipernyl butoxide insectacide), phosphoric acid, aliphatic naptha, ZEP-Amine A (ethanol and ammonium chlorides), acetylene, oxygen and nitrous oxide.

B.4.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) were collected by passing air through multisorbent cartridges containing Tenax TA, charcoal, and ambersorb (200 mm x 6 mm o.d., Envirochem, Kimblesville, PA). For analysis, VOCs on exposed cartridges were thermally desorbed then analyzed by gas chromatography/mass spectrometry (GC/MS). Identification of unknown sample constituents was performed using an electronic search of the NIH/EPA/MSDC Mass Spectral Data Base (NIST library) and the Registry of Mass Spectral Library (Wiley Library). Manual review of the data was performed to verify computer identifications and to identify compounds not found using the computer literature search. A semiquantitative estimate of the identified compounds was made using the total ion peak area for each compound and the total ion response factor measured for toluene. A concentration estimate for total volatile organic compounds was made using the same approach. Example VOCs that are amenable to analysis by the multisorbant method are shown in Table B-1.

Samples for VOCs were collected at a flow rate of nominally 15 cc/min for 5 hours in the bin wash area workbench, over Microwave Unit No. 1 and over Microwave Unit No. 2.

Several VOCs were observed at the facility. They are listed in Tables B-2 to B-5 and Figures B-3 to B-6. The concentrations given are based upon the formula weight of toluene, and only those VOCs in excess of 0.05 mg/m^3 are reported. The total VOC content will comprise both those from the waste stream and from truck exhaust from the trucks unloading at the facility. No OSHA permissible exposure limits (PELs) nor ACGIH threshold limit values (TLVs) were exceeded. Field control recoveries are shown in Table B-6.

B.4.2 Hydrochloric Acid and Chlorine

The microwave facility was not using chlorine-based biocides and was not tested for hydrochloric acid or chlorine.

B.4.3 Aldehydes and Ketones

Formaldehyde is a contaminant that may be emitted during the treatment of medical waste. Formaldehyde as well as other volatile aldehydes and ketones were screened for using a silica gel/DNPH-(2,4-dinitrophenylhydrazine) (Waters Assoc., Medfor, Ma) method (US EPA, 1988). During sampling, aldehydes and ketones instantaneously react on the cartridge to form the DNPH derivative. For analysis, the DNPH/aldehyde ketone derivatives were eluted from the cartridge with acetonitrile. This extract was then analyzed by high performance liquid chromatography (HPLC). Aldehydes and ketones were identified by comparison of their chromatographic retention times with those of purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range 0.02 to 15 ng/μL of the DNPH/aldehyde derivatives. Standards were analyzed and a calibration curve calculated by linear regression of the concentration and chromatographic data. A list of aldehydes and ketones analyzed during Phase 1 screening are shown in Table B-7.

Aldehydes were collected at a flow rate of nominally 120 cc/min for 7 hours near the bin wash area workbench, over Microwave Unit No. 1, and over Microwave Unit No. 2.

The aldehyde results (Table B-8) indicated minimal concentrations ranging from 0.007 mg/m^3 to 0.2 mg/m^3; several orders of magnitude lower than the respective OSHA PELs.

Table B-1. Example VOCs That Are Amenable to Analysis by the Multisorbent Method

1,2-Dichloropropane	C_3-Benzenes	Bromoform
1,1,2,2-Tetrachloroethane	C_4-Benzene	Isopropanol
Dibromochloromethane	Methylene Chloride	Propanol
Bromodichloromethane	Bromethane	Butanol
cis-1,3-Dichloropropene	Chloroethane	Pentanol
1,1,2-Trichloroethane	Chloromethane	Benzene
1,1-Dichloroethane	Chloroform	Toluene
1,2-Dichloroethene (Total)	Trichloroethene	Acrolein
trans-1,3-Dichloropropene	Chlorobenzene	Acrylonitrile
1,2-Dichloroethane	Ethyl Benzene	Styrene
1,1,1-Trichloroethane	Dichlorobenzenes	Vinyl Chloride
Carbon Tetrachloride	1-1-Dichloroethene	Xylenes
	Tetrachloroethene	

Table B-2. VOC Results
Site 2 Microwave Unit No. 1

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4358

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
4.13	Methane, dichlorodifluoro-	93	448
6.21	Oxybismethane	60	38
6.3-6.9	Acetonitrile	47	1228
6.72	Oxybismethane	60	8.6
7.07	2-Propanone	27	213
7.12	Trichlorofluoromethane	76	156
7.4-8.7	2-Propanol	67	2318
8.32	Methylene chloride	(c)	6.7
9.10	2-Propanol, 2-methyl-	76	9.5
11.56	Acetic acid, ethyl ester	83	17
12.07	Furan, tetrahydro-	93	4.5
12.54	Ethane, 1,2-dichloro-	89	17
15.10	Ethene, trichloro-	86	3.2
15.50	Methyl methacrylate	(c)	10
15.67	Heptane	93	52
16.56	Pyridine	96	13
18.00	Benzene, methyl-	93	30
21.86	Benzene, ethyl-	87	42
22.24	m/p-Xylene	96	178
22.50	Cyclohexanone	86	126
22.89	Styrene	95	11
23.11	o-Xylene	96	51
23.29	Ethanol, 2-butoxy-	78	28
25.11	Terpene isomer	(c)	4.1
25.70	Phenol	94	9.3
27.65	Benzenemethanol	89	26
27.83	1-Hexanol, 2-ethyl-	79	28
28.35	Terpene isomer	(c)	77
28.88	C11 alkane	(c)	54
29.55	Naphthalene, decahydro-, trans-	73	64
37.85	Phenol, 2,6-bis(1-methylethyl)-	96	6.3
	Total Volatile Organic Hydrocarbons		6572

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure B-3. VOC Results
Site 2 Microwave Unit No. 1

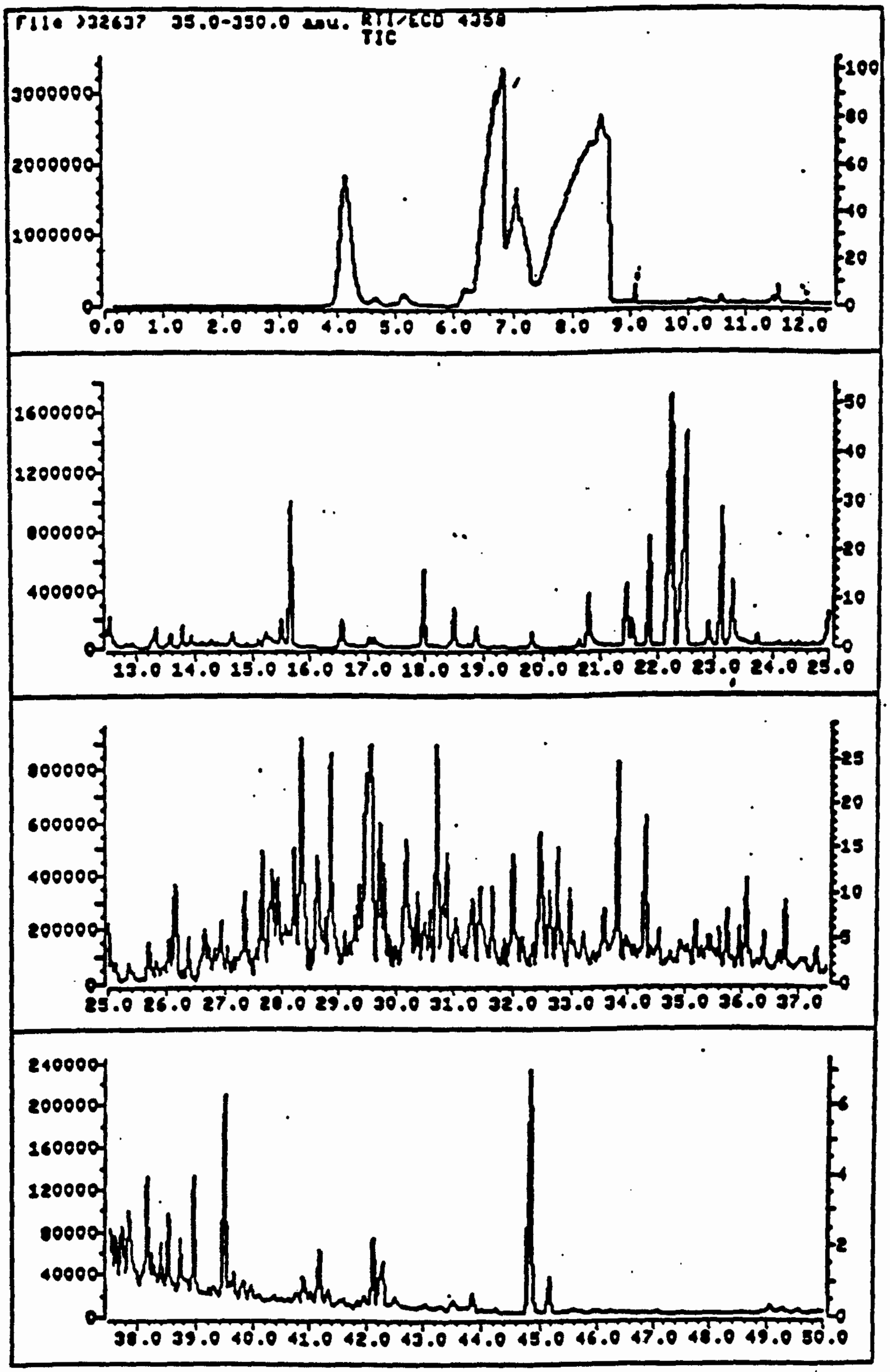


Table B-3. VOC Results
Site 2 Microwave Unit No. 2

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4360

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
4.11	Methane, dichlorodifluoro-	89	129
4.63	2-methyl propane	(c)	105
6.38	Methane, oxybis-	60	108
6.45	Acetonitrile	83	51
6.83	2-Propanone	78	43
7.07	Methane, trichlorofluoro-	83	39
7.63	2-Propanol	79	495
8.30	Methane, dichloro-	86	5.8
8.51	Carbon disulfide	76	25
11.49	Acetic acid, ethyl ester	83	9.8
17.96	Benzene, methyl-	95	7.7
22.18	m/p-Xylene	96	25
22.40	Cyclohexanone	87	24
23.07	o-Xylene	97	7.5
23.25	Ethanol, 2-butoxy-	86	16
25.69	Phenol	91	2.6
	Total Volatile Organic Hydrocarbons		1510

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure B-4. VOC Results
Site 2 Microwave Unit No. 2

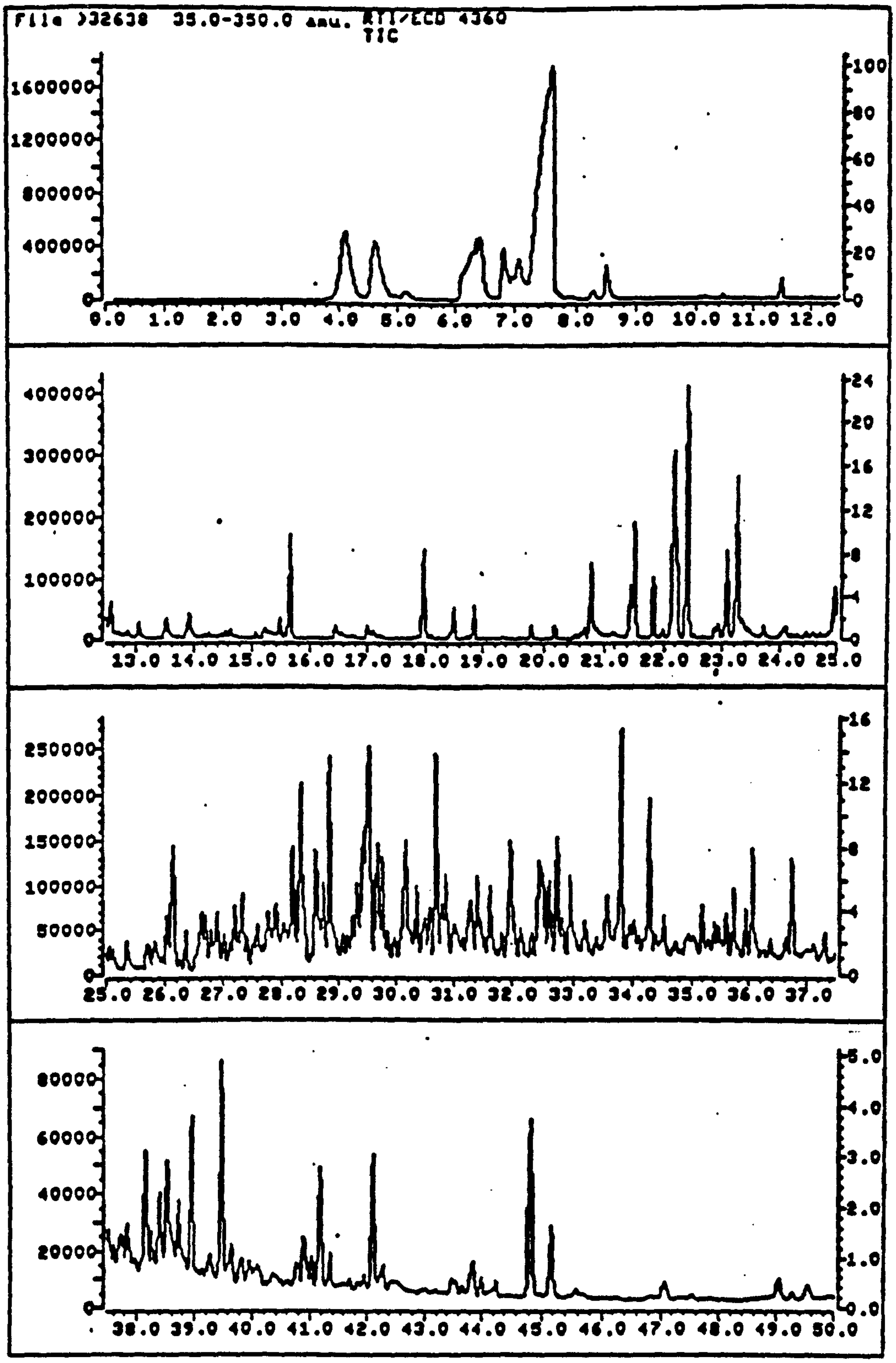


Table B-4. VOC Results
Site 2 Near Bin Wash Area

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4362

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
4.16	Methane, dichlorodifluoro-	89	149
6.23	Methane, oxybis-	60	95
6.50	Acetonitrile	25	171
6.89	2-Propanone	78	70
7.12	Methane, trichlorofluoro-	83	68
7.93	2-Propanol	79	986
8.31	Methane, dichloro-	87	11
8.55	Carbon disulfide	76	61
11.52	Acetic acid, ethyl ester	83	9.7
12.53	Ethane, 1,2-dichloro-	89	5.3
15.48	Methyl methacrylate	(c)	3.5
16.47	Pyridine	96	3.4
17.98	Benzene, methyl-	95	11
22.19	m/p-Xylene	96	58
22.43	Cyclohexanone	87	46
22.87	Styrene	96	2.7
23.08	o-Xylene	96	17
23.37	Ethanol, 2-butoxy-	83	159
27.62	Benzenemethanol	89	4.5
28.34	Terpene isomer	(c)	57
29.57	Naphthalene, decahydro-, trans-	69	78
30.73	Undecane	93	58
31.04	Naphthalene, decahydro-, cis-	68	16
33.86	Dodecane	93	85
34.33	C13 Alkane	(c)	69
	Total Volatile Organic Hydrocarbons		3837

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure B-5. VOC Results
Site 2 Near Bin Wash Area

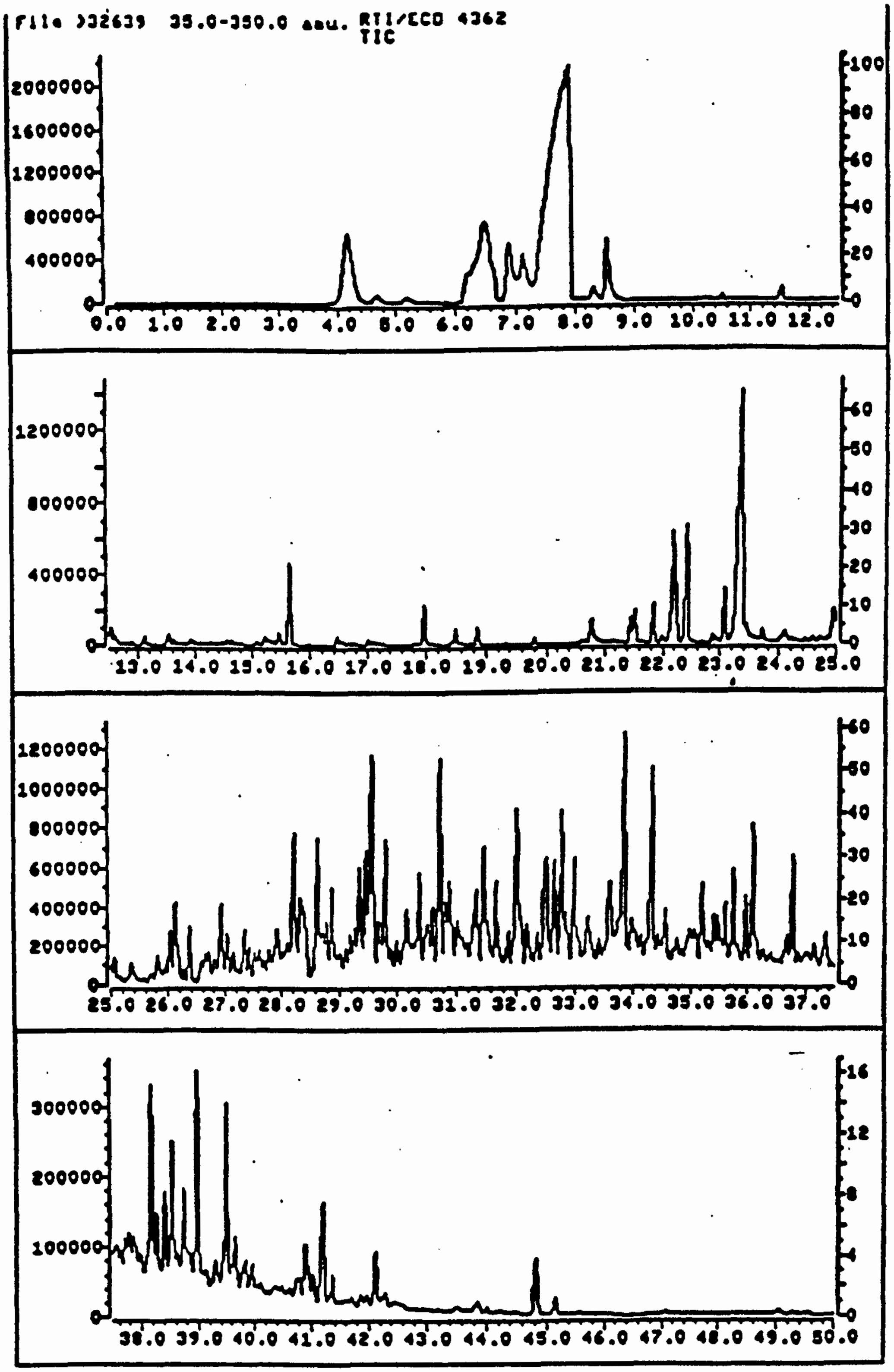


Table B-5. VOC Results
Site 2 Field Blank

QUALITATIVE IDENTIFICATION REPORT

FB-1 SITE-2

Retention Time (min.)	Peak Identification(a)	Fit(b)
12.59	Internal standard	
21.53	Internal standard	

a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

b) % Fit versus reference spectra.

c) Manual interpretation.

Figure B-6. VOC Results
Site 2 Field Blank

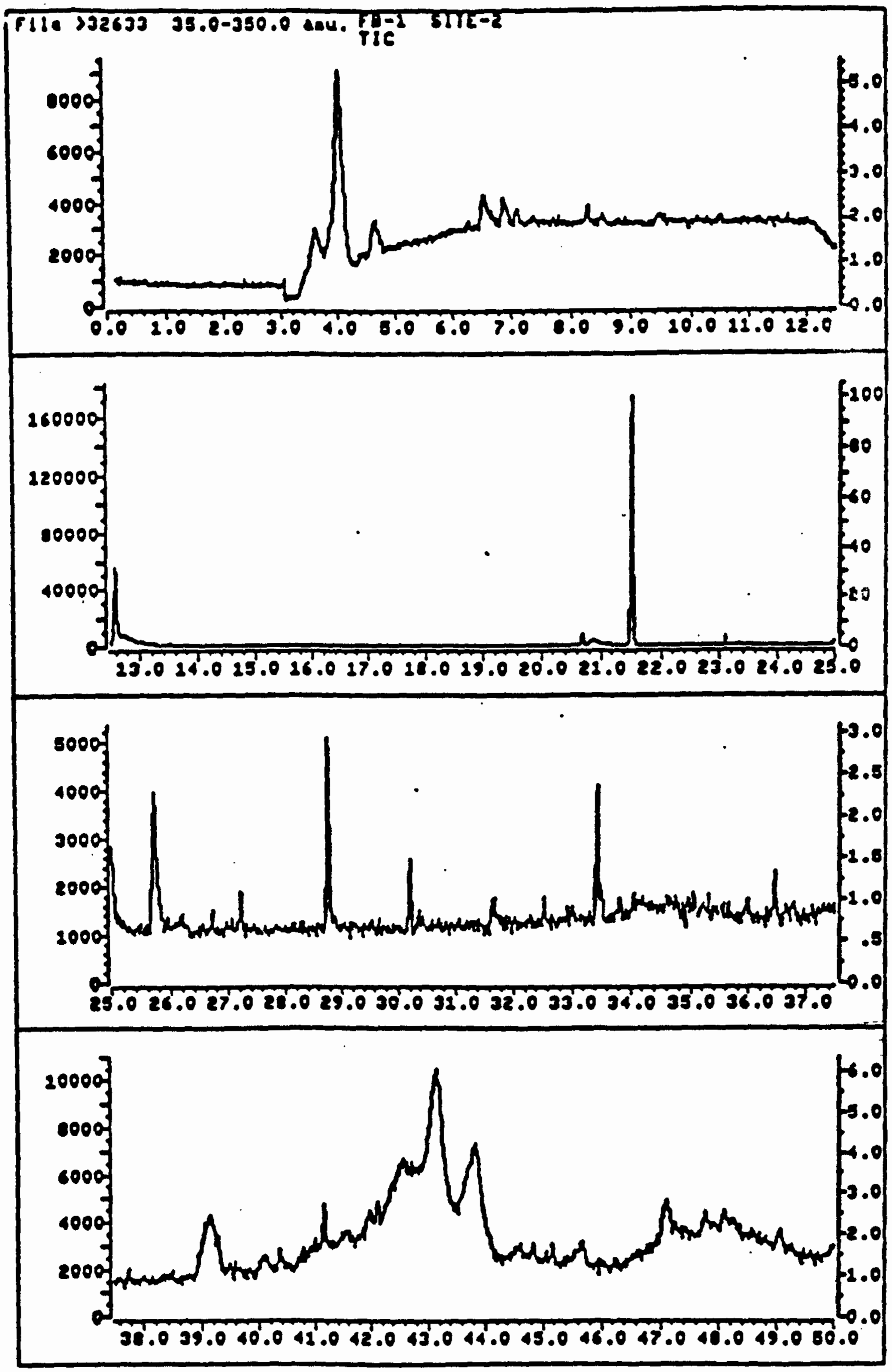


Table B-6. Medical Waste
Field Control Recoveries VOC's

	Site 2 % Recovery FC vs. LC
Chloroform	107.3
Toluene	116.2
o-Xylene	106.8
Vinyl Chloride	88.8
Benzene	103.2
Trichloroethylene	103.1

Table B-7. Example Aldehydes and Ketones
Analyzed During Phase 1 Screening

Formaldehyde	Acetaldehyde	Acetone	Acrolein
n-Propanal	Crotonaldehyde	n-Butanone	n-Butanal
Benzaldehyde	n-Pentanal	n-Tolualdehyde	n-Hexanal

Table B-8.
Results of Aldehyde Analysis

Sample ID	Location	Air Volume
4364	Microwave Unit No. 1	52.0 L
4365	Microwave Unit 2	50.4 L
4366	Tub Wash Area	50.7 L
4367	Tub Wash Area Duplicate	50.5 L
FB-2	Field blank	0.0 L

Concentrations Expressed in ($\mu g/m^3$)							
Sample ID	**Field Control**	**Solution Blank**	**4364**	**4365**	**4366**	**4367**	**Field Blank**
Compound	**% Recovery**						
Formaldehyde	93	<2.6	16	8.5	7.8	8.3	<2.6
Acetaldehyde	100	<2.6	81	17	29	32	<2.6
Acetone	119	<2.6	203	59	74	77	3.8
Acrolein	0	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Propionaldehyde	81	<2.6	6.1	<2.6	<2.6	<2.6	<2.6
Crotonaldehyde	6	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
2-Butanone	230	<2.6	15	2.8	4.2	4.9	<2.6
Methacrolein	44	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Butyraldehyde	86	<2.6	6.9	<2.6	<2.6	2.6	<2.6
Benzaldehyde	98	<2.6	5.1	<2.6	<2.6	2.9	<2.6
Valeraldehyde	81	<2.6	3.8	<2.6	<2.6	21	<2.6
m-Tolualdehyde	89	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Hexanal	80	<2.6	5.9	<2.6	3.3	3.1	<2.6

B.4.4 Metals

The methodology used for metals sampling used EPA draft method 29 sampling train for combustion source emissions (US EPA, 1986). The sample system incorporates a glass fiber filter followed by two (2) impingers containing acidified peroxide solution for collection of aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), labile mercury (Hg^{+2}), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl) and zinc (Zn). Following the peroxide impingers were two impingers containing acidified potassium permanganate for the collection of elemental mercury (Hg°). A miniaturized version of the sampling train that incorporates midget impingers (1 - 2 L/min sampling rates) instead of the Greenburg/Smith impingers (approximately 20 L/min) was used.

Metals were collected at a flow rate of nominally 1 L/min in the areas over Microwave Unit No. 1 and Microwave Unit No. 2.

The measurement of these resulting samples included graphite furnace atomic absorption (GFAA) for As, Sb, and Se, cold vapor atomic absorption (CVAA) for Hg and inductively coupled plasma mass spectrometry (ICP/MS) (EPA Method 200.8) for Al, Sb, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Ni, Ag, Tl and Zn emission spectrometry for Al, Fe, Zn, P, and inductively coupled plasma. These methods are described in both the NIOSH Manual of Analytical Methods (NIOSH, 1994) and in EPA "Methods for Chemical Analysis of Water and Wastes" (EPA 600/479-020).

The results of the metals sampling (Tables B-9 through B-11) indicate minimal levels (most are less than the detection limits), of the following metals: Be, Al, Cr, Mn, Fe, Co, Ni, Zn, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg. Quality control data for the metals testing is shown in Table B-12.

B.4.5 Indoor Air Quality

The indoor air quality was evaluated from 4/10/ 96 to 4/11/96 using a Metrosonics Air Quality Monitor AQ-501 (S/N 1613). The air was evaluated for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO). The results (Table B-13) indicate adequate indoor air during the sampling period.

B.5 NOISE, ERGONOMICS, AND RADIATION

B.5.1 Noise

A noise survey was conducted on 4/10/96 using a Quest Sound Level Meter (S/N DL8110002) calibrated with a Quest Calibrator (S/N J8100013). The noise survey demonstrated that noise levels ranged from 59 to 75 dBA in the process area and from 42 to 47 dBA in the office area (Figure B-7). A Quest Noise Dosimeter (S/N HM 0010038A) was also used to collect

Table B-9. Site 2
Metals Analysis ($\mu g/m^3$)
Blank Corrected

Location	Microwave Unit No. 1						
RTI/ECDNo. Identifier Air Volume (m^3)	4296 Prefilter 0.419	4290 Impinger 1 0.419	4291 Impinger 2 0.419	4292 Impinger 3 0.419	4293 Impinger 4 0.419	4294 Impinger 5 0.419	4295 Impinger 6 0.419
<u>Metals</u>							
Be	<0.07	<0.07	<0.07	<0.07	a	a	a
Al	<7.2	<7.2	<7.2	<7.2	a	a	a
Cr	<1.2	<1.2	<1.2	<1.2	a	a	a
Mn	0.32	0.06	2.94	3.25	a	a	a
Fe	7.6	1.26	<0.4	0.74	a	a	a
Co	<0.48	<0.48	<0.48	<0.48	a	a	a
Ni	<0.24	<0.24	<0.24	<0.24	a	a	a
Zn	2.86	<1.2	<1.2	<1.2	a	a	a
Cu	0.50	<0.07	<0.07	0.33	a	a	a
Cd	<0.02	<0.02	<0.02	<0.02	a	a	a
Sb	<0.02	<0.02	<0.02	<0.02	a	a	a
Ba	0.36	0.05	0.10	0.13	a	a	a
Tl	<0.02	<0.02	<0.02	<0.02	a	a	a
Pb	0.12	<0.11	<0.11	0.12	a	a	a
Hg^{+2}	0.27	<0.05	<0.05	<0.05	a	a	a
Hg°	b	b	b	b	1.85	<0.03	0.63
As	<0.12	<0.12	<0.12	<0.12	a	a	a
Se	<0.12	<0.12	<0.12	<0.12	a	a	a
Ag	<0.12	<0.12	<0.12	<0.12	a	a	a
P	<11.9	<11.9	<11.9	<11.9	a	a	a

a. Impingers 4-6 analyzed only for Hg°
b. Prefilter and impingers 1-3 analyzed for Hg^{+2}

Table B-10. Site 2
Metals Analysis ($\mu g/m^3$) Set 2
Blank Corrected

Location	Microwave Unit No. 2						
RTI/ECDNo. Identifier Air Volume (m^3)	4303 Prefilter 0.410	4297 Impinger 1 0.410	4298 Impinger 2 0.410	4299 Impinger 3 0.410	4300 Impinger 4 0.410	4301 Impinger 5 0.410	4302 Impinger 6 0.410
Metals							
Be	<0.07	<0.07	<0.07	<0.07	a	a	a
Al	<7.3	<7.3	<7.3	<7.3	a	a	a
Cr	<1.22	<1.22	<1.22	<1.22	a	a	a
Mn	0.09	0.15	<0.07	0.53	a	a	a
Fe	6.4	2.88	0.39	0.76	a	a	a
Co	<0.49	<0.49	<0.49	<0.49	a	a	a
Ni	<0.24	<0.24	<0.24	<0.24	a	a	a
Zn	<1.22	<1.22	<1.22	<1.22	a	a	a
Cu	0.12	<0.07	<0.07	0.09	a	a	a
Cd	<0.02	<0.02	<0.02	<0.02	a	a	a
Sb	<0.02	<0.02	<0.02	<0.02	a	a	a
Ba	0.13	0.19	0.15	0.13	a	a	a
Tl	<0.02	<0.02	<0.02	<0.02	a	a	a
Pb	<0.12	<0.12	<0.12	<0.12	a	a	a
Hg^{+2}	<0.05	<0.05	<0.05	<0.05	a	a	a
Hg°	b	b	b	b	0.69	<0.03	0.08
As	<0.12	<0.12	<0.12	<0.12	a	a	a
Se	<0.12	<0.12	<0.12	<0.12	a	a	a
Ag	<0.12	<0.12	<0.12	<0.12	a	a	a
P	<12.2	<12.2	<12.2	<12.2	a	a	a

a. Impingers 4-6 analyzed only for Hg°
b. Prefilter and impingers 1-3 analyzed for Hg^{+2}

Table B-11. Site 2
Metals Analysis (Total μg)
Blank Data

RTI/ECD No. Identifier	4309 Filter Blank	4305 Metals Impinger Blank	4307 Mercury Impinger Blank
<u>Metals</u>			
Be	<0.03	<0.03	a
Al	<3.0	<3.0	a
Cr	<0.5	<0.5	a
Mn	<0.03	<0.03	a
Fe	<0.5	0.83	a
Co	<0.2	<0.2	a
Ni	<0.1	<0.1	a
Zn	<0.5	<0.5	a
Cu	<0.03	0.053	a
Cd	<0.01	<0.01	a
Sb	<0.01	<0.01	a
Ba	<0.03	<0.03	a
Tl	<0.01	<0.01	a
Pb	<0.05	<0.05	a
Hg^{+2}	<0.02	<0.02	a
Hg°	b	b	0.0102
As	<0.05	<0.05	a
Se	<0.05	<0.05	a
Ag	<0.05	<0.05	a
P	<5.0	<5.0	a

a. Mercury impinger analyzed only for Hg°
b. Metals impinger analyzed for Hg^{+2}

Table B-12.
Quality Control For Metals
(Spike Recoveries)

	Solution		Filter	
Metal	**Total μg**	**% Recovery**	**Total μg**	**% Recover**
Be	110	110	10.0	100
Al	1020	102	N/A	--
Cr	86.5	86.5	9.88	98.8
Mn	90.0	90.0	10.1	101
Fe	992	99.2	21.4	85.6
Co	64.0	64.0	9.4	94.0
Ni	440.	88.	10.1	101.
Zn	101	101.	43.4	86.8
Cu	96.2	96.2	25.2	101.
Cd	101	101	9.52	95.2
Sb	4.74	94.8	N/A	--
Ba	102	102.	9.7	97.0
Tl	4.85	97.0	9.42	94.2
Pb	346	69.2	24.7	98.8
Hg	N/A		N/A	--
As	5.2	104.	48.4	96.8
Se	4.85	97.0	25.0	100.0
Ag	N/A		4.4	88.0
P	488	97.6	N/A	--

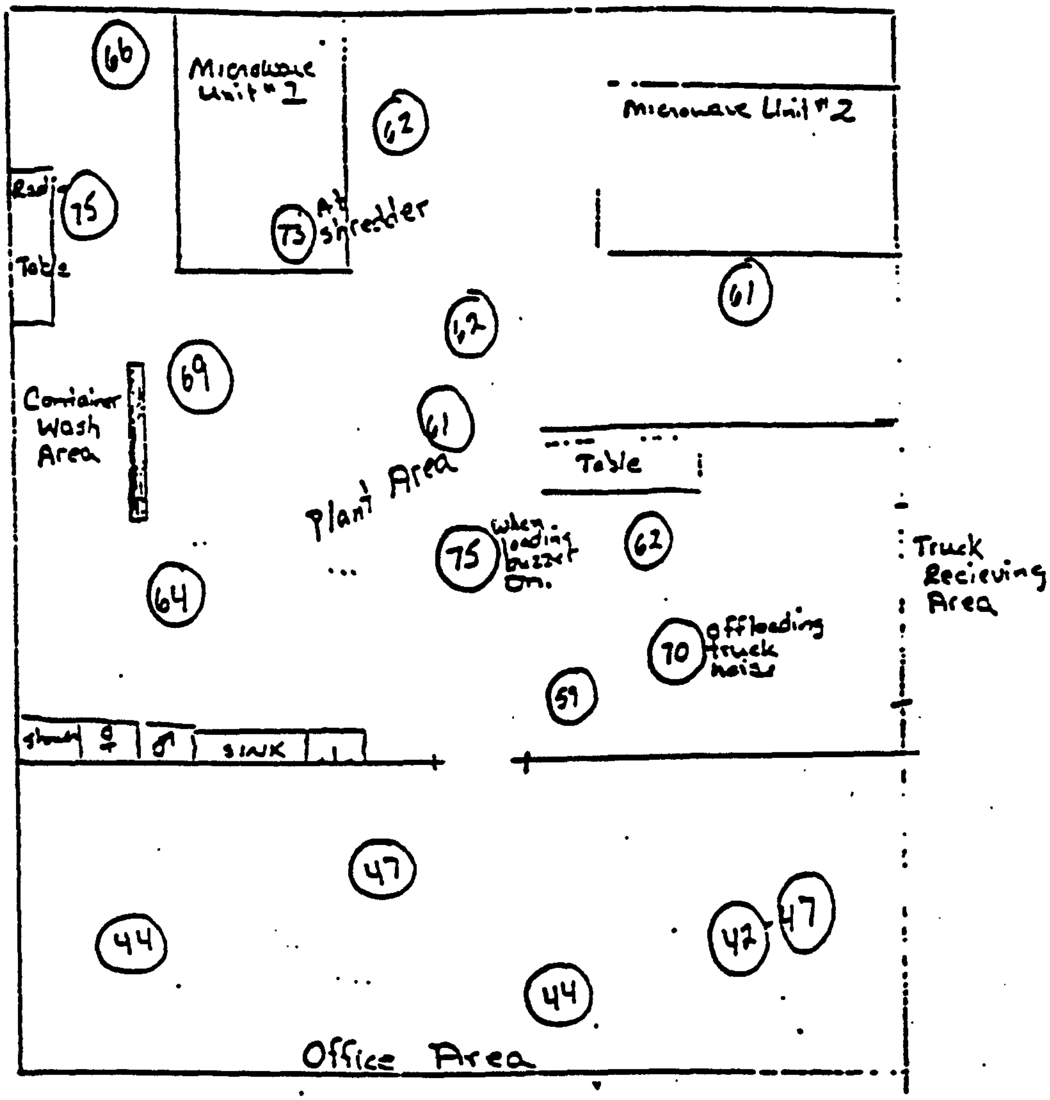
Table B-13.
Indoor Air Quality

ample Dates	4/10/96	4/10/96	4/10/96	4/10 to 4/11/96	4/11/96	4/11/96
ocation	**First Floor Office Area Near Copier**	**Sink Area in Plant**	**Bench Near Container Wash in Plant**	**Weighing Area Near Telephone in Plant**	**Outside Background**	**First Floor Behind Reception Desk**
O_2 average SHA PEL[a] TI Suggested Limit	412 ppm 10,000 ppm 1,000 ppm[b]	490 ppm 10,000 ppm 1,000 ppm	469 ppm 10,000 ppm 1,000 ppm	354 ppm 10,000 ppm 1,000 ppm	323 ppm 10,000 ppm 1,000 ppm	342 ppm 10,000 ppm 1,000 ppm
O average SHA PEL	1 ppm 35 ppm	0 ppm 35 ppm	0 ppm 35 ppm	0 ppm 35 ppm	0 ppm 35 ppm	1 ppm 35 ppm
emp. average minimum maximum	70.8°F 68.9°F 76.7°	74.6°F 69.1°F 76.0°F	77.8°F 75.5°F 79.2°F	64.2°F 55.1°F 77.6°F	61.5°F 60.8°F 62.1°F	73.4°F 63.3°F 76.7°F
elative humidity average minimum maximum	 25.6% 21.7% 27.4%	 23.3 % 19.8% 33.2%	 18.5% 12.7% 26.5%	 31.4% 17.3% 44.0%	 29.5% 22.5% 30.5%	 23.9% 22.5% 30.5%

)SHA PEL is the Occupational Safety and Health Administration Permissible Exposure Limit for an 8 hour vorkday.

,000 ppm is the current limit adopted by the State of Washington.

Figure B-7.
Noise Survey



Area Noise Survey
4-10-96

O = Noise readings in dBA

an eight hour time weighted average noise exposure for the plant area. The results from the noise dosimeter (Table B-14) indicated an average noise level of 59.5 dBA in the plant. The noise exposures were below the OSHA permissible exposure limit for noise of 90 dBA for an eight hour exposure.

B.5.2 Ergonomic Issues

Ergonomics is the science of human motion. It can be evaluated by classic industrial hygiene practices including recognition, evaluation and control. The purpose of an ergonomic assessment is to prevent the occurrence of work related musculoskeletal disorders. Work related musculoskeletal disorders are usually attributable to the following work practice which was observed at the facility; "unassisted manual lifting and lowering of anything weighing more than 25 pounds more than once during the work shift."

Workers were observed removing bins (weighing nominally 40 pounds) from the top of a stack of three, and dropping the bin down on the ground (to perform a sort of preliminary compaction and remove any material stuck the bin lid). They then opened the lid and picked up the red bags and placed them into a large waste bin. This process involved lifting, lowering and twisting of the torso. The potential for injury is strong.

B.5.3 Microwave Radiation

A survey of the microwave units was conducted using a Narda Microlien Electromagnetic Leakage Monitor Model 8210 (S/N 03012), calibrated by the manufacturer on 7/95. The survey demonstrate a leak around the microwave closest to the shredder in unit number 2. The levels exceeded 10 mW/cm^2, and pegged the survey meter offscale. This was brought to the attention of the operator who immediately tightened the unit and reduced the leakage to <0.1 mW/cm^2.

It is noteworthy that the facility is supposed to check the microwave units daily. Two microwave survey meters were observed; however, the meter located at unit no. 1 was out of calibration (due 10/92) and had dead batteries while the meter at unit no. 2 was usable but the calibration was past due 12/95.

B.6 ENGINEERING CONTROLS

The areas of emphasis of this section are ventilation and engineering controls. However, much of the engineering control aspects of this inspection are covered in more depth in the safety report. Relevant details about the plant are presented first followed by data, then recommendations.

Table B-14.
Quest Noise Dosimeter
(Bench/Phone Area in Plant)

Sound Level	64.6 dBA
Maximum Level	118.1 dBA
Average Level	59.5 dBA
% Dose	1.44
OL Time	0.00
Run Time	7 hr 54 min

B.6.1 Plant Description

The facility is approximately 60' x 75' including both microwaves and the loading area, but not the offices. The plant ceiling is 24' high on average. Bathrooms and shower are available directly off the plant floor. A drink machine and water fountain are located next to the unloading area for the untreated waste. The area outside the truck door is clear, partly rocky and partly paved. The air supply to the offices is located outside at ground level near a no smoking sign. Smokers do however congregate near this inlet in disregard for the sign.

The 2 days during which the Phase 1 assessment was performed were both very windy. Most of the gusts were directed toward the facilities doorless side or toward the microwave number 1 location. Thus most of the naturally entering air came in through the door next to Unit 1 and exited through the loading door.

There are four "swamp coolers" in the roof that can blow into the facility. These coolers are used and intended solely for temperature control, not for ventilation. Operators choose whether to turn them on. The biggest fan has a thermostat control to prevent running too much for economy sake. The ducting for the fans is located over the bins near the loading dock, over the 2 units, and over the washer area. Thus the fans blow whatever gases or aerosol vents upward from the units back into the breathing zone of the workers and into the plant in general. There are plans to convert two of the vents to exhaust or to add exhaust ventilation to the existing facility, pending the results of our survey. This plan should definitely take place. Since the existing vents are directly over the units' exhausts, these should be used for the exhaust. However, the temperature control provided by the swamp coolers may not be met and incoming air may need to be provided elsewhere to meet that need. A hood above each units' exhaust would assist in drawing the venting air toward the exhaust duct. However, the most important aspect is that the microwave units exhaust should not be blown at the workers by the incoming air.

The plant floor is slippery. There is a visibility problem when the workers are pushing tubs three high, as shown when one investigator was almost run over by one worker who didn't see her. The corners of the room are used for miscellaneous storage.

The basic procedure used to process the waste consists of: tubs are unloaded from the truck, weighed and identified by scanner, moved to a waiting area near one of the microwave units, moved up to dump, dumped, moved to washer, stacked into washer, unloaded and stacked in the "clean area" and loaded back into trucks. This requires a lot of manual labor. However, the tubs are self contained, the ones observed were dry on the outside, and didn't appear to be hazardous other than the dangers inherent in tall stacks of fairly heavy containers. The stages where the workers would be likely to be exposed begin once the lids are removed. The tubs are usually simply picked up and dumped into the bin. However, some of the tubs come in with the red plastic liner around the edges, instead of tied. The worker has to loosen the liner before dumping. On occasion the worker picked up the bags to load into the bin. When the bins are dumped, the potential exists for a bag to fall off rather than into the microwave. A guard should be in place to prevent the possibility that the bag could fall on a worker. Inspection of the top of Unit 1 did show a loose syringe and other untreated waste that had fallen out during dumping. A worker is scheduled to clean this area regularly but the hazards of dealing with loose medical waste are much higher than when the waste is contained.

When the bins are lifted onto the washracks, much liquid can be poured out at or on the worker, especially his feet, lower legs, and arms. The contamination hazard appears to be much less when the workers load the tubs into the lower rack (which according to management is the preferred level). However, the upper level was used by preference during the Phase 1 assessment visit.

The microwave units have lights that blink when the machine is ready to vent, but a button must be pushed before the venting occurs. This makes sure the worker(s) know that the machine is about to open.

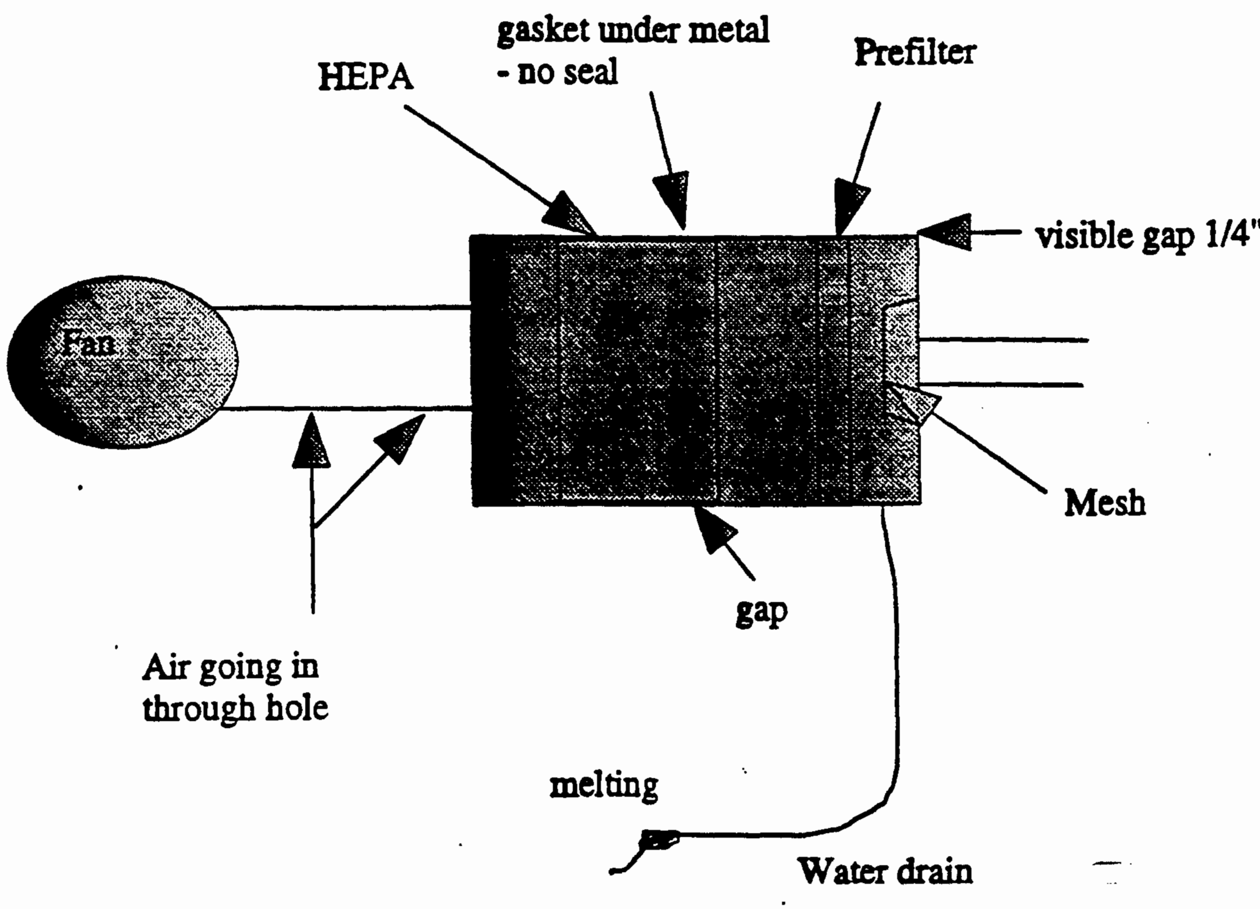
B.6.2 Exhaust Air Cleaners

Just before the microwave units open, the steam is pulled out of the unit and vented through air cleaners to the outdoors. Unit 1's system was due to be overhauled shortly after the Phase 1 visit, so some of the problems described below may have been addressed. The top of Unit 1 when the lid was open was 88" from the ceiling. In that position the top is 9'5" from the floor. A rough schematic of the Unit 1 air cleaner system is shown in Figure B-8. Unit 1 had much steam venting when the lid opened due to malfunctions in the system. Before opening up the air cleaner, the airflow through the circular 6" duct (at approximately 2.5 inches into the duct) was 400 fpm or approximately 80 cfm. Since the fan is rated at 750 cfm, this, in conjunction with the large amount of steam venting when the machine was opened, indicated serious problems.

Examination of the Unit 1 air cleaner showed a number of problems. Initially air was entering the pipe going to the fan through a hole in the pipe and a hole due to a dent at the juncture of the box and pipe, as well as through the pipe. The gasket between the box containing the filters and its cover had dropped down across the top so that there was no seal at the top of the box. From the upper right hand looking down at the unit there was a visible gap of approximately 1/4". There was a leak outward where the inlet pipe meets the box and a gap in between the cover and the box at the bottom. The water drain had water in it. Also one section of the drain tubing that was lying against some equipment below the air cleaner was black and melting; the drain needs to be tied up or otherwise keep from hot surfaces.

After duct taping the holes in the system, the flow through the exhaust pipe increased to 330 fpm. When the screen in the hopper was cleaned, the flow pegged out the velocity meter at 2000 fpm both when the microwave unit was open and closed (indicating at least a 5 fold increase in flow). Thus the screen should be cleaned regularly and the air cleaner housing should be fixed.

Figure B-8.
Unit 1 Air Cleaner System



The HEPA filter in Unit 1 was in backwards, resulting in no seal. It is recommended that (in addition to facing the HEPA the correct way) additional gasketting material be added to complete the seal as the filter didn't seal very well when installed in the right direction. Current practice is to change the HEPA and prefilter when the pressure drop across the HEPA exceeds the manufacturer's recommendation. Once the HEPA is in correct position and is sealed in, this monitoring will be possible. It should be noted that the monitoring gauge read no pressure drop before the HEPA was turned around. A reading of zero pressure drop should be an indication of a problem and workers should be notified of this. Zero pressure drop is not possible across a properly installed filter in an active air flow. It is recommended that the prefilter be changed more often than the HEPA in order to allow better air flow and probably extend the life of the HEPA. A schedule based on replacing the prefilter twice as often as the HEPA seems reasonable as the unit does not have a monitor for the prefilter's pressure drop. The best recommendation would be to upgrade the Unit 1 air cleaner system to one similar to the Unit 2 system. It is recommend that the velocity tap in the exit duct be located away from the water tap.

The air cleaner on Unit 2 was in good condition and appeared to be operating well. This unit has a carbon filter to remove odors from the vented steam, in addition to the particle filters that both units have. The pressure tap is located in a logical spot, the HEPA is well sealed, the prefilter does need a better seal, but is still in better shape than Unit 1's. The inlet baffle is better designed than Unit 1's. The foam in the door is loose, but the carbon sheets looked good. It is recommended that the velocity tap in exit duct be located away from the water tap.

B.6.3 Air Velocities

As has been addressed earlier, the airflows in the building were gusty. The air velocities were so variable that most of the readings consisted of determining a low and high velocity for the range over which the meter needle swung. For the case where the readings were mainly at one level with brief gusts or calm spells, an average wind velocity was estimated by watching the gauge for several minutes. The airflow measurements are shown in Table B-15. These measurement show sufficient air movement to easily exceed 20 cfm per person. However, it is impossible to tell with our data if this would be true on a still outdoors day.

The airflow into the offices is essentially zero as long as one door is closed.

Soap bubbles used on day 2 showed air slowly exiting through the loading door, slowly entering the door in the Unit 2 room, all 4 blowers blowing in, airflow into the door near Unit 2, into plant from the back door to Unit 2, neutral at the Unit 2 exit, and into Unit 2 from the front.

B.6.4 Recommendations

Suggestions that may result in improvements include: stressing preferential use of the lower rack in the washer area when only one rack is needed and draining of the liquid in the tubs before lifting tubs above head level.

Table B-15.
Airflow Measurements
Note: 4/10/96 and 4/11/96 were windy days

Location	Velocity (fpm) or Velocity Range	Notes
4/10/96		
At truck door	20-175	empty (no truck), breezy
Outside near Unit 1	1000-1500	
Door near Unit 2	200-300	outward
Large Opening between Units	75-300	
Door Near Unit 1	100-550	inward
4/11/96		
Door near Unit 1	25-40	
Outside near Unit 2	5-40	
Unit 2	5-40	
Loading Door	10-70 20	 average

The proposed exhaust systems for the microwave units should be installed directly above the units' exhausts. Cooling air may need to be supplied in a location that will not cause the effluent to blow into the worker's breathing zones.

The screen in the hopper should be cleaned regularly and the air cleaner housing for Unit 1 should be fixed. In order to determine if the air cleaners are functioning properly, airflow probes should be installed in straight portions of the exiting ducts not near any flow perturbations, so that decreases in the airflow can be easily monitored. When the airflow decreases, the screen should be cleaned even if it is not the regularly scheduled cleaning time. If this does not eliminate the problem, it is time to check on the filters' conditions.

The HEPA filter in Unit 1 should be sealed in facing the correct direction. It is recommended that, in addition to facing the HEPA the right way, additional gasket material should be added to complete the seal as the filter didn't seal very well when installed in the correct direction. A reading of zero pressure drop across the HEPA should be an indication of a problem and workers should be notified of this. It is recommended that the prefilter be changed more often than the HEPA in order to allow better air flow and probably extend the life of the HEPA. A schedule based on replacing the prefilter twice as often as the HEPA seems reasonable as the unit does not have a monitor for the prefilter's pressure drop. The best recommendation would be to upgrade the Unit 1 air cleaner system to one similar to the Unit 2 system.

The air cleaner on Unit 2 needs a better seal on the prefilter. Gasketting material should suffice. The foam in the door is loose and should be secured. A velocity tap is recommended in the exit duct not too near water tap. A similar pattern for replacing the filters should be used for this unit as well as unit 1, in that the prefilter should be changed out more often than the HEPA.

As discussed later in this report (Section B.8) blood splatters from the units during dumping are a potential hazard. If this area is to be addressed with engineering controls, it would entail adding a splash shield to the unit. If this can be done and the units can still load efficiently, this would be a beneficial option to pursue.

B.7 RESPIRABLE AEROSOL SCREENING

Aerosol measurements were taken with the hand held aerosol monitor (HAM) that measures mass concentration from 0.3-2 μm and with the Laser Particle Counter (LPC) that measures number of particles in various size rangesas described in Appendix I. An average density of 1.5 g/cm^3 was assumed and mass concentration below 5 μm and total up to 15 μm were calculated. The HAM results are shown in Table B-16 and the LPC data are shown in Table B-17. None of the measurement exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified. None of the indoor HAM measurements even exceed the outdoor air National Ambient Air Quality Standard, except the one measurement in the steam plume of unit 2. Likewise the LPC measurements are low relative to the standards except for those outside or near the exit.

Table B-16.
HAM Aerosol Concentration Measurements for the Microwave Facility

Location	Mass Concentration (mg/m3)	Notes
Office Area	0.010	
Outside - near truck	0.018	very breezy
Truck entrance	0.021	just inside, no activity
Near sink	0.018	
Among tubs	0.014	
About 3' from shredder	0.009	outdoors
Near washer	0.014	not in use
Unit 1 - inside back	0.011	
Shredder 2	0.016	outside
Unit 2 - back	0.011	
Unit 2 - above	0.013	
Unit 2 - tubs dumped	0.014	
Tub washing	0.021	
Unit 2 -bin dumping	0.016	
Unit 1 - bin dumping	0.025	steam rising
Unit 1 - bin hits bottom	0.014	
Unit 1 - in bin	0.014	after dumping
Unit 2 - in room	0.006	
Unit 2 - while loading	0.007- 0.017	

Table B-17.
Aerosol Mass Concentrations
based on LPC data and an assumed density of 1.5 g/cm^3

Location	Mass <5 µm (mg/m3)	Total Mass (mg/m3)	Notes
Conference Room	0.003	0.021	
Loading Door	0.013	0.121	no activity
Outside truck loading area	0.003	0.011	
Unit 2 dump	0.001	0.072	outdoors, upwind of unit
Unit 1 dump	0.001	0.057	upwind
Loading door	0.007	0.104	nearby, while moving bins
Loading door	0.007	0.041	while unloading
Box near Unit 2	0.011	0.082	
Near washer, running	0.007	0.034	
4/11/96			
Loading area -	0.005	0.046	dumpster being left
Outside Unit 2 dump	0.004	0.026	upwind, not very breezy

In addition these numbers do reflect the concentrations for a very gusty day when much outdoor air entered the facility. On a windless day the level may be much higher. However, strictly from the particle concentrations, no problems can be diagnosed that need addressing.

B.8 ASSESSMENT OF BLOOD ON SURFACES

On April 10-11, 1996, Phase 1 environmental sampling and analysis was conducted to assess the extent of blood contamination on a variety of surfaces and materials in the processing area of a medical waste facility using microwave technology for waste treatment. Evaluation of blood and/or blood containing body fluids on surfaces in the processing area could provide important information relative to identifying the most potentially hazardous steps in the treatment process, which through modifications in engineering and/or work practice controls, could minimize worker exposures. Visual inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection, was carried out throughout the processing area, but focused primarily in the waste loading and washing areas. In the waste loading area, tubs of waste are manually opened and dumped into a treatment bin that is hydraulically hoisted up the front of the unit, where the bin is tipped and the waste is dumped into the grinding chamber. From the dumping area, all reusable tubs are moved to a nearby washing area where they are decontaminated and deodorized.

Fifty one (51) wipe samples were collected and processed immediately for the presence of hemoglobin. Results are presented in Table B-18. Thirty two (63%) of the samples were positive, primarily those associated with manual waste dumping including liquid drips and spills on the concrete floor, walls adjacent to the dumpers, the waste dumper surfaces, the microwave unit control panel, worker gloves, and sink surfaces. Worker goggles, telephone, scanning gun, computer keyboard, and drink machine were all negative.

Visual assessment of the work flow, along with hemoglobin test results, shows that the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Both automatic and manual waste dumping results in the splatter and splash of blood and liquids from untreated medical waste. Also, blood residuals detected at the sink used for washing hands suggests the need for routine decontamination and cleaning of the area. Based on the Phase 1 observations and test results, it is recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes using personal sampling techniques.

Recommendations to reduce exposure to blood and body fluid splashes include providing adequate splash protection especially personal protective equipment. One specific hazard in this plant was the fine spray of blood-laced liquid when the tubs were dumped as shown by the splatters from floor level up to about 12 ft on the wall near unit 2; this could be addressed by requiring the workers and other personnel in the vicinity to wear a shield protecting the head and face such as a hard hat with face shield or by installion of a canopy over the control station.

Table B-18.
Phase 1 Surface Blood Field Test Results

Sample #	Date	Location / Description	Area	Hemastix	Comment
Microwave 46	04/10/96	Drips on floor by dumper,Unit 1	4"x 4"	+++	
Microwave 47	04/10/96	Tub lid liquid on top, Unit 1	4"x 4"	+++	
Microwave 48	04/10/96	Dumper edge, Unit 1	4"x 4"	+++	Dry visible blood
Microwave 49	04/10/96	Dumper shroud ext. area, right Unit 1	8"x 4"	+++	Dry visible blood
Microwave 50	04/10/96	Cntrl Pnl @ stop button, Unit 1		+	
Microwave 51	04/10/96	Gloves of operator after dumping		+Nhm	
Microwave 52	04/10/96	Goggles of operator		Neg	
Microwave 53	04/10/96	Fluid drip under grinder		Neg	
Microwave 54	04/10/96	Waste chamber dr, top edge, Unit 1	6"x 5"	+	Dry splatters, streaks
Microwave 55	04/10/96	End washer wall near Unit 1	7"x 7"	+++	
Microwave 56	04/10/96	Tub wash solution test		Neg	
Microwave 57	04/10/96	Handle, door to inside Unit 2	1/2 handle	Neg	
Microwave 58	04/10/96	Dumper shroud ext. area, left, Unit 2	6"x 6"	+++	Visible blood streaks
Microwave 59	04/10/96	Spots on wall oppos. dumper, Unit 2		++	
Microwave 60	04/10/96	Cntrl Pnl buttons, stop, lift, Unit 2		+Ht	
Microwave 61	04/10/96	Floor in loading area	6"x 6"	Neg	
Microwave 62	04/10/96	Sink counter	12"x 12"	+Ht	
Microwave 63	04/10/96	Top towel dispenser	9"x 5"	+	Dusty
Microwave 64	04/10/96	Tub, dry drip on cleaned tub	4"x 4"	+Nht	
Microwave 65	04/10/96	Telephone receiver		Neg	
Microwave 66	04/10/96	Scanning gun		Neg	
Microwave 67	04/10/96	Wall corner by stored waste, Unit 2	6"x 6"	Neg	
Microwave 68	04/10/96	Far end tub washer wall, near sink	9"x 7"	Neg	
Microwave 69	04/10/96	Water cooler base top	1/2 area	Neg	
Microwave 70	04/10/96	Ladder rung to top Unit 1		+	
Microwave 71	04/10/96	Eye wash basin next to Unit 1		Neg	
Microwave 72	04/11/96	Shroud, outer left, Unit 1	6"x 6"	+++	
Microwave 73	04/11/96	Shroud, inside, left, Unit 1	6"x 6"	+++	
Microwave 74	04/11/96	Dumper lip, Unit 1	7"x 3"	+++	
Microwave 75	04/11/96	Shroud, inside, right, Unit 1	6"x 6"	+++	
Microwave 76	04/11/96	Shroud, outer right, Unit 1	6"x 6"	+++	
Microwave 77	04/11/96	Floor under dumper, Unit 1	6"x 6"	+++	Dried red spots
Microwave 78	04/11/96	Cntrl Pnl, Unit 1	6"x 6"	+	
Microwave 79	04/11/96	Washer wall end near Unit 1	7"x 7"	+++	
Microwave 80	04/11/96	Wash wall far end toward office	7"x 7"	Neg	
Microwave 81	04/11/96	Door left side Unit 1	6"x 6"	Neg	Dried streaks
Microwave 82	04/11/96	Worker gloves after dumping, Unit 1		+++	
Microwave 83	04/11/96	Floor after mopping blood spill, Unit 1	6"x 6"	+++	
Microwave 84	04/11/96	Shroud, outer left, Unit 2	6"x 6"	+++	

Sample #	Date	Location / Description	Area	Hemastix	Comment
Microwave 85	04/11/96	Shroud, inside left, Unit 2	6"x 6"	+++	
Microwave 86	04/11/96	Shroud, inside right, Unit 2	6"x 6"	+++	
Microwave 87	04/11/96	Shroud, outer right, Unit 2	6"x 6"	+++	
Microwave 88	04/11/96	Control Panel Unit 2	6"x 6"	+	
Microwave 89	04/11/96	Wall oppos. dumper Unit 2	6"x 6"	+++	
Microwave 90	04/11/96	Goggles after dumping		Neg	
Microwave 91	04/11/96	Clean bin	6"x 2'	Neg	
Microwave 92	04/11/96	Keyboard	6"x 6"	Neg	
Microwave 93	04/11/96	Under lid incoming bin	6"x 6"	Neg	
Microwave 94	04/11/96	Top towel rack at wash sink	6"x 6"	+Ht	
Microwave 95	04/11/96	Drink machine, can deposit area	12" x 3"	Neg	
Microwave 96	04/11/96	Locker		Neg	

Hemastix Key

Neg Negative - No color change
+Nht Positive non-hemolyzed trace
+Nhm Positive non-hemolyzed moderate

+Ht Positive hemolyzed trace
+ Positive small
++ Positive moderate
+++ Positive large

Detection limit = 5000 RBC/ml sample which corresponds to 0.000027 ml blood eluted from gauze wiped over a surface.

Another option would be to require the workers to leave the immediate area when the tubs are dumping. In addition a uniform policy on the use of gloves especially when working on the control panels should be adopted. A separate eating/break area would reduce the likelihood of contamination through intentional ingestion; this hazard is highlighted by the positive samples at the sink near the drink machines. Protective clothing that is not worn home should be worn in the plant. Suggestions include the use of removable overalls in the plant or the addition of pants to the already provided shirts and mandatory changing before leaving the facility. To reduce transfer from the microwave areas to the office area, shoes that have been worn in the plant should be changed or covered before entering the office area. Alternatively shoes may be covered before entry to the plant floor and the covers removed before returning to the office area. The bathrooms between the plant and the office area should be designated as part of the "clean" office area.

B.9 SURFACE MICROBIAL CONTAMINATION

On March 10-11, 1996, Phase 1 environmental sampling and analysis was conducted to assess the extent of microbial contamination on a variety of surfaces and materials in the processing area of a medical waste facility using microwave technology for waste treatment. Detection of the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*, could assist in determining the extent of microbial contamination from untreated medical waste throughout the facility, and the potential for worker contact exposures. Sampling was conducted primarily in the waste dumping area where splatters and splashes are common, the unit control panel where workers touched buttons, worker gloves, and door handles and doorknobs.

A total of 50 surface samples, including three controls were collected and processed using a surface wipe and direct plate technique as described in Appendix K. Results are shown in Tables B-19 and B-20. Although samples were collected from many wet areas to include liquids from waste dumping and associated spills, no *S. aureus* was isolated from any sample, and only three samples were positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but they are inconsequential relative to assessing potential worker exposures to recognized human pathogens. The presence of some viable indicator bacteria suggest that some of the waste processed was recently generated. Otherwise, the organisms should have had time to die during transport and storage as indicated in Appendix K. The implication of not finding a significant number of samples positive for indicator bacteria does not rule out the potential for survival in the waste of environmentally resistant and virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses.

B.10 SUMMARY AND CONCLUSIONS

The microwave facility is located in a light industrial building essentially built of concrete block with steel rafter/supports and a lightweight, corrugated roof. It is approximately 60 feet x

Table B-19.
Staphylococcus aureus Test Results

Sample #	Date	Location	Area	Total CFU	Total S. aureus	Other
Microwave 54	04/10/96	Dumper edge, Unit 1	2"x 2"	30	0	10 Bacillus
Microwave 55	04/10/96	Cap access port to waste, Unit 1	2"x 2"	0	0	
Microwave 56	04/10/96	Dumper shroud left side, Unit 1	2"x 2"	2	0	
Microwave 57	04/10/96	Liquid spill under dumper, Unit 1	2"x 2"	484	0	
Microwave 58	04/10/96	Dumper control pnl, Unit 1	2"x 2"	2	0	
Microwave 59	04/10/96	Dumper shroud inside left, Unit 1	2"x 2"	5	0	
Microwave 60	04/10/96	Dumper shroud inside right, Unit 1	2"x 2"	1	0	
Microwave 61	04/10/96	Dumper shroud outside right, Unit 1	2"x 2"	7	0	
Microwave 62	04/10/96	Inside truck on floor - wet	2"x 2"	27	0	12 Bacillus
Microwave 63	04/10/96	Washer wall end near Unit 1	2"x 2"	2	0	
Microwave 64	04/10/96	Tub lid top, wet from waste, Unit 1	2"x 2"	2	0	
Microwave 65	04/10/96	Tub dumper edge, Unit 2	2"x 2"	TNTC	0	2 Bacillus
Microwave 66	04/10/96	Dumper shroud outside left, Unit 2	2"x 2"	0	0	
Microwave 67	04/10/96	Dumper shroud inside left, Unit 2	2"x 2"	3	0	1 Bacillus
Microwave 68	04/10/96	Dumper shroud inside right, Unit 2	2"x 2"	10	0	
Microwave 69	04/10/96	Dumper shroud outside right, Unit 2	2"x 2"	3	0	2 Bacillus
Microwave 70	04/10/96	Dumper control pnl, Unit 2	2"x 2"	6	0	
Microwave 71	04/10/96	Cap access port to waste, Unit 2	2"x 2"	49	0	5 Bacillus
Microwave 72	04/10/96	Door handle to inside Unit 2	2"x 2"	6	0	
Microwave 73	04/10/96	Door knob, exit to office area		3	0	1 Bacillus
Microwave 74	04/10/96	Gloves from operator after loading		43	0	5 Bacillus
Microwave 75	04/10/96	Arm of hydraulic lifter	2"x 2"	45	0	4 Bacillus
Microwave 76	04/10/96	Toilet rim -office mens (Control)	2"x 2"	8	0	1 Bacillus
Microwave 77	04/10/96	Toilet seat - office mens (Control)	2"x 2"	77	0	
Microwave 78	04/10/96	Toilet handle - office mens (Control)		3	0	
Microwave 79	04/11/96	Dumpr frnt outside below lip, Unit 1	2"x 2"	26	0	6 Bacillus
Microwave 80	04/11/96	Dumper shroud outside left, Unit 1	2"x 2"	9	0	1 Bacillus
Microwave 81	04/11/96	Dumper shroud inside left, Unit 1	2"x 2"	26	0	26 Bacillus
Microwave 82	04/11/96	Dumper shroud inside right, Unit 1	2"x 2"	1	0	
Microwave 83	04/11/96	Dumper shroud outside right, Unit 1	2"x 2"	8	0	1 Bacillus
Microwave 84	04/11/96	Cntrl pnl below buttons, Unit 1	2"x 2"	2	0	1 Bacillus
Microwave 85	04/11/96	Floor drips below dumper, Unit 1	2"x 2"	23	0	
Microwave 86	04/11/96	Wash wall edge near Unit 1	4"x 2"	43	0	
Microwave 87	04/11/96	Wash wall edge far end towrd office	4"x 2"	0	0	
Microwave 88	04/11/96	Tub lip wet spot, Unit 1	2"x 2"	82	0	23 Bacillus
Microwave 89	04/11/96	Liquid, edge dumped tub, Unit 1	1"x 2"	TNTC	0	
Microwave 90	04/11/96	Dumpr sfc waste contacts, Unit 1	2"x 2"	51	0	1 Bacillus
Microwave 91	04/11/96	Dumper front lip, Unit 2	2"x 2"	189	0	1 Bacillus
Microwave 92	04/11/96	Dumper shroud outside left, Unit 2	2"x 2"	3	0	1 Bacillus

Sample #	Date	Location	Area	Total CFU	Total S. aureus	Other
Microwave 93	04/11/96	Dumper shroud inside left, Unit 2	2"x 2"	162	0	3 Bacillus
Microwave 94	04/11/96	Dumper shroud inside right, Unit 2	2"x 2"	228	0	228 Bacillus
Microwave 95	04/11/96	Dumper shroud outside right, Unit 2	2"x 2"	7	0	1 Bacillus
Microwave 96	04/11/96	Cap access port to waste, Unit 2		74	0	9 Bacillus
Microwave 97	04/11/96	Liquid floor drips near dumpr, Unit 2		47	0	6 Bacillus
Microwave 98	04/11/96	Cntrl pnl lift buttons, Unit 2		46	0	11 Bacillus
Microwave 99	04/11/96	Operator gloves aft dumping, Unit 2		71	0	13 Bacillus
Microwave 100	04/11/96	Door knob exit to offices		6	0	
Microwave 101	04/11/96	Toilet rim womn office (Control)		1	0	
Microwave 102	04/11/96	Toilet seat womn office (Control)		1	0	
Microwave 103	04/11/96	Toilet handle womn office (Control)		2	0	1 Bacillus

Table B-20. E. coli Test Results

Sample #	Date	Location	Area	Total CFU	Total E. coli	Other
Microwave 54	04/10/96	Dumper edge, Unit 1	2"x 2"	TNTC	0	
Microwave 55	04/10/96	Cap access port to waste, Unit 1	2"x 2"	2	0	
Microwave 56	04/10/96	Dumper shroud left side, Unit 1	2"x 2"	87	0	
Microwave 57	04/10/96	Liquid spill under dumper, Unit 1	2"x 2"	TNTC	0	
Microwave 58	04/10/96	Dumper control pnl, Unit 1	2"x 2"	17	0	
Microwave 59	04/10/96	Dumper shroud inside left, Unit 1	2"x 2"	TNTC	0	
Microwave 60	04/10/96	Dumper shroud inside right, Unit 1	2"x 2"	38	0	38 Bacillus
Microwave 61	04/10/96	Dumper shroud outside right, Unit 1	2"x 2"	TNTC	0	9 Bacillus
Microwave 62	04/10/96	Inside truck on floor - wet	2"x 2"	TNTC	0	
Microwave 63	04/10/96	Washer wall end near Unit 1	2"x 2"	2	0	
Microwave 64	04/10/96	Tub lid top, wet from waste, Unit 1	2"x 2"	TNTC	8	
Microwave 65	04/10/96	Tub dumper edge, Unit 2	2"x 2"	TNTC	0	
Microwave 66	04/10/96	Dumper shroud outside left, Unit 2	2"x 2"	31	0	
Microwave 67	04/10/96	Dumper shroud inside left, Unit 2	2"x 2"	24	16	3 Bacillus
Microwave 68	04/10/96	Dumper shroud inside right, Unit 2	2"x 2"	TNTC	0	
Microwave 69	04/10/96	Dumper shroud outside right, Unit 2	2"x 2"	112	0	35 Bacillus
Microwave 70	04/10/96	Dumper control pnl, Unit 2	2"x 2"	16	1	
Microwave 71	04/10/96	Cap access port to waste, Unit 2	2"x 2"	82	0	
Microwave 72	04/10/96	Door handle to inside Unit 2	2"x 2"	28	0	10 Bacillus
Microwave 73	04/10/96	Door knob, exit to office area		3	0	
Microwave 74	04/10/96	Gloves from operator after loading		36	0	2 Bacillus
Microwave 75	04/10/96	Arm of hydraulic lifter	2"x 2"	14	0	10 Bacillus
Microwave 76	04/10/96	Toilet rim -office mens (Control)	2"x 2"	14	0	6 Bacillus
Microwave 77	04/10/96	Toilet seat - office mens (Control)	2"x 2"	3	0	
Microwave 78	04/10/96	Tiolet handle - office mens (Control)		6	0	4 Bacillus
Microwave 79	04/11/96	Dumpr frnt outside below lip, Unit 1	2"x 2"	TNTC	0	
Microwave 80	04/11/96	Dumper shroud outside left, Unit 1	2"x 2"	206	0	51 Bacillus
Microwave 81	04/11/96	Dumper shroud inside left, Unit 1	2"x 2"	TNTC	0	
Microwave 82	04/11/96	Dumper shroud inside right, Unit 1	2"x 2"	TNTC	0	
Microwave 83	04/11/96	Dumper shroud outside right, Unit 1	2"x 2"	20	0	
Microwave 84	04/11/96	Cntrl pnl below buttons, Unit 1	2"x 2"	9	0	4 Bacillus
Microwave 85	04/11/96	Floor drips below dumper, Unit 1	2"x 2"	TNTC	0	
Microwave 86	04/11/96	Wash wall edge near Unit 1	4"x 2"	TNTC	0	
Microwave 87	04/11/96	Wash wall edge far end towrd office	4"x 2"	4	0	
Microwave 88	04/11/96	Tub lip wet spot, Unit 1	2"x 2"	TNTC	0	Bacillus
Microwave 89	04/11/96	Liquid, edge dumped tub, Unit 1	1"x 2"	TNTC	0	
Microwave 90	04/11/96	Dumpr sfc waste contacts, Unit 1	2"x 2"	TNTC	0	Bacillus
Microwave 91	04/11/96	Dumper front lip, Unit 2	2"x 2"	TNTC	0	Bacillus

Sample #	Date	Location	Area	Total CFU	Total E. coli	Other
Microwave 92	04/11/96	Dumper shroud outside left, Unit 2	2"x 2"	TNTC	0	Bacillus
Microwave 93	04/11/96	Dumper shroud inside left, Unit 2	2"x 2"	TNTC	0	
Microwave 94	04/11/96	Dumper shroud inside right, Unit 2	2"x 2"	84	0	
Microwave 95	04/11/96	Dumper shroud outside right, Unit 2	2"x 2"	55	0	
Microwave 96	04/11/96	Cap access port to waste, Unit 2		20	0	2 Bacillus
Microwave 97	04/11/96	Liquid floor drips near dumpr, Unit 2		TNTC	0	Bacillus
Microwave 98	04/11/96	Cntrl pnl lift buttons, Unit 2		12	0	5 Bacillus
Microwave 99	04/11/96	Operator gloves aft dumping, Unit 2		54	0	10 Bacillus
Microwave 100	04/11/96	Door knob exit to offices		6	0	
Microwave 101	04/11/96	Toilet rim womn office (Control)		1	0	
Microwave 102	04/11/96	Toilet seat womn office (Control)		0	0	
Microwave 103	04/11/96	Toilet handle womn office (Control)		5	0	

110 feet x 24 feet in height. Approximately 1/3 of the building was used for two floors of offices which were divided from the plant side by a floor to ceiling wall. The plant side had free space from floor to ceiling. One section approximately 24 feet x 24 feet had been created with permanent block walls and housed one microwave treatment unit. Another unit was in the larger, open section of the plant. The plant side was protected by a charged water sprinkler system. The office side had no sprinkler system. Occupancy was about 6 in the offices and 3-6 in the plant at any given time.

Untreated medical waste is placed in "red" plastic bags or sharps containers by the microwave facility customers and the bags are placed in 48 gallon rigid plastic containers. The sharps containers were normally segregated and handled separately from the plastic containers. The microwave facility drivers manually load the containers into microwave facility owned/operated trucks and bring them to the facility. The containers are manually pulled to a lift gate on the truck, off loaded, and manually stacked up to 3 high using no mechanical aids. Each container nominally weighs approximately 40 pounds. After weighing, the containers are manually dumped into a large bin attached to one of the microwave units. The process cycle is machine controlled with limited worker action. Upon signal from the microwave unit, a worker manually initiates a control on the unit which activates a lift mechanism. The lift elevates the bin approximately 12 feet and tips it while simultaneously opening a large cover to a hopper. Once the medical waste has dropped in the hopper, the lid closes over the hopper, and the bin is lowered to ground level.

An automatic grinding cycle commences in which the waste is ground up. During treatment, the waste is augured up a closed, inclined tube. The tube has six (6) microwave units mounted on top and several ports allow steam injection. The microwave units heat the steam and waste. The treated waste product is dropped into a dumpster located outside the building. An attached hydraulic ram periodically compacts the waste into the dumpster. When full, a contractor hauls the dumpster to the city landfill to be emptied.

The facility had some inherent hazards needing attention as well as the need for establishment of certain routine preventive procedures. A large component of the material handling was manual, without aids. The primary worker exposure hazard was liquid exposure during bin loading, bin dumping, and container cleaning. Back and muscle strain exposure hazards were noted during the truck loading/unloading, pulling, stacking, and dumping of the containers. Puncture hazards were found from waste dumped into the hopper rolling off the top of the unit to the worker standing at the control location and from workers pushing red bags in the bin to more efficiently load the bin.

Management was very interested and proactive in providing workers with training of many types and providing protective equipment. The microwave facility had an active safety committee. Written programs and documentation were good. A strong emphasis on good housekeeping in the active work area was evident, but needed improvement in several areas. The electrical safety program needs attention including clearing 36" in front of all panels, adding circuit labels to several electrical panels, and repairing worn wiring on portable air compressor cord. Fall protection is needed above both units. Suggestions to reduce the cross contamination problems include the workers need a means to quickly remove potentially contaminated work/protective clothing and take food/water breaks and a separate place to take the breaks. Fire safety concerns include a large rock adjacent to the fire hydrant which could inhibit firefighters access to the hydrant and the need to have the safety station fire extinguisher mounted for ease in access.

The job safety analysis and ergonomic assessment showed a need to reduce the manual component of the job to reduce the strong potential for work related musculoskeletal disorders due to the large amount of handling of the nominally 40 lb bins. Suggestions include stacking tubs only two high and the use of a dolly to minimize pulling. The primary hazard in loading the hoppers was exposure to splashes/drips/falling material. Personal clothing should be protected and contaminated clothing should not be worn home.

Several VOCs were observed at the facility, but no OSHA permissible exposure limits (PELs) nor ACGIH threshold limit values (TLVs) were exceeded. The compound with the highest concentrations for all three sampling sites was 2-propanol at 2318, 495, and 986 $\mu g/m^3$.

The aldehyde results indicated minimal concentrations ranging from 0.007 mg/m^3 to 0.2 mg/m^3; several orders of magnitude lower than the respective OSHA PELs.

The results of the metals sampling indicate minimal levels (most are less than the detection limits), of the following metals: Be, Al, Cr, Mn, Fe, Co., Ni, Zn, Cu, As, Se, Ag, Cd, Sb, Ba, Tl, Pb and Hg.

The indoor air quality was evaluation included temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO). The results indicated adequate indoor air during the sampling period.

The noise survey demonstrated that noise levels ranged from 59 to 75 dBA in the process area and from 42 to 47 dBA in the office area. The results for the eight hour time weighted average noise exposure for the plant area indicated an average noise level of 59.5 dBA in the plant. The noise exposures were below the OSHA permissible exposure limit for noise of 90 dBA for an eight hour exposure.

The nonionizing radiation survey demonstrate a leak around the microwave closest to the shredder in unit number 2. The levels exceeded 10 mW/cm^2, and pegged the survey meter offscale. This was brought to the attention of the operator who immediately tightened the unit and reduced the leakage to <0.1 mW/cm^2.

The 2 sampling days were very windy. Most of the gusts were directed toward the facilities doorless side or toward the microwave number 1 location. Thus most of the entering air came in through the door next to Unit 1 and exited through the loading door. The four "swamp coolers" in the roof that can blow into the facility are intended solely for temperature control, not for ventilation. The biggest fan has a thermostat control to prevent running too much for economy sake. The ducting for the fans is located over the bins near the loading dock, over the 2 units, and over the washer area. Thus the fans blow whatever gases or aerosol vents upward from the units back into the breathing zone of the workers and into the plant in general. There are plans to convert two of the vents to exhaust or to add exhaust ventilation to the existing facility, pending the results of our survey. This plan should take place. Since the existing vents are directly over the units' exhausts, it would be reasonable to use these for the exhaust. However, the temperature control aspects of the swamp coolers may not be met and that incoming air may need to be positioned elsewhere to meet that need. A hood above each units' exhaust would assist in drawing the venting air toward the exhaust duct. However, the most important aspect is that this exhaust should not be blown at the workers.

The airflows in the building were gusty with extremely variable air velocities. These measurements do show sufficient air movement to easily exceed 20 cfm per person. However, it is impossible to tell with our data if this would be true on a still outdoors day.

The HEPA screens to the air cleaners should be cleaned regularly and the air cleaner housing for Unit 1 should be fixed. In order to determine if the air cleaners are functioning properly, airflow probes should be installed in straight portions of the exiting ducts not near any flow perturbations, so that decreases in the airflow can be easily monitored. When the airflow decreases, the screen should be cleaned even if it is not the regularly scheduled cleaning time. If this does not eliminate the problem, it is time to check on the filters' conditions.

The HEPA filter in Unit 1 should be sealed in facing the correct direction. Additional gasket material should be added to complete the seal as the filter didn't seal very well when installed in the correct direction. A reading of zero pressure drop across the HEPA should be an indication of a problem and workers should be notified of this. It is recommended that the prefilter be changed more often than the HEPA in order to allow better air flow and probably extend the life of the HEPA. The best recommendation would be to upgrade the Unit 1 air cleaner system to one similar to the Unit 2 system.

The air cleaner on Unit 2 needs a better seal on the prefilter. Gasketting material should suffice. The foam in the door is loose and should be secured. A velocity tap is recommended in the exit duct not too near water tap. A similar pattern for replacing the filters should be used for this unit as well as unit 1, in that the prefilter should be changed out more often than the HEPA.

None of the aerosol measurements exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified. None of the indoor HAM measurements even exceed the outdoor air National Ambient Air Quality Standard, except the one measurement in the steam plume of unit 2 which was 0.081 mg/m^3. Likewise the LPC measurements are low relative to the standards except for those outside or near the exit.

Inspection for visible blood on surfaces, along with the collection of wipe samples for hemoglobin detection, was carried out throughout the processing area, but focused primarily in the waste loading and washing areas. 63% of the samples tested for the presence of hemoglobin were positive, primarily those associated with manual waste dumping. Worker goggles, telephone, scanning gun, computer keyboard, and drink machine were all negative.

Visual assessment of the work flow, along with hemoglobin test results, shows that the tub dumping area is the most contaminated and provides the greatest potential for worker exposure to bloodborne pathogens. Also, blood residuals detected at the sink used for washing hands suggests the need for routine decontamination and cleaning of the area. Based on the Phase 1 results, it is recommended that Phase 2 monitoring focus on assessment of workers' exposure to blood and body fluid splashes using personal sampling techniques.

Recommendations to reduce this type of exposure include providing adequate splash protection especially personal protective equipment. The fine spray of blood-laced liquid when the tubs were dumped could be addressed by requiring personnel in the vicinity to wear a hard hat with face shield. In addition a uniform policy on the use of gloves should be adopted. A separate eating/break area would reduce the likelihood of cross contamination. Protective clothing that is not worn home should be used in the plant. To reduce transfer from the microwave areas to the office area, shoes that have been worn in the plant should be changed or covered before entering the office area. Alternatively shoes may be covered before entry to the plant floor and the covers removed before returning to the office area. The bathrooms between the plant and the office area should be designated as part of the "clean" office area.

Phase 1 microbial contamination sampling for the microbial indicator pathogens, *Staphylococcus aureus* and *Escherichia coli*, was conducted primarily in the waste dumping area, the unit control panel, worker gloves, and door handles and doorknobs. No *S. aureus* was isolated from any of the 50 samples, and only three samples were positive for *E. coli*. Other non-pathogenic environmental organisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but they are inconsequential relative to assessing potential worker exposures to recognized human pathogens. The presence of some viable indicator bacteria suggest that some of the waste processed was recently generated. Otherwise, the organisms should have had time to die during transport and storage. The implication of not finding a significant number of samples positive for indicator bacteria does not rule out the potential for survival in the waste of environmentally resistant and virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses.

ADDENDUM TO APPENDIX B

This section is a summary of comments made about the draft version of Appendix B and about the microwave equipment by a consultant to the microwave unit manufacturer. Comments that were appropriately dealt with in the main body of this report have been included.

In addition to the concerns of the project team about the hazards of debris falling to the top of a unit or off the unit during loading, this reviewer expressed his concerns that attempts to overload the particular type of microwave unit may cause waste to fall from the top. To reduce some of the waste handling problems, he recommended that wheeled containers be used, when appropriate. He noted that "a procedure is in place should entry into the hopper be required." This procedure includes the recommendation that the hopper be steamed for two hours.

He states that obtaining moveable stairs and installing railings for fall protection (including toe boards) will be strongly recommended to all facilities with these units to minimize fall hazards.

With regards to the effluent air cleaning system, he points out that the maintenance program offered by the unit manufacturer to field service personnel includes reviewing the operation of the filtration system. In addition, concerns, such as those addressed in this report over the problems with the older units filtration system, led to the development of the newer air cleaning system. One of Appendix B's recommendations was to increase the frequency of the changeout of the pre-filter. The company is changing the recommendations for the changeout schedule to reflect this suggestion. The new schedule will include changing the pre-filter every 2 months and when the HEPA filter is changed. All units are now manufactured to discharge to the roof of the units.

APPENDIX C.

PYROLYSIS MWTF SCREENING REPORT

C.1 INTRODUCTION

This report focuses on an initial assessment of a medical waste treatment facility using a pyrolysis technique. This document will serve as one appendix to an overall contract report presenting similar reports on three types of treatment and comparisons of the three.

The Medical Waste Tracking Act (MWTA) of 1988 defined medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals in research pertaining thereto, or in the production or testing of biologicals...". It categorized potentially infectious or "regulated medical waste" into seven types: culture and stocks; pathological wastes; human blood and blood products; sharps; animal waste; isolation wastes; and unused sharps. Treatment was defined as "any method, technique, or process designed to change the biological character or composition of any regulated medical waste so as to reduce or eliminate its potential for causing disease." The MWTA also had a destruction requirement that regulated medical waste be "ruined, torn apart, or mutilated," so as to be unrecognizable and non-reusable. Many of today's available technologies employ destruction as part of the treatment process.

This year more than 500,000 tons of medical waste will be processed in the United States prior to its ultimate disposal. Waste processing will be carried out at various "off-site" commercial treatment facilities, or "on-site" at health care facilities, laboratories, or industrial operations where the waste is generated. As the waste is transported, unloaded, treated, and disposed of, workers can be exposed to a variety of potentially hazardous medical waste components and treatment residues, to include biological and nonbiological aerosols, infectious agents, toxic chemicals, and radioactive materials. They may also be at risk regarding a number of safety related concerns including: injuries, noise, nonionizing radiation exposure, and duties and equipment having poor ergonomics. At the present time there is a significant lack of information on the identification, evaluation, and control of hazards associated with the treatment of medical waste.

A recent survey identified 114 commercial medical waste treatment facilities throughout the 50 states (Malloy, 1995). On average, such facilities operate two to three work shifts and process up to 100 tons of medical waste each day. Thus an estimate of the total number of medical waste treatment workers in the United States easily exceeds 10,000. Thus, the CDC determined that basic information on the current practices in MWTF should be collected.

C.1.1 Project Overview

The scope of the overall project encompasses all currently-available medical waste treatment technologies, with emphasis on the identification, evaluation, and control of all hazards associated with at least three different treatment systems. Hazards may include, but are not limited to: aerosols (biological and nonbiological), organic vapors, vapors and gases of biocidal agents, nonionizing radiation, materials handling, and safety issues (sharps, ergonomics, etc.).

The project tasks can be broken down into 4 categories: 1) conduct literature and field studies necessary to identify all currently-available disinfection systems for infectious waste; 2) recommend three technologies and associated sites for field evaluation; 3) conduct on-site field studies to assess worker exposures to the identified hazards using conventional and novel industrial hygiene methodologies, conduct an assessment of biological contaminants contained in the detailed study plan and experimental design, and evaluate facility engineering controls for worker protection; and 4) providing a detailed and comprehensive final report. The final report will contain descriptions of all investigated treatment technologies, sampling and analytical methods, facility health and safety evaluations, data analyses and risk assessments, evaluation of engineering controls, discussion of results, recommendations to reduce worker exposures, and conclusions.

This research has several purposes, all of which are related to a better understanding of the medical waste treatment occupation, and its potential health and safety hazards. The study includes the accumulation of a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), risk assessment, and prevention and control. The information collected was specific to the sites tested and the workers' environments; thus, the data reflect a combination of the facility practices and the technology used.

For the requisite field evaluations, two phases were planned. Each Phase 1 visit includes an industrial hygiene survey and safety assessment for identification of occupational hazards (chemical and physical), potential treatment system emission points, and engineering controls. The Phase 2 visit will evaluate hazard exposures by conducting comprehensive personnel and area sampling and analyses (as indicated by Phase 1 results) using conventional and novel industrial hygiene practices for organic vapors, mercury, metals, bioaerosols, biological surface contamination, non-ionizing radiation, noise, particles, air quality factors, and evaluate the effectiveness of engineering controls to protect the workers.

C.1.2 Technology Overview

Traditionally, incineration has been a method of treatment and destruction of hazardous chemical waste, municipal solid waste, and pathological waste. It was logical that incineration would be used when concern regarding infectious disease agents such as the AIDS and hepatitis B viruses prompted the treatment of all medical waste and hence a new industry. Over the past several years however, environmental pollution concerns have fostered the development of a variety of medical waste technologies that are presently regarded as viable alternatives to incineration. Such technologies include steam autoclave, microwave, pyrolysis and mechanical/chemical disinfection. This report focuses on a prototype, pyrolysis facility.

Pyrolysis units treat medical waste by pyrolizing waste in a controlled temperature and pressure environment. Pyrolysis reduces the waste to gases and a small amount of dust and solid debris. Metals and ceramics will not be reduced in size but will be disinfected by the very high temperature of the treatment unit. All remaining solid waste residue is collected in a dust bin and emptied as needed. An air cleaning unit is employed to remove unacceptable contaminants, such as metals, from the effluent gas stream.

Concern for medical waste treatment workers comes from the unique character of the waste material and varying treatment technologies. Medical waste contains numerous chemicals that are themselves hazardous to worker health, and the MWTF technologies have the potential to generate others. Emissions from incineration have been extensively studied (US EPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies. Several types of health hazards are of particular concern in this respect: infectious agents (blood-borne pathogens and others); hazardous drugs and chemicals; and non-ionizing radioactivity. Routes of exposure can include skin, mucous membranes, inhalation, and ingestion; with hazards present or generated during treatment as aerosols, particulates, fluids, and sharps. The nature of the MWTF technologies can generate special concerns, such as exposure to non-ionizing radiation. Other concerns include safety hazards and risks of injury related to lifting, moving, slips, falls, machine guarding, and electrical problems. While significant hazard information and statistics are available for "health care workers," medical waste handlers and treatment workers have not been included in the data gathering. It is prudent to assume that medical waste workers are at risk for the same occupational illnesses and injuries as health care workers.

C.1.3 Methodology Overview

Phase 1 of this project focused primarily on emissions, safety, controls, and biohazards. It consisted of the following:

- an industrial hygiene survey,
- a comprehensive safety assessment,
- identification of potential emission points from the treatment system or process,
- area sampling for identification of target volatile organic compounds (VOCs),
- area sampling for airborne metals,
- area sampling for aldehydes,
- identification and assessment of existing engineering controls,
- preliminary respirable aerosol assessment,

- the assessment of blood on surfaces, and
- the assessment of microbial surface contamination.

Each of these assessed areas are discussed in detail later in this report. Details of the specific methodologies used are addressed in Appendices E-P. This Phase 1 survey was carried out by a field team of five people: a certified industrial hygienist (CIH), a certified safety professional (CSP), an experienced microbiologist, an engineer, and an environmental field sampling specialist. The Phase 1 survey did not attempt to determine if the technology was efficiently treating the waste. This assessment examined worker exposures due to the environment at the individual facility due to the technology, the work procedures including the handling of the waste, and the facility itself. It is important to note that the effect on the individual worker's environment of safety features and dangers inherent in each technology is dependent on the use of the equipment in a given facility, the care given to following the manufacturers established procedures, the design of the facility (especially as regards to waste handling and ventilation), and the individual worker's adherence to the procedures at the given facility (for example, use of provided personal protective equipment).

The industrial hygiene and safety assessment surveys observed the waste treatment workflow and process, identified the hazards and routes of exposure unique to the waste treatment technology/facility; secured floor plans, engineering control diagrams, and written safety policy; defined work shifts and worker populations; examined policy related to health promotion (e.g. hepatitis B vaccine, TB testing); described potential routes of exposure relative to specific job assignments, identified chemical compounds used or stored in the facility; identified potentially unsafe procedures, practices or conditions, addressed safety concerns, including machine guarding, slips and falls, and ergonomics; and identified training and personal protection devices currently used.

The samples for Phase 1 included for air emissions: VOCs, metals, mercury, aldehydes, ketones, and particles; and surface contamination from blood or microbial. Potential chemical and biological emission points were identified to ensure that subsequent sampling was properly targeted. The identification was performed by visual inspection and facility usage determination, as appropriate. The results of this screening were used to identify areas and personnel on which to concentrate additional sampling.

Ventilation and HVAC control devices as applicable to the facilities air supply were investigated. Measurements of airflow were taken. The airflow measurements were used to determine if sufficient air is entering the facility based on the ASHRAE standard for indoor ventilation requirements. An attempt was made to determine if contaminated air from the disposal facility is being vented to any other indoor location (such as entering the return air to a main air distribution location). Control devices that could create hazards of themselves were investigated in conjunction with the hazard identification. The evaluation of other engineering controls such as machine guarding, handrails, lifting assistance, noise control, and workplace ergonomics were included.

Phase 1 included aerosol measurements to provide a concentration profile for the room. The aerosol monitor was used to measure concentrations near each identified potential emission point and in several locations throughout the room. The concentration in the incoming outdoor air was determined.

Surface blood contamination is also an important consideration in medical waste treatment. Treatment system surfaces with which workers may come in contact were monitored each day for blood contamination by a wiping procedure using sterile gauze. The gauze was then eluted with sterile water and the eluate was tested for blood using the Hemastix detection method.

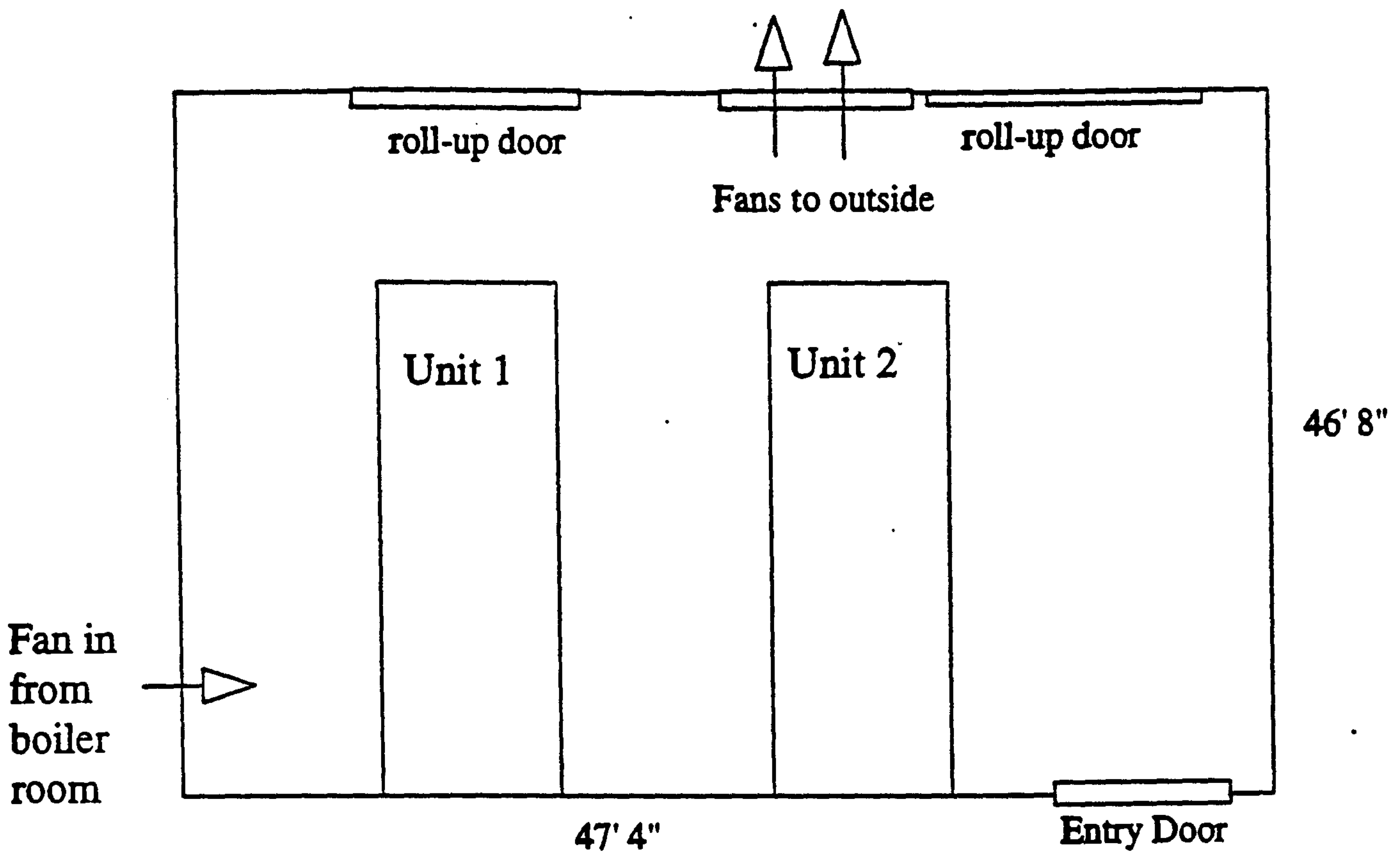
The risk of medical waste treatment workers to dermal contact with infectious disease agents were assessed by sampling and analysis of treatment system surfaces for human pathogen indicator organisms. Suspect surface areas were evaluated by sampling and analysis for two strains of vegetative bacteria associated with human infection and/or contamination, *Staphylococcus aureus* and *Escherichia coli.*

C.2 GENERAL SAFETY EVALUATION OF A PYROLYSIS FACILITY

C.2.1 Summary

This facility, shown in Figure C-1, contains two, prototype, approximately forty pound per hour, pyrolysis units installed on hospital property. The hospital constructed an addition to their facility near the service entrance/boiler room enclosing a corner of the existing single story brick structure. The finished building is approximately 48 ft. x 48 ft. by 20 ft. high, using two walls from the existing hospital with steel framing and light metal walls for the other two sides. Pedestrian entrance is through a doorway which faces the service area of the hospital. Equipment can be moved in and out through either of two metal rollup doors (9 ft. x 12 ft. each) on the back side of the structure. The structure floor is concrete and has a steel covered concrete trench in the shape of a square with the outer edge approximately 4 feet from each wall. The trench is about 6 inches wide and 6 inches deep. Utilities in the room include electricity and water. No restrooms or separate office space is within the structure. The facility roof is flat and accessible by means of a steel staircase which is fixed to the brick wall of the hospital which houses the maintenance staff and equipment. This faculty is run both to treat the hospital waste and to allow the pyrolysis equipment manufacturer to test and improve the equipment and procedures. Units to be available for commercial use in the future will reflect changes made as a result of knowledge gained at this facility. The vendor/facility operator is in the process of developing procedures and documentation as the technology is tested and improved. This report addresses the status of the facility and the technology as of the dates of the assessment with updated information from the vendor included in an addendum.

Figure C-1.
Pyrolysis Facility Layout



C.2.2 General Facility Review (Pyrolysis Area Only)

Significant Positives

- Active, interested hospital management.
- Energetic vendor staff willing to make improvements.
- Pyrolysis unit facility was contiguous to hospital for minimal waste transport but had separate, controlled entry.
- Facility was well maintained.

Significant Negatives

- Electrical safety needs attention, particularly high voltage breaker panel with open space and cover, unlabeled breakers, and <3 foot clearance in front.
- Highly flammable liquids/gases (acetylene) were stored indiscriminately among several non-flammable storage cabinets.
- A drench shower was unavailable despite high volume of caustics and caustics piped overhead.

C.2.3 Other Safety Concerns - Facility

Electrical

- Extension cord to cart was being used a permanent wiring.
- The welder extension cord fed through the former window to the boiler room and was used as permanent wiring.
- No emergency lighting.
- Missing cover plate for 4" x 4" junction box located above former window.

Fire

- EXIT sign/light needed at entry door (interior).
- Evacuation diagram needed.

- NFPA or DOT diamond signage needed for all 55 gallon barrels, both inside and outside facility i.e. better labeling of barrels.

- All fire extinguishers should be mounted and clearly marked for ease of location.

- Acetylene bottle needed base clamp and should be stored in segregated flammable space.

Miscellaneous

- Toeboard needed on landing platform at top of stairs leading to roof.

- The valve shutoff to the eyewash should be removed (i.e. any water shutoff to the eyewash should also shutoff other routinely used water to force rapid repair and preclude inadvertent/forgotten closure.

- All personal protective equipment should be segregated from all other equipment/chemicals.

- Additional informational labels needed on all piping.

- All containers with chemicals need to be clearly labeled.

- Spill control - several 55 gallon barrels of caustic liquid were stored outside the floor space protected by the floor trench thus allowing a potential spill to be released to the environment.

Operational

- The Material Safety Data Sheet book should be tabbed for ease in quickly finding a sheet.

C.2.4 Training Materials, Compliance Documentation, and Program Administration

Hospital

- The hospital had a good, comprehensive, written plan.

- Infectious Waste Management Plan, p. 10, 2(a)(5)(b); All sharps containers should NOT be labeled "hazardous waste."

- Hazard Chemical Waste Management Plan - Section II p. 18, 1; Hazardous chemicals being saved for recycling should be segregated by compatibility class, not comingled in one container.

- Hazardous Chemical Waste Management Plan - Section II (Revised 09/94);

  p. 20, #4. The drain strainer should NOT be the strainer for tissue. Use a pre-screen strainer.

  p. 20, #6.(d). The perforated drum should NOT be burned out.

Pyrolysis Contractor

- The vendor had limited written safety documentation. Significant omissions included:

  - written respiratory protection program
  - written electrical lockout/tagout program
  - written hot work permit program
  - review/written program for permit required confined space

All of the required written OSHA programs were not readily available in work area. Some were written, some in draft stage, some unwritten. The company relied heavily on the hospital for service/support in many of these areas. Documentation of agreements and required annual training documentation was not obtained. A confined space review of the pyrolysis unit is needed.

Overall, attention is needed in the personal protective equipment, respiratory protection, lockout/tagout, and hot work permit (fire prevention) written programs. Appropriate training records for all staff need to be established.

C.2.4 Job Safety Analysis

There were essentially no routine jobs amenable to job safety analysis. Both pyrolysis units were prototype units with constant modification in process. The conveyor belt did have an emergency cable to stop the belt. The panels enclosing various parts of the unit were NOT interlocked.

C.2.4 Personal Protection Equipment

The pyrolysis operator had a variety of personal protection equipment (PPE) which was worn at different times throughout the work shift. The PPE included a back brace, heat resistant gloves, latex gloves, face shield, a dust/mist respirator, and a combination organic vapor/HEPA filter half face respirator. The respirators were not properly maintained and were observed stored loose in a cabinet; one disposable respirator was found on top of a vacuum attachment used to clean out the pyrolysis unit. The respirators should have been stored in clean, sealed, plastic bags with dates and employee names clearly labeled.

Street clothes are worn in the facility and there was no written requirement for steel-toed safety shoes. Employees do not have to shower or change after their shift, though facilities are available in the adjacent hospital.

C.3 EMISSION POINT IDENTIFICATION

During the initial visit to the pyrolysis facility potential chemical and biological emission points within the facility were identified to allow for subsequent, properly targeted, area sampling. The identified potential emission sites for the facility included the pyrolysis units especially at the loading site and near the dust pans when they are cleaned.

C.4 CHEMICAL MEASUREMENT RESULTS

The medical waste as received is not chemically treated. The waste itself may contain any number of chemicals, potentially including volatile metals such as mercury, volatile organic compounds, or aldehydes such as formaldehyde. The most abundant chemical used at the facility is a 50% solution of sodium hydroxide (NaOH). There were also miscellaneous chemicals such as muriatic acid, lacquer thinner, motor oil, and acetylene located in the shop area adjacent to the pyrolysis units.

C.4.1 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) were collected by passing air through multisorbent cartridges containing Tenax TA, charcoal, and ambersorb (200 mm x 6 mm o.d., Envirochem, Kimblesville, PA). For analysis, VOCs on exposed cartridges were thermally desorbed then analyzed by gas chromatography/mass spectrometry (GC/MS). Identification of unknown sample constituents was performed using an electronic search of the NIH/EPA/MSDC Mass Spectral Data Base (NIST library) and the Registry of Mass Spectral Library (Wiley Library). Manual review of the data was performed to verify computer identifications and to identify compounds not found using the computer literature search. A semiquantitative estimate of the identified compounds was made using the total ion peak area for each compound and the total ion response factor measured for toluene. A concentration estimate for total volatile organic compounds was made using the same approach. Example VOCs that are detectable by the multisorbent method are shown in Table C-1. The compounds found in the test samples will be a subset of these.

Table C-1. Example VOCs That Are Detectable by the Multisorbent Method

1,2-Dichloropropane	C_3-Benzenes	Bromoform
1,1,2,2-Tetrachloroethane	C_4-Benzene	Isopropanol
Dibromochloromethane	Methylene Chloride	Propanol
Bromodichloromethane	Bromethane	Butanol
cis-1,3-Dichloropropene	Chloroethane	Pentanol
1,1,2-Trichloroethane	Chloromethane	Benzene
1,1-Dichloroethane	Chloroform	Toluene
1,2-Dichloroethene (Total)	Trichloroethene	Acrolein
trans-1,3-Dichloropropene	Chlorobenzene	Acrylonitrile
1,2-Dichloroethane	Ethyl Benzene	Styrene
1,1,1-Trichloroethane	Dichlorobenzenes	Vinyl Chloride
Carbon Tetrachloride	1,1-Dichloroethene	Xylenes
	Tetrachloroethene	

VOCs were collected at a flow rate of nominally 15 cc/min for 5 hours, next to pyrolysis unit number 1, between pyrolysis units number 1 and number 2 and at the back of pyrolysis unit number 2 in the shop area.

Several VOCs were observed at the facility. They are listed in Tables C-2 to C-4 and Figures C-2 to C-4. The concentrations given are based upon the formula weight of toluene, and only those VOCs in excess of 0.05 mg/m^3 are reported. No OSHA permissible exposure limits (PELs) or ACGIH threshold limit values (TLVs) were exceeded. Two VOC samples were lost at this facility. One sampler was knocked over and broke and the field control was inadvertently used to replace the broken sample thus invalidating both.

C.4.2 Hydrochloric Acid and Chlorine

The pyrolysis facility did not report the use of chlorine-based biocides to the assessment team and was not tested for hydrochloric acid or chlorine.

C.4.3 Aldehydes and Ketones

Formaldehyde is a contaminant that may be emitted during the treatment of medical waste. Formaldehyde as well as other volatile aldehydes and ketones were screened for using a silica gel/DNPH-(2,4-dinitrophenylhydrazine) method (US EPA, 1988). During air sampling, aldehydes and ketones instantaneously react on the cartridge to form the DNPH derivative. For analysis, the DNPH/aldehyde/ ketone derivatives were eluted from the cartridge with acetonitrile. This extract was then analyzed by high performance liquid chromatography (HPLC). Aldehyde/ketones were identified by comparison of their chromatographic retention times with those of purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range 0.02 to 15 ng/μL of the DNPH/aldehyde derivatives. Standards were analyzed and a calibration curve calculated by linear regression of the concentration and chromatographic data. A list of aldehydes/ketones to be analyzed during Phase 1 screening are shown in Table C-5.

Air samples for aldehydes were collected at a flow rate of nominally 120 cc/min for 6 hours, next to pyrolysis unit number 1, between the pyrolysis units, and at the back of pyrolysis unit number 2 in the shop area.

The aldehyde results (Table C-6) indicated concentrations of formaldehyde in the range of 0.08 to 0.18 mg/m^3 as compared to the OSHA PEL of 0.94 mg/m^3 and the ACGIH TLV of 0.37 mg/m^3 (ceiling limit). Acetaldehyde and acetone were also observed but at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs of 360 and 2400 mg/m^3.

Table C-2. VOC Results
Site 3 Between Pyrolysis Units No. 1 and No. 2

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4421

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
3.45	Background	(c)	—
6.30	Acetonitrile	78	0.60
12.41	Internal standard	(c)	—
18.68	Hexanal	71	0.70
20.49	Background	(c)	—
21.32	Internal standard	(c)	—
21.97	m/p-Xylene	88	0.59
23.78	Internal standard	(c)	—
25.44	Phenol	94	1.7
27.02	Background	83	—
29.98	Nonanal	59	1.4
33.22	Decanal	76	1.3
	Total Volatile Organic Hydrocarbons		17

(a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

(b) % Fit versus reference spectra.

(c) Manual interpretation.

Figure C-2. VOC Results
Site 3 Between Pyrolysis Units No. 1 and No. 2

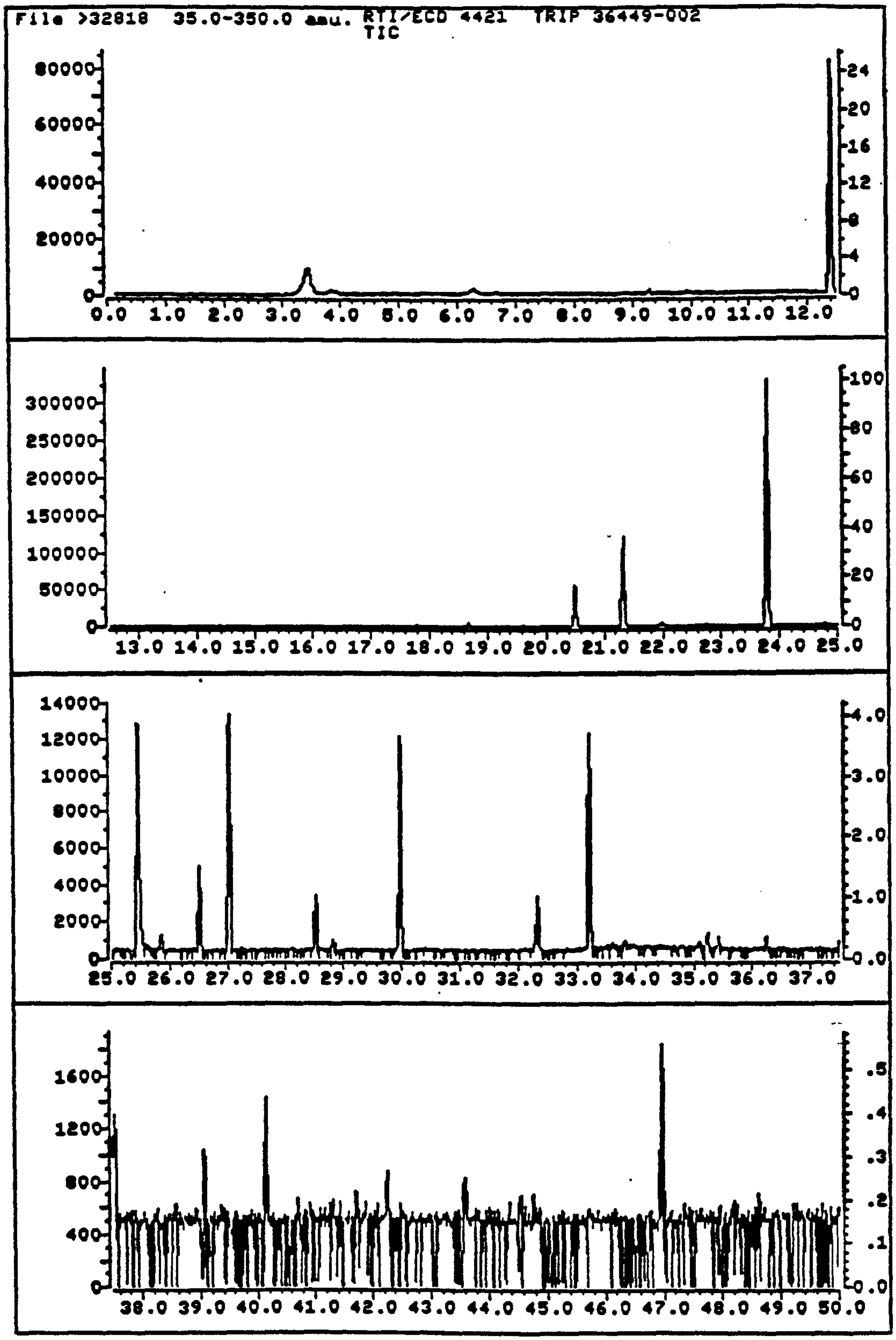


Table C-3. VOC Results
Site 3 Shop Area

QUALITATIVE IDENTIFICATION REPORT

RTI/ECD 4426

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
3.44	Background	(c)	—
9.28	Unknown	(c)	0.41
12.40	Internal standard	(c)	—
18.68	Hexanal	83	1.9
19.44	3-Methyl furan	60	0.60
20.49	Background	(c)	—
21.33	Internal standard	(c)	—
22.74	Heptanal	81	1.4
23.79	Internal standard	(c)	—
26.50	Octanal	89	5.3
28.53	1-Phenyl ethanone	87	0.7
29.99	Nonanal	93	12
32.22	Unknown	(c)	0.4
33.23	Decanal	86	16
33.83	Benzothiazole	52	0.52
35.42	Unknown	(c)	0.49
36.23	Dodecanal	21	0.76
	Total Volatile Organic Hydrocarbons		78

(a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

(b) % Fit versus reference spectra.

(c) Manual interpretation.

Figure C-3. VOC Results
Site 3 Shop Area

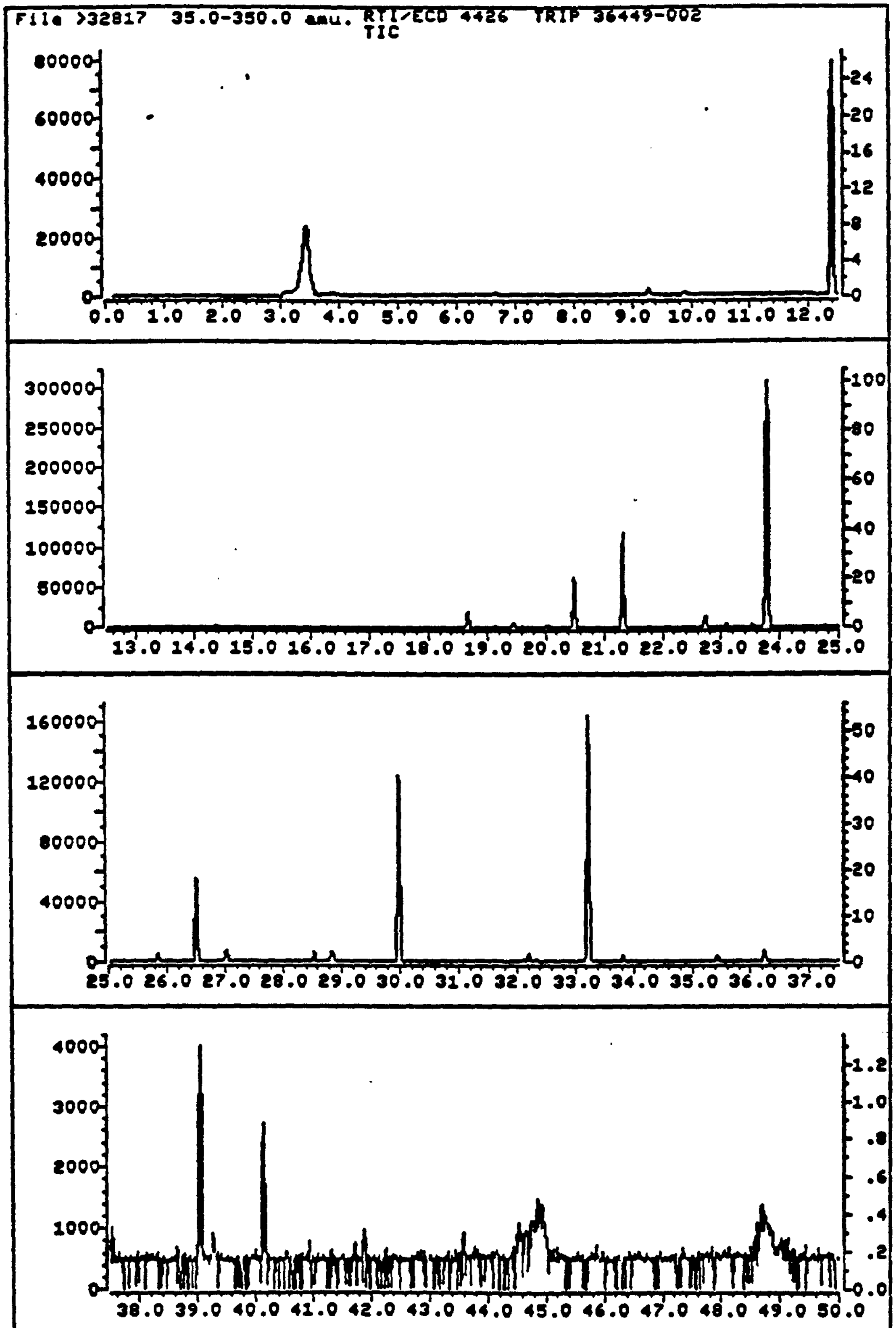


Table C-4. VOC Results
Site 3 Field Blank

QUALITATIVE IDENTIFICATION REPORT

FB-1: TRIP 3

Retention Time (min.)	Peak Identification(a)	Fit(b)	Concentration (ug/m3)
3.48	Backgorund	(c)	—
12.43	Internal standard	(c)	—
21.33	Internal standard	(c)	—
23.79	Internal standard	(c)	—
	Total Volatile Organic Hydrocarbons		ND

(a) Based on an electronic database search of the NIH/EPA/MSDC Mass Spectral Data Base (NBS Library) and the Registry of Mass Spectral Data (Wiley Library).

(b) % Fit versus reference spectra.

(c) Manual interpretation.

Figure C-4. VOC Results
Site 3 Field Blank

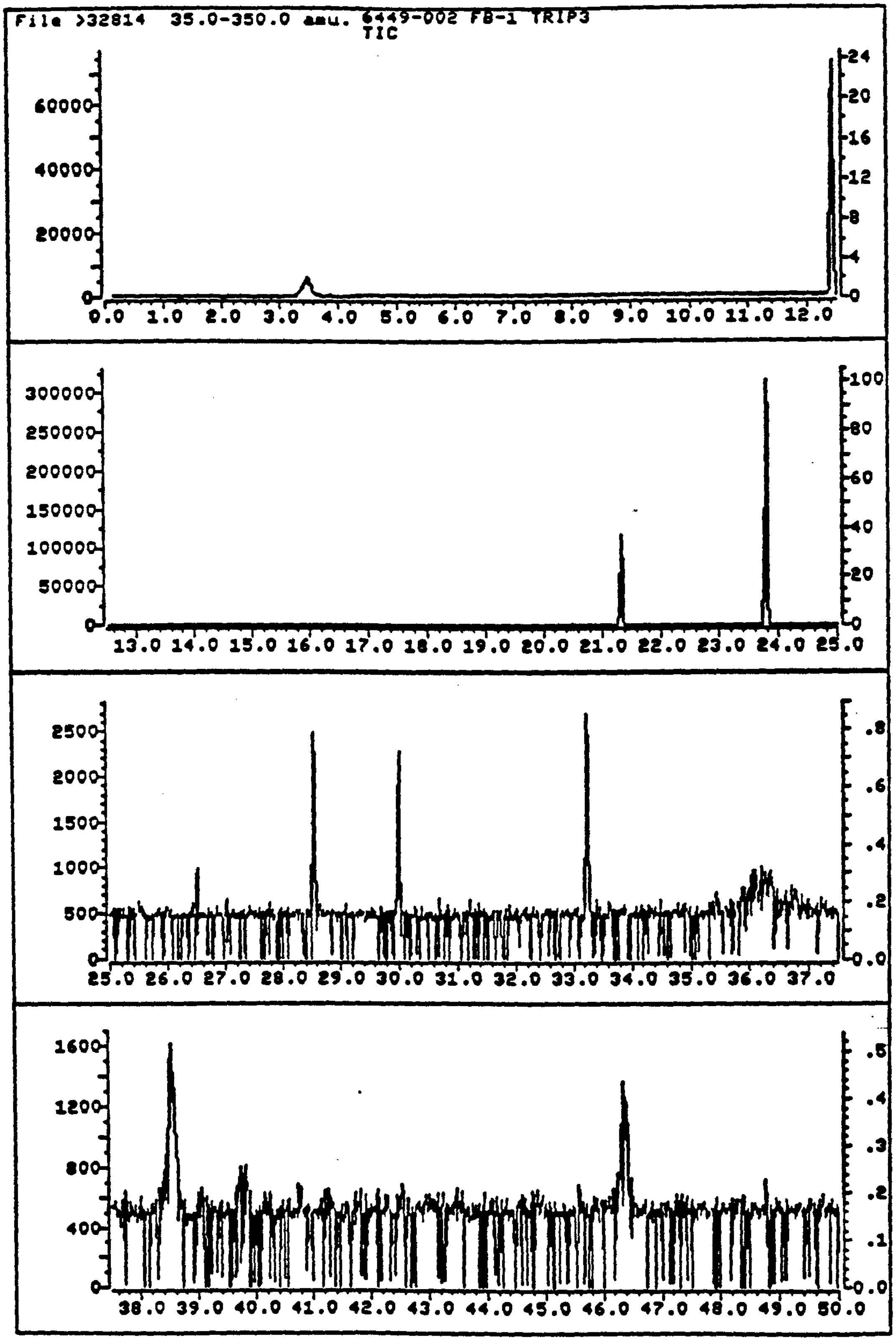


Table C-5. Example Aldehyde/ketones to Be Analyzed During Phase 1 Screening

Formaldehyde	Acetaldehyde	Acetone	Acrolein
n-Propanal	Crotonaldehyde	n-Butanone	n-Butanal
Benzaldehyde	n-Pentanal	n-Tolualdehyde	n-Hexanal

C.4.4 Metals sampling and analysis

The methodology used for metals sampling utilized the EPA draft method 29 sampling train for combustion source emissions (US EPA, 1986). The sample system incorporates a glass fiber filter followed by two (2) impingers containing acidified peroxide solution for collection of aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), labile mercury (Hg^{+2}), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl) and zinc (Zn). Following the peroxide impingers were two impingers containing acidified potassium permanganate for the collection of elemental mercury (Hg°). The draft method has been evaluated extensively at RTI and other laboratories, particularly for mercury species. In addition, the method has been used in the field by a large number of industrial stack testing contractors. A miniaturized version of the sampling train that incorporates midget impingers (1 - 2 L/min sampling rates) instead of the Greenburg/Smith impingers (approximately 20 L/min) was used.

Metals were collected at a flow rate of nominally 1 L/min for 6 ½ hours, next to pyrolysis unit number 1 and between the pyrolysis units.

The measurement of these resulting samples included graphite furnace atomic absorption (GFAA) for As, Sb, and Se; cold vapor atomic absorption (CVAA) for Hg°, inductively coupled plasma mass spectrometry (ICP/MS) (EPA Method 200.8) for Al, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Ni, Ag, Tl and Zn; and inductively coupled plasma emission spectrometry for Al, Fe, Zn and P. These methods are described in both the NIOSH Manual of Analytical Methods (NIOSH, 1994) and in EPA "Methods for Chemical Analyses of Water and Wastes" (EPA 600/4-79-020).

The results of the metals sampling (Tables C-7 to C-10) indicate minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co., Ni, Zn, Cu, As, Se, P, Ag, Cd, Sb, Ba, Tl, Pb and Hg.

Table C-6. Results of Aldehyde Analysis

Sample ID	Location	Air Volume
4427	Between Pyrolysis Units No. 1 and 2	43.0 L
4428	Between Pyrolysis Units No. 1 and 2 duplicate	42.2 L
4429	Pyrolysis Unit No. 1	42.4 L
4430	Shop Area	42.1 L
FB-3	Site 3 - field blank	0.0 L

Concentrations expressed in ($\mu g/m^3$)

Sample	Field Control % Recovery	4427	4428	4429	4430	Field Blank
Compound						
Formaldehyde	90	3.7	3.7	3.7	4.4	<2.6[b]
Acetaldehyde	90	9.1	8.1	8.0	7.0	7.7
Acetone	184[a]	91	86	99	8.9	52
Acrolein	0	<2.6	<2.6	<2.6	<2.6	<2.6
Propionaldehyde	89	<2.6	<2.6	<2.6	<2.6	<2.6
Crotonaldehyde	0	<2.6	2.6	3.6	3.0	<2.6
2-Butanone	230[a]	2.6	2.6	3.2	3.6	<2.6
Methacrolein	44	<2.6	<2.6	<2.6	<2.6	<2.6
Butyraldehyde	89	<2.6	<2.6	<2.6	<2.6	≤2.6
Benzaldehyde	98	14	13	18	16	<2.6
Valeraldehyde	86	<2.6	<2.6	<2.6	<2.6	<2.6
m-Tolualdehyde	96	<2.6	<2.6	<2.6	<2.6	<2.6
Hexanal	86	<2.6	<2.6	<2.6	<2.6	<2.6

[a] Interference present

[b] 2.6 $\mu g/m^3$ is the limit of detection

Table C-7. Site 3
Metals Analysis ($\mu g/m^3$)
Blank Corrected

Location	Between the Pyrolysis Units.						
RTI/ECD No. Identifier Air Volume (m^3)	4407 Prefilter 0.416	4401 Impinger 1 0.416	4402 Impinger 2 0.416	4403 Impinger 3 0.46	4404 Impinger 4 0.416	4405 Impinger 5 0.416	4406 Impinger 6 0.416
<u>Metals</u>							
Be	<0.02	<0.02	<0.02	<0.02	a	a	a
Al	<9.6	<9.6	<9.6	<9.6	a	a	a
Cr	1.269	<1.2	<1.2	<1.2	a	a	a
Mn	<0.1	<0.1	<0.1	<0.1	a	a	a
Fe	<4.8	<4.8	<4.8	<4.8	a	a	a
Co	<0.2	<0.2	<0.2	<0.2	a	a	a
Ni	<0.2	<0.2	<0.2	<0.2	a	a	a
Zn	<1.2	<1.2	<1.2	<1.2	a	a	a
Cu	<0.05	<0.05	<0.05	<0.05	a	a	a
Cd	<0.1	<0.1	<0.1	<0.1	a	a	a
Sb	<0.02	<0.02	<0.02	<0.02	a	a	a
Ba	0.055	<0.05	<0.05	<0.05	a	a	a
Tl	<0.02	<0.02	<0.02	<0.02	a	a	a
Pb	0.069	<0.02	0.035	0.078	a	a	a
Hg^{+2}	<0.03	0.0450	<0.03	<0.03	a	a	a
Hg°	b	b	b	b	<0.03	<0.03	0.0411
As	<0.05	<0.05	<0.05	<0.05	a	a	a
Se	<0.5	<0.5	<0.5	<0.5	a	a	a
Ag	<0.05	<0.05	<0.05	<0.05	a	a	a
P	<12	<12	<12	<12	a	a	a

Impingers 4-6 analyzed only for Hg°
Impingers 1-3 analyzed for Hg^{+2}

Table C-8. Site 3
Metals Analysis ($\mu g/m^3$) Set 2
Blank Corrected

Location	Pyrolysis Unit No. 1						
RTI/ECD No. Identifier Air Volume(m^3)	4414 Prefilter 0.410	4408 Impinger 1 0.410	4409 Impinger 2 0.410	44410 Impinger 3 0.410	4411 Impinger 4 0.410	4412 Impinger 5 0.410	4413 Impinger 6 0.410
<u>Metals</u>							
Be	<0.02	<0.02	<0.02	<0.02	a	a	a
Al	<9.6	<9.6	<9.6	<9.6	a	a	a
Cr	<1.2	<1.2	<1.2	<1.2	a	a	a
Mn	<0.12	<0.12	0.32	<0.12	a	a	a
Fe	<4.8	<4.8	<4.8	<4.8	a	a	a
Co	<0.2	<0.2	<0.2	<0.2	a	a	a
Ni	<0.2	<0.2	<0.2	<0.2	a	a	a
Zn	<1.2	1.79	<1.2	1.23	a	a	a
Cu	0.11	0.14	0.06	0.40	a	a	a
Cd	<0.1	<0.1	<0.1	<0.1	a	a	a
Sb	<0.02	<0.02	<0.02	<0.02	a	a	a
Ba	0.052	<0.05	<0.05	<0.05	a	a	a
Tl	<0.02	<0.02	<0.02	<0.02	a	a	a
Pb	<0.02	0.09	0.10	0.16	a	a	a
Hg^{+2}	<0.03	<0.03	0.0449	<0.03	a	a	a
Hg°	b	b	b	bc	<0.03	<0.03	0.0402
As	<0.05	<0.05	<0.05	<0.05	a	a	a
Se	<0.5	<0.5	<0.5	<0.5	a	a	a
Ag	<0.05	<0.05	<0.05	<0.05	a	a	a
P	<12	<12	<12	<12	a	a	a

a. Impingers 4-6 analyzed only for Hg°
b. Impingers 1-3 analyzed for Hg^{+2}

Table C-9. Site 3
Metals Analysis (Total μg)
Blank Data

RTI/ECD No. Identifier	4420 Filter Blank	4416 Metals Impinger Blank	4418 Mercury Impinger Blank
<u>Metals</u>			
Be	<0.01	<0.01	a
Al	<4.0	<4.0	a
Cr	<0.5	<0.5	a
Mn	<0.05	<0.05	a
Fe	<2.0	<2.0	a
Co	<0.1	<0.1	a
Ni	<0.1	<0.1	a
Zn	<0.5	<0.5	a
Cu	<0.02	<0.02	a
Cd	<0.05	<0.05	a
Sb	<0.01	<0.01	a
Ba	<0.02	<0.02	a
Tl	<0.01	<0.01	a
Pb	<0.01	<0.01	a
Hg^{+2}	<0.012	<0.012	a
Hg°	b	b	0.012
As	<0.02	<0.02	a
Se	<0.2	<0.2	a
Ag	<0.02	<0.02	a
P	<5	<5	a

a. Mercury impinger blank analyzed for Hg°
b. Metals impinger blank analyzed for Hg^{+2}

Table C-10. Site 3
Metals Quality Control

	Solution		Filter	
Metal	**Total μg**	**% Recovery**	**Total μg**	**% Recovery**
Be	89.41	89	8.54	85
Al	1068	107	N/A	
Cr	103.6	104	11.69	117
Mn	100.3	100	11.19	112
Fe	1080	108	24.45	98
Co	99.54	100	9.26	93
Ni	517.1	103	9.24	92
Zn	109.0	109	48.75	98
Cu	104.4	104	22.87	91
Cd	106.2	106	9.55	96
Sb	5.262	105	N/A	
Ba	90.32	90	10.15	101
Tl	5.138	103	9.92	99
Pb	554.2	111	25.05	100
Hg^{+2}	1.0090	110	N/A	
Hg°	9.5638	95.6	N/A	
As	4.924	98	39.82	80
Se	2.631	53	23.06	92
Ag	N/A		4.26	85
P	520	104	N/A	

N/A Metal was not spiked

C.4.5 Indoor Air Quality

The indoor air quality was evaluated from 5/29/ 96 to 5/30/96, using a Metrosonics Air Quality Monitor AQ-501 (S/N 1613). The air was evaluated for temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO). The results (Table C-11), indicate adequate indoor air during the sampling period.

C.5 NOISE

A noise survey was conducted on 5/29/96 using a Quest Sound Level Meter (S/N DL8110002) calibrated with a Quest Calibrator (S/N J8100013). The noise survey demonstrated that noise levels ranged from 66 - 81 dBA. The source of the loudest noise (81 dBA) was a compressor located in the shop support area. The noise levels next to the pyrolysis units reached a maximum of 75 dBA near the pump/motor area attached to the unit (Figure C-5).

C.6 ERGONOMIC ISSUES

The purpose of an ergonomic assessment is to prevent the occurrence of work related musculoskeletal disorders. Work related musculoskeletal disorders can be attributable to the "unassisted manual lifting and lowering of anything weighing more than 25 pounds more than once during the work shift. The hospital employees (housekeeping/environmental services) brought nominally 4-6 boxes per hour to the pyrolysis unit and loaded the conveyor belt. The boxes weighed 15-30 pounds. The number of boxes was dependant on the hospital schedule with the greatest number of boxes coming to the pyrolysis units post surgery.

The pyrolysis operators performed minimal handling of the waste, controlled the pyrolysis unit with a PC, and troubleshooted/maintained the system.

C.7 ENGINEERING CONTROLS

The areas of emphasis of this section are ventilation and engineering controls. However, much of the engineering control aspects of this inspection are covered more in depth in the safety report. Relevant details about the plant are presented first followed by data, then recommendations.

C.7.1 Plant Description

The two pyrolysis units are located in a single room built adjoining the hospital. The basic layout is shown (not to scale) in Figure C-1. There is no air flow from the facility directly into the hospital. The only airflow into the facility that is not from outdoors is from the boiler room. There is ducting entering the room from an air conditioner in the hospital; however, the ducting takes the air out back out of the facility with no apparent leakage into the facility. Louvres above the door admit air. The amount of this air is controlled by fan settings for the fans on the opposite

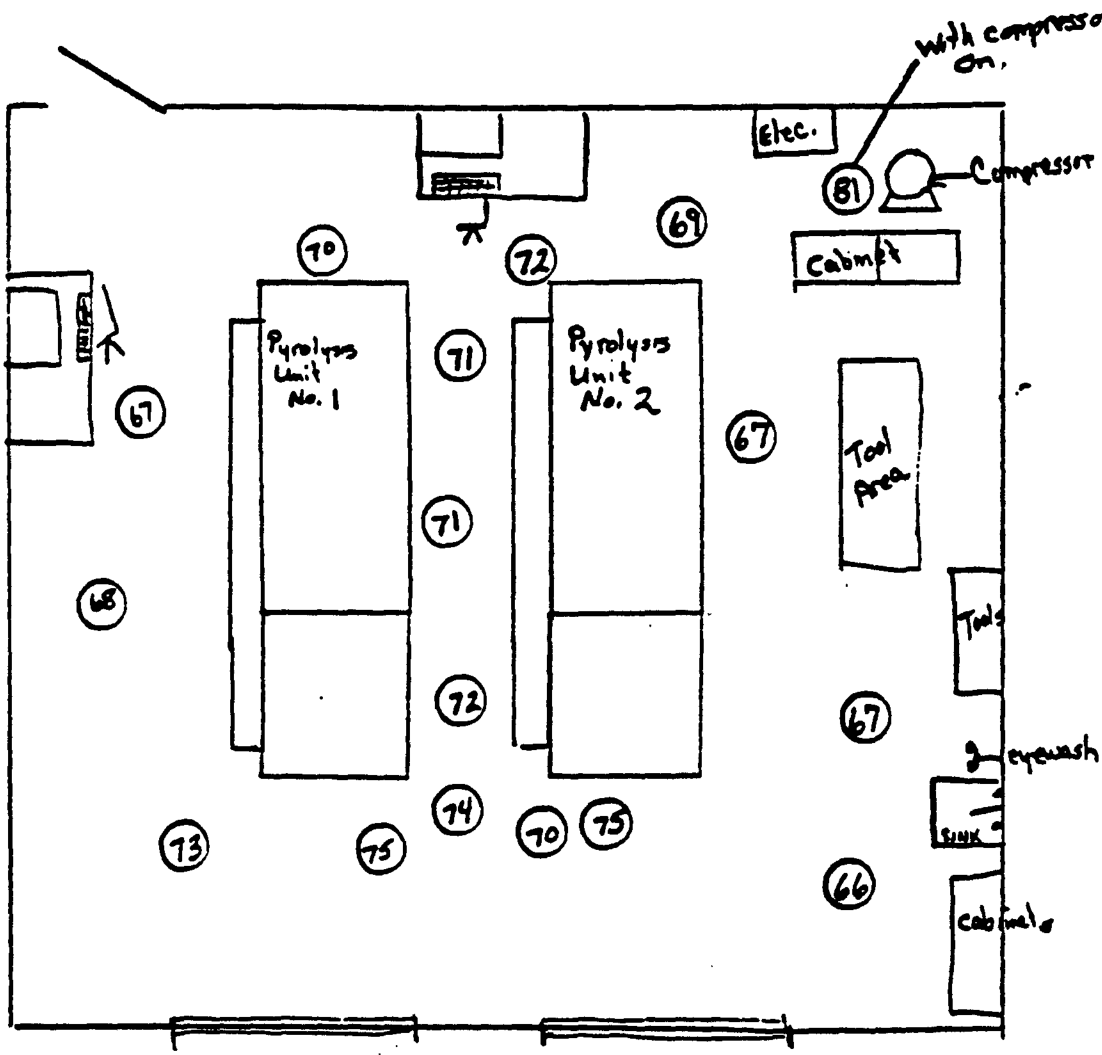
Table C-11. Indoor Air Quality

Sample Dates	2/29/96	2/29/96 to 2/30/96
Location	**Next to Pyrolysis unit 1**	**Behind pyrolysis unit 2, near shop area**
CO_2 average OSHA PEL[a] RTI Suggested Limit	358 ppm 10,000 ppm 1,000 ppm[b]	378 ppm 10,000 ppm 1,000 ppm[b]
CO average OSHA PEL	0 ppm 35 ppm	0 ppm 35 ppm
Temp. average minimum maximum	68.0°F 65.1°F 69.9°F	75.7°F 70.0°F 82.1°F
Relative humidity average minimum maximum	 61.8% 54.1% 69.6%	 43.5% 35.3% 54.2%

[a] OSHA PEL is the Occupational Safety and Health Administration Permissible Exposure Limit for an 8 hour workday.

[b] 1,000 ppm is the current limit adopted by the State of Washington.

Figure C-5. Noise Survey



Noise Survey 5/29/96

○ = Noise reading in dBA

side of the room. These fans are turned on and off by the operators for their comfort. These fans are approximately 46" diameter. In addition to the fans, when the facility gets uncomfortably hot (the temperature is reported to reach mid-90s in the summer), the two roll-up doors at the back are opened to allow even more airflow.

Waste to be treated by this facility comes in several times a day from the hospital and several off-site small scale generators. All waste arrived in sealed cardboard boxes. Any wet or damaged boxes are returned to the producers for repackaging. Specifically, the person bringing the waste in (this will not be anyone employed in the pyrolysis facility) must return the waste to the transport cart and take it back to the generation site. Thus the repackaging and handling of the box is not done by the waste treatment plant employees. The dangers inherent in dealing with the waste fall to the transporter and generator.

All boxes heavier than 50 lbs are returned for repackaging; the weight limit is for the safety of the operators. However, the boxes are not weighed until the conveyor belt takes them to the unit loading platform. The boxes are manually stacked in one corner by the deliverer. They are then lifted to the conveyor belts for the units as space becomes available, usually 1-4 boxes at a time. The facility operator(s) only pick up one box at a time. Due to the low throughput, this does not constitute much total lifting. One or two operators are on duty at a time.

After the box is loaded onto the conveyor belt, the unit moves the box onto a lifting pad situated behind a transparent shield. Here the box is weighed (and rejected if over 50 lb) and the barcode noting point of origin is read. The box is then lifted up several feet to the door of the unit, and moved into the unit. The unit closes the door, treats the waste, and moves the next box up. The units are extensively computerized, although back up switches are in place on the units to allow manual operation if needed. The manual switches are located outside the protective shield and should not ever contact the waste. The computer system is available for off site downloading of data but there must be an on-site operator available to OK access. Some control of the units and much monitoring is available through the off-site computer. The units are often run 24 hours/day for 4 days (T-F) then are down for two days (the weekend), then maintenance and service and upgrades on Mon.

The heat generated by the units is partially reused in the hospital boiler room as water pipes circulate water heated by the pyrolysis units to heat exchangers in the boiler room. All heat sources appear to be well shielded, not presenting danger to visitors or operators.

The solid waste exiting the units is mostly in the form of dust collected below the pyrolysis section. Dumping the dust pan entails some exposure to the dust and bending and lifting the collection pan. Improvements to the system that are being planned include a higher level pan and a new dumping procedure. Waste that can not be pyrolized also falls into the collection pan.

C.7.1.1 Effluent Gas Cleanup

After the pyrolysis section of the unit, the effluent gas stream runs through a packed bed scrubber and a wet electrostatic preciptator for effluent air cleanup before exiting through the roof stack. A carbon unit was tried but is not currently implemented. The scrubber treats the air with neutralized liquid. NaOH is used to neutralize the HCl gas and maintain the liquid pH between 6-8. The NaOH is metered into the liquid as needed from drums located to the sides of the room. The scrubber liquid is recirculated through a "bag filter" to remove particles. These bags are cleaned out regularly and the resultant waste is fed back through the unit along with other operator generated waste, such as used gloves. The scrubber liquid is replaced once a week. Used liquid is stored in drums in the facility until it is hauled off as waste. The liquid is tested then disposed of or treated if determined to be hazardous. According to plant personnel the liquid waste could simply be drained to the sewer according to the regulations, but the company is trying to be as close to a zero effluent operation as possible, thus they are investigating a way to concentrate the liquid to reduce total mass of effluent at least as an option for future units. The caustic delivery sytem entails tubing running from the drums to the metering point. In addition, this system is under consideration for upgrade to avoid long lines filled with NaOH as well as the need for the large drums of caustic in the room.

The tall effluent stack is on the roof along with two hooded heat exchangers. Roof access is simple by way of railed stairs. There are no roof rails, but the heat exchangers are safely away from the edge of the roof. The stack is near the edge, but should not require attendance as the stack sampling for regulation compliance is performed inside the facility. This sampling, required only once a year, is performed by replacing a section of pipe with a sampling manifold.

C.7.1.2 Planned Model Improvements

The next model is scheduled to have better pressure seal and minor explosion vent to prevent such episodes as the minor pop and short venting of particles/hot air as was seen once during our visit. In addition, plans are being made to make the filter changing simpler.

C.7.2 Air Velocities

As has been addressed earlier, the facility was breezy. The air velocities were somewhat variable so that most of the readings consisted of determining a low and high velocity for the range over which the meter needle swung. For the case where the readings were mainly at one level with brief gusts or calm spells, an average wind velocity was estimated by watching the gauge for several minutes. The airflow measurements are shown in Table C-12. These measurement show sufficient air movement to easily exceed 20 cfm per person.

No air flows into the hospital from this facility. The outward air flow from the facility is through the units or through the ventilation fans blowing out above the parking lot.

Table C-12. Airflow Measurements for the Pyrolysis Facility
May 29, 1996

Location	Velocity (fpm) or Velocity Range	Notes
Between and parallel to length of units	25-50	
Between and perpendicular to length of units	15-45	
Parallel to Unit 2 near Door	10-50	
Perpendicular to Unit 2 near door	20-70	
Near boiler room	10-25	
In front of fan from boiler room about 4" from wall at centerline	50-400 300	into facility average
Through open entry door	600	into facility
Louvre above door, center	875	into facility
Back wall fan. unit closer to boiler room	950	out of room
Back wall fan, farther from boiler room	800	out of room louvres farther open

C.7.3 Recommendations

Beyond the potential direct exposure of the worker to dust when dumping the dust pan and the release of dust into the air when the unexpected puffs occur, there are no apparent particle or lack-of-airflow problems. Since the puff problem has been addressed in the newer version of the unit and did not in any case appear to be a major concern with the current unit, this problem did not warrant RTI recommendations. Thus there are no recommendations in these two areas.

Other possible recommendations in the areas of engineering controls are already being considered and implemented for the newer versions of the pyrolysis units. These include a simpler way to clean the sensor, a safer way to clean the filter, modifications to the caustic delivery system, and an improved dust collection/dumping system.

C.8 RESPIRABLE AEROSOL SCREENING

Aerosol measurements were taken with the hand held aerosol monitor (HAM) that measures mass concentration from 0.3-2 μm and with the Laser Particle Counter (LPC) that measures number of particles in various size ranges as described in Appendix I. An average density of 1.5 g/cm^3 was assumed and mass concentration below 5 μm and total up to 15 μm were calculated. The HAM results are shown in Table C-13 and the LPC data are shown in Table C-14. None of the measurements exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified. None of the indoor HAM measurements even exceed the outdoor air National Ambient Air Quality Standard. In fact the measurements were so low that the instrument was taken outside and tested by blowing into some dust to make sure that the instrument would read the presence of dust even after rechecking the zeroes and spanning the HAM showed no instrument problems. Hence the last entry in Table C-13.

In addition these numbers do reflect the concentrations for a day when much outdoor air entered the facility. When the fans are off or run less due to cold or if outdoor levels are higher, the levels indoors may be higher. However, strictly from the particle concentrations, no problems can be diagnosed that need addressing.

C.9 ASSESSMENT OF BLOOD ON SURFACES

The May 29-30, 1996, Phase 1 environmental sampling and analysis assessed the extent of blood contamination on a variety of surfaces and materials in the processing area of an on-site medical waste facility using a pyrolysis process for waste treatment. Waste for treatment is delivered in cardboard boxes, stacked in a corner, then placed on a conveyor that moves the material into the pyrolysis unit by means of a controlled cycle. Exposure to blood and body fluids is minimized as opening of the boxes and dumping of the waste is not required. Exposure could occur if waste boxes leak onto the floor of the facility or the waste conveyor.

Table C-13. HAM Measurements for Pyrolysis Facility
May 29, 1996

Location	Mass conc (mg/m3)	Notes
Near Open Door to Outside	0.006	
Near Unit 2	0.018	when door opened to clean photoelectric eye
Between units	0.004	
In front of fan from boiler room	0.004	
Roll-up door at Unit 1	0.004	
Roll-up door at Unit 2	0.004	
Outside entry door	0.002	
In dust cloud at dumpster	0.017	dust blown up to check instrument response

Table C-14. Mass Concentrations for Pyrolysis Facility
based on LPC data and assumed density of 1.5 g/cm3

Location	Mass <5 mg/m3	Total Mass mg/m3	Notes
May 29, 1996			
On Table	0.0004	0.0033	
Near Door for residue before opening	0.0009	0.0015	no 10-15 µm particles counted
Near Door for residue, tray empty thus no time or particles for large measurement	0.0004		mass < 1 µm
Near table, shortly after Unit door opened	0.0009	0.0054	
Between Units	0.0007	0.0040	
Near Boiler Room	0.0006	0.0121	
May 30, 1996			
Near stacked boxes	0.0006	0.0051	

Twenty (20) wipe samples were collected and processed immediately for the presence of hemoglobin, using collection and analysis methods described in Appendix J. Samples were collected from various locations on the floor near the two pyrolysis units, where spots or stains were suspected of being from blood contamination, and also from conveyor belts, lifters, and associated conveyor framework for both units. Results are presented in Table C-15. Twelve (60%) of the samples were positive. Since the facility appeared quite clean and blood had not been seen splashing out of boxes, when three of the four samples from the conveyor belts were positive for hemoglobin, the personnel were questioned about likely sources. At this point the assessment team was told that the belts are periodically cleaned with Comet brand cleanser. A quick test with the cleanser performed on-site by the assessment team showed that the Comet produced a false positive result. When the other tests were also positive, the personnel were questioned but no likely source of chlorine contamination was mentioned to the team. Later in response to the draft version of this report, the management detailed the use of disinfectant for the floor and other surfaces. The assessment team did not test the product in use but acknowledges that the false positives may have resulted solely, or in part, from the cleansers used in the facility.

If the positives did indicate blood for some of the spots it is likely that the blood came from occasional leaking waste boxes. The presence of such residuals would indicate the need for greater attention to routine cleaning and decontamination. While facility personnel are equipped to effectively handle large blood spills, greater attention could be paid to decontamination and cleaning of minor drops and splatters. Many of the suspect areas sampled and found positive had obviously been there for a significant length of time.

In addition to the recommendation for greater attention to routine cleaning and decontamination, preferably on a daily basis, it is also recommended that facility workers who load the waste boxes onto the conveyors wear protective clothing such as gowns or lab coats. On several occasions workers were observed loading the boxes onto the conveyors with latex gloves for hand protection, but without protection of their street clothes. Without a protective gown or coat, a leaking box could easily splatter clothing, perhaps unknowingly to the worker.

C.10 SURFACE MICROBIAL CONTAMINATION

The Phase 1 survey assessed the extent of microbial contamination on a variety of surfaces and materials in the processing area of an on-site medical waste facility using a pyrolysis process for waste treatment. Sampling was conducted to detect the viable bacterial indicator pathogens *Staphylococcus aureus* and *Escherichia coli*, which could assist in determining the extent of microbial contamination from untreated medical waste throughout the facility, and the potential for worker contact exposures to a variety of potentially infectious agents. Sampling was conducted on various surfaces of the two pyrolysis units including the conveyor framework and belts, in addition to control panels and handles that the operators would touch in the performance

Table C-15. Phase 1 Surface Blood Field Test Results

Sample #	Date	Location / Description	Area	Hemastix	Comment
Pyrolysis 97	05/29/96	Conveyor edge, lifter end, Unit 1	1"x 24"	+Ht	
Pyrolysis 98	05/29/96	Conveyor edge, mid, Unit 1	1"x 24"	Neg	
Pyrolysis 99	05/29/96	Conveyor edge, bay door end, Unit 1	1"x 24"	+	
Pyrolysis 100	05/29/96	Conveyor edge, lifter end, Unit 2	1"x 36"	Neg	
Pyrolysis 101	05/29/96	Conveyor edge, mid, Unit 2	1"x 36"	Neg	
Pyrolysis 102	05/29/96	Conveyor edge, bay door end, Unit 2	1"x 36"	Neg	
Pyrolysis 103	05/29/96	Conveyor belt Unit 1	width x 24"	Neg	
Pyrolysis 104	05/29/96	Conveyor belt Unit 2	width x 24"	+Nhm	
Pyrolysis 105	05/29/96	Floor by conveyor, Unit 1	12"x 12"	+Nht	Dried spots
Pyrolysis 106	05/29/96	Floor by conveyor end Unit 1	12"x 12"	+Nht	Dried spots
Pyrolysis 107	05/30/96	Conveyor edge, lifter end, Unit 1	3"x 24"	+Nht	
Pyrolysis 108	05/30/96	Conveyor edge, mid, Unit 1	3"x 24"	+++	
Pyrolysis 109	05/30/96	Conveyor edge, bay door end, Unit 1	3"x 24"	++	
Pyrolysis 110	05/30/96	Conveyor belt Unit 1	width x 24"	+Nht	
Pyrolysis 111	05/30/96	Conveyor edge, lifter end, Unit 2	1.5"x 36"	Neg	
Pyrolysis 112	05/30/96	Conveyor edge, mid, Unit 2	1.5"x 36"	Neg	
Pyrolysis 113	05/30/96	Conveyor edge, bay door end, Unit 2	1.5"x 36"	Neg	
Pyrolysis 114	05/30/96	Conveyor belt Unit 2	width x 24"	++	
Pyrolysis 115	05/30/96	Floor by Unit 1	12"x 12"	+Nhm	
Pyrolysis 116	05/30/96	Floor by Unit 2 near bay door	12"x 12"	+++	
Pyrolysis 117	05/29/96	Comet test 0.1 gram		+++	

Hemastix Key

Neg	Negative - No color change
+Nht	Positive non-hemolyzed trace
+Nhm	Positive non-hemolyzed moderate
+Ht	Positive hemolyzed trace
+	Positive small
++	Positive moderate
+++	Positive large

Detection limit = 5000 RBC/ml sample which corresponds to 0.000027 ml blood eluted from gauze wiped over a surface of their duties. Various surfaces in and around a toilet in the main hospital building away from the treatment facility were sampled as environmental controls.

A total of 50 surface samples and three controls were collected and processed for each of the indicator organisms using a surface wipe and direct plate technique as described in Appendix K. Results are shown in Tables C-16 and C-17. No *S. aureus* was isolated from any sample, and *E. coli* was isolated only from a stained area on the edge of the Unit 1 conveyor. Other non-pathogenic environmental microorganisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but can be regarded as inconsequential relative to assessing potential worker exposures to recognized human pathogens. While the results in general show little waste contamination of facility surfaces, the *E. coli* isolate does indicate that surface contamination may be present at any time, possibly from leaking waste boxes that could contain more virulent pathogens such as *Mycobacterium tuberculosis* or a variety of bloodborne viruses. Accordingly it is again recommended that attention be given to daily routine cleaning and decontamination of treatment unit and other facility surfaces. Also, a uniform policy should be established and enforced as regards the wearing of gloves to operate buttons and switches on the various control panels of the pyrolysis units.

C.11 SUMMARY AND CONCLUSIONS

This report discusses a facility containing two, prototype, pyrolysis units installed on hospital property. The hospital constructed an addition to their facility near the service entrance/boiler room enclosing a corner of the existing single story brick structure. The finished building is approximately 48 ft. x 48 ft. by 20 ft. high, using two walls from the existing hospital with steel framing and light metal walls for the other two sides. Pedestrian entrance is through a doorway which faces the service area of the hospital. Equipment can be moved in and out through either of two metal rollup doors on the back side of the structure. The structure floor is concrete and has a steel covered concrete trench in the shape of a square with the outer edge approximately 8 feet from each wall. Utilities in the room include electricity and water. No restrooms or separate office space is within the structure. The facility roof is flat and accessible by means of a steel staircase which is fixed to the brick wall of the hospital which houses the maintenance staff and equipment.

Each pyrolysis unit has a footprint of approximately 8 feet x 34 feet. The exhaust from each unit joins within the building and discharges through a single stack which is approximately 8 inches in diameter and rises about 20 feet above the roofline. Each pyrolysis unit uses electricity as the heat source. The waste is contained in fiber boxes which were packaged and sealed prior to delivery. A conveyor that parallels the length of each unit is loaded with the boxes. At the pyrolysis chamber end each box is automatically weighed. When the pyrolysis chamber is empty, the box is lifted vertically, then moved horizontally through an outer door into an airlock. The outer door closes and then a second door, inside the airlock, opens and the box falls into the pyrolysis chamber.

Table C-16.
E. coli Test Results

Sample #	Date	Location	Area	Total CFU	Total E. coli	Other
Pyrolysis 104	05/29/96	Conveyor edge above switch, Unit 1	2"x 2"	TNTC	0	
Pyrolysis 105	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	TNTC	0	
Pyrolysis 106	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	14	0	
Pyrolysis 107	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	15	0	1 Bacillus
Pyrolysis 108	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	27	1	7 Bacillus
Pyrolysis 109	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	36	0	12 Bacillus
Pyrolysis 110	05/29/96	Conveyor belt under waste box, Unit 1		13	0	3 Bacillus
Pyrolysis 111	05/29/96	Conveyor belt under waste box, Unit 1		24	0	3 Bacillus
Pyrolysis 112	05/29/96	Conveyor belt under waste box, Unit 1		9	0	1 Bacillus
Pyrolysis 113	05/29/96	Conveyor edge above motor, Unit 2	1"x 4"	23	0	5 Bacillus
Pyrolysis 114	05/29/96	Conveyor edge, Unit 2	1"x 4"	77	0	67 Bacillus
Pyrolysis 115	05/29/96	Conveyor edge, Unit 2	1"x 4"	44	0	
Pyrolysis 116	05/29/96	Conveyor edge, Unit 2	1"x 4"	TNTC	0	mucoid
Pyrolysis 117	05/29/96	Conveyor edge, Unit 2	2"x 2"	17	0	
Pyrolysis 118	05/29/96	Conveyor belt, Unit 2	2"x 2"	5	0	
Pyrolysis 119	05/29/96	Conveyor belt, Unit 2	2"x 2"	13	0	
Pyrolysis 120	05/29/96	Conveyor belt, Unit 2	2"x 2"	1	0	
Pyrolysis 121	05/29/96	Conveyor belt, Unit 2	2"x 2"	2	0	
Pyrolysis 122	05/29/96	Handle, shield waste loader, Unit 1		1	0	
Pyrolysis 123	05/29/96	Handle, shield waste loader, Unit 2		0	0	
Pyrolysis 124	05/29/96	Control Panel, Unit 1		0	0	
Pyrolysis 125	05/29/96	Control Panel, Unit 2		0	0	
Pyrolysis 126	05/29/96	Toilet handle, men, hospital (Control)		15	0	
Pyrolysis 127	05/29/96	Toilet seat, men, hospital (Control)	4"x 4"	TNTC	0	
Pyrolysis 128	05/29/96	Toilet rim ,men, hospital (Control)		0	0	
Pyrolysis 129	05/30/96	Conveyor edge, Unit 1	2"x 2"	35	0	
Pyrolysis 130	05/30/96	Conveyor edge, Unit 1	2"x 2"	35	0	9 Bacillus
Pyrolysis 131	05/30/96	Conveyor edge, Unit 1	2"x 2"	51	0	9 Bacillus
Pyrolysis 132	05/30/96	Conveyor edge, Unit 1	2"x 2"	14	0	
Pyrolysis 133	05/30/96	Conveyor edge, Unit 1	2"x 2"	21	0	10 Bacillus
Pyrolysis 134	05/30/96	Conveyor belt, Unit 1	2"x 2"	1	0	
Pyrolysis 135	05/30/96	Conveyor belt, Unit 1	2"x 2"	TNTC	0	Bacillus
Pyrolysis 136	05/30/96	Conveyor belt, Unit 1	2"x 2"	4	0	
Pyrolysis 137	05/30/96	Conveyor belt, Unit 1	2"x 2"	25	0	1 Bacillus
Pyrolysis 138	05/30/96	Conveyor edge, Unit 2	2"x 2"	6	0	
Pyrolysis 139	05/30/96	Conveyor edge, Unit 2	2"x 2"	6	0	
Pyrolysis 140	05/30/96	Conveyor edge, Unit 2	2"x 2"	4	0	
Pyrolysis 141	05/30/96	Conveyor edge, Unit 2	2"x 2"	23	0	
Pyrolysis 142	05/30/96	Conveyor edge, Unit 2	2"x 2"	50	0	7 Bacillus

Sample #	Date	Location	Area	Total CFU	Total E. coli	Other
Pyrolysis 143	05/30/96	Conveyor belt, Unit 2	2"x 2"	21	0	5 Bacillus
Pyrolysis 144	05/30/96	Conveyor belt, Unit 2	2"x 2"	4	0	
Pyrolysis 145	05/30/96	Conveyor belt, Unit 2	2"x 2"	2	0	
Pyrolysis 146	05/30/96	Conveyor belt, Unit 2	2"x 2"	6	0	1 Bacillus
Pyrolysis 147	05/30/96	Control Panel Handle, Unit 1		1	0	
Pyrolysis 148	05/30/96	Rear Control Panel Handle, Unit 1		0	0	
Pyrolysis 149	05/30/96	Control Panel Handle, Unit 2		1	0	
Pyrolysis 150	05/30/96	Rear Control Panel Handle, Unit 2		2	0	
Pyrolysis 151	05/30/96	Toilet seat, men, hospital (Control)		176	0	
Pyrolysis 152	05/30/96	Toilet handle, men, hospital (Control)		18	0	
Pyrolysis 153	05/30/96	Toilet rim, men, hospital (Control)		TNTC	0	

Table C-17. Staphylococcus aureus Test Results

Sample #	Date	Location	Area	Total CFU	Total S. aureus	Other
Pyrolysis 104	05/29/96	Conveyor edge above switch, Unit 1	2"x 2"	9	0	2 Bacillus
Pyrolysis 105	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	118	0	9 Bacillus
Pyrolysis 106	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	51	0	
Pyrolysis 107	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	20	0	3 Bacillus
Pyrolysis 108	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	22	0	6 Bacillus
Pyrolysis 109	05/29/96	Conveyor edge, stained area, Unit 1	2"x 2"	64	0	4 Bacillus
Pyrolysis 110	05/29/96	Conveyor belt under waste box, Unit 1		1	0	1 Bacillus
Pyrolysis 111	05/29/96	Conveyor belt under waste box, Unit 1		38	0	4 Bacillus
Pyrolysis 112	05/29/96	Conveyor belt under waste box, Unit 1		4	0	4 Bacillus
Pyrolysis 113	05/29/96	Conveyor edge above motor, Unit 2	1"x 4"	5	0	2 Bacillus
Pyrolysis 114	05/29/96	Conveyor edge, Unit 2	1"x 4"	45	0	3 Bacillus
Pyrolysis 115	05/29/96	Conveyor edge, Unit 2	1"x 4"	33	0	2 Bacillus
Pyrolysis 116	05/29/96	Conveyor edge, Unit 2	1"x 4"	30	0	6 Bacillus
Pyrolysis 117	05/29/96	Conveyor edge, Unit 2	2"x 2"	23	0	1 Bacillus
Pyrolysis 118	05/29/96	Conveyor belt, Unit 2	2"x 2"	1	0	
Pyrolysis 119	05/29/96	Conveyor belt, Unit 2	2"x 2"	4	0	3 Bacillus
Pyrolysis 120	05/29/96	Conveyor belt, Unit 2	2"x 2"	2	0	
Pyrolysis 121	05/29/96	Conveyor belt, Unit 2	2"x 2"	9	0	2 Bacillus
Pyrolysis 122	05/29/96	Handle, shield waste loader, Unit 1		0	0	
Pyrolysis 123	05/29/96	Handle, shield waste loader, Unit 2		8	0	1 Bacillus
Pyrolysis 124	05/29/96	Control Panel, Unit 1		2	0	1 Bacillus
Pyrolysis 125	05/29/96	Control Panel, Unit 2		1	0	1 Bacillus
Pyrolysis 126	05/29/96	Toilet handle, men, hospital (Control)		51	0	
Pyrolysis 127	05/29/96	Toilet seat, men, hospital (Control)	4"x 4"	TNTC	0	
Pyrolysis 128	05/29/96	Toilet rim ,men, hospital (Control)		TNTC	0	
Pyrolysis 129	05/30/96	Conveyor edge, Unit 1	2"x 2"	4	0	4 Bacillus
Pyrolysis 130	05/30/96	Conveyor edge, Unit 1	2"x 2"	66	0	5 Bacillus
Pyrolysis 131	05/30/96	Conveyor edge, Unit 1	2"x 2"	50	0	5 Bacillus
Pyrolysis 132	05/30/96	Conveyor edge, Unit 1	2"x 2"	2	0	
Pyrolysis 133	05/30/96	Conveyor edge, Unit 1	2"x 2"	68	0	4 Bacillus
Pyrolysis 134	05/30/96	Conveyor belt, Unit 1	2"x 2"	6	0	3 Bacillus
Pyrolysis 135	05/30/96	Conveyor belt, Unit 1	2"x 2"	2	0	1 Bacillus
Pyrolysis 136	05/30/96	Conveyor belt, Unit 1	2"x 2"	4	0	3 Bacillus
Pyrolysis 137	05/30/96	Conveyor belt, Unit 1	2"x 2"	10	0	4 Bacillus
Pyrolysis 138	05/30/96	Conveyor edge, Unit 2	2"x 2"	1	0	
Pyrolysis 139	05/30/96	Conveyor edge, Unit 2	2"x 2"	10	0	1 Bacillus
Pyrolysis 140	05/30/96	Conveyor edge, Unit 2	2"x 2"	10	0	6 Bacillus
Pyrolysis 141	05/30/96	Conveyor edge, Unit 2	2"x 2"	16	0	4 Bacillus
Pyrolysis 142	05/30/96	Conveyor edge, Unit 2	2"x 2"	15	0	3 Bacillus
Pyrolysis 143	05/30/96	Conveyor belt, Unit 2	2"x 2"	9	0	6 Bacillus

Sample #	Date	Location	Area	Total CFU	Total S. aureus	Other
Pyrolysis 144	05/30/96	Conveyor belt, Unit 2	2"x 2"	7	0	7 Bacillus
Pyrolysis 145	05/30/96	Conveyor belt, Unit 2	2"x 2"	20	0	3 Bacillus
Pyrolysis 146	05/30/96	Conveyor belt, Unit 2	2"x 2"	0	0	
Pyrolysis 147	05/30/96	Control Panel Handle, Unit 1		2	0	
Pyrolysis 148	05/30/96	Rear Control Panel Handle, Unit 1		0	0	
Pyrolysis 149	05/30/96	Control Panel Handle, Unit 2		6	0	2 Bacillus
Pyrolysis 150	05/30/96	Rear Control Panel Handle, Unit 2		3	0	
Pyrolysis 151	05/30/96	Toilet seat, men, hospital (Control)		TNTC	0	
Pyrolysis 152	05/30/96	Toilet handle, men, hospital (Control)		50	0	
Pyrolysis 153	05/30/96	Toilet rim, men, hospital (Control)		TNTC	0	

The written safety program was somewhat difficult to review since there was considerable overlap/use of programs/training between the hospital and the pyrolysis unit vendor. In general, the hospital had a good written program while the vendor either was in process of writing various sections or had yet to address needed documentation. A job safety analysis was essentially impossible to conduct since only the loading of the conveyor was "routine" and it was done very infrequently.

The hospital management was active and interested. Energetic vendor staff were willing to make improvements. The pyrolysis facility was contiguous to hospital for minimal waste transport but had separate, controlled entry and the facility was well maintained. However, electrical safety needs attention, particularly the high voltage breaker panel with open space and cover, unlabeled breakers, and <3 foot clearance in front. Highly flammable liquids/gases (acetylene) should not be stored indiscriminately among the non-flammable storage cabinets and a drench shower was unavailable despite the high volume of caustics and caustics piped overhead .

All of the required written OSHA programs were not readily available in work area. The company relied heavily on the hospital for service/support in many of these areas. Documentation of agreements and required annual training documentation was not obtained. A confined space review of the pyrolysis unit is needed.

Overall, attention is needed in the personal protective equipment, respiratory protection, lockout/tagout, and hot work permit (fire prevention) written programs. Appropriate training records for all staff need to be established. The pyrolysis operator had a variety of personal protection equipment (PPE) which was worn at different times throughout the work shift. The PPE included a back brace, heat resistant gloves, latex gloves, face shield, a dust/mist respirator, and a combination organic vapor/HEPA filter half face respirator. The respirators were not properly maintained and were observed stored loose in a cabinet; one disposable respirator was found on top of a vacuum attachment used to clean out the pyrolysis unit. Street clothes are worn in the facility and there was no written requirement for steel-toed safety shoes. Employees do not have to shower or change after their shift, though facilities are available in the adjacent hospital.

Air samples for VOCs were collected at a flow rate of nominally 15 cc/min for 5 hours, next to pyrolysis unit number 1, between pyrolysis units number 1 and number 2 and at the back of pyrolysis unit number 2 in the shop area. Several VOCs were observed at the facility, but no OSHA permissible exposure limits (PELs) or ACGIH threshold limit values (TLVs) were exceeded. The highest concentration VOC found between the units was phenol at 1.7 $\mu g/m^3$ and in the shop area was decanal at 16 $\mu g/m^3$.

Aldehyde air samples were collected at a flow rate of nominally 120 cc/min for 6 hours, next to pyrolysis unit number 1, between the pyrolysis units, and at the back of pyrolysis unit number 2 in the shop area. The aldehyde results indicated concentrations of formaldehyde in the range of 0.08 to 0.18 mg/m^3 as compared to the OSHA PEL of 0.94 mg/m^3 and the ACGIH TLV of 0.37 mg/m^3 (ceiling limit). Acetaldehyde and acetone were also observed but at concentrations of nominally 0.07 mg/m^3, several orders of magnitude lower than the respective PELs of 360 and 2400 mg/m^3.

Metals were collected at a flow rate of nominally 1 L/min for 6 ½ hours, next to pyrolysis unit number 1 and between the pyrolysis units. The results of the metals sampling indicate minimal levels (most are less than the detection limits), of the following metals, Be, Al, Cr, Mn, Fe, Co., Ni, Zn, Cu, As, Se, P, Ag, Cd, Sb, Ba, Tl, Pb and Hg.

The indoor air quality evaluation of temperature, humidity, carbon dioxide (CO_2), and carbon monoxide (CO) indicated adequate indoor air during the sampling period.

The noise survey demonstrated that noise levels ranged from 66 - 81 dBA. The source of the loudest noise (81 dBA) was a compressor in the shop support area. The noise levels next to the pyrolysis units reached a maximum of 75 dBA near the pump/motor area attached to the unit.

After the pyrolysis section of the unit, the effluent gas stream runs through an air cleanup system before exiting through the roof stack. The scrubber treats the air with neutralized liquid. NaOH is used to neutralize the HCl gas and maintain the liquid pH between 6-8. The scrubber liquid is replaced once a week. Used liquid is stored in drums in the facility until it is hauled off as waste. The solid waste exiting the units is mostly in the form of dust collected below the pyrolysis section. Dumping the dust pan entails some exposure to the dust and bending and lifting the collection pan. Improvements to the system that are being planned include a higher level pan and a new dumping procedure. Waste that can not be pyrolized also falls into the collection pan.

The facility was breezy. The air velocities were somewhat variable so that most of the readings consisted of determining a low and high velocity for the range over which the meter needle swung. These measurement show sufficient air movement to easily exceed 20 cfm per person.

None of the indoor aerosol measurements exceeded the TWA of 10 mg/m^3 for particulates not otherwise classified or even the outdoor air National Ambient Air Quality Standard. The highest mass concentration found was 0.018 mg/m^3. Based on these particle concentrations, no problems can be diagnosed that need addressing.

Twenty (20) wipe samples were collected and processed immediately for the presence of hemoglobin. Twelve (60%) of the samples were positive. However cleansers that may give false positives were used, so these data are not reliable. The facility appeared clean and blood was not seen dripping from the boxes.

A total of 50 surface samples and three controls were collected and processed for *Staphylococcus aureus* and *Escherichia coli* using a surface wipe and direct plate. No *S. aureus* was isolated from any sample, and *E. coli* was isolated only from a stained area on the edge of the

Unit 1 conveyor. Other non-pathogenic environmental microorganisms, notably a variety of *Bacillus* species, were isolated in the sampling and analysis process, but can be regarded as inconsequential relative to assessing potential worker exposures to recognized human pathogens. While the results in general show little waste contamination of facility surfaces, the *E. coli* isolate does indicate that surface contamination may be present at any time, notably from leaking waste boxes that could contain more virulent pathogens.

Thus, it is recommended that workers apply greater attention to routine cleaning and decontamination, preferably on a daily basis, and that facility workers who load the waste boxes onto the conveyors wear protective clothing such as gowns or lab coats. On several occasions workers were observed loading the boxes onto the conveyors with latex gloves for hand protection, but without protection of their street clothes. Without a protective gown or coat, a leaking box could easily splatter clothing. Also, a uniform policy should be established and enforced as regards the wearing of gloves to operate buttons and switches on the various control panels of the pyrolysis units.

C.11 ADDENDUM TO PHASE 1 TRIP REPORT

As of September 1996, the pyrolysis vendor reports the following changes made after or during, and, in part, due to the Phase 1 assessment. Some of the changes may have been planned before the assessment and implemented afterward as this is a relatively new, constantly upgraded facility and treatment method. The following are changes that were reported to the assessment team by the vendor:

a) The electrical deficiencies have been corrected.
b) Flammables are now stored in a flammable storage locker.
c) A safety shower will be installed shortly by the hospital.
d) The cart extension cord has been replaced.
e) The welder extension cord was replaced.
f) The missing 4"x4" cover plate has been replaced.
g) An exit sign/light has been installed at the entry door.
h) An evacuation diagram has been prepared and posted.
i) Diamond signs have been obtained and placed on all barrels.
j) A base clamp has been installed on the acetylene bottle.
k) The hospital is installing mounts and signs for all fire extinguishers.
l) The shutoff valve to the eyewash has been lockwired open.
m) Personal protective equipment has been segregated from all other equipment.
n) All piping and chemical containers have been labeled.
o) A system to allow discharge of the scrubber blow-down water is being installed to eliminate the accumulation of barrels.
p) The hospital has been informed of the need for a toeboard at the top of the steps leading to the roof.
q) The vendor has hired a health and safety specialist to prepare the written

respiratory protection program, electrical lockout/tagout program, hot work permit program, and the program for permit required confined space, if needed.

r) Personnel now wear uniforms which will be changed and laundered daily.

s) Arrangements are being made for showering and changing at the hospital before workers return home.

t) The frequency of disinfection has been increased to once per day.

u) The compressor has been moved to the hospital's boiler room.

In addition, the vendor stated that, over the three years the facility has been in operation, there have been very few leaking boxes. Any wet or damaged boxes are repackaged by the hospital staff. He also states that boxes are stacked on the floor only when there is no space on the conveyors which usually occurs only after a weekend or unplanned maintenance. The project team notes, that for the two days of this assessment, there were always boxes stacked on the floor. However the assessment only covered two days and may not reflect the average status.

Improvements reported for newer units include access from the outside of the enclosure for most maintenance, and automated residue removal.

APPENDIX D.

STEAM AUTOCLAVE MWTF PERSONAL SAMPLER AND EXPOSURE REPORT

D.1 INTRODUCTION

The Medical Waste Tracking Act (MWTA) of 1988 defined medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals in research pertaining thereto, or in the production or testing of biologicals...". It categorized potentially infectious or "regulated medical waste" into seven types: culture and stocks; pathological wastes; human blood and blood products; sharps; animal waste; isolation wastes; and unused sharps. Treatment was defined as "any method, technique, or process designed to change the biological character or composition of any regulated medical waste so as to reduce or eliminate its potential for causing disease." The MWTA also had a destruction requirement that regulated medical waste be "ruined, torn apart, or mutilated," so as to be unrecognizable and non-reusable. Many of today's available technologies employ destruction as part of the treatment process.

This year more than 500,000 tons of medical waste will be processed in the United States prior to its ultimate disposal. Waste processing will be carried out at various "off-site" commercial treatment facilities, or "on-site" at health care facilities, laboratories, or industrial operations where the waste is generated. As the waste is transported, unloaded, treated, and disposed of, workers can be exposed to a variety of potentially hazardous medical waste components and treatment residues, to include biological and nonbiological aerosols, infectious agents, toxic chemicals, and radioactive materials. They may also be at risk regarding a number of safety related concerns including: injuries, noise, nonionizing radiation exposure, and duties and equipment having poor ergonomics. At the present time there is a significant lack of information on the identification, evaluation, and control of hazards associated with the treatment of medical waste.

A recent survey identified 114 commercial medical waste treatment facilities throughout the 50 states (Malloy, 1995). On average, such facilities operate two to three work shifts and process up to 100 tons of medical waste each day. We estimate that the total number of medical waste treatment workers in the United States easily exceeds 10,000. Thus, the CDC determined that basic information on the current practices in MWTF should be collected.

D.1.1 Project Overview

The scope of the overall project encompasses all currently-available medical waste treatment technologies, with emphasis on the identification, evaluation, and control of all hazards associated with at least three different treatment systems. Hazards may include, but are not limited to: aerosols (biological and nonbiological), organic vapors, vapors and gases of biocidal agents, nonionizing radiation, materials handling, and safety issues (sharps, ergonomics, etc.).

The project tasks can be broken down into 4 categories: 1) conduct literature and field studies necessary to identify all currently-available disinfection systems for infectious waste; 2) recommend three technologies and associated sites for field evaluation; 3) conduct on-site field studies to assess worker exposures to the identified hazards using conventional and novel industrial hygiene methodologies, conduct an assessment of biological contaminants contained in the detailed study plan and experimental design, and evaluate facility engineering controls for worker protection; and 4) providing a detailed and comprehensive final report. The final report contains descriptions of all investigated treatment technologies, sampling and analytical methods, facility health and safety evaluations, data analyses and risk assessments, evaluation of engineering controls, discussion of results, recommendations to reduce worker exposures, and conclusions.

This research has several purposes, all of which are related to a better understanding of the medical waste treatment occupation, and its potential health and safety hazards. The study included the accumulation of a significant base of knowledge relevant to hazards identification, potential routes of exposure, evaluation (sampling and analysis), risk assessment, and prevention and control.

For the requisite field evaluations, two phases were planned. Each Phase 1 visit included an industrial hygiene survey and safety assessment for identification of occupational hazards (chemical and physical), potential treatment system emission points, and engineering controls. The Phase 2 visit evaluated hazard exposures by conducting comprehensive personnel and area sampling and analyses (as indicated by Phase 1 results) using conventional and novel industrial hygiene practices for organic vapors, biological surface contamination, noise, and air quality factors.

D.1.2 Technology Overview

Traditionally, incineration has been a method of treatment and destruction of hazardous chemical waste, municipal solid waste, and pathological waste. It was logical that incineration would be used when concern regarding infectious disease agents such as the AIDS and hepatitis B viruses prompted the treatment of all medical waste and hence a new industry. Over the past several years however, environmental pollution concerns have fostered the development of a variety of medical waste technologies that are presently regarded as viable alternatives to incineration. Such technologies include steam autoclave, microwave, pyrolysis and mechanical/chemical disinfection. This report focuses on a steam autoclave facility.

Steam autoclave treatment combines moisture, heat, and pressure to inactivate microorganisms. The process has been used for sterilizing medical instruments in hospitals for decades, and the validation of autoclaving as a sterilization technique for medical equipment and supplies is well documented. Off-site commercial treatment autoclaves typically operate at 160°C and 80-85 psi and can treat some 3,000 lbs per cycle.

Concern for medical waste treatment workers comes from the unique character of the waste material and varying treatment technologies. Medical waste contains numerous chemicals that are themselves hazardous to worker health, and the MWTF technologies have the potential to generate others. Emissions from incineration have been extensively studied (US EPA, 1991). Little has been done however to characterize the environmental emissions from alternative technologies. Several types of health hazards are of particular concern in this respect: infectious agents (blood-borne pathogens and others); hazardous drugs and chemicals; and non-ionizing radioactivity. Routes of exposure can include skin, mucous membranes, inhalation, and ingestion; with hazards present or generated during treatment as aerosols, particulates, fluids, and sharps. The nature of the MWTF technologies can generate special concerns, such as exposure to non-ionizing radiation. Other concerns include safety hazards and risks of injury related to lifting, moving, slips, falls, machine guarding, and electrical problems. While significant hazard information and statistics are available for "health care workers," medical waste handlers and treatment workers have not been included in the data gathering. It is prudent to assume that medical waste workers are at risk for the same occupational illnesses and injuries as health care workers.

D.1.3 Methodology Overview

Phase 1 of this project focused primarily on emissions, safety, controls, and biohazards. It consisted of the following:

- an industrial hygiene survey,
- a comprehensive safety assessment,
- identification of potential emission points from the treatment system or process,
- area sampling for identification of target volatile organic compounds (VOCs),
- area sampling for airborne metals,
- area sampling for aldehydes,
- noise and nonionizing radiation measurements,
- identification and assessment of existing engineering controls,
- preliminary respirable aerosol assessment,
- the assessment of blood on surfaces, and
- the assessment of microbial surface contamination.

The Phase 2 survey at each of the three sites focused (or will focus) on worker personal exposure monitoring using primarily active personal samplers. Phase 2 sampling was planned to consist of:

- Personal monitoring for VOCs identified in Phase 1,
- Air quality monitoring (temperature, relative humidity, CO, CO_2).

- Personal monitoring for blood aerosol, and
- Area and emission point monitoring for microbial aerosols.

The actual sampling performed (or to be performed) was determined for each site based on the Phase 1 assessments. No area sampling for VOCs was conducted during Phase 2, and no metals sampling of any kind was performed for Phase 2. The Phase 1 results showed low respirable particle counts, so no Phase 2 aerosol sampling was performed. Also a blood splash protocol replaced the planned blood aerosol testing. Since medical waste can vary on a day to day basis, sampling was conducted over two days. One shift per day was monitored. The field team consisted of three people including an industrial hygienist, microbiologist, and environmental sampling specialist. One of the three trips was made in the first year of the project.

Each of these areas that were actually performed are discussed in detail later in this report. Details of the specific methodologies used are addressed in Appendices E-P.

D.2 CHEMICAL AND PHYSICAL EXPOSURE RESULTS

A Phase 2 field study focusing on personal exposures was conducted at the Medical Waste Treatment Facility using the autoclave system on June 25-26, 1996. The Phase 1 results for this facility are reported in Appendix A. This section contains the results of the industrial hygiene survey relating to chemical and physical (noise) exposures. This industrial hygiene survey included personal monitoring for volatile organic compounds (VOCs), ethanol, and formaldehyde. Area samples were collected for methanol, n-propanol, and ammonia. A noise survey was conducted and a noise dosimeter was utilized to collect a composite noise survey in the operator control area. Additionally, an air quality monitor was used to obtain temperature, relative humidity, carbon dioxide and carbon monoxide measurements.

It was originally planned to collect 5 personal samples on 5 workers over each of 2 days, however, the facility had modified the work schedule to accommodate a reduction in the volume of medical waste received. Some employees were working 12 hour shifts from 11 a.m. to 11 p.m. or 12 p.m. to 12 a.m. To accomplish obtaining 5 complete shifts, it was necessary to change the personal samplers from one employee to another when the shift changed. Two job titles, Supervisor and one Laborer, required two employees from two shifts to share (trade-off) the chemical sampling equipment. One job (Maintenance) was performed from 0500-1330, so the first day of sampling only a 5 hour sample was collected. For the second day of sampling the maintenance employee was outfitted with sampling pumps, badges and collection media by 0500 to enable collection of an 8 hour sample.

The results of the study demonstrate that the medical waste treatment workers at the autoclave system have minimal exposure to most chemicals with the exception of formaldehyde, where concentrations of 0.021 to 0.086 ppm were observed [the OSHA Permissible Exposure Limit (PEL) is 0.75 ppm and the NIOSH Recommended Exposure Limit (REL) is 0.016 ppm].

Additionally, a maintenance worker was exposed to brief episodes of ammonia at concentrations exceeding 30 ppm (the OSHA short term exposure limit (STEL) is 50 ppm, the OSHA vacated 1989 STEL is 35 ppm, and the NIOSH REL and ACGIH TLV are both 25 ppm).

D.2.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) were monitored in Phase II using the same multisorbent cartridge method (Tenax TA, charcoal, and ambersorb) that was employed in Phase I. The samples were collected at nominally 16 cc/min for 7-8 hours on 5 workers on each of 2 days. Several VOCs were identified and quantified (Tables D-1 through D-3). All of the VOC results were less than OSHA PELs, NIOSH RELs, and ACGIH threshold limit values (TLVs).

D.2.2 Formaldehyde

Formaldehyde samples were collected using 3M 3720 passive formaldehyde badges. Again 5 workers were sampled for 7-8 hours on each of 2 days. Formaldehyde concentrations on the workers ranged from 0.021 to 0.086 ppm (Table D-4). The control sample taken on an office worker was 0.04 ppm, higher than any plant workers on 6/26/96. The OSHA PEL for formaldehyde is 0.75 ppm, the ACGIH TLV is a ceiling value of 0.3 ppm, while the NIOSH REL is 0.016 ppm.

D.2.3 Ethanol

Ethanol was measured using a direct reading passive Dräger diffusion tube (part no. 81 01 151) with a detection range of 125-3100 ppm. Five workers were sampled for 7-8 hours on each of 2 days. No ethanol was detected on any of the personal direct reading Dräger tubes (Table D-5). The minimum detection limit for an 8 hour sampling period is 125 ppm. The OSHA PEL, NIOSH REL, and the ACGIH TLV are 1000 ppm for ethanol.

D.2.4 Ammonia

Ammonia was sampled using a direct reading Dräger tube (part no. 67 33 231) with a detection range of 0.5 - 30 ppm. Samples were collected over nominally one minute using a hand held pump (n = 5 strokes). Five samples were collected on each of 2 days in the boiler room adjacent to the autoclave processing area. High concentrations of ammonia (Table D-6) were observed in the boiler room during the transfer operation of ammonia from the drum to the vat. The ammonia transfer procedure takes about 1 minute to complete. On the first day of sampling, the maintenance worker held his breath while he performed the transfer. The second day the worker wore a full face respirator with ammonia cartridges while performing the transfer. The ammonia Dräger tube indicated concentrations exceeding 30 ppm after 1 stroke on the pump (requires n = 5 strokes). The OSHA short term exposure limit is 50 ppm and the vacated 1989 OSHA STEL is 35 ppm. The NIOSH REL and the ACGIH TLV is 25 ppm with a STEL of 35 ppm.

Table D-1. Personal VOC Sampling
6/25/96

RTI/ECD No. Employee No. Job Title Air Volume (L)	4436 1 Maintenance 6.071	4437 2 Laborer 8.424	4438 3a & 3b Laborer 8.116	4439 4 Laborer 6.838	4440 5a & 5b Supervisor 6.890	4441 Blank 0	LOD[a]
VOC concentration ($\mu g/m^3$)							
Dichlorodifluoro-methane	53	104	45	61	51	ND	3.0
Methyl ether	ND[b]	ND	ND	ND	ND	ND	2.3
2-Methylpropane	37	42	22	26	35	ND	5.8
Acetonitrile	3.9	3.4	ND	ND	2.2	ND	1.1
Acetone	35	41	NC[c]	25	22	ND	1.1
2-Propanol	26	14	ND	6.8	9.3	ND	5.3
Carbon disulfide	3.7	2.2	8.1	2.5	2.3	ND	1.7
Chloroform	1.5	ND	3.6	ND	ND	ND	1.3
Benzene	ND	ND	ND	ND	ND	ND	1.5
Toluene	ND	ND	ND	ND	ND	ND	1.5
2-Furancarbox-aldehyde	ND	ND	ND	ND	ND	ND	2.0
Ethylbenzene	ND	ND	ND	ND	ND	ND	1.5
m,p-Xylene	ND	ND	ND	ND	ND	ND	1.2
Cyclohexanone	ND	ND	ND	ND	ND	ND	1.6
o-Xylene	ND	ND	ND	ND	ND	ND	1.5
Styrene	ND	ND	ND	ND	ND	ND	1.5
2-Ethyl-1-hexanol	ND	ND	ND	ND	ND	ND	1.4
Limonene	ND	ND	ND	ND	ND	ND	1.1

a. LOD, Limit of Detection based on average volume of 7.4 L
b Not detected
c. Not calculated due to interference

Table D-2. Personal VOC Sampling
6/26/96

RTI/ECDNo. Employee No. Job Title Air Volume (L)	4443 1 Maintenance 7.747	4444 2 Laborer 6.76	4445 3a & 3b Laborer 10.471	4446 4 Laborer 6.76	4447 5a & 5b Supervisor 6.14
VOC ($\mu g/m^3$)					
Dichlorodifluoromethane	59	69	49	91	50
Methyl ether	3	12	11	5	13
2-Methylpropane	57	14	22	12	16
Acetonitrile	NC[a]	ND[b]	ND	ND	ND
Acetone	62	23	78	37	97
2-Propanol	77	6.2	81	13	146
Carbon disulfide	63	2.3	14	2.6	43
Chloroform	5.7	ND	1.3	ND	5.3
Benzene	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND
2-Furancarboxaldehyde	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND
m,p-Xylene	ND	ND	ND	ND	ND
Cyclohexanone	ND	ND	ND	ND	ND
o-Xylene	ND	ND	ND	ND	ND
Styrene	ND	ND	ND	ND	ND
2-Ethyl-1-hexanol	ND	ND	ND	ND	ND
Limonene	ND	ND	ND	ND	ND

a. Not calculated due to interferences
b. Not detected

Table D-3. Personal VOC Sampling Field Controls

Medical Waste Trip 1, Phase 2 Field Control	% Recovery
Vinyl chloride	31
Chloroform	71
Benzene	82
Trichloroethylene	73
Toluene	102
o-Xylene	100

Table D-4. Personal Formaldehyde Sampling

Date: 6/25/96						
RTI/ECDNo. 3M No. Employee No. Job Title Sample Time (min)	4450 VC 05167 1 Maintenance 354	4451 VC 05186 2 Laborer 450	4452 VC 04699 3a & 3b Laborer 455	4453 VC 04872 4 Laborer 435	4454 VC 04843 5a & 5b Supervisor 440	4455 VC 04946 Field Blank -- 0
Formaldehyde concentration (ppm)	0.032	0.065	0.086	0.070	0.074	<0.014

Date: 6/26/96						
RTI/ECDNo. 3M No. Employee No. Job Title Sample Time (min)	4457 VC 04786 1 Maintenance 480	4458 VC 04893 2 Laborer 375	4459 VC 04957 3a & 3b Laborer 420	4460 VC 04818 4 Laborer 428	4461 VC 04843 5a & 5b Supervisor 390	4462 VC 04941 Control Secretary 375
Formaldehyde concentration (ppm)	0.021	0.033	0.021	0.038	0.034	0.040

Table D-5. Personal Ethanol Sampling

Date: 6/25/96						
RTI/ECDNo. Employee No. Job Title Sample Time (min)	**4464 1 Maintenance 354**	**4465 2 Laborer 450**	**4466 3a & 3b Laborer 455**	**4467 4 Laborer 435**	**4468 5a & 5b Supervisor 440**	**4469 Blank**
Ethanol concentration (ppm)	N/D[a]	N/D	N/D	N/D	N/D	N/D

Date: 6/26/96					
RTI/ECDNo. Employee No. Job Title Sample Time (min)	**4471 1 Maintenance 480**	**4472 2 Laborer 375**	**4473 3a & 3b Laborer 420**	**4474 4 Laborer 428**	**4475 5a & 5b Supervisor 390**
Ethanol concentration (ppm)	N/D	N/D	N/D	N/D	N/D

a. N/D not detected, no color change noted on Dräger tube. The range of measurement for an eight hour sample (980 minutes) is 125 - 3,100 ppm.

Table D-6. Ammonia Sampling in Boiler Room

Sample No.	Date	Location	Ammonia Concentration
1	6/25/96	Next to ammonia drum during transfer	>30 ppm
2	6/25/96	Next to ammonia vat during transfer	>30 ppm
3	6/25/96	6 ft. away from ammonia vat during transfer	0.5 ppm
4	6/25/96	3 ft. away from ammonia vat during transfer	1.0 ppm
5	6/25/96	Next to ammonia drum after transfer complete	10.0 ppm
6	6/25/96	Floor drain near vat	2.0 ppm
7	6/26/96	Far side of boiler	<0.5 ppm
8	6/26/96	3 ft. away from ammonia drum	0.5 ppm
9	6/26/96	Between ammonia drum and vat	0.5 ppm
10	6/26/96	Floor drain near vat	2.0 ppm

D.2.5 Methanol and N-propanol

Methanol and n-propanol were sampled using a direct reading Dräger tube (part no. 26 112) with a detection range of 25-5000 ppm. Samples were collected over one minute using a hand held pump (n = 10 strokes). Five samples were collected on each of 2 days in the autoclave processing area and adjacent boiler room. No methanol or propanol was detected on the Dräger tubes used for area samples (Table D-7). The minimum detection limit of the method is 25 ppm and the OSHA PELs, NIOSH RELs and the ACGIH TLVs for methanol and propanol are 200 ppm.

D.2.6 Noise

A noise survey was conducted using a Quest Sound Level Meter (s/n DL8110002) calibrated with a Quest Calibrator (s/n J8100013). A Quest Micro 14 Noise Dosimeter (s/n HM0010038A), calibrated with Quest Model CA-12B Sound Calibrator (s/n U0010007) was used to collect three integrated noise surveys at the control panel. The area noise surveys (Figures D-1 and D-2) showed noise levels ranging from 70 to 100 dBA within the boiler room. The loudest noise in the boiler room (100 dBA) was from a motor. The maintenance worker indicated that it was not normally that loud and was in need of repair. The motor was coming on intermittently.

Noise levels ranged from 69 to 97 dBA in the process area. The source of the loudest noise in the process area was the venting/blowdown of the autoclaves, where noise levels peaked at 97 dBA. This noise lasted nominally 2-3 minutes and occurred once every 50 minute cycle on each of two autoclaves.

A noise dosimeter was placed in the plant on top of the control panel. This area is located in the middle of the room near most of the employees activities. Three separate noise surveys were collected. The results (Table D-8) demonstrated that all three surveys had average noise levels less than the OSHA PEL of 90 dBA (the average noise levels were 77.8, 81.3 and 73.9 dBA).

Company management has a hearing conservation program in place that requires employees to wear hearing protection whenever working between the two autoclaves during the ramping segment, when cleaning inside of the autoclave, and when removing debris from the autoclave waste bins, and whenever the TWA exceeds 85 dBA. However, the boiler room was not separately posted, not was the attendant wearing any hearing protection.

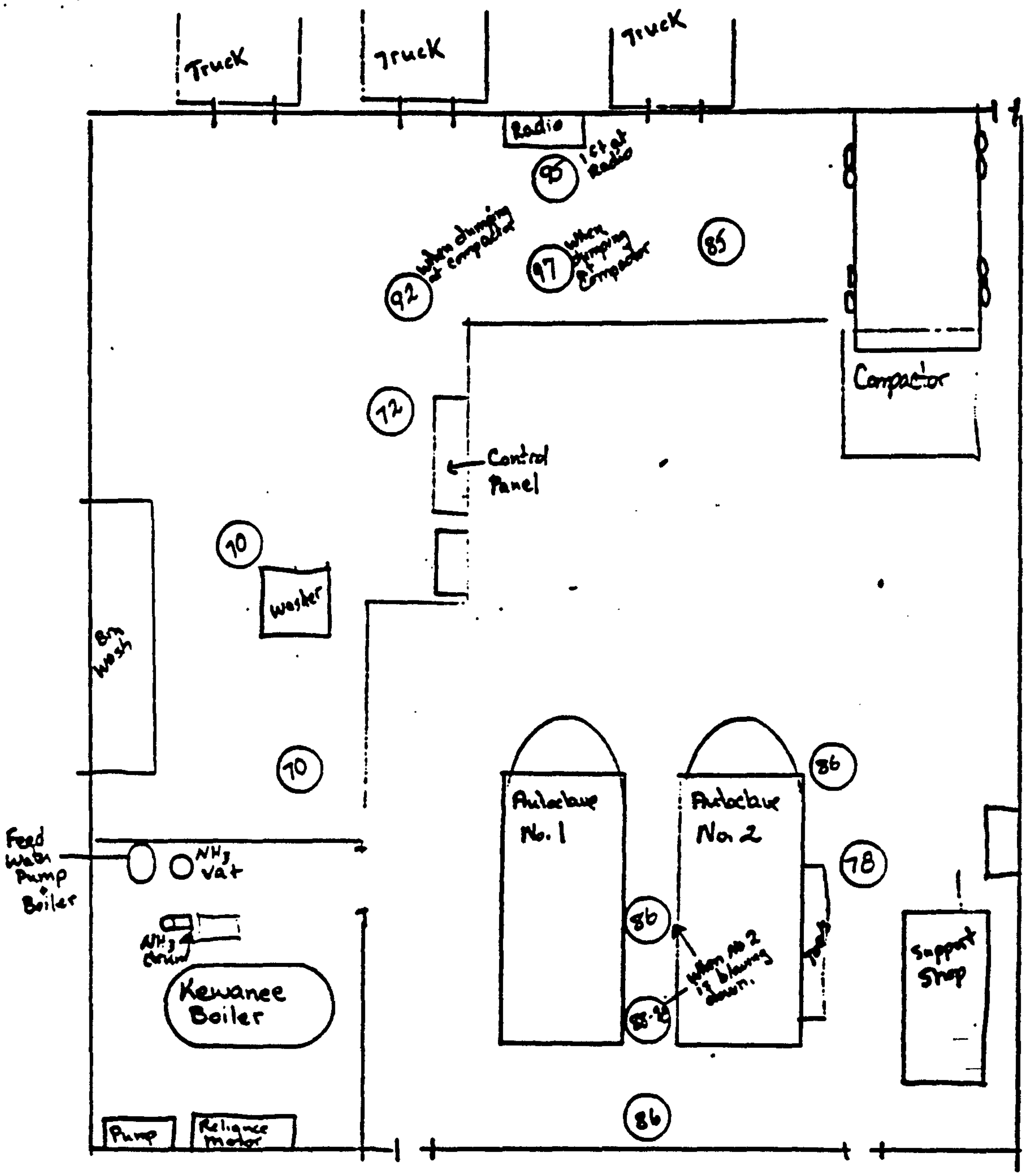
D.2.7 Total Dust Sampling

Phase I indicated no need to sample as the environment was not dusty.

Table D-7. Methanol and n-Propanol Sampling

Sample No.	Date	Location	Alcohol Concentrations
1	6/25/96	Between autoclaves	<25 ppm
2	6/25/96	Near bin washer	<25 ppm
3	6/25/96	Control Panel	<25 ppm
4	6/25/96	Large dumping ins	<25 ppm
5	6/25/96	Loading dock, near asphalt release	<25 ppm
6	6/26/96	Boiler room	<25 ppm
7	6/26/96	On top of bins not yet autoclaved	<25 ppm
8	6/26/96	Near ZEP asphalt release drum	<25 ppm
9	6/26/96	Inside truck offloading cardboard boxes	<25 ppm
10	6/26/96	Laboratory	<25 ppm

Figure D-1. Medical Waste Treatment Facility
Site No. 1 Autoclave
Noise Measured in dBA 6/25/96



Medical Waste Treatment Facility
Site No. 1 Autoclave
◯ Noise measured in dBA 6/25/96

Figure D-2. Medical Waste Treatment Facility
Site No. 1 Autoclave
Noise Measured in dBA 6/26/96

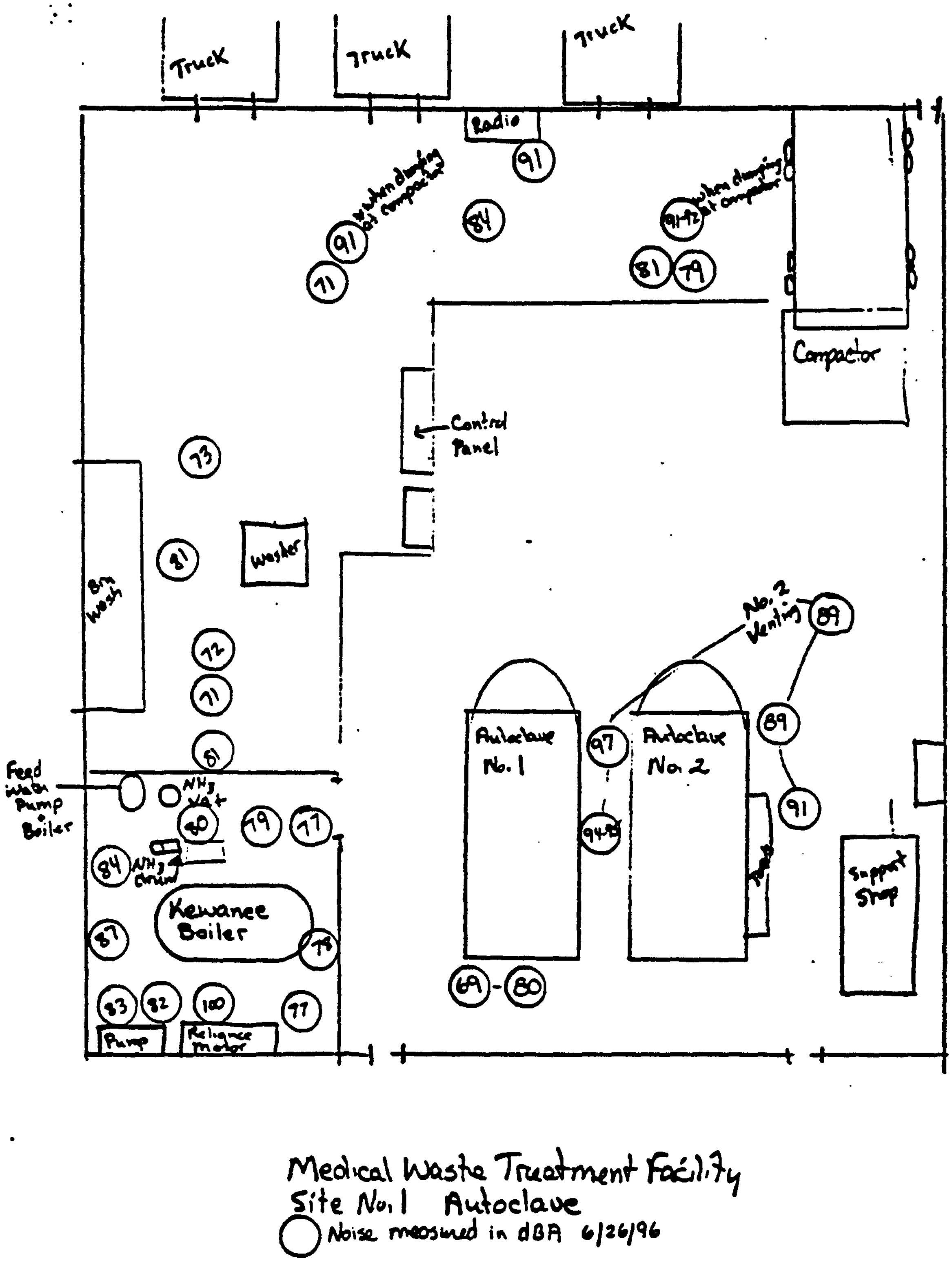


Table D-8. Noise Dosimeter Results

Date	6/25/96	6/25 to 6/26/96	6/26/96
Runtime	7 hr 41 min	16 hr 06 min	5 hr 17 min
Avg. Level	77.8 dBA	81.32 dBA	73.9 dBA
Max. Level	114 dBA	133.5 dBA	107.2 dBA
% Dose	17.85%	60.86%	7.12%
OL Time[a]	0	:14	0

[a] Overlimit time. Time over the limit of 115 dBA.

D.3 AREA AIR QUALITY MONITORING RESULTS

Air quality measurements for temperature, relative humidity, carbon dioxide and carbon monoxide were collected using a Metrosonics AQ-501 Air Quality Monitor (s/n 1228). The AQ-501 was positioned on the control panel in the center of the processing area for 26 hours. One additional sample was collected outdoors for reference. The indoor air quality measurements of temperature, relative humidity, carbon dioxide and carbon monoxide indicated that adequate outdoor (fresh) air was being introduced into the plant process area. The data (Table D-9) demonstrates an average values of 79.4 °F, 53.5% relative humidity, 345 ppm carbon dioxide and 0 ppm carbon monoxide.

D.4 RESULTS OF PERSONAL MONITORING FOR BLOOD SPLASHES

Results from the Phase 1 evaluation indicated a risk for blood and body fluid splashes to workers loading untreated regulated medical waste into the large treatment bins prior to steam autoclaving. A splash assessment protocol was developed to collect samples for residual hemoglobin from the upper torso area of the workers, in addition to residuals on face shields. Upper body splashes were assessed using cotton patches in cardboard holders pinned to the front and back of the workers' shirts. Following a work shift, the patches were assessed for visible blood and processed using the hemoglobin detection method as previously described. Worker face shields were wipe sampled prior to a work shift and then again at the end of the shift. Both methods for sampling and blood detection are described in Appendix O.

Results of assessment of blood splashes on workers' clothes are shown in Table D-10. Seven workers were evaluated over two days, with blood detected visibly and confirmed by hemoglobin testing on 2 of 6 sample patches from two workers. Results of assessment of blood splashes on workers' face shields are shown in Table D-11. Of seven workers' face shields monitored over the two days, two were positive for hemoglobin after the work shift. A moderate amount of hemoglobin was detected on one face shield, while a trace amount was detected on another.

The personal monitoring that was conducted to assess worker exposures to blood splashes did confirm that workers in the facility who are responsible for the direct handling of the untreated medical waste are at risk for bloodborne pathogen exposures. The test results also confirmed visual observations of the waste loading or dumping operation that was conducted during the Phase 1 evaluation where environmental splashes of blood and other fluids were noted. Based on these results, it is recommended that, in the absence of engineering controls that fully automate the waste dumping procedures, management enforce the wearing and proper use of personal protective clothing and equipment, particularly face shields.

Table D-9. Indoor Air Quality

Sample Dates	6/25/96	6/25/96 to 6/26/96
Location	**Outside background air**	**Control panel in process area**
CO_2 average OSHA PEL[a] RTI Suggested Limit	323 ppm 10,000 ppm 1,000 ppm[b]	345 ppm 10,000 ppm 1,000 ppm
CO average OSHA PEL	1 ppm 35 ppm	0 ppm 35 ppm
Temp. average minimum maximum	79.2°F 78.4°F 80.6°	79.4°F 70.5°F 87.2°F
Relative humidity average minimum maximum	 51.8% 48.0% 57.8%	 53.5% 39.8% 73.3%

[a] OSHA PEL is the Occupational Safety and Health Administration Permissible Exposure Limit for an 8 hour workday.

[b] 1,000 ppm is the current limit adopted by the State of Washington.

Table D-10. Blood Splash Assessment of Workers' Clothes at a Commercial Off-site Steam Autoclave MWTF

6/25/96				6/26/96			
Worker Number	Patch Loc.	Visual Result	Hemastix Result[1]	Worker Number	Patch Loc.	Visual Result	Hemastix Result
1	A	Clear	Negative	1	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
	C	Clear	Negative		C	Clear	Negative
	D	Clear	Negative		D	Clear	Negative
	E	Not Done	Not Done		E	Not Done	Not Done
	F	Not Done	Not Done		F	Not Done	Not Done
2	A	Clear	Negative	2	A	Clear	Negative
	B	Clear	Negative		B	Clear, cardboard wet	Negative
	C	Clear	Negative		C	Clear	Negative
	D	Clear	Negative		D	Clear	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
3A	A	Red swath 4"x 0.5"	+++	3A	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
	C	Clear	Negative		C	Clear	Negative
	D	12 red spots < 0.25"	+++		D	Clear	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
3B	A	Clear	Negative	3B	A	Clear	Negative
	B	Clear	Negative		B	Clear	nht
	C	Blotch faint pink,patch holder wet	Negative		C	Clear	Negative
	D	Clear	Negative		D	Clear	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
4	A	Clear	Negative	4	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative

6/25/96				6/26/96			
Worker Number	Patch Loc.	Visual Result	Hemastix Result[1]	Worker Number	Patch Loc.	Visual Result	Hemastix Result
	C	Patch of moisture - clear fluid	Negative		C	Clear	nht
	D	Clear	Negative		D	Clear	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
5A	A	Clear	Negative	5A	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
	C	5 red spots < 0.25"	+++		C	Clear	Negative
	D	2 red spots <0.25"	+++		D	Spot of dirt	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
5B	A	Clear	Negative	5B	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
	C	Clear - one small wet spot	Negative		C	Clear	Negative
	D	Clear	Negative		D	Clear	Negative
	E	Not Done	Not Done		E	Clear	Negative
	F	Not Done	Not Done		F	Clear	Negative
OC12	A	Clear	Negative	OC1	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
OC2	A	Clear	Negative	OC2	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
OC3	A	Clear	Negative	OC3	A	Clear	Negative
	B	Clear	Negative		B	Clear	Negative
Blank			Negative				

1 Cotton patches attached to workers' clothes, then removed and eluted into 25 ml FTA Hemagglutination Buffer.
Hemastix Test Indicator Scale: +++ Strong, ++Moderate, + Small, ht hemolyzed trace, N.M. Non hemolyzed moderate, nht Non-hemolyzed trace, Negative.

2 Three office workers were tested as controls.

Table D-11. Blood Splash Assessment of Workers' Face Shields at a Commercial Off-site Steam Autoclave MWTF

	6/25/96			6/26/96		
Worker Number	Hemastix Result[1]			Hemastix Result		
	Before Shift	After Shift	Comment	Before Shift	After Shift	Comment
1	Negative	Negative		Not Done	Not Done	
2	Negative	Negative		Negative	Negative	
3A	Negative	Negative		Negative	ht	
3B	Negative	++	3 visible blood spots, 3 mm	Negative	ht	
4	Negative	Negative		Negative	Negative	
5A	Negative	Negative		Negative	Negative	
5B	Negative	Negative		Negative	Negative	

1 Gauze wipe eluted into 25 ml FTA Hemagglutination Buffer.
Hemastix Test Indicator Scale: +++ Strong, ++Moderate, + Small, ht hemolyzed trace, nhm Non hemolyzed moderate, nht Non-hemolyzed trace, Negative.
The detection limit was 2.5 x 10^{-5} ml of blood eluted from the gauze wipe.

D.5 RESULTS OF AREA MONITORING FOR BLOOD AEROSOLS

A single area, 6 hour air filter sample for blood aerosols was collected on each of the two days and processed for hemoglobin as previously described. The samples were collected in the waste handling area. Results are shown in Table D-12. Both samples were negative, indicating that the waste handling process does not generate significant small airborne blood particles. Rather, the greatest blood exposure risk is from blood splashes as discussed above.

D.6 RESULTS OF BIOAEROSOL EMISSIONS MONITORING

To assess the potential for infectious agents to be liberated from the steam autoclave treatment process, bioaerosol monitoring was conducted during the treatment of indicator organism spiked and non-spiked medical waste, at previously identified potential emission points. Indicator organisms used included specific strains of *Bacillus stearothermophilus* and *Bacillus subtilis globigii* var *niger*. The monitoring protocol is described in detail in Appendix P. Results of the monitoring using Mattson-Garvin impactor and AGI-30 impinger bioaerosol samplers are shown in Tables D-13 and Table D-14. Three potential emission points were identified: 1) above the autoclave doors as they were opened at the end of the treatment cycle, 2) between the autoclaves as steam was liberated from a condensate drain, and 3) at the top of the compactor as the treated waste was dumped and compacted.

Results from the M/G samplers were negative for the recovery of any indicator spores from both the non-spiked and spiked treatment cycles. The AGI-30s however, recovered indicator spores from both the non-spiked and spiked treatment cycles at all three locations. The difference in results shows the value of utilizing two different types of volumetric aerosol samplers. It also shows that in regard to the monitoring conducted, the results are inconclusive as to definitively confirming or rejecting the potential for microorganisms to be emitted during the steam autoclave process. The results suggest that within the facility are residuals of *Bacillus* indicator spores on various surfaces, particularly as monitoring was conducted very close to soiled surfaces such as near the floor between the autoclaves and at the waste compactor. It is recognized that medical waste will contain these indicator spores from positive controls that are run in hospitals to assess sterilization procedures.

While the data are inconclusive, it must be recognized that parametric monitoring of the treatment autoclaves indicated proper functioning of each cycle relative to temperature, pressure, and time, and that internal routine monitoring of the treatment process by the facility, using biological indicators, routinely demonstrates sterilization conditions. Also, and perhaps most importantly, the greatest potential for emissions from an autoclave is during the initial exhaust of the chamber prior to pressurization. In the studied facility that exhaust is ducted to and run through a carbon bed filter.

Table D-12. Airborne Blood Assessment at the Waste Loading Area of a Commercial Off-site Steam Autoclave MWTF

Sample[1]	Date	Time Start	Time Stop	Flow Rate (m^3/min)	Air Volume Sampled (m^3)	Hemastix Result
1	6/25/96	12:30:00	18:30:00	0.018	6.48	Negative
2	6/26/96	08:15:00	14:15:00	0.018	6.48	Negative

1 Air was drawn through 25 mm, 0.45 micron Nucleopore Filters (SN 322375, Lot 819/933J239) at 18 liters per minute for six hours near the waste loading station. The filter was then eluted in 25 ml of buffer FTA Hemagglutination Buffer and tested with Hemastix for the presence of blood. The detection limit was 2.5×10^{-5} ml of blood eluted from the filter.

Table D-13. Indicator Organism Recovery from Air Impactor Samples at a Commercial Off-site Steam Autoclave Medical Waste Treatment Facility

M/G Air Samples[1]	Colony Forming Units (CFU) Recovered					
	Bacillus stearothermophilus			*Bacillus subtilis* var *niger*		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
	Non-spiked[4]	Non-spiked[4]	Spiked[5]	Non-spiked[4]	Non-spiked[4]	Spiked[5]
Above autoclave door[2]	0	0	0	0	0	0
Above compactor[3]	0	0	0	0	0	0

1 Mattson-Garvin slit to agar samplers operated at 1 cubic foot per minute for 15 minutes. Samples were collected on Trypticase Soy Agar (TSA) and were incubated at 55C for *B. stearothermophilus*. Samples were collected on TSA with actidione and incubated at 35C for *B. subtilis* var *niger*.

2 Two M/G were placed above the autoclave door and were operated as the door opened after a treatment cycle. For run 1, autoclave number 1 was used. For runs 2 and three, autoclave number 2 was used.

3 Two M/G were placed above the compactor and were operated during waste dumping and compaction.

4 The autoclave was operated as usual.

5 The waste load was spiked with indicator organisms which had been placed onto 0.2 µm, 37 mm filters. Ten filters of each organism were placed on top of each of five loaded treatment bins. The average spore count was 5.0×10^7 CFU per filter for *B. stearothermophilus*. The average spore count was 2.3×10^7 CFU per filter for *B. subtilis* var *niger*.

Table D-14. Indicator Organism Recovery from Impinger Samples at a Commercial Off-site Steam Autoclave MWTF

Impinger[1] Location	Colony Forming Units (CFU) Recovered											
	Bacillus stearothermophilus						*Bacillus subtilis* var *niger*					
	Run 1 Non-spiked[5]		Run 2 Non-spiked[5]		Run 3 Spiked[6]		Run 1 Non-spiked[5]		Run 2 Non-spiked[5]		Run 3 Spiked[6]	
	Plates[7]	Filter[8]	Plates[7]	Filter[8]	Plates[7]	Filter[8]	Plates[7]	Filter[8]	Plates[7]	Filter[8]	Plates[7]	Filter[8]
Above autoclave door[2]	0,0	50	1,0	1	1,0	1	0,2	15	2,0	0	0,0	3
Above autoclave door	18,2	18	3,1	1	1,1	3	0,0	9	0,0	16	0,0	0
Between autoclaves[3]	5,1	44	0,0	0	3,0	40	0,0	8	0,0	1	0,1	2
Between autoclaves	0,0	5	0,0	0	0,0	0	1,1	16	0,0	1	0,0	6
Between autoclaves	1,0	3	0,0	6	0,0	5	0,0	6	0,0	4	0,0	0
Above compactor[4]	0,2	20	0,1	3	0,0	50	0,0	5	0,0	6	0,0	4
Above compactor	0,0	10	4,0	0	0,0	25	0,0	1	0,0	1	0,1	1

1 All glass impingers (AGI-30), 12 liters per minute for 10 minutes. For run 1, autoclave number 1 was used. For runs 2 and three, autoclave number 2 was used.

2 Duplicate, simultaneous air samples were taken. Samples were taken above the autoclave door as the door opened after a treatment cycle.

3 Three consecutive samples were taken between the autoclaves in the steam plume during treatment.

4 Duplicate, simultaneous air samples were taken. Samples were taken above the compactor during waste dumping and compaction.

5 The autoclave was operated as usual.

6 The waste load was spiked with indicator organisms which had been placed onto 0.2 µm, 37mm filters. Ten filters of each organism were placed on top of each of five loaded treatment bins. The average spore count was 5.0×10^7 CFU per filter for *B. stearothermophilus*. The average spore count was 2.3×10^7 CFU per filter for *B. subtilis* var *niger*.

7 Number of indicator organism CFU isolated from duplicate 0.1 mL impinger fluid plated onto TSA (incubated at 55C for *B. stearothermophilus*), and TSA/actidione (incubated at 35C for B. subtilis).

8 Number of indicator organism CFU isolated from filtering half of the remaining impinger fluid and placing one filter on TSA (incubated at 55C for *B. stearothermophilus*), and the other on TSA/actidione (incubated at 35C for B. subtilis). The CFU values shown for the filters are less than or equal to the actual values.

D.7 SUMMARY AND CONCLUSIONS

A Phase II field study focusing on personal exposures was conducted at the Medical Waste Treatment Facility using the autoclave system on June 25-26, 1996. To obtain 5 complete worker shift samples, it was necessary to change the personal samplers from one employee to another when the shift changed. Two job titles, Supervisor and one Laborer, required two employees from two shifts to share (trade-off) the chemical sampling equipment. One job (Maintenance) was performed from 0500-1330, so the first day of sampling only a 5 hour sample was collected. For the second day of sampling the maintenance employee was outfitted with sampling pumps, badges and collection media by 0500 to enable collection of an 8 hour sample.

Although several VOCs were identified and quantified, all were less than OSHA PELs, NIOSH RELs, and ACGIH TLVs. Formaldehyde concentrations on the workers ranged from 0.021 to 0.086 ppm. The control sample taken on an office worker was 0.04 ppm, higher than any plant workers on 6/26/96. The OSHA PEL for formaldehyde is 0.75 ppm, the ACGIH TLV is a ceiling value of 0.3 ppm, while the NIOSH REL is 0.016 ppm.

No ethanol was detected on any of the personal direct reading Dräger tubes. The minimum detection limit for an 8 hour sampling period is 125 ppm. The OSHA PEL and the ACGIH TLV are 1000 ppm for ethanol. No methanol or propanol was detected on the Dräger tubes used for area samples. The minimum detection limit of the method is 25 ppm and the OSHA PELs and the ACGIH TLVs for methanol and propanol are 200 ppm.

High concentrations of ammonia were observed in the boiler room during the approximately one minute long transfer of ammonia from the drum to the vat. On the first day of sampling, the maintenance worker held his breath while he performed the transfer. The second day the worker wore a full face respirator with ammonia cartridges while performing the transfer. The ammonia Dräger tube indicated concentrations exceeding 30 ppm after the first of five strokes on the pump. The OSHA short term exposure limit is 50 ppm and the vacated 1989 OSHA STEL is 35 ppm. The ACGIH TLV is 25 ppm with a STEL of 35 ppm.

The area noise surveys showed noise levels ranging from 70 to 100 dBA within the boiler room. The loudest noise in the boiler room (100 dBA) was from a motor that was in need of repair. Noise levels ranged from 69 to 97 dBA in the process area. The source of the loudest noise in the process area was the venting/blowdown of the autoclaves, where noise levels peaked at 97 dBA. The noise dosimeter results demonstrated that all three surveys had average noise levels less than the OSHA PEL of 90 dBA (the average noise levels were 77.8, 81.3 and 73.9 dBA).

The indoor air quality measurements of temperature, relative humidity, carbon dioxide and carbon monoxide taken at the control panel indicated that adequate outdoor (fresh) air was being introduced into the plant process area. Average values of 79.4 °F, 53.5% relative humidity, 345 ppm carbon dioxide and 0 ppm carbon monoxide were obtained.

The splash assessment protocol was used to collect samples for residual hemoglobin from the upper torso area of the workers, in addition to residuals on face shields. Following a work shift, the patches were assessed for visible blood and processed using the hemoglobin detection method. Worker face shields were wipe sampled prior to a work shift and then again at the end of the shift. Seven workers were evaluated over two days, with blood detected visibly and confirmed by hemoglobin testing on 2 of 6 sample patches from two workers. Of seven workers' face shields monitored over the two days, two were positive for hemoglobin after the work shift.

The personal monitoring, conducted to assess worker exposures to blood splashes, did confirm that workers in the facility who direct handle the untreated medical waste are at risk for bloodborne pathogen exposures. The test results also confirmed visual observations of the waste loading or dumping operation that was conducted during the Phase 1 evaluation where environmental splashes of blood and other fluids were noted. Based on these results, it is recommended that management should ensure that the wearing and proper use of personal protective clothing and equipment, particularly face shields, is enforced.

The area sampling for blood aerosols were collected on each of the two days in the waste handling area. Both samples were negative, indicating that the waste handling process does not generate significant small particle aerosols.

Bioaerosol monitoring was conducted during the treatment of spiked and non-spiked medical waste. Indicator organisms used were *Bacillus stearothermophilus* and *Bacillus subtilis globigii* var *niger*. Three potential emission points were sampled: above the autoclave doors as they were opened at the end of the treatment cycle; between the autoclaves as steam was liberated from a condensate drain; and at the top of the compactor as the treated waste was dumped and compacted. Results from the M/G samplers were negative for the recovery of any indicator spores from both the non-spiked and spiked treatment cycles. The AGI-30s however, recovered indicator spores from both the non-spiked and spiked treatment cycles at all three locations. The results suggest that within the facility are residuals of *Bacillus* indicator spores on various surfaces. It is recognized that medical waste will contain these indicator spores from positive controls that are run in hospitals to assess sterilization procedures.

While the data are inconclusive, it must be recognized that parametric monitoring of the treatment autoclaves indicated proper functioning of each cycle relative to temperature, pressure, and time, and that internal routine monitoring of the treatment process by the facility, using biological indicators, routinely demonstrates sterilization conditions. Also, the greatest potential for emissions from an autoclave is during the initial exhaust of the chamber prior to pressurization. In the studied facility that exhaust is ducted to a carbon bed filter.

Thus, the major apparent source of risk to the workers is from blood splashes and the main recommendation is that the use of protective clothing, including face shields, be carefully enforced.

APPENDIX E. MWTF SAFETY ASSESSMENT PROTOCOL

The safety assessment of medical waste treatment facilities recognizes that facilities and treatment methods, materials treated, and staff will vary from site to site. Accordingly, the protocol will be broad in scope but flexible to allow focus on specific detail as necessary. Three main features will be reviewed: the material control and the engineering controls on the process technology used to protect staff; the staff and their training including program administration; and a sequential job safety analysis.

Initially the physical plant will be reviewed. A standard "OSHA Self-Inspection" checklist will be used as the primary data collecting tool. RTI has added several sections to the standard OSHA checklist, particularly a review of the bloodborne pathogen standard. It is expected that not all parts of the checklist will be used at all sites. Because of the variability of facilities and processes, some sections may be omitted or only selective items examined. To supplement post-site visit data review, photographs of the facilities will be taken with year/date/month noted on each. These photographs will be available to the project officer as needed.

Staff training will be reviewed by a combination of selected records review and talks with selected staff. Also, verification that required written programs and associated material will be done. These items are included on the OSHA checklist.

Finally, an overall job safety analysis will be done evaluating each component of the process. This will involve following the process from the "raw material" arrival through each handling/process step, to final output. A job safety analysis form will be used. This will be done during the actual processing operation.

At the conclusion, a site/process specific safety assessment report will be generated. The report will note specific findings at each location. Also, generalized findings that can be applied to all similar processes, will be noted.

Radioactive Materials

- ☐ Is a program in place to eliminate radioactive materials from entering the waste stream?
- ☐ Are staff trained on procedures to do if a radioactive package is observed in the waste stream?
- ☐ Is any radioactive material monitoring conducted to periodically verify that no radioactive materials are present?
- ☐ Is any area monitoring (e.g. film badge/TLD) for radiation conducted?
- ☐ What instrumentation is available?
- ☐ Has it been calibrated?
- ☐ Are staff trained in its use?

Hazardous Materials Wastes

- ☐ Is there a written program?
- ☐ Is a program in place to eliminate hazardous/materials/wastes from entering the waste stream?
- ☐ Are staff trained in procedures for control/cleanup of spilled waste?
- ☐ Are appropriate supplies and equipment readily available?
- ☐ Are chemicals, lubricating oils, etc. properly segregated and stored?
- ☐ Are unused chemicals properly disposed?

Bloodborne Pathogens

- ☐ Is there a written exposure control plan? Does it include:
  - ☐ exposure determination by job classification?
  - ☐ methods of compliance:
    - ☐ general (either universal precautions or body substance isolation (BSI)?
    - ☐ engineering and work practice controls?
    - ☐ personal protective equipment?
    - ☐ housekeeping?

- ☐ handling of regulated waste?
- ☐ Hepatitis B vaccination and post-exposure evaluation and follow-up?
- ☐ communication of hazards to employees?
- ☐ recordkeeping?
- ☐ procedure for evaluation of exposure incidents?

☐ Is the exposure control plan accessible to employees?

☐ Are engineering and work practice controls in place to minimize employee exposure?

- ☐ Are they in good working order?
- ☐ Are they regularly maintained?

☐ Is adequate personal protective equipment provided and is it used appropriately?

☐ Are handwashing facilities readily accessible? Are they used after removal of PPE?

☐ Are there adequate procedures in place for cleaning and decontamination of equipment and environmental and working surfaces that come into contract with blood or other potentially infectious materials?

☐ Is contaminated laundry containerized, labeled, and handled appropriately?

☐ Is training provided at the time of initial employment and at least annually thereafter?

☐ Is the hepatitis B vaccine made available to all exposed employees?

☐ Is a confidential medical evaluation and follow-up made immediately available to an employee who experiences an exposure incident?

☐ Are training records kept, including the content of the training and qualifications of the trainer?

☐ Is regulated waste appropriately containerized, labeled, and handled?

☐ Is equipment decontaminated prior to servicing or repair?

SELF-INSPECTION CHECK LISTS

These check lists are by no means all-inclusive. You should add to them or delete portions or items that do not apply to your operations. However, carefully consider each item as you come to it and then make your decision.

EMPLOYER POSTING

- ☐ Is the required OSHA workplace poster displayed in a prominent location where all employees are likely to see it?
- ☐ Are emergency telephone numbers posted where they can be readily found in case of emergency?
- ☐ Where employees may be exposed to any toxic substances or harmful physical agents, has appropriate information concerning employee access to medical and exposure records, and "Material Safety Data Sheets," etc., been posted or otherwise made readily available to affected employees?
- ☐ Are signs concerning "Exiting from buildings," room capacities, floor loading, exposures to x-ray, microwave, or other harmful radiation or substances posted where appropriate?
- ☐ Is the Summary of Occupational Illnesses and Injuries posted in the month of February?

RECORDKEEPING

- ☐ Are all occupational injury or illnesses, except minor injuries requiring only first aid, being recorded as required on the OSHA 200 log?
- ☐ Are employee medical records and records of employee exposure to hazardous substances or harmful physical agents up-to-date?
- ☐ Have arrangements been made to maintain required records for the legal period of time for each specific type record? (Some records must be maintained for at least 40 years.)
- ☐ Are operating permits and records up-to-date for such items as elevators, air pressure tanks, liquefied petroleum gas tanks, etc.?

SAFETY AND HEALTH PROGRAM

- ☐ Do you have an active safety and health program in operation?
- ☐ Is one person clearly responsible for the overall activities of the safety and health program?
- ☐ Do you have a safety committee or group made up of management and labor representatives that meet regularly and report in writing on its activities?
- ☐ Do you have a working procedure for handling in-house employee complaints regarding safety and health?
- ☐ Are you keeping your employees advised of the successful effort and accomplishments you and/or your safety committee have made in assuring they will have a workplace that is safe and healthful?

MEDICAL SERVICES AND FIRST AID

- ☐ Do you require each employee to have a pre-employment physical examination?
- ☐ Is there a hospital, clinic, or infirmary for medical care in proximity of your workplace?
- ☐ If medical and first aid facilities are not in proximity of your workplace, is at least one employee on each shift currently qualified to render first aid?
- ☐ Are medical personnel readily available for advice and consultation on matters of employees' health?
- ☐ Are emergency phone numbers posted?
- ☐ Are first aid kits easily accessible to each work area, with necessary supplies available, periodically inspected and replenished as needed?
- ☐ Have first aid kit supplies been approved by a physician, indicating that they are adequate for a particular area or operation?
- ☐ Are means provided for quick drenching or flushing of the eyes and body in areas where corrosive liquids or materials are handled?

FIRE PROTECTION

- ☐ Is your local fire department well acquainted with your facilities, its location and specific hazards?
- ☐ If you have a fire alarm system, is it certified as required?
- ☐ If you have a fire alarm system, is it tested at least annually?
- ☐ If you have interior stand pipes and valves, are they inspected regularly?
- ☐ If you have outside private fire hydrants, are they flushed at least once a year and on a routine preventive maintenance schedule?
- ☐ Are fire doors and shutters in good operating condition?
- ☐ Are fire doors and shutters unobstructed and protected against obstructions, including their counterweights?
- ☐ Are fire door and shutter fusable links in place?
- ☐ Are automatic sprinkler system water control valves, air and water pressure checked weekly/periodically as required?
- ☐ Is the maintenance of automatic sprinkler systems assigned to responsible persons or to a sprinkler contractor?
- ☐ Are sprinkler heads protected by metal guards, when exposed to physical damage?
- ☐ Is proper clearance maintained below sprinkler heads?
- ☐ Are portable fire extinguishers provided in adequate number and type?
- ☐ Are fire extinguishers mounted in readily accessible locations?
- ☐ Are fire extinguishers recharged regularly and noted on the inspection tag?
- ☐ Are employees periodically instructed in the use of extinguishers and fire protection procedures?

PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

- ☐ Are protective goggles or face shields provided and worn where there is any danger of flying particles or corrosive materials?
- ☐ Are approved safety glasses required to be worn at all times in areas where there is a risk of eye injuries such as punctures, abrasions, contusions or burns?
- ☐ Are employees who need corrective lenses (glasses or contacts) in working environments having harmful exposures, required to wear *only* approved safety glasses, protective goggles, or use other medically approved precautionary procedures.
- ☐ Are protective gloves, aprons, shields, or other means provided against cuts, corrosive liquids and chemicals?
- ☐ Are hard hats provided and worn where danger of falling objects exists?
- ☐ Are hard hats inspected periodically for damage to the shell and suspension system?
- ☐ Is appropriate foot protection required where there is the risk of foot injuries from hot, corrosive, poisonous substances, falling objects, crushing or penetrating actions?
- ☐ Are approved respirators provided for regular or emergency use where needed?
- ☐ Is all protective equipment maintained in a sanitary condition and ready for use?
- ☐ Do you have eye wash facilities and a quick Drench Shower within the work area where employees are exposed to injurious corrosive materials?
- ☐ Where special equipment is needed for electrical workers, is it available?
- ☐ Where lunches are eaten on the premises, are they eaten in areas where there is no exposure to toxic materials or other health hazards?
- ☐ Is protection against the effects of occupational noise exposure provided when sound levels exceed those of the OSHA noise standard?
- ☐ Are adequate work procedures, protective clothing and equipment provided and used when cleaning up spilled toxic or otherwise hazardous materials or liquids?

GENERAL WORK ENVIRONMENT

- ☐ Are all worksites clean and orderly?
- ☐ Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?
- ☐ Are all spilled materials or liquids cleaned up immediately?
- ☐ Is combustible scrap, debris and waste stored safely and removed from the worksite promptly?
- ☐ Are accumulations of combustible dust routinely removed from elevated surfaces including the overhead structure of buildings, etc.?
- ☐ Is combustible dust cleaned up with a vacuum system to prevent the dust going into suspension?
- ☐ Is metallic or conductive dust prevented from entering or accumulating on or around electrical enclosures or equipment?
- ☐ Are covered metal waste cans used for oily and paintsoaked waste?
- ☐ Are all oil and gas fired devices equipped with flame failure controls that will prevent flow of fuel if pilots or main burners are not working?
- ☐ Are paint spray booths, dip tanks, etc., cleaned regularly?
- ☐ Are the minimum number of toilets and washing facilities provided?
- ☐ Are all toilets and washing facilities clean and sanitary?
- ☐ Are all work areas adequately illuminated?
- ☐ Are pits and floor openings covered or otherwise guarded?

- ☐ Are aisles and passageways kept clear?
- ☐ Are aisles and walkways marked as appropriate?
- ☐ Are wet surfaces covered with non-slip materials?
- ☐ Are holes in the floor, sidewalk or other walking surface repaired properly, covered or otherwise made safe?
- ☐ Is there safe clearance for walking in aisles where motorized or mechanical handling equipment is operating?
- ☐ Are materials or equipment stored in such a way that sharp projectives will not interfere with the walkway?
- ☐ Are spilled materials cleaned up immediately?
- ☐ Are changes of direction or elevations readily identifiable?
- ☐ Are aisles or walkways that pass near moving or operating machinery, welding operations or similar operations arranged so employees will not be subjected to potential hazards?
- ☐ Is adequate headroom provided for the entire length of any aisle or walkway?
- ☐ Are standard guardrails provided wherever aisle or walkway surfaces are elevated more than 30 inches above any adjacent floor or the ground?
- ☐ Are bridges provided over conveyors and similar hazards?

FLOOR AND WALL OPENINGS

- ☐ Are floor openings guarded by a cover, a guardrail, or equivalent on all sides (except at entrance to stairways or ladders)?
- ☐ Are toeboards installed around the edges of permanent floor opening (where persons may pass below the opening)?
- ☐ Are skylight screens of such construction and mounting that they will withstand a load of at least 200 pounds?
- ☐ Is the glass in the windows, doors, glass walls, etc., which are subject to human impact, of sufficient thickness and type for the condition of use?
- ☐ Are grates or similar type covers over floor openings such as floor drains, of such design that foot traffic or rolling equipment will not be affected by the grate spacing?
- ☐ Are unused portions of service pits and pits not actually in use either covered or protected by guardrails or equivalent?
- ☐ Are manhole covers, trench covers and similar covers, plus their supports designed to carry a truck rear axle load of at least 20,000 pounds when located in roadways and subject to vehicle traffic?
- ☐ Are floor or wall openings in fire resistive construction provided with doors or covers compatible with the fire rating of the structure and provided with self closing feature when appropriate?

STAIRS AND STAIRWAYS

- ☐ Are standard stair rails or handrails on all stairways having four or more risers?
- ☐ Are all stairways at least 22 inches wide?
- ☐ Do stairs have at least a 6'6" overhead clearance?
- ☐ Do stairs angle no more than 50 and no less than 30 degrees?
- ☐ Are stairs of hollow-pan type treads and landings filled to noising level with solid material?
- ☐ Are step risers on stairs uniform from top to bottom, with no riser spacing greater than 7½ inches?
- ☐ Are steps on stairs and stairways designed or provided with a surface that renders them slip resistant?
- ☐ Are stairway handrails located between 30 and 34 inches above the leading edge of stair treads?
- ☐ Do stairway handrails have at least 1½ inches of clearance between the handrails and the wall or surface they are mounted on?
- ☐ Are stairway handrails capable of withstanding a load of 200 pounds, applied in any direction?
- ☐ Where stairs or stairways exit directly into any area where vehicles may be operated, are adequate barriers and warnings provided to prevent employees stepping into the path of traffic?
- ☐ Do stairway landings have a dimension measured in the direction of travel, at least equal to the width of the stairway?
- ☐ Is the vertical distance between stairway landings limited to 12 feet or less?

ELEVATED SURFACES

- ☐ Are signs posted, when appropriate, showing the elevated surface load capacity?
- ☐ Are surfaces elevated more than 30 inches above the floor or ground provided with standard guardrails?
- ☐ Are all elevated surfaces (beneath which people or machinery could be exposed to falling objects) provided with standard 4-inch toeboards?
- ☐ Is a permanent means of access and egress provided to elevated storage and work surfaces?
- ☐ Is required headroom provided where necessary?
- ☐ Is material on elevated surfaces piled, stacked or racked in a manner to prevent it from tipping, falling, collapsing, rolling or spreading?
- ☐ Are dock boards or bridge plates used when transferring materials between docks and trucks or rail cars?

EXITING OR EGRESS

- ☐ Are all exits marked with an exit sign and illuminated by a reliable light source?
- ☐ Are the directions to exits, when not immediately apparent, marked with visible signs?
- ☐ Are doors, passageways or stairways, that are neither exits nor access to exits and which could be mistaken for exits, appropriately marked "NOT AN EXIT," "TO BASEMENT," "STOREROOM," etc.?
- ☐ Are exit signs provided with the word "EXIT" in lettering at least 5 inches high and the stroke of the lettering at least ½-inch wide?
- ☐ Are exit doors side-hinged?
- ☐ Are all exits kept free of obstructions?
- ☐ Are at least two means of egress provided from elevated platforms, pits or rooms where the absence of a second exit would increase the risk of injury from hot, poisonous, corrosive, suffocating, flammable, or explosive substances?
- ☐ Are there sufficient exits to permit prompt escape in case of emergency?
- ☐ Are special precautions taken to protect employees during construction and repair operations?
- ☐ Is the number of exits from each floor of a building and the number of exits from the building itself, appropriate for the building occupancy load?
- ☐ Are exit stairways which are required to be seperated from other parts of a building, enclosed by at least 2-hour fire-resistive construction in buildings more than four stories in height, and not less than 1-hour fire-resistive constructive elsewhere?
- ☐ Where ramps are used as part of required exiting from a building, is the ramp slope limited to 1 ft. vertical and 12 ft. horizontal?
- ☐ Where exiting will be through frameless glass doors, glass exit doors, storm doors, etc., are the doors fully tempered and meet the safety requirements for human impact?

EXIT DOORS

- ☐ Are doors which are required to serve as exits designed and constructed so that the way of exit travel is obvious and direct?
- ☐ Are windows which could be mistaken for exit doors, made inaccessible by means of barriers or railings?
- ☐ Are exit doors openable from the direction of exit travel without the use of a key or any special knowledge or effort when the building is occupied?
- ☐ Is a revolving, sliding or overhead door prohibited from serving as a required exit door?
- ☐ Where panic hardware is installed on a required exit door, will it allow the door to open by applying a force of 15 pounds or less in the direction of the exit traffic?
- ☐ Are doors on cold storage rooms provided with an inside release mechanism which will release the latch and open the door even if it's padlocked or otherwise locked on the outside?
- ☐ Where exit doors open directly onto any street, alley or other area where vehicles may be operated, are adequate barriers and warnings provided to prevent employees stepping into the path of traffic?
- ☐ Are doors that swing in both directions and are located between rooms where there is frequent traffic, provided with viewing panels in each door?

PORTABLE LADDERS

- ☐ Are all ladders maintained in good condition, joints between steps and side rails tight, all hardware and fittings securely attached and moveable parts operating freely without binding or undue play?
- ☐ Are non-slip safety feet provided on each ladder?
- ☐ Are non-slip safety feet provided on each metal or rung ladder?
- ☐ Are ladder rungs and steps free of grease and oil?
- ☐ Is it prohibited to place a ladder in front of doors opening toward the ladder except when the door is blocked open, locked or guarded?
- ☐ Is it prohibited to place ladders on boxes, barrels, or other unstable bases to obtain additional height?
- ☐ Are employees instructed to face the ladder when ascending or descending?
- ☐ Are employees prohibited from using ladders that are broken, missing steps, rungs, or cleats, broken side rails or other faulty equipment?
- ☐ Are employees instructed not to use the top step of ordinary stepladders as a step?
- ☐ When portable rung ladders are used to gain access to elevated platforms, roofs, etc., does the ladder always extend at least 3 feet above the elevated surface?
- ☐ Is it required that when portable rung or cleat type ladders are used, the base is so placed that slipping will not occur, or it is lashed or otherwise held in place?
- ☐ Are portable metal ladders legibly marked with signs reading "CAUTION" - Do Not Use Around Electrical Equipment" or equivalent wording?
- ☐ Are employees prohibited from using ladders as guys, braces, skids, gin poles, or for other than their intended purposes?
- ☐ Are employees instructed to only adjust extension ladders while standing at a base (not while standing on the ladder or from a position above the ladder)?

☐ Are the rungs of ladders uniformly spaced at 12 inches, center to center?

HAND TOOLS AND EQUIPMENT

☐ Are all tools and equipment (both company and employee-owned) used by employees at their workplace in good condition?

☐ Are hand tools such as chisels, punches, etc. which develop mushroomed heads during use, reconditioned or replaced as necessary?

☐ Are broken or fractured handles on hammers, axes and similar equipment replaced promptly?

☐ Are worn or bent wrenches replaced regularly?

☐ Are appropriate handles used on files and similar tools?

☐ Are employees made aware of the hazards caused by faulty or improperly used hand tools?

☐ Are appropriate safety glasses, face shields, etc. used while using hand tools or equipment which might produce flying materials or be subject to breakage?

☐ Are jacks checked periodically to assure they are in good operating condition?

☐ Are tool handles wedged tightly in the head of all tools?

☐ Are tool cutting edges kept sharp so the tool will move smoothly without binding or skipping?

☐ Are tools stored in dry, secure location where they won't be tampered with?

☐ Is eye and face protection used when driving hardened or tempered spuds or nails?

PORTABLE (POWER OPERATED) TOOLS AND EQUIPMENT

☐ Are grinders, saws and similar equipment provided with appropriate safety guards?

☐ Are power tools used with the correct shield, guard, or attachment, recommended by the manufacturer?

☐ Are portable circular saws equipped with guards above and below the base shoe?

☐ Are circular saw guards checked to assure they are not wedged up, thus leaving the lower portion of the blade unguarded?

☐ Are rotating or moving parts of equipment guarded to prevent physical contact?

☐ Are all cord-connected, electrically-operated tools and equipment effectively grounded or of the approved double insulated type?

☐ Are effective guards in place over belts, pulleys, chains, sprockets, on equipment such as concrete mixers, air compressors, etc.?

☐ Are portable fans provided with full guards or screens having openings ½ inch or less?

☐ Is hoisting equipment available and used for lifting heavy objects, and are hoist ratings and characteristics appropriate for the task?

☐ Are ground-fault circuit interrupters provided on all temporary electrical 15 and 20 ampere circuits, used during periods of construction?

☐ Are pneumatic and hydraulic hoses on power-operated tools checked regularly for deterioration or damage?

ABRASIVE WHEEL EQUIPMENT-GRINDERS

☐ Is the work rest used and kept adjusted to within ⅛ inch of the wheel?

☐ Is the adjustable tongue on the top side of the grinder used and kept adjusted to within ¼ inch of the wheel?

☐ Do side guards cover the spindle, nut, and flange and 75 percent of the wheel diameter?

☐ Are bench and pedestal grinders permanently mounted?

☐ Are goggles or face shields always worn when grinding?

☐ Is the maximum RPM rating of each abrasive wheel compatible with the RPM rating of the grinder motor?

☐ Are fixed or permanently mounted grinders connected to their electrical supply system with metallic conduit or other permanent wiring method?

☐ Does each grinder have an individual on and off control switch?

☐ Is each electrically operated grinder effectively grounded?

☐ Before new abrasive wheels are mounted, are they visually inspected and ring tested?

☐ Are dust collectors and powered exhausts provided on grinders used in operations that produce large amounts of dust?

☐ Are splash guards mounted on grinders that use coolant to prevent the coolant reaching employees?

☐ Is cleanliness maintained around grinders?

POWDER ACTUATED TOOLS

☐ Are employees who operate powder-actuated tools trained in their use and carry a valid operators card?

☐ Is each powder-actuated tool stored in its own locked container when not being used?

reading "POWDER-ACTUATED TOOL IN USE" conspicuously posted when the tool is being used?

- ☐ Are powder-actuated tools left unloaded until they are actually ready to be used?
- ☐ Are powder-actuated tools inspected for obstructions or defects each day before use?
- ☐ Do powder-actuated tool operators have and use appropriate personal protective equipment such as hard hats, safety goggles, safety shoes and ear protectors?

MACHINE GUARDING

- ☐ Is there a training program to instruct employees on safe methods of machine operation?
- ☐ Is there adequate supervision to ensure that employees are following safe machine operating procedures?
- ☐ Is there a regular program of safety inspection of machinery and equipment?
- ☐ Is all machinery and equipment kept clean and properly maintained?
- ☐ Is sufficient clearance provided around and between machines to allow for safe operations, set up and servicing, material handling and waste removal?
- ☐ Is equipment and machinery securely placed and anchored, when necessary to prevent tipping or other movement that could result in personal injury?
- ☐ Is there a power shut-off switch within reach of the operator's position at each machine?
- ☐ Can electric power to each machine be locked out for maintenance, repair, or security?
- ☐ Are the noncurrent-carrying metal parts of electrically operated machines bonded and grounded?
- ☐ Are foot-operated-switches guarded or arranged to prevent accidental actuation by personnel or falling objects?
- ☐ Are manually operated valves and switches controlling the operation of equipment and machines clearly identified and readily accessible?
- ☐ Are all emergency stop buttons colored red?
- ☐ Are all pulleys and belts that are within 7 feet of the floor or working level properly guarded?
- ☐ Are all moving chains and gears properly guarded?
- ☐ Are splash guards mounted on machines that use coolant to prevent the coolant from reaching employees?
- ☐ Are methods provided to protect the operator and other employees in the machine area from hazards created at the point of operation, ingoing nip points, rotating parts, flying chips, and sparks?
- ☐ Are machinery guards secure and so arranged that they do not offer a hazard in their use?
- ☐ If special handtools are used for placing and removing material, do they protect the operator's hands?

... revolving drums, barrels, and containers required to be guarded by an enclosure that is interlocked with the drive mechanism, so that revolution cannot occur unless the guard enclosures is in place, so guarded?

- ☐ Do arbors and mandrels have firm and secure bearings and are they free from play?
- ☐ Are provisions made to prevent machines from automatically starting when power is restored after a power failure or shutdown?
- ☐ Are machines constructed so as to be free from excessive vibration when the largest size tool is mounted and run at full speed?
- ☐ If machinery is cleaned with compressed air, is air pressure controlled and personal protective equipment or other safeguards utilized to protect operators and other workers from eye and body injury?
- ☐ Are fan blades protected with a guard having openings no larger than ½ inch, when operating within 7 feet of the floor?
- ☐ Are saws used for ripping, equipped with anti-kick back devices and spreaders?
- ☐ Are radial arm saws so arranged that the cutting head will gently return to the back of the table when released?

LOCKOUT BLOCKOUT PROCEDURES

- ☐ Is all machinery or equipment capable of movement, required to be de-energized or disengaged and blocked or locked-out during cleaning, servicing, adjusting or setting up operations, whenever required?
- ☐ Where the power disconnecting means for equipment does not also disconnect the electrical control circuit:

  Are the appropriate electrical enclosures identified?

  Is means provided to assure the control circuit can also be disconnected and locked-out?
- ☐ Is the locking-out of control circuits in lieu of locking-out main power disconnects prohibited?
- ☐ Are all equipment control valve handles provided with a means for locking-out?
- ☐ Does the lock-out procedure require that stored energy (mechanical, hydraulic, air, etc.) be released or blocked before equipment is locked-out for repairs?
- ☐ Are appropriate employees provided with individually keyed personal safety locks?
- ☐ Are employees required to keep personal control of their key(s) while they have safety locks in use?
- ☐ Is it required that only the employee exposed to the hazard, place or remove the safety lock?
- ☐ Is it required that employees check the safety of the lock-out by attempting a start up after making sure no one is exposed?

- ☐ Are employees instructed to always push the control circuit stop button prior to re-energizing the main power switch?
- ☐ Is there a means provided to identify any or all employees who are working on locked-out equipment by their locks or accompanying tags?
- ☐ Are a sufficient number of accident preventive signs or tags and safety padlocks provided for any reasonably foreseeable repair emergency?
- ☐ When machine operations, configuration or size requires the operator to leave his or her control station to install tools or perform other operations, and that part of the machine could move if accidentally activated, is such element required to be separately locked or blocked out?
- ☐ In the event that equipment or lines cannot be shut down, locked-out and tagged, is a safe job procedure established and rigidly followed?

WELDING, CUTTING AND BRAZING

- ☐ Are only authorized and trained personnel permitted to use welding, cutting or brazing equipment?
- ☐ Does each operator have a copy of the appropriate operating instructions and are they directed to follow them?
- ☐ Are compressed gas cylinders regularly examined for obvious signs of defects, deep rusting, or leakage?
- ☐ Is care used in handling and storage of cylinders, safety valves, relief valves, etc., to prevent damage?
- ☐ Are precautions taken to prevent the mixture of air or oxygen with flammable gases, except at a burner or in a standard torch?
- ☐ Are only approved apparatus (torches, regulators, pressure-reducing valves, acetylene generators, manifolds) used?
- ☐ Are cylinders kept away from sources of heat?
- ☐ Are the cylinders kept away from elevators, stairs, or gangways?
- ☐ Is it prohibited to use cylinders as rollers or supports?
- ☐ Are empty cylinders appropriately marked and their valves closed?
- ☐ Are signs reading: DANGER—NO SMOKING, MATCHES, OR OPENLIGHTS, or the equivalent, posted?
- ☐ Are cylinders, cylinder valves, couplings, regulators, hoses, and apparatus kept free of oily or greasy substances?
- ☐ Is care taken not to drop or strike cylinders?
- ☐ Unless secured on special trucks, are regulators removed and valve-protection caps put in place before moving cylinders?
- ☐ Do cylinders without fixed and wheels have keys, handles, or non-adjustable wrenches on stem valves when in service?
- ☐ Are liquefied gases stored and shipped valve-end up with valve covers in place?
- ☐ Are provisions made to never crack a fuel-gas cylinder valve near sources of ignition?
- ☐ Before a regulator is removed, is the valve closed and gas released from the regulator?
- ☐ Is red used to identify the acetylene (and other fuel-gas) hose, green for oxygen hose, and black for inert gas and air hose?
- ☐ Are pressure-reducing regulators used only for the gas and pressures for which they are intended?
- ☐ Is open circuit (No Load) voltage of arc welding and cutting machines as low as possible and not in excess of the recommended limits?
- ☐ Under wet conditions, are automatic controls for reducing no load voltage used?
- ☐ Is grounding of the machine frame and safety ground connections of portable machines checked periodically?
- ☐ Are electrodes removed from the holders when not in use?
- ☐ Is it required that electric power to the welder be shut off when no one is in attendance?
- ☐ Is suitable fire extinguishing equipment available for immediate use?
- ☐ Is the welder forbidden to coil or loop welding electrode cable around his body?
- ☐ Are wet machines thoroughly dried and tested before being used?
- ☐ Are work and electrode lead cables frequently inspected for wear and damage, and relaced when needed?
- ☐ Do means for connecting cable lengths have adequate insulation?
- ☐ When the object to be welded cannot be moved and fire hazards cannot be removed, are shields used to confine heat, sparks, and slag?
- ☐ Are fire watchers assigned when welding or cutting is performed in locations where a serious fire might develop?
- ☐ Are combustible floors kept wet, covered by damp sand, or protected by fire-resistant shields?
- ☐ When floors are wet down, are personnel protected from possible electrical shock?
- ☐ When welding is done on metal walls, are precautions taken to protect combustibles on the other side?
- ☐ Before hot work is begun, are used drums, barrels, tanks, and other containers so thoroughly cleaned that no substances remain that could explode, ignite, or produce toxic vapors?
- ☐ Is it required that eye protection helmets, hand shields and goggles meet appropriate standards?
- ☐ Are employees exposed to the hazards created by welding, cutting, or brazing operations protected with personal protective equipment and clothing?
- ☐ Is a check made for adequate ventilation in and where welding or cutting is performed?

- ☐ When working in confined places, are environmental monitoring tests taken and means provided for quick removal of welders in case of an emergency?

COMPRESSORS AND COMPRESSED AIR

- ☐ Are compressors equipped with pressure relief valves, and pressure gauges?
- ☐ Are compressor air intakes installed and equipped so as to ensure that only clean uncontaminated air enters the compressor?
- ☐ Are air filters installed on the compressor intake?
- ☐ Are compressors operated and lubricated in accordance with the manufacturer's recommendations?
- ☐ Are safety devices on compressed air systems checked frequently?
- ☐ Before any repair work is done on the pressure system of a compressor, is the pressure bled off and the system locked-out?
- ☐ Are signs posted to warn of the automatic starting feature of the compressors?
- ☐ Is the belt drive system totally enclosed to provide protection for the front, back, top, and sides?
- ☐ Is it strictly prohibited to direct compressed air towards a person?
- ☐ Are employees prohibited from using highly compressed air for cleaning purposes?
- ☐ If compressed air is used for cleaning off clothing, is the pressure reduced to less than 10 psi?
- ☐ When using compressed air for cleaning, do employees wear protective chip guarding and personal protective equipment?
- ☐ Are safety chains or other suitable locking devices used at couplings of high pressure hose lines where a connection failure would create a hazard?
- ☐ Before compressed air is used to empty containers of liquid, is the safe working pressure of the container checked?
- ☐ When compressed air is used with abrasive blast cleaning equipment, is the operating valve a type that must be held open manually?
- ☐ When compressed air is used to inflate auto tires, is a clip-on chuck and an inline regulator preset to 40 psi required?
- ☐ Is it prohibited to use compressed air to clean up or move combustible dust if such action could cause the dust to be suspended in the air and cause a fire or explosion hazard?

COMPRESSORS AIR RECEIVERS

- ☐ Is every receiver equipped with a pressure guage and with one or more automatic, spring-loaded safety valves?
- ☐ Is the total relieving capacity of the safety valve capable of preventing pressure in the receiver from exceeding the maximum allowable working pressure of the receiver by more than 10 percent?
- ☐ Is every air receiver provided with a drain pipe and valve at the lowest point for the removal of accumulated oil and water?
- ☐ Are compressed air receivers periodically drained of moisture and oil?
- ☐ Are all safety valves tested frequently and at regular intervals to determine whether they are in good operating condition?
- ☐ Is there a current operating permit used by the Division of Occupational Safety and Health?
- ☐ Is the inlet of air receivers and piping systems kept free of accumulated oil and carbonaceous materials?

COMPRESSED GAS CYLINDERS

- ☐ Are cylinders with a water weight capacity over 30 pounds, equipped with means for connecting a valve protector device, or with a collar or recess to protect the valve?
- ☐ Are cylinders legibly marked to clearly identify the gas contained?
- ☐ Are compressed gas cylinders stored in areas which are protected from external heat sources such as flame impingement, intense radiant heat, electric arcs, or high temperature lines?
- ☐ Are cylinders located or stored in areas where they will not be damaged by passing or falling objects or subjects to tampering by unauthorized persons?
- ☐ Are cylinders stored or transported in a manner to prevent them creating a hazard by tipping, falling or rolling?
- ☐ Are cylinders containing liquefied fuel gas, stored or transported in a position so that the safety relief device is always in direct contact with the vapor space in the cylinder?
- ☐ Are valve protectors always placed on cylinders when the cylinders are not in use or connected for use?
- ☐ Are all valves closed off before a cylinder is moved, when the cylinder is empty, and at the completion of each job?

☐ Are low pressure fuel-gas cylinders checked periodically for corrosion, general distortion, cracks, or any other defect that might indicate a weakness or render it unfit for service?

☐ Does the periodic check of low pressure fuel-gas cylinders include a close inspection of the cylinders' bottom?

HOIST AND AUXILLIARY EQUIPMENT

☐ Is each overhead electric hoist equipped with a limit device to stop the hook travel at its highest and lowest point of safe travel?

☐ Will each hoist automatically stop and hold any load up to 125 percent of its rated load, if its actuating force is removed?

☐ Is the rated load of each hoist legibly marked and visible to the operator?

☐ Are stops provided at the safe limits of travel for trolley hoist?

☐ Are the controls of hoist plainly marked to indicate the direction of travel or motion?

☐ Is each cage-controlled hoist equiped with an effective warning device?

☐ Are close-fitting guards or other suitable devices installed on hoist to assure hoist ropes will be maintained in the sheave groves?

☐ Are all hoist chains or ropes of sufficient length to handle the full range of movement of the application while still maintaining two full wraps on the drum at all times?

☐ Are nip points or contact points between hoist ropes and sheaves which are permanently located within seven feet of the floor, ground or working platform, guarded?

☐ Is it prohibited to use chains or rope slings that are kinked or twisted?

☐ Is it prohibited to use the hoist rope or chain wrapped around the load as a substitute, for a sling?

☐ Is the operator instructed to avoid carrying loads over people?

INDUSTRIAL TRUCKS—FORKLIFTS

☐ Are only employees who have been trained in the proper use of hoists allowed to operate them?

☐ Are only trained personnel allowed to operate industrial trucks?

☐ Is substantial overhead protective equipment provided on high lift rider equipment?

☐ Are the required lift truck operating rules posted and enforced?

☐ Is directional lighting provided on each industrial truck that operates in an area with less than 2 foot candles per square foot of general lighting?

☐ Does each industrial truck have a warning horn, whistle, gong, or other device which can be clearly heard above the normal noise in the areas where operated?

☐ Are the brakes on each industrial truck capable of bringing the vehicle to a complete and safe stop when fully loaded?

☐ Will the industrial trucks' parking brake effectively prevent the vehicle from moving when unattended?

☐ Are industrial trucks operating in areas where flammable gases or vapors, or combustible dust or ignitable fibers may be present in the atmosphere, approved for such locations?

☐ Are motorized hand and hand/rider trucks so designed that the brakes are applied, and power to the drive motor shuts off when the operator releases his or her grip on the device that controls the travel?

☐ Are industrial trucks with internal combustion engine, operated in buildings or enclosed areas, carefully checked to ensure such operations do not cause harmful concentration of dangerous gases or fumes?

SPRAYING OPERATIONS

☐ Is adequate ventilation assured before spray operations are started?

☐ Is mechanical ventilation provided when spraying operations is done in enclosed areas?

☐ When mechanical ventilation is provided during spraying operations, is it so arranged that it will not circulate the contaminated air?

☐ Is the spray area free of hot surfaces?

☐ Is the spray area at least 20 feet from flames, sparks, operating electrical motors and other ignition sources?

☐ Are portable lamps used to illuminate spray areas suitable for use in a hazardous location?

☐ Is approved respiratory equipment provided and used when appropriate during spraying operations?

☐ Do solvents used for cleaning have a flash point to 100°F or more?

☐ Are fire control sprinkler heads kept clean?

☐ Are "NO SMOKING" signs posted in spray areas, paint rooms, paint booths, and paint storage areas?

☐ Is the spray area kept clean of combustible residue?

☐ Are spray booths constructed of metal, masonry, or other substantial noncombustible material?

☐ Are spray booth floors and baffles noncombustible and easily cleaned?

☐ Is infrared drying apparatus kept out of the spray area during spraying operations?

☐ Is the spray booth completely ventilated before using the drying apparatus?

☐ Is the electric drying apparatus properly grounded?

☐ Are lighting fixtures for spray booths located outside of the booth and the interior lighted through sealed clear panels?

or ducts?

- ☐ Are belts and pulleys inside the booth fully enclosed?
- ☐ Do ducts have access doors to allow cleaning?
- ☐ Do all drying spaces have adequate ventilation?

ENTERING CONFINED SPACES

- ☐ Are confined spaces thoroughly emptied of any corrosive or hazardous substances, such as acids or caustics, before entry?
- ☐ Are all lines to a confined space, containing inert, toxic, flammable, or corrosive materials valved off and blanked or disconnected and separated before entry?
- ☐ Is it required that all impellers, agitators, or other moving equipment inside confined spaces be locked-out if they present a hazard?
- ☐ Is either natural or mechanical ventilation provided prior to confined space entry?
- ☐ Are appropriate atmospheric tests performed to check for Oxygen deficiency, toxic substances and explosive concentrations in the confined space before entry?
- ☐ Is adequate illumination provided for the work to be performed in the confined space?
- ☐ Is the atmosphere inside the confined space frequently tested or continuously monitored during conduct of work?
- ☐ Is there an assigned safety standby employee outside of the confined space, when required, whose sole responsibility is to watch the work in progress, sound an alarm if necessary, and render assistance?
- ☐ Is the standby employee appropriately trained and equipped to handle an emergency?
- ☐ Is the standby employee or other employees prohibited from entering the confined space without lifelines and respiratory equipment if there is any question as to the cause of an emergency?
- ☐ Is approved respiratory equipment required if the atmosphere inside the confined space cannot be made acceptable?
- ☐ Is all portable electrical equipment used inside confined spaces either grounded and insulated, or equipped with ground fault protection?
- ☐ Before gas welding or burning is started in a confined space, are hoses checked for leaks, compressed gas bottles forbidden inside of the confined space, torches lightly only outside of the confined area and the confined area tested for an explosive atmosphere each time before a lighted torch is to be taken into the confined space?
- ☐ If employees will be using oxygen-consuming equipment such as salamanders, torches, furnaces, etc., in a confined space, is sufficient air provided to assure combustion without reducent by volume?
- ☐ Whenever combustion-type equipment is used in a confined space, are provisions made to ensure the exhaust gases are vented outside of the enclosure?
- ☐ Is each confined space checked for decaying vegetation or animal matter which may produce methane?
- ☐ Is the confined space checked for possible industrial waste which could contain toxic properties?
- ☐ If the confined space is below the ground and near areas where motor vehicles will be operating, is it possible for vehicle exhaust or carbon monoxide to enter the space?

ENVIRONMENTAL CONTROLS

- ☐ Are all work areas properly illuminated?
- ☐ Are employees instructed in proper first air and other emergency procedures?
- ☐ Are hazardous substances identified which may cause harm by inhalation, ingestion, skin absorption or contact?
- ☐ Are employees aware of the hazards involved with the various chemicals they may be exposed to in their work environment, such as ammonia, chlorine, epoxies, caustics, etc.?
- ☐ Is employee exposure to chemicals in the workplace kept within acceptable levels?
- ☐ Can a less harmful method or produce be used?
- ☐ Is the work area's ventilation system appropriate for the work being performed?
- ☐ Are spray painting operations done in spray rooms or booths equipped with an appropriate exhaust system?
- ☐ Is employee exposure to welding fumes controlled by ventilation, use of respirators, exposure time, or other means?
- ☐ Are welders and other workers nearby provided with flash shields during welding operations?
- ☐ If forklifts and other vehicles are used in buildings or other enclosed areas, are the carbon monoxide levels kept below maximum acceptable concentration?
- ☐ Has there been a determination that noise levels in the facilities are within acceptable levels?
- ☐ Are steps being taken to use engineering controls to reduce excessive noise levels?
- ☐ Are proper precautions being taken when handling asbestos and other fibrous materials?
- ☐ Are caution labels and signs used to warn of asbestos?
- ☐ Are wet methods used, when practicable, to prevent the emission of airborne asbestos fibers, silica dust and similar hazardous materials?

... used whenever possible rather than blowing or sweeping dust?

- ☐ Are grinders, saws, and other machines that produce respirable dusts vented to an industrial collector or central exhaust system?
- ☐ Are all local exhaust ventilation systems designed and operating properly such as air flow and volume necessary for the application, ducts not plugged or belts slipping?
- ☐ Is personal protective equipment provided, used and maintained wherever required?
- ☐ Are there written standard operating procedures for the selection and use of respirators where needed?
- ☐ Are restrooms and washrooms kept clean and sanitary?
- ☐ Is all water provided for drinking, washing, and cooking potable?
- ☐ Are all outlets for water not suitable for drinking clearly identified?
- ☐ Are employees' physical capacities assessed before being assigned to jobs requiring heavy work?
- ☐ Are employees instructed in the proper manner of lifting heavy objects?
- ☐ Where heat is a problem, have all fixed work areas been provided with spot cooling or air conditioning?
- ☐ Are employees screened before assignment to areas of high heat to determine if their health condition might make them more susceptible to having an adverse reaction?
- ☐ Are employees working on streets and roadways where they are exposed to the hazards of traffic, required to wear bright colored (traffic orange) warning vests?
- ☐ Are exhaust stacks and air intakes so located that contaminated air will not be recirculated within a building or other enclosed area?
- ☐ Is equipment producing ultra-violet radiation properly shielded?

FLAMMABLE AND COMBUSTIBLE MATERIALS

- ☐ Are combustible scrap, debris and waste materials (oily rags, etc.) stored in covered metal receptacles and removed from the worksite promptly?
- ☐ Is proper storage practiced to minimize the risk of fire including spontaneous combustion?
- ☐ Are approved containers and tanks used for the storage and handling of flammable and combustible liquids?
- ☐ Are all connections on drums and combustible liquid piping, vapor and liquid tight?
- ☐ Are all flammable liquids kept in closed containers when not in use (e.g. parts cleaning tanks, pans, etc.)?
- ☐ Are bulk drums of flammable liquids grounded and bonded to containers during dispensing?
- ☐ Do storage rooms for flammable and combustible liquids have explosion-proof lights?
- ☐ Do storage rooms for flammable and combustible liquids have mechanical or gravity ventilation?
- ☐ Is liquified petroleum gas stored, handled, and used in accordance with safe practices and standards?
- ☐ Are no smoking signs posted on liquified petroleum gas tanks?
- ☐ Are liquified petroleum storage tands guarded to prevent damage from vehicles?
- ☐ Are all solvent wastes, and flammable liquids kept in fire-resistant, covered containers until they are removed from the worksite?
- ☐ Is vacuuming used whenever possible rather than blowing or sweeping combustible dust?
- ☐ Are firm separators placed between containers of combustibles or flammables, when stacked one upon another, to assure their support and stability?
- ☐ Are fuel gas cylinders and oxygen cylinders separated by distance, fire resistant barriers, etc. while in storage?
- ☐ Are fire extinguishers selected and provided for the types of materials in areas where they are to be used?

  Class A Ordinary combustible material fires.

  Class B Flammable liquid, gas or grease fires.

  Class C Energized-electrical equipment fires.

- ☐ Are appropriate fire extinguishers mounted within 75 feet of outside areas containing flammable liquids, and within 10 feet of any inside storage area for such materials?
- ☐ Are extinguishers free from obstructions or blockage?
- ☐ Are all extinguishers serviced, maintained and tagged at intervals not to exceed one year?
- ☐ Are all extinguishers fully charged and in their designated places?
- ☐ Where sprinkler systems are permanently installed, are the nozzle heads so directed or arranged that water will not be sprayed into operating electrical switch boards and equipment?
- ☐ Are "NO SMOKING" signs posted where appropriate in areas where flammable or combustible materials are used or stored?
- ☐ Are safety cans used for dispensing flammable or combustible liquids at a point of use?
- ☐ Are all spills of flammable or combustible liquids cleaned up promptly?
- ☐ Are storage tanks adequately vented to prevent the development of excessive vacuum or pressure as a result of filling, emptying, or atmosphere temperature changes?
- ☐ Are storage tanks equipped with emergency venting that will relieve excessive internal pressure caused by fire exposure?
- ☐ Are "NO SMOKING" rules enforced in areas involving storage and use of hazardous materials?

HAZARDOUS CHEMICAL EXPOSURE

☐ Are employees trained in the safe handling practices of hazardous chemicals such as acids, caustics, etc.?

☐ Are employees aware of the potential hazards involving various chemicals stored or used in the workplace such as acids, bases, caustics, epoxies, phenols, etc.?

☐ Is employee exposure to chemicals kept within acceptable levels?

☐ Are eye wash fountains and safety showers provided in areas where corrosive chemicals are handled?

☐ Are all containers, such as vats, storage tanks, etc., labeled as to their contents, e.g., "CAUSTICS"?

☐ Are all employees required to use personal protective clothing and equipment when handling chemicals (gloves, eye protection, respirators, etc.)?

☐ Are flammable or toxic chemicals kept in closed containers when not in use?

☐ Are chemical piping systems clearly marked as to their content?

☐ Where corrosive liquids are frequently handled in open containers or drawn from storage vessels or pipe lines, is adequate means readily available for neutralizing or disposing of spills or overflows properly and safely?

☐ Have standard operating procedures been established and are they being followed when cleaning up chemical spills?

☐ Where needed for emergency use, are respirators stored in a convenient, clean, and sanitary location?

☐ Are respirators intended for emergency use adequate for the various uses for which they may be needed?

☐ Are employees prohibited from eating in areas where hazardous chemicals are present?

☐ Is personal protective equipment provided, used and maintained whenever necessary?

☐ Are there written standard operating procedures for the selection and use of respirators where needed?

☐ If you have a respirator protection program, are your employees instructed on the correct usage and limitations of the respirators? Are the respirators NIOSH approved for this particular application? Are they regularly inspected and cleaned, sanitized and maintained?

☐ If hazardous substances are used in your processes, do you have a medical or biological monitoring system in operation?

☐ Are you familiar with the Threshold Limit Values or Permissible Exposure Limits of airborne contaminants and physical agents used in your workplace?

☐ Have control procedures been instituted for hazardous materials, where appropriate, such as respirators, ventilation systems, handling practices, etc.?

☐ Whenever possible are hazardous substances handled in properly designed and exhausted booths or similar locations?

☐ Do you use general dilution or local exhaust ventilation systems to control dusts, vapors, gases, fumes, smoke, solvents or mists which may be generated in your workplace?

☐ Is ventilation equipment provided for removal of contaminants from such operations as: Production grinding, buffing, spray painting, and/or vapor degreasing, and is it operating properly?

☐ Do employees complain about dizziness, headaches, nausea, irritation, or other factors of discomfort when they use solvents or other chemicals?

☐ Is there a dermatitis problem? Do employees complain about dryness, irritation, or sensitization of the skin?

☐ Have you considered the use of an industrial hygienist or environmental health specialist to evaluate your operation?

☐ If internal combustion engines are used, is carbon monoxide kept within acceptable levels?

☐ Is vacuuming used, rather than blowing or sweeping dusts whenever possible for clean-up?

☐ Are materials which give off toxic asphyxiant, suffocating or anesthetic fumes, stored in remote or isolated locations when not in use?

HAZARDOUS SUBSTANCES COMMUNICATION

☐ Is there a list of hazardous substances used in your workplace?

☐ Is there a written hazard communication program dealing with Material Safety Data Sheets (MSDS), labeling, and employee training?

☐ Is each container for a hazardous substance (i.e., vats, bottles, storage tanks, etc.) labeled with product identity and a hazard warning (communication of the specific health hazards and physical hazards)?

☐ Is there a Material Safety Data Sheet readily available for each hazardous substance used?

☐ Is there an employee training program for hazardous substances?

Does this program include:

- ☐ (1) An explanation of what an MSDS is and how to use and obtain one.
- ☐ (2) MSDA contents for each hazardous substance or class of substances.
- ☐ (3) Explanation of "Right to Know."
- ☐ (4) Identification of where an employee can see the employers written hazard communication program and where hazardous substances are present in their work areas.
- ☐ (5) The physical and health hazards of substances in the work area, and specific protective measures to be used.
- ☐ (6) Details of the hazard communication program, including how to use the labeling system and MSDS's.

ELECTRICAL

☐ Do you specify compliance with OSHA for all contract electrical work?

☐ Are all employees required to report as soon as practicable any obvious hazard to life or property observed in connection with electrical equipment or lines?

☐ Are employees instructed to make preliminary inspections and/or appropriate tests to determine what conditions exist before starting work on electrical equipment or lines?

☐ When electrical equipment or lines are to be serviced, maintained or adjusted, are necessary switches opened, locked-out and tagged whenever possible?

☐ Are portable electrical tools and equipment grounded or of the double insulated type?

☐ Are electrical appliances such as vacuum cleaners, polishers, vending machines, etc., grounded?

☐ Do extension cords being used have a grounding conductor?

☐ Are multiple plug adaptors prohibited?

☐ Are ground-fault circuit interrupters installed on each temporary 15 or 20 ampere, 120 volt AC circuit at locations where construction, demolition, modifications, alterations or excavations are being performed?

☐ Are all temporary circuits protected by suitable disconnecting switches or plug connectors at the junction with permanent wiring?

☐ Do you have electrical installations in hazardous dust or vapor areas? If so, do they meet the National Electrical Code (NEC) for hazardous locations?

☐ Is exposed wiring and cords with frayed or deteriorated insulation repaired or replaced promptly?

☐ Are flexible cords and cables free of splices or taps?

☐ Are clamps or other securing means provided on flexible cords or cables at plugs, receptacles, tools, equipment, etc., and is the cord jacket securely held in place?

☐ Are all cord, cable and raceway connections intact and secure?

☐ In wet or damp locations, are electrical tools and equipment appropriate for the use or location or otherwise protected?

☐ Is the location of electrical power lines and cables (overhead, underground, underfloor, other side of walls, etc.) determined before digging, drilling or similar work is begun?

☐ Are metal measuring tapes, ropes, handlines or similar devices with metallic thread woven into the fabric prohibited where they could come in contact with energized parts of equipment or circuit conductors?

☐ Is the use of metal ladders prohibited in areas where the ladder or the person using the ladder could come in contact with energized parts of equipment, fixtures or circuit conductors?

☐ Are all disconnecting switches and circuit breakers labeled to indicate their use or equipment served?

☐ Are disconnecting means always opened before fuses are replaced?

☐ Do all interior wiring systems include provisions for grounding metal parts of electrical raceways, equipment and enclosures?

☐ Are all electrical raceways and enclosures securely fastened in place?

☐ Are all energized parts of electrical circuits and equipment guarded against accidental contact by approved cabinets or enclosures?

☐ Is sufficient access and working space provided and maintained about all electrical equipment to permit ready and safe operations and maintenance?

☐ Are all unused openings (including conduit knockouts) in electrical enclosures and fittings closed with appropriate covers, plugs or plates?

☐ Are electrical enclosures such as switches, receptacles, junction boxes, etc., provided with tight-fitting covers or plates?

☐ Are disconnecting switches for electrical motors in excess of two horsepower, capable of opening the circuit when the motor is in a stalled condition, without exploding? (Switches must be horsepower rated equal to or in excess of the motor hp rating.)?

☐ Is low voltage protection provided in the control device of motors driving machines or equipment which could cause probable injury from inadvertent starting?

- ☐ Is each motor disconnecting switch or circuit breaker located within sight of the motor control device?
- ☐ Is each motor located within sight of its controller or the controller disconnecting means capable of being locked in the open position or is a separate disconnecting means installed in the circuit within sight of the motor?
- ☐ Is the controller for each motor in excess of two horsepower, rated in horsepower equal to or in excess of the rating of the motor it serves?
- ☐ Are employees who regularly work on or around energized electrical equipment or lines instructed in the cardio-pulmonary resuscitation (CPR) methods?
- ☐ Are employees prohibited from working alone on energized lines or equipment over 600 volts?

NOISE

- ☐ Are there areas in the workplace where continuous noise levels exceed 85dBA?
- ☐ Is there an ongoing preventive health program to educate employees in: safe levels of noise, exposures; effects of noise on their health; and the use of personal protection?
- ☐ Have work areas where noise levels make voice communication between employees difficult been identified and posted?
- ☐ Are noise levels being measured using a sound level meter or an octave band analyzer and records being kept?
- ☐ Have engineering controls been used to reduce excessive noise levels? Where engineering controls are determined to not be feasible, are administrative controls (i.e. worker rotation) being used to minimize individual employee exposure to noise?
- ☐ Is approved hearing protective equipment (noise attenuating devices) available to every employee working in noisy areas?
- ☐ Have you tried isolating noisy machinery from the rest of your operation?
- ☐ If you use ear protectors, are employees properly fitted and instructed in their use?
- ☐ Are employees in high noise areas given periodic audiometric testing to ensure that you have an effective hearing protection system?

FUELING

- ☐ Is it prohibited to fuel an internal combustion engine with a flammable liquid while the engine is running?
- ☐ Are fueling operations done in such a manner that likelihood of spillage will be minimal?
- ☐ When spillage occurs during fueling operations, is the spilled fuel washed away completely, evaporated, or other measures taken to control vapors before restarting the engine?
- ☐ Are fuel tank caps replaced and secured before starting the engine?
- ☐ In fueling operations, is there always metal contact between the container and the fuel tank?
- ☐ Are fueling hoses of a type designed to handle the specific type of fuel?
- ☐ Is it prohibited to handle or transfer gasoline in open containers?
- ☐ Are open lights, open flames, or sparking, or arcing equipment prohibited near fueling or transfer of fuel operations?
- ☐ Is smoking prohibited in the vicinity of fueling operations?
- ☐ Are fueling operators prohibited in building or other enclosed areas that are not specifically ventilated for this purpose?
- ☐ Where fueling or transfer of fuel is done through a gravity flow system, are the nozzles of the self-closing type?

IDENTIFICATION OF PIPING SYSTEMS

- ☐ When nonpotable water is piped through a facility, are outlets or taps posted to alert employees that it is unsafe and not to be used for drinking, washing or other personal use?
- ☐ When hazardous substances are transported through above ground piping, is each pipeline identified at points where confusion could introduce hazards to employees?
- ☐ When pipelines are identified by color painting, are all visible parts of the line so identified?
- ☐ When pipelines are identified by color painted bands or tapes, are the bands or tapes located at reasonable intervals and at each outlet, valve or connection?
- ☐ When pipelines are identified by color, is the color code posted at all locations where confusion could introduce hazards to employees?
- ☐ When the contents of pipelines are identified by name or name abbreviation, is the information readily visible on the pipe near each valve or outlet?
- ☐ When pipelines carrying hazardous substances are identified by tags, are the tags constructed of durable materials, the message carried clearly and permanently distinguishable and are tags installed at each valve or outlet?
- ☐ When pipelines are heated by electricity, steam or other external source, are suitable warning signs or tags placed at unions, valves, or other serviceable parts of the system?

MATERIAL HANDLING

- ☐ Is there safe clearance for equipment through aisles and doorways?
- ☐ Are aisleways designated, permanently marked, and kept clear to allow unhindered passage?
- ☐ Are motorized vehicles and mechanized equipment inspected daily or prior to use?
- ☐ Are vehicles shut off and brakes set prior to loading or unloading?
- ☐ Are containers of combustibles or flammables, when stacked while being moved, always separated by dunnage sufficient to provide stability?
- ☐ Are dock boards (bridge plates) used when loading or unloading operations are taking place between vehicles and docks?
- ☐ Are trucks and trailers secured from movement during loading and unloading operations?
- ☐ Are dock plates and loading ramps constructed and maintained with sufficient strength to support imposed loading?
- ☐ Are hand trucks maintained in safe operating condition?
- ☐ Are chutes equipped with sideboards of sufficient height to prevent the materials being handled from falling off?
- ☐ Are chutes and gravity roller sections firmly placed or secured to prevent displacement?
- ☐ At the delivery end of the rollers or chutes, are provisions made to brake the movement of the handled materials?
- ☐ Are pallets usually inspected before being loaded or moved?
- ☐ Are hooks with safety latches or other arrangements used when hoisting materials so that slings or load attachments won't accidentally slip off the hoist hooks?
- ☐ Are securing chains, ropes, chockers or slings adequate for the job to be performed?
- ☐ When hoisting material or equipment, are provisions made to assure no one will be passing under the suspended loads?
- ☐ Are material safety data sheets available to employees handling hazardous substances?

TRANSPORTING EMPLOYEES AND MATERIALS

- ☐ Do employees who operate vehicles on public thoroughfares have valid operator's licenses?
- ☐ When seven or more employees are regularly transported in a van, bus or truck, is the operator's license appropriate for the class of vehicle being driven?
- ☐ Is each van, bus or truck used regularly to transport employees, equipped with an adequate number of seats?
- ☐ When employees are transported by truck, are provisions provided to prevent their falling from the vehicle?
- ☐ Are vehicles used to transport employees equipped with lamps, brakes, horns, mirrors, windshields and turn signals in good repair?
- ☐ Are transport vehicles provided with handrails, steps, stirrups or similar devices, so placed and arranged that employees can safely mount or dismount?
- ☐ Are employee transport vehicles equipped at all times with at least two reflective type flares?
- ☐ Is a full charged fire extinguisher, in good condition, with at least 4 B:C rating maintained in each employee transport vehicle?
- ☐ When cutting tools or tools with sharp edges are carried in passenger compartments of employee transport vehicles, are they placed in closed boxes or containers which are secured in place?
- ☐ Are employees prohibited from riding on top of any load which can shift, topple, or otherwise become unstable?

CONTROL OF HARMFUL SUBSTANCES BY VENTILATION

- ☐ Is the volume and velocity of air in each exhaust system sufficient to gather the dusts, fumes, mists, vapors or gases to be controlled, and to convey them to a suitable point of disposal?
- ☐ Are exhaust inlets, ducts and plenums designed, constructed, and supported to prevent collapse or failure of any part of the system?
- ☐ Are clean-out ports or doors provided at intervals not to exceed 12 feet in all horizontal runs of exhaust ducts?
- ☐ Where two or more different type of operations are being controlled through the same exhaust system, will the combination of substances being controlled, constitute a fire, explosion or chemical reaction hazard in the duct?
- ☐ Is adequate makeup air provided to areas where exhaust systems are operating?
- ☐ Is the source point for makeup air located so that only clean, fresh air, which is free of contaminates, will enter the work environment?
- ☐ Where two or more ventilation systems are serving a work area, is their operation such that one will not offset the functions of the other?

SANITIZING EQUIPMENT AND CLOTHING

- ☐ Is personal protective clothing or equipment that employees are required to wear or use, of a type capable of being cleaned easily and disinfected?
- ☐ Are employees prohibited from interchanging personal protective clothing or equipment, unless it has been properly cleaned?

materials that could be injurious to employees, cleaned and/or decontaminated before being overhauled or placed in storage?

- ☐ Are employees prohibited from smoking or eating in any area where contaminates that could be injurious if ingested are present?
- ☐ When employees are required to change from street clothing into protective clothing, is a clean change room with separate storage facility for street and protective clothing provided?
- ☐ Are employees required to shower and wash their hair as soon as possible after a known contact has occurred with a carcinogen?
- ☐ When equipment, materials, or other items are taken into or removed from a carcinogen regulated area, is it done in a manner that will contaminate non-regulated areas or the external environment?
- ☐ Where tires are mounted and/or inflated on drop center wheels, is a safe practice procedure posted and enforced?
- ☐ Where tires are mounted and/or inflated on wheels with split rims and/or retainer rings, is a safe practice procedure posted and enforced?
- ☐ Does each tire inflation hose have a clip-on chuck with at least 24 inches of hose between the chuck and an in-line hand valve and gauge?
- ☐ Does the tire inflation control valve automatically shutoff the air flow when the valve is released?
- ☐ Is a tire restraining device such as a cage, rack or other effective means used while inflating tires mounted on split rims, or rims using retainer rings?
- ☐ Are employees strictly forbidden from taking a position directly over or in front of a tire while it's being inflated?

Job Safety Analysis Form

Step (Describe Action)	Hazards Involved With This Process Step	Personal Protective Equipment (PPE) and/or Safety Aids Used	Suggested Changes to This Step

APPENDIX F.

AREA CHEMICAL EMISSIONS MEASUREMENT PROTOCOL

F.1 INTRODUCTION

VOCs are expected to be components of medical waste and may be formed and emitted during the treatment process. Thus there is a high potential for worker exposure to VOCs although the nature and extent of this exposure are largely unknown. Emissions of gaseous and particulate contaminants from medical waste treatment technologies have not been well characterized. Therefore, data were not available for selecting target chemicals to monitor at the waste facilities. To overcome this, the screening measurements described below were performed to identify hazardous chemicals to better target the Phase 2 personal sampling. The measurement parameters, sampling methods, and analysis methods used during the Phase 1 screening are summarized in Table F-1.

F.2 PHASE 1 VOC SAMPLING STRATEGY

Again, the primary purpose of the Phase 1 testing was to develop the sampling protocols for Phase 2. This included not only the identification of target chemicals for personal monitoring, but it also involved selecting monitoring locations that accurately represented chemical emissions from the facilities.

F.3 PHASE 1 VOC SAMPLE COLLECTION

Samples were collected over integrated time periods of approximately 4 to 6 hours during one day at each facility. Using this approach, samples were collected over periods during which the composition of the waste stream can be expected to vary. This is an alternative to collecting many short-term samples for multiple batches of waste or for short periods during continuous operations. Integrated samples over long time periods should contain representative contaminants throughout the day even if the waste composition is varying. Actual sampling locations were selected at each facility during the initial site visit with revisions as deemed appropriate during Phase 1. The locations for the different types of facilities were as follows:

Steam Autoclave: (1) above the autoclave door, (2) in the room/building near the dumpster (fugitive emissions), and (3) in the process area near the control panel.
Microwave: (1) in the bin wash area and (2 and 3) over both microwave units.
Pyrolysis: (1) next to one unit, (2) between the two units, and (3) in the shop area.

Table F-1. Measurement Parameters and Methods for Phase 1 Sampling

Pollutant	Sampling Method	Reference	Analysis Method	Analysis Method Reference	PQL[a]
Air Emissions					
VOCs	Multisorbent cartridges	Sheldon (1993)	GC/MS-full Scan[b]	Sheldon (1993)	~1 $\mu g/m^3$ [c]
Metals	Impingers	EPA-29 (Draft)	GFAA, ICP	NIOSH, EPA	
Mercury	Impingers		CVAA	NIOSH, EPA	
Formaldehyde, other aldehydes ketone	Silica gel DNPH	EPA-T011	HPLC	EPA - T011	5 ppb
Hydrochloric acid	Detector tube	ASTM D4490	Colorimetric	-	0.5 ppm[d]
Chlorine	Detector tube	ASTM D4490	Colorimetric	-	0.2 ppm[d]
Particulate matter	Respirable Aerosol Monitor	-	Photometric	-	0-200 mg/m^3
Liquid Effluents					
SVOCs	Grab samples	SW846	GC/MS-Full Scan	Method 8270	10 $\mu g/L$
Surface Contam.					
Blood	Gauze wipes	Heinsohn	Hemastix	-	Semi-quant.
Microbial	Swabs	Various	Various	-	Qualitative

[a] Practical Quantitation Limit as defined in the analysis method unless otherwise indicated.
[b] Gas chromatography/mass spectrometry; in full scan mode for qualitative analysis and quantitative analysis for tentative identification of non-target compounds.
[c] Based on historical RTI date; varies by analyte.
[d] Manufacturer's specification.

F.4 MULTISORBENT CARTRIDGE METHOD

During both Phase 1 and Phase 2 surveys, VOCs were monitored using a multisorbent cartridge method. This method has been validated at RTI and has been used in our laboratory for the analysis of thousands of air samples. Side-by-side comparisons with the Tenax sorbent method during field monitoring showed good agreement between the two methods for the nonpolar VOCs (Sheldon 1993, Sheldon and Keever 1994). In addition, the multisorbent cartridge method demonstrated good performance for the analysis of the entire range of very volatile, volatile, and polar VOCs that are not captured by other methods. Examples of VOCs of concern that can be analyzed by this method are given in Table F-2.

VOCs were collected by passing air through multisorbent cartridges containing Tenax TA, charcoal, and ambersorb (200 mm x 6 mm o.d., Envirochem, Kimblesville, PA). Sample volumes of approximately 5.0 L were collected over a 4 to 6 hour monitoring period. For analysis, VOCs on exposed cartridges were thermally desorbed then analyzed by gas chromatography/mass spectrometry (GC/MS). During Phase 1, identification of unknown sample constituents were performed using an electronic search of the NIH/EPA/MSDC Mass Spectral Data Base (NIST library) and the Registry of Mass Spectral Library (Wiley Library). Manual review of the data were performed to verify computer identifications and to identify compounds not found using the computer literature search. A semiquantitative estimate of the identified compounds were made using the total ion peak area for each compound and the total ion response factor measured for toluene. A concentration estimate for total volatile organic compounds were made using the same approach.

F.5 VOC TARGET LIST

Screening results for the VOC analysis at each facility were used to select a target list of compounds for quantitative analysis. Target chemicals were selected based on their relative abundance in the screening samples and reported health or irritancy effects. The final list of target VOCs for each facility were submitted to the CDC/NIOSH Project Officer prior to the comprehensive survey.

F.6 ALDEHYDES/KETONES

Formaldehyde is a contaminant that may be emitted during the treatment of medical waste. Low levels of formaldehyde have been reported in air emissions from a mechanical/chemical treatment system. Formaldehyde as well as other volatile aldehydes and ketones were screened for using a silica gel/DNPH (2,4-dinitrophenylhydrazine) method (US EPA, 1988). Aldehydes and ketones were collected by passing air through silica gel cartridges impregnated with DNPH (Waters Assoc., Medford, Ma). During sampling, aldehydes/ketones instantaneously react on the cartridge to form the DNPH derivative. Sample volumes of 24 to 36 L were collected over a 4 to 6 hour period. For analysis, the DNPH/aldehyde/ketone derivatives were eluted from the cartridge with acetonitrile. This extract is then analyzed by high performance liquid chromatography (HPLC). Aldehyde/ketones were identified by comparison

Table F-2. Example VOCs That Are Amenable to Analysis by the Multisorbent Method

1,2-Dichloropropane	C_3-Benzenes	Bromoform
1,1,2,2-Tetrachloroethane	C_4-Benzene	Isopropanol
Dibromochloromethane	Methylene Chloride	Propanol
Bromodichloromethane	Bromethane	Butanol
cis-1,3-Dichloropropene	Chlroethane	Pentanol
1,1,2-Trichloroethane	Chloromethane	Benzene
1,1-Dichloroethane	Chloroform	Toluene
1,2-Dichloroethene (Total)	Trichloroethene	Acrolein
trans-1,3-Dichloropropene	Chlorobenzene	Acrylonitrile
1,2-Dichloroethane	Ethyl Benzene	Styrene
1,1,1-Trichloroethane	Dichlorobenzenes	Vinyl Chloride
Carbon Tetrachloride	1,1-Dichloroethene	Xylenes
	Tetrachloroethene	

Table F-3. Example Aldehyde/ketones to Be Analyzed During Phase 1 Screening

Formaldehyde	Acetaldehyde	Acetone	Acrolein
n-Propanal	Crotonaldehyde	n-Butanone	n-Butanal
Benzaldehyde	n- Pentanal	n-Tolualdehyde	n-Hexanal

of their chromatographic retention times with those of purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range 0.02 to 15 ng/μL of the DNPH/aldehyde derivatives. Standards were analyzed and a calibration curve was calculated by linear regression of the concentration and chromatographic data. A list of aldehydes/ketones to be analyzed during Phase 1 screening are shown in Table F-3.

Only those aldehydes/ketones that were measured during Phase 1 screening were target compounds for Phase 2. Personal sampling for target aldehydes/ketones were conducted at those facilities where screening results were sufficiently high to suggest substantial worker exposure. As with the VOCs, the list of target aldehydes/ketones and facilities for personal sampling was submitted the CDC/NIOSH Project Officer prior to implementing the comprehensive survey.

F.7 HYDROCHLORIC ACID AND CHLORINE

Hydrochloric acid and chlorine are potential contaminants from mechanical/chemical systems that use high concentrations of sodium hypochlorite or other chlorine based biocides. To screen for the presence of these chemicals in air, length-of-stain detector tubes were used (ASTM D4490, 1992). During screening, a known volume of air was drawn through the tube. As air is drawn through the tube, a colorimetric reaction occurs; the concentration is read from the demarcations on the tube.

F.8 SEMIVOLATILE ORGANIC COMPOUNDS

For semivolatile organic compounds (SVOCs), chemical concentrations in the liquid effluent rather than the air were measured. For SVOCs which are not readily volatilized into the surrounding air, direct contact with or splashing of the liquid effluent is the most likely route of exposure. Measurement of SVOCs in the liquid was intended to provide information on the potential for exposure to these compounds rather than direct exposure estimates. Data on SVOC concentrations provide useful information on direct release of these chemicals into sanitary sewer systems. Examples of the types of SVOCs that are amenable to analysis are given in Table F-4.

The sample collection and analysis procedures were based on EPA methods for waste samples. At each sampling location, a single composite 1 L effluent sample was collected in an amber glass bottle. Sampling was performed over a 4 to 6 hour period that coincides with air monitoring. Times for collecting individual composites were selected at each facility to capture the expected variability in the waste samples. The samples were treated, preserved, and stored as described in the EPA methods. Samples were extracted with methylene chloride and analyzed by GC/MS using procedures consistent with EPA Method 8270 (U.S. EPA, 1986). As with the VOCs, identification of unknown sample constituents was performed using electronic library searches with manual verification of the data. Semiquantitative estimates of identified compounds were made as described for the VOCs. If deemed appropriate by the CDC/NIOSH Project Officer, screening results for the SVOC analysis at each facility can be used to select a

Table F-4. Example SVOCs Amenable to Analysis by EPA 8270

Naphthalene	n-Propylbenzene	1,2,4-Trimethylbenzene	o-Toluidine
p-Nitrotoluene	2-Methylphenol	1,3,5-Trimethylbenzene	2-Nitroaniline
Pentachlorophenol	1,3-Dichlorobenzene	2,4,6-Trichlorphenol	Anthracene
2,4-Dinitrotoluene	1,4-Dichlorobenzene	2-Chloronaphthalene	Fluoranthene
Benz(a)anthracene	2,6-Dinitrotoluene	4-Bromophenylphenylether	Phenol
Benzo(g,h,i)perylene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Chrysene
3,3'-Dichlorobenzidine			

target list of compounds for the Phase 2 comprehensive survey. Target chemicals would be selected based on their relative abundance in the screening samples and reported health or irritancy effects.

F.9 METALS SAMPLING AND ANALYSIS

The methodology used for Phase 1 metals sampling use the EPA draft method 29 sampling train for combustion source emissions (US EPA, 1986). Two area samples were collected for metals analysis. The sample system incorporated a glass fiber filter followed by two (2) impingers containing acidified peroxide solution for collection of aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), labile mercury (Hg^{+2}), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl) and zinc (Zn). Following the peroxide impingers were two impingers containing acidified potassium permanganate for the collection of elemental mercury (Hg°). The draft method has been evaluated extensively at RTI and other laboratories, particularly for mercury species. In addition, the method has been used in the field by a large number of industrial stack testing contractors. A miniaturized version of the sampling train that incorporates midget impingers (1 - 2 L/min [LPM] sampling rates) instead of the Greenburg/Smith impingers (approximately 30 L/min) was used. This miniaturized version has also been exhaustively tested at RTI and elsewhere, especially for mercury compounds.

In addition to the analysis of particulate matter captured on the glass filter of the modified Method 29 train, the two separate bulk incinerator ash samples were analyzed. RTI has extensive experience with bulk ash analysis from coal fixed power plants and gasifiers and municipal waste incinerators using a variety of digestion techniques for both volatile and non-volatile elements. The digestion technique used for the Method 29 filter particulate matter is also suitable for bulk dust samples.

The measurement of these resulting samples included graphite furnace atomic absorption (GFAA) for As, Sb, and Se, cold vapor atomic absorption (CVAA) for Hg and inductively couple plasma (ICP) emission spectrometry for the remaining elements. These methods are described in adequate detail both in the NIOSH Manual of Analytical Methods (NIOSH, 1994) and in EPA "Methods for Chemical Analyses of Water and Wastes" (EPA 600/4-79-020). In addition, a 10-100 times improvement in sensitivity over the above methods may be obtained using recently acquired instrumentation - inductively coupled plasma mass spectrometry (ICP/MS). The technique was recently approved by EPA as method 200.8.

APPENDIX G.

NOISE AND RADIATION MEASUREMENT

G.1 NOISE MEASUREMENT

Noise was measured at all facilities. A Quest Precision Sound Level Meter Model 155 was calibrated using a Quest Calibrator Model CA-22. Additionally, a Quest Micro-14 Noise Dosimeter calibrated with a Quest Calibrator Model CA 12B was used to obtain an integrated noise dose measurement. The Quest calibrators are calibrated at the manufacturer and then used to calibrate the noise meters on site prior to and after every survey.

G.2 NONIONIZING RADIATION

Nonionizing radiation was measured around those units utilizing microwave treatment technologies. A Narda Microline Microwave detector Model 8200 with a Narda Microwave Probe Model 8221 (calibrated at 2450 MHZ) was used to measure microwave radiation on the outside surfaces of the microwave generators located in the interior of each of the two treatment units where six 2450 MHZ units operate.

APPENDIX H.

ENGINEERING CONTROLS ASSESSMENT PROTOCOL

H.1 VENTILATION AND HVAC CONTROL DEVICES

Preparation for the Phase 1 screening of each site began with a study of site descriptions, as available from the operators. This information along with knowledge of typical operation for each type of disposal method allowed the site team to determint which engineering controls to expect. For example, each facility was expected to have some type of ventilation system. Exhaust hoods would be expected for stationary, frequent emission sources such as near the openings to autoclaves. After potential source locations are identified, the engineer on the site team identified those engineering controls that are in-place at the sites. Locations (especially relative to the sources), types of controls, benefits of the controls, flaws in the operation (such as leaks) were noted.

For control devices that include airflow (including the building heating, ventilating, and air-conditioning (HVAC) and hoods), the vane anemometer was used to perform flow measurements to determine if adequate airflow at sufficient velocities are maintained. Single, central measurements of the air velocity or velocity traverses will be performed as appropriate. Operating procedures that could influence the performance of the control devices were investigated. For example, the investigator looked for sources of cross drafts that might prevent contaminants from venting through hoods, or standard ducts, including room doors that might open during the venting process or nearby movement of large equipment. When in-duct measurements were deemed necessary and a port was available, the site team used a pitot tube to take the velocity measurements. Temperature and relative humidity for the room air were measured.

The airflow measurements determined if the HVAC is operating as designed as per the systems schematics. The HVAC output were also checked against the ASHRAE standard for indoor ventilation requirements. Since the ASHRAE standard no longer specifies a specific industrial facility requirement, the minimum cited standard of 15 cfm will be used as a reference point.

An attempt was made to determine if contaminated air from the disposal facility is being vented to any other indoor location (such as entering the return air to a main air distribution location). This was examined using the airflow measurements and the HVAC design.

Control devices that could create hazards of themselves were investigated in conjunction with the hazard identification. For example liquid effluent drains from a high temperature treatment unit could present a heat hazard while performing quite adequately to prevent worker contact with a hazardous waste stream.

It was expected that the engineering controls would be adequately screened through the initial survey, however, the data collected was correlated with the exposure assessment to determine if additional data should be collected during the Phase 2 comprehensive survey. A possible need for additional data would occur if a certain area is determined through the screening measurements to have much higher than expected contamination levels, then the controls would be reexamined.

H.2 OTHER ENGINEERING CONTROLS

As with the ventilation control evaluation, the evaluation of other engineering controls such as machine guarding, handrails, lifting assistance, noise control, and workplace ergonomics began with an evaluation of the site plan. The Safety Evaluation Protocol identified the areas to be investigated.

APPENDIX I.

RESPIRABLE AEROSOL SCREENING PROTOCOLS

Phase 1 included aerosol measurements to meet two needs: 1) provide a concentration profile for the room, and 2) give approximate concentration levels to allow sampling times and volumes to be set for the more intensive Phase 2 aerosol surveys. A PPM Inc. Handheld Aerosol Dust Monitor was used for this screening. This real-time device measures total aerosol concentration in the 0.3 to 2 μm range. Larger particles are removed by absolute filters before the sampling occurs. This size range does not cover the entire range needed for the comprehensive survey, but highlights contaminated areas and gives approximate respirable concentrations. This device measures up to 200 mg/m^3 but can be used with a full scale reading of 2 mg/m^3; thus, this unit is adequate for a wide range of environments.

Measurements were also taken with the Laser Particle Counter (LPC) that measures number of particles in 5 size ranges: up to 0.5 μm, 0.5 to 1 μm, 1 to 5 μm, 5 to 10 μm, and 10-15 μm. The following equation was used to convert the number of particles counted to a mass concentration:

$$Mass\ Concentration = \frac{N_P V_P \rho_P}{Q t}$$

where: N_P = Number of particles counted in the size range,
V_P = Volume of particle based on average diameter for size range,
ρ_P = assumed average density for the particles,
Q = flowrate through sensor, and
t = time of sample.

The aerosol monitor measured concentrations near each identified potential emission point and in several locations throughout the room. Measurements were taken in the regions identified as worker breathing zones to begin to estimate worker exposure to aerosols. Since this instrument works quickly, replicate measurements could be taken at each point. Measurements were taken, when possible, both when the equipment was operating and during down time. This meant sampling while the worker was loading a machine, when the machine was running, and when the machine was opened. Each site had different requirements. The concentration in the incoming ventilation air or outdoor air (if air supply was from outdoors) was taken.

The results of this respirable aerosols survey were used to determine if there were hot spots, such as areas outside the operators normal work space that might have contamination to which other workers are exposed. This situation would have lead to additional, area sampling in Phase 2 and identified additional engineering controls needs.

APPENDIX J.
BLOOD ON SURFACES SCREENING PROTOCOL

J.1 INTRODUCTION

The Occupational Safety and Health Administration standard under section 6(b) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 655 is to eliminate or minimize occupational exposure to Hepatitis B Virus (HBV), Human Immunodeficiency Virus (HIV) and other blood borne pathogens. Blood borne pathogen exposure can be minimized or eliminated in a wide range of occupational settings where the potential exposure to such blood borne pathogens exist. Workers who routinely handle the collection, transport, treatment, and disposal of regulated medical waste are at risk of exposure by direct contact with blood on contaminated surfaces from spills or ruptured containers directly onto open skin cuts, abrasions, eyes, or mucous membranes, accidental needle, scalpel, or glass puncture wounds, or inhaling blood aerosols which may be generated from various handling and processing methods. OSHA has reported data from one medical waste company that the annual needle injury rate is 11 injuries per 1000 workers (OSHA 1991). In a survey of occupational exposure of waste industry workers to infectious waste, fifty percent of the respondents reported having received cuts and scratches, and twenty-two percent reported direct contact with waste blood (Jensen, 1995). Workers in various medical waste treatment technologies have been observed handling wastes which were leaking blood and residual fluids, resulting in blood-contaminated surfaces. These accounts indicated a definite need to characterize worker exposure to blood borne pathogens on surfaces in the medical waste treatment industry.

J.2 METHOD DEVELOPMENT

Three references from the technical literature were cited on sampling and detecting blood aerosols from surgical and dental procedures by eluting filter collection medium in water and testing for the presence of hemoglobin with commercially available Hemastix® (Miles, Inc. Elkhart, Ind.) urinalysis test strips (Miller, 1995; Jewett et al, 1992; Heinsohn et al, 1991).

A similar method was derived for this study to assess levels of surface blood contamination at each of the selected treatment technologies. Treatment system surfaces with which workers may come in contact were monitored for blood contamination by wiping with sterile gauze. The gauze was then be eluted into 25 ml aliquot of sterile buffer and the eluate was tested for blood using the Hemastix® method. Prior to field testing, laboratory tests were conducted to determine detection limits and suitable blood collection and elution media.

Serial dilutions from 10^{-1} through 10^{-7} of defibrinated sheep blood (Crane Laboratories, Inc., Syracuse, NY) were done with FTA Hemagglutination Buffer (FTAB) (Beckton Dickinson BBL11248, Cockeysville, MD) and 0.85% saline. The dilutions were then tested with Hemastix®. To test the ability to detect blood that has potentially been treated in a steam autoclave, the dilutions were autoclaved at 121 C at 15 psig for 20 minutes and re-tested with Hemastix® after cooling. The results indicated that either elution medium was probably adequate but FTAB was selected because it seemed to indicate a better result at the detection limit endpoints of the serial dilutions. The dilution detection limit was 10^{-6} for the non-autoclaved and 10^{-4} for the autoclaved solutions. It is probable that most or all of the hemoglobin was destroyed at the lower concentrations but, at higher concentrations, enough remained undamaged to be detectable. These results are shown in Table J-1.

The Hemastix® literature reports a detection limit of five to twenty red blood cells (RBC) per microliter of fluid which converts to a minimum of 5×10^3 RBC per ml of fluid (assuming five RBC per microliter). The detection limit found in our non-autoclaved dilutions can be calculated by assuming an average concentration of 5×10^9 RBC per ml of human blood (Campbell, 1987). In the 10^{-6} dilution, the detection limit concentration is approximately 5×10^3 RBC/ml which is the same as Hemastix® reports.

The blood surface detection limit was derived as follows. In the surface blood detection test, a sterile 4"x 4" gauze is moistened with FTAB (25 ml in a 50 ml sterile centrifuge tube), wiped over a measured surface area, and then placed into the 25 ml of FTAB. After shaking vigorously for 30 seconds, the eluate is tested with Hemastix®. To calculate the minimum amount of blood needed to produce a positive result, multiply the RBC detection limit (5×10^3 RBC/ml) by the volume of FTAB (25 ml). This yields 1.25×10^5 RBC needed to be eluted from the sterile gauze. Assuming 5×10^9 RBC/ml of human blood, the minimum volume of blood needed to produce a positive result from a wiped surface is approximately 2.5×10^{-5} ml of blood. This indicates a very sensitive blood surface test.

Additional laboratory tests show that the method was viable for detecting potentially small amounts of liquid and dried blood that could be encountered on a treatment facility surface. Small volumes of defibrinated sheep blood (0.1 ml and 1 µl) were each placed into 25 ml of sterile FTAB in a 50 ml centrifuge tube. The tubes were shaken for 30 seconds and tested with Hemastix®. Both solutions yielded +++ (strongly positive) results immediately after elution and again when tested five days later. The test was repeated by placing the same volumes of blood onto clean 4"x 4" gauze. The results were +++ (strongly positive) for both volumes of blood immediately after elution. Testing with Hemastix® after five days showed the 0.1 ml eluted from the gauze remained +++ and the 1 µl eluted from the gauze showed a weaker positive response of nht (Non-hemolyzed trace). This indicated that liquid drops of blood as small as 1 µl could easily be detected with this method.

Blood dried on surfaces was tested in the non-treated and steam autoclaved form. Eight microscope slides were inoculated with 1 µl of defibrinated sheep blood and autoclaved for 15 minutes at 121 C, and 15 psig. An additional eight microscope slides were inoculated with 1 µl fresh defibrinated sheep blood and allowed to dry at laboratory conditions for at least 15 minutes before testing. One of each type of slide was then wiped with a 4"x 4" gauze, placed into 25 ml sterile FTAB, shaken for 30 seconds, and tested with Hemastix® at time intervals of 0 hr, 1 hr, 2 hr, 3 hr, 4 hr, 5 hr, 21.5 hr, and 22.5 hr. All of the non-autoclaved dried blood was detectable over the time intervals. The steam autoclaved, denatured blood was not detected in the first three time intervals presumably because the blood collected onto the gauze seemed to remain as

Table J-1. Hemastix and Sheep Blood Dilution Test Results

Dilution[1]	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
			Hemastix® Result[2]				
Diluent Before Steam Autoclave							
FTAB	+++	+++	+++	+++	++	ht	-
0.85% Saline	+++	+++	+++	+++	++	nht	-
Diluent Post Steam Autoclave[3]							
FTAB	+++	+++	+++	++	-	-	-
0.85% Saline	+++	+++	+++	+	-	-	-

1- Serial dilutions of defibrinated sheep blood were made 0.5 ml to 4.5 ml.
2- Hemastix® Test Indicator Scale: +++ Strong, ++ Moderate, + Small, ht Hemolyzed Trace, nhm Non-Hemolyzed Moderate, nht Non Hemolyzed Trace, - Negative. (One minute reading)
3- Dilutions steam autoclaved 20 minutes, 121 C, 15 psig.

a slightly moist elastic mass and did not appear to dissolve into the FTAB easily. At the 3hr time interval, the autoclaved blood seemed to have dried and become more brittle, and appeared to more easily dissolve into the FTAB, resulting in a positive result. The dried autoclaved blood remained positive for the remainder of the time intervals. These results are shown in Table J-2.

J.3 POTENTIAL INTERFERENCES

As explained in the Hemastix® product literature, the test is based on the peroxidase-like activity of hemoglobin that catalyzes the reaction of diisopropylbenzene dihydroperoxide and 3,3',5,5'- tetramethylbenzidine. The resulting color ranges from orange through green and the result is recorded one-minute from the time of wetting the Hemastix®. Certain oxidizing contaminants , such as hypochlorite, may produce false positive results. Since hypochlorite is used in some medical waste treatment systems or in washing and disinfection procedures, laboratory tests were performed to check levels of hypochlorite that may produce a false positive result.

Clorox (The Clorox Company, Oakland, CA), a commercially available 5.25% (52,500 ppm) hypochlorite solution, was serially diluted from 10^{-1} through 10^{-5} and tested with Hemastix®. Results showed a +++ (strong), false positive at the approximately 525 ppm concentration within seconds of exposure. At the next dilution and those following, with concentrations less that approximately 52 ppm, negative results were found. These results remained valid until the one-minute recording time had elapsed. The results are shown in Table J-3. The potential for hypochlorite interference is addressed separately for each treatment technology.

J.4 THE FINALIZED FIELD METHOD

The laboratory method development experimental procedures and results indicated that the following procedures should be used to assess levels of surface blood contamination at medical waste treatment facilities.

1. Identify surfaces and or protective equipment such as face shields with which workers may come in contact that could be potentially blood-contaminated.
2. While wearing clean latex gloves, open a prepared 50 ml container with 25 ml sterile FTAB solution, and moisten a 4"x 4" clean gauze.
3. Measure (when appropriate) or approximate an area and thoroughly wipe the area with the moistened gauze.
4. Place the gauze into the remainder of the 25 ml FTAB.
5. Shake vigorously for 30 seconds.
6. Test eluate with Hemastix® and record result after one minute.

Table J-2. Fresh and Steam Autoclaved Sheep Blood Dried onto Surfaces

Time Interval, (hours)	0	1	2	3	4	5	21.5	22.5
	Hemastix® Result[1]							
Non steam autoclaved dried blood[2]	++	++	++	++	ht	++	+	++
Steam autoclaved dried blood[3]	-	-	-	+	ht	ht	+	ht

1 Hemastix® Test Indicator Scale: +++ Strong, ++ Moderate, + Small, ht Hemolyzed Trace, nhm Non-Hemolyzed Moderate, nht Non Hemolyzed Trace, - Negative. (One minute reading)

2 1 µl defibrinated sheep blood placed onto a microscope slide and allowed to dry 15 minutes before test began.

3 1 µl defibrinated sheep blood placed onto a microscope slide and steam autoclaved for 15 minutes at 121 C, 15 psig, and allowed to cool before test began.

Table J-3. The Reaction of Hypochlorite with Hemastix®

Hypochlorite Concentration[1] (ppm)	52,500	5,250	525	52	5	0.5
Hemastix® Result[2]	+++	+++	+	-	-	-

1 Approximate concentration of serial dilutions of commercially available Clorox®

2 Hemastix® Test Indicator Scale: +++ Strong, ++ Moderate, + Small, ht Hemolyzed Trace, nhm Non-Hemolyzed Moderate, nht Non Hemolyzed Trace, - Negative. (One minute reading)

APPENDIX K
SURFACE MICROBIAL CONTAMINATION PROTOCOL

K.1 INTRODUCTION

The risk to medical waste treatment workers of dermal contact with infectious disease agents was assessed by sampling and analysis of treatment system surfaces for human pathogen indicator organisms. Areas of treatment systems were selected that might harbor surface contamination included conveyor belts, doors and surfaces to grinding and loading mechanisms, waste carts, worker's gloves, and other surfaces in and around the treatment areas. The indicator organisms selected were *Staphylococcus aureus*, and *Escherichia coli*, which are two strains of vegetative bacteria associated with human infection and/or contamination. *S. aureus* is a leading human infectious agent of skin, organs, and tissues, and is expected to be present in various types of medical waste. Its presence would indicate the potential for contamination by other virulent pathogens to include the agents of tuberculosis, pneumonia, meningitis, and others. *E. coli* is a bacterium associated with fecal contamination, and is an indicator for other enteric pathogens causing serious diseases such as typhoid, dysentery, viral enteritis, and infectious hepatitis.

K.2 METHOD DEVELOPMENT

The method of using sterile, moistened swabs to sample a surface and directly inoculate microbiological media is a common environmental contamination investigative method. Laboratory experiments were performed as a method verification for this study. Cultures of *S. aureus* and *E. coli* in Trypticase Soy Broth (BBL 4321715/4321716, Becton Dickinson and Company, Cockeysville, MD) were incubated for 24-hours and broth concentrations were calculated by plating serial dilutions. *S. aureus* was plated on Mannitol Salt Agar (MSA), (BBL 4311407, Becton Dickinson and Company, Cockeysville, MD) and was incubated at 32 C. *E.coli* was plated on EMB Agar, Levine (BBL 11191, Becton Dickinson and Company, Cockeysville, MD) with lactose (BBL 11881, Becton Dickinson and Company, Cockeysville, MD) and was incubated at 37 C.

Twelve microscope slides were inoculated with 0.1 ml of the 10^{-4} dilution of each organism. The inoculum organism count on each slide was approximately 9×10^3 for *S. aureus* and 7×10^3 for *E. coli*. A sterile swab (Calgiswab®, Type 2, Spectrum® Laboratories, Inc., Dallas, TX) moistened with FTA Hemagglutination Buffer (BBL 11248, Becton Dickinson and Company, Cockeysville, MD) was used to swab one of each organism slide and plate onto the previously indicated media at time intervals of 0, 1,2,3,4,5,6, 22.5, 23.5, 24.5, 28.5, and 29.5 hours. This allowed an evaluation of the detectability of the indicator organisms as they were freshly deposited and as they dried over time. The results are shown in Table K-1.

Table K-1 shows that *S. aureus* was easily detectable after immediate inoculation when the inoculum was wet. After one hour there was a large decrease in the amount detected as the inoculum began to dry. At two hours the inoculum was completely dry and there seemed to be a

Table K-1. *Staphylococcus aureus*[1] (SA) and *Escherichia coli*[2] (EC) Recovery from Microscope Slides with Moistened Swabs

Time (Hours)	SA Recovery	EC Recovery	Comment
0	TNTC[3]	TNTC	Inoculum very wet
1	TNTC	TNTC	Inoculum slightly wet
2	97	7	Inoculum dry residue
3	79	5	Inoculum dry residue
4	23	6	Inoculum dry residue
5	20	1	Inoculum dry residue
6	9	3	Inoculum dry residue
22.5	0	0	Inoculum dry residue
23.5	3	0	Inoculum dry residue
24.5	6	1	Inoculum dry residue
28.5	4	1	Inoculum dry residue
29.5	3	1	Inoculum dry residue

1 *S. aureus,* with approximately 9×10^3 inoculated onto each microscope slide, was collected with a swab (Calgiswab®, Type 2, Spectrum® Laboratories, Inc., Dallas, TX) pre-moistened with FTAB (BBL 11248, Becton Dickinson and Company, Cockeysville, MD). The swab was then directly plated onto MSA (BBL 4311407, Becton Dickinson and Company, Cockeysville, MD) and was incubated at 32 C for 24 hours.

2 *E.coli* , with approximately 7×10^3 inoculated onto each microscope slide, was collected with a swab (Calgiswab®, Type 2, Spectrum® Laboratories, Inc., Dallas, TX) pre-moistened with FTAB (BBL 11248, Becton Dickinson and Company, Cockeysville, MD). The swab was then directly plated onto EMB Agar, Levine (BBL 11191, Becton Dickinson and Company, Cockeysville, MD) with lactose (BBL 11881, Becton Dickinson and Company, Cockeysville, MD) and was incubated at 37 C.

3 Too numerous to count

gradual decrease in the amount detected up to six hours. None were detected at 22.5 hours, but some were detected between 23.5 and 29.5 hours. *E. coli* detection was similarly very good when it was first inoculated onto the slide, but it appeared to be somewhat less viable as the inoculum dried. It was not detected at 22.5 and 23.5 hours, but one organism was detected at the remaining periods to 29.5 hours. For this method in environmental surface evaluations, the ability to detect the organism is the most significant result, while the number of organisms detected can be a qualitative measure of contamination levels.

K.3 THE FINALIZED FIELD METHOD

1. Identify surfaces and or protective equipment such as face shields with which workers may come in contact.
2. Aseptically moisten a sterile swab with FTAB solution.
3. Measure (when appropriate) or approximate an area and thoroughly wipe the area with the moistened swab.
4. Plate the material collected on the swab to MSA for the isolation and identification of *Staphylococcus aureus*. Another swab from an adjacent, similar area is plated onto EMB agar for the isolation and identification of *Escherichia coli*.

APPENDIX L.

PHASE 2 CHEMICAL EXPOSURE MONITORING PROTOCOL

The chemical sampling of Phase 2 was dependent upon the results of the Phase 1 screening, as the Phase I results were planned to indicate exactly which chemicals are being generated at each medical waste treatment facility. The Phase 2 chemical exposure monitoring consisted of the following chemicals and analysis methods. The plan was to collect 5 personal samples on 5 workers over each of 2 days, adjusted as needed for each site.

Volatile organic compounds (VOCs) were monitored in Phase II using the same multisorbent cartridge method (Tenax TA, charcoal, and ambersorb) that was employed in Phase I. The samples were collected at nominally 16 cc/min for 7-8 hours on 5 workers on each of 2 days.

Formaldehyde samples were collected using 3M 3720 passive formaldehyde badges. Again 5 workers were sampled for 7-8 hours on each of 2 days.

Ethanol was measured using a direct reading passive Dräger diffusion tube (part no. 81 01 151) with a detection range of 125-3100 ppm. Five workers were sampled for 7-8 hours on each of 2 days.

Ammonia was sampled using a direct reading Dräger tube (part no. 67 33 231) with a detection range of 0.5 - 30 ppm. Samples were collected over nominally one minute using a hand held pump (n = 5 strokes). Five samples were collected on each of 2 days in the boiler room adjacent to the autoclave processing area.

Methanol and n-propanol were sampled using a direct reading Dräger tube (part no. 26 112) with a detection range of 25-5000 ppm. Samples were collected over one minute using a hand held pump (n = 10 strokes). Five samples were collected on each of 2 days in the autoclave processing area and adjacent boiler room.

APPENDIX M
AIR QUALITY MONITORING PROTOCOL

Area air quality measurements were automatically recorded with a Metrosonics AQ-501 (Metrosonics, Rochester, NY) at several work area locations at each treatment technology site. The instrument measured and automatically recorded temperature, relative humidity, and concentrations of carbon dioxide and carbon monoxide. Data was averaged over pre-programmed time intervals of 5-minutes for a period of several hours at each selected worker area location. The instrument stored data which was downloaded later into a spreadsheet or graph for analysis. The Metrosonics was calibrated in the laboratory prior to use in the field with purchased, certified concentrations of carbon monoxide and carbon dioxide. The temperature and relative humidity sensors were calibrated by the manufacturer. The air quality monitor provided a means to determine if there was adequate ventilation at worker locations.

The field use protocol was as follows:

1. Select worker locations that appear to be appropriate based on worker activity and location.
2. Activate the Metrosonics and allow it to equilibrate for 10 minutes at the measurement location.
3. Press the "record" button and collect data from a location over several hours noting the time and location of the instrument in a separate project notebook.
4. After data has been collected from several locations at a site, the data was downloaded into a spreadsheet for analysis.

APPENDIX N.

PERSONAL AND AREA MONITORING FOR AIRBORNE BLOOD

N.1 INTRODUCTION

The Occupational Safety and Health Administration standard under section 6(b) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 655 is to eliminate or minimize occupational exposure to Hepatitis B Virus (HBV), Human Immunodeficiency Virus (HIV) and other blood borne pathogens. Blood borne pathogen exposure can be minimized or eliminated in a wide range of occupational settings where the potential exposure to such blood borne pathogens exist. Workers who routinely handle the collection, transport, treatment, and disposal of regulated medical waste are at risk of exposure by direct contact with blood on contaminated surfaces from spills or ruptured containers directly onto open skin cuts, abrasions, eyes, or mucous membranes, accidental needle, scalpel, or glass puncture wounds, or inhaling blood aerosols which may be generated from various handling and processing methods. OSHA has reported data from one medical waste company that the annual needle injury rate is 11 injuries per 1000 workers (OSHA 1991). In a survey of occupational exposure of waste industry workers to infectious waste, fifty percent of the respondents reported having received cuts and scratches, and twenty-two percent reported direct contact with waste blood (Jensen, 1995). Workers in various medical waste treatment technologies have been observed handling wastes which were leaking blood and residual fluids, resulting in blood-contamination flying through the air and landing on surfaces. These accounts indicated a need to characterize worker exposure to airborne blood in the medical waste treatment industry.

N.2 METHOD DEVELOPMENT

RTI originally proposed to characterize the potential for worker exposure to airborne blood by using personal sampling with 0.2 μm polycarbonate filters and personal sampling pumps. Three references from the technical literature were cited on sampling and detecting blood aerosols from surgical and dental procedures by eluting filter collection medium in water and testing for the presence of hemoglobin with commercially available Hemastix® (Miles, Inc. Elkhart,Ind.) urinalysis test strips (Miller, 1995; Jewett, et al, 1992; Heinsohn, et al, 1991). As elucidated in Appendix J of this report, a similar method was derived for this study to assess levels of <u>surface</u> blood contamination at each of the selected treatment technologies. Treatment system surfaces with which workers may come in contact are monitored for blood contamination by wiping with sterile gauze. The gauze is then eluted into 25 ml aliquot of sterile buffer and the eluate is tested for blood using the Hemastix® method described. Prior to field testing, laboratory tests conducted to determine detection limits and suitable blood collection and elution media are also shown in Appendix J of this report.

After completion of initial site visits and Phase 1 testing, data collected indicated low particle counts such that personal sampling at the proposed personal sampling rate of 2 L/min for particles (ie. blood aerosols) would probably not be feasible. A new approach was developed in which blood aerosols are tested as an area sample with a much larger flow rate. A test was devised such that at least one blood aerosol area sample is taken per day near an area where there is highly visible fluid during waste loading. A 0.45 micron filter is attached to a pump set to sample at 17 liters per minute for most of (a timed interval) an entire shift. At the end of the shift, the filter is eluted in buffer and tested with Hemastix® as outlined in Appendix J.

Observations from Phase 1site visits indicated that other techniques might be suitable to augment the monitoring of blood aerosols and splashes by providing both visual and analytical results. NIOSH had previously developed a specially manufactured, 4 x 4 inch patch sample holder to determine pesticide deposition on worker clothing (Letter from Wayne T. Sanderson of NIOSH to Eugene C. Cole of DynCorp). The patches are loaded with pre-cleaned sorbent materials and are taped to worker clothing. They are then analyzed to determine levels of pesticide on the patches. This method was modified for blood splash monitoring. The patches are used to house clean cotton pads which are attached to the workers. After wearing the patches for a shift, the patches are removed, visually inspected, and tested via the Hemastix® method as outlined in Appendix J.

Additional monitoring was done on the workers' face shields. Before a work shift, workers' face shields are cleaned per normal facility protocol, then wiped with a clean gauze. The gauze is then eluted in buffer and the eluate is tested with Hemastix®. After the shift, the shield is visually inspected and re-tested with the Hemastix® method. This provides some assessment of the potential for exposure to blood splashes on the face. The Hemastix® test method is outlined in Appendix J.

N.3 THE FINALIZED FIELD METHOD FOR PERSONAL AND AREA MONITORING FOR AIRBORNE BLOOD

Three test methods used are outlined below to asseess worker exposure to blood splashes and aerosols:

1. Blood splash on face shield surfaces

This Hemastix® surface splash test is performed the same as the surface blood monitoring done in Phase 1 as described in Appendix J, except that it is limited to the workers' face shields only. All procedures are performed with sterile gloves. The surface area of the face shield is measured.

a) Prior to the shift, the face shields of up to five workers are cleaned per facility protocol.

1) Each shield is then wiped with a 4" x 4" clean gauze wetted with sterile buffer.

2) The gauze is then eluted in 25 ml of sterile buffer and tested with Hemastix®.
3) The shield is then issued to the worker.

b) After each shift.

1) Visually inspect shield noting number and approximate size of splashes.
2) Wipe shield with 4 x 4 inch clean gauze wetted with sterile buffer.
3) The gauze is then eluted in 25 ml of sterile buffer and tested with Hemastix®.

c) Test extra shields similarly as blanks by leaving them in a clean area.

2. Blood splash on clothing surfaces

This personal monitoring test uses previously developed, specially manufactured, 4 x 4 inch NIOSH patch sample holders. The patches are loaded with clean, 4 x 4 inch cotton pads. Patch locations on workers' upper body are shown in Figure N-1. All sampling procedures are performed with sterile gloves. Up to five workers per shift for two shifts are tested. The Hemastix® test method is outlined in Appendix J.

a) Before each shift

1) Assemble required number of patches.
2) Attach up to six patches to the same relative locations of the upper body of up to five workers. Label the patches according to location.
3) Place 10% of patches in an appropriate field blank location.
4) Allow workers to work their shift.

b)At the end of each shift

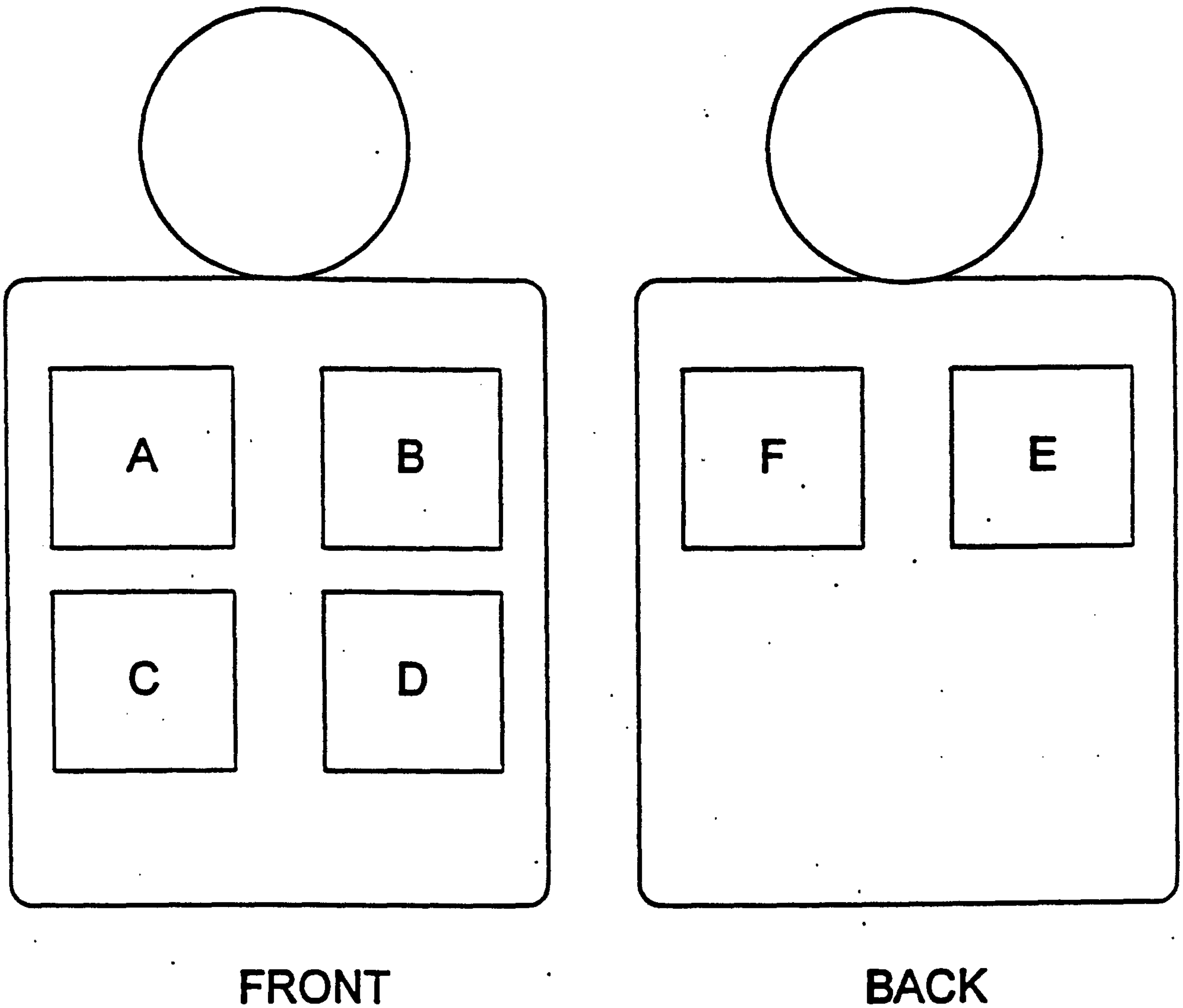
1) Visually inspect patches for blood splashes. Note number or percent covered.
2) The patches and blanks are then eluted in 25 ml of sterile buffer and tested with Hemastix®.

3. Blood aerosols

At least 1 blood aerosol area sample is taken per day near an area where there is highly visible fluid during waste loading. The Hemastix® test method is outlined in Appendix J.

1) Attach a 0.45 micron filter (SN 322375, Nucleopore Corp., Pleasanton, CA) to a 1/3 horsepower pump (Gast Manufacturing Corp., Benton Harbor, MI) set to sample at 17 liters per minute for an entire shift.

Figure N-1 Locations of Blood Splash Detection Patches on Workers



2) Check the flow rate with a rotometer at the start and finish of the sample time.

3) At the end of the shift, the filter is eluted in buffer and tested with Hemastix®. Blanks consist of unused filters.

APPENDIX O. BIOAEROSOL MONITORING PROTOCOL

O.1 GENERAL OVERVIEW

Due to site-specific conditions and management concerns, the general bioaerosol monitoring protocol as outlined in this paragraph may differ somewhat for each treatment facility. Ideally, bioaerosol emissions should be measured for two purposes at each treatment facility: 1) to measure worker area bioaerosol area loadings, and 2) to measure the emission from MWTF as they process spiked and non-spiked regulated medical waste. The worker area measurements should include both outdoor and appropriate indoor bioaerosol measurements using up to three media. Samples should be taken on both days of the site visit.

Spiked/non-spiked waste emissions sampling will be conducted at up to four locations, depending on the process, on each of the two days. Spiked waste will be seeded with large numbers of intrinsically chemical and heat resistant bacterial indicator spores of *Bacillus stearothermophilus* (ATCC 10149) and *Bacillus subtilis* var *globigii* (ATCC 9372). These spores may be in liquid suspension or dried onto membrane filters (simulating spilled, dried organisms). The indicator spores are organisms that are not expected to be common in the natural medical waste flow. The evaluation will consist of monitoring bioaerosol emissions from previously identified aerosol emission points while the MWTF is processing spiked and non-spiked waste. Detection of the indicator organisms will demonstrate the potential for bioaerosol emissions from the tested location or process.

O.2 SAMPLERS

For this study, bioaerosol monitoring will be conducted using samplers required or recommended in published standards and guidelines, primarily the American Society for Testing Materials (ASTM) Standard Practice for Sampling Airborne Microorganisms at Municipal Solid-Waste Processing Facilities. The bioaerosol samplers to be used may include AGI-30 all-glass impingers, Andersen cascade impactors, and Mattson/Garvin (M/G) slit-to-agar rotating plate samplers.

The AGI-30s will be loaded with 20 ml of sterile AOAC phosphate dilution buffer water (PBDW) and will sample air at 12.5 Lpm for ten minutes. After sampling, the impinger fluid volume and a rinse with PBDW will be measured and collected into a sterile container. The impinger fluid will be stored on ice for transport to RTI laboratories. The impinger fluid will be analyzed by vortexing and plating aliquots onto duplicate plates of Trypticase Soy Agar (TSA) (BBL 4311043, Becton Dickenson and Company, Cockeysville, MD) incubated at 55°C for *B. stearothermophilus* and onto duplicate plates of TSA with actidione incubated at 35°C for *B. subtilis*. The remaining impinger fluid will be split with one-half filtered through a 0.2 micron membrane filter and placed on TSA for incubation at 55°C for *B. stearothermophilus* and the other half filtered and placed on TSA with actidione for incubation at 35°C for *B. subtilis*.

The Andersen cascade impactor samplers will be run in duplicate at selected locations with one containing TSA for incubation at 55°C for *B. stearothermophilus* and the other containing TSA with actidione for incubation at 35°C for *B. subtilis*. After sample collection the agar plates are taped closed, placed into ziplock bags, and into an insulated container for transport to RTI laboratories for incubation and analysis. The M/G samplers will be run similarly.

O.3 IDENTIFICATION OF INDICATOR ORGANISMS

The selected indicator organisms *B. stearothermophilus* (ATCC 10149) and *B. subtilis* var *globigii* (ATCC 9372) will initially be identified by colony morphology and pigmentation. Further laboratory tests will be conducted to verify indicator organism identity. Suspected *B. stearothermophilus* colonies will be subcultured onto TSA for reincubation at 40°C and 65°C. Growth at both temperatures will be considered a positive indicator for *B. stearothermophilus*. Suspected colonies of *B. subtilis globigii* var *niger*, which appear orange on TSA with actidione, will be subcultured on Tyrosine agar and incubated at 35°C. Black pigmented colonies on Tyrosine agar will be a positive indicator for *B. subtilis globigii* var *niger*.

O.4 BIOAEROSOL MONITORING AT THE COMMERCIAL OFF-SITE STEAM AUTOCLAVE

O.4.1 Sampling Scheme

After an initial site visit and discussions with facility management and the project research team, it was decided that the focus of bioaerosol monitoring at the steam autoclave would be to measure the emissions for indicator organisms only from MWTF as they process spiked and non-spiked regulated medical waste. Observations from the initial site visit and Phase 1 testing indicated that there were three emission points from the autoclave units which had the potential to emit microorganisms into the work area. The potential emission points were identified as: A) above the autoclave door as the door opened post-treatment, B) between the two autoclaves as steam exhausted during a treatment cycle, and C) at the top of the compactor as the treated waste was dumped and compacted.

The sampling scheme for both spiked and non-spiked tests at the steam autoclave was as follows: At sampling point A, two Mattson-Garvins and two AGI-30 impingers were placed above the autoclave door and were started as the door opened at the end of a treatment cycle. At sample point B, three ten-minute AGI-30 impingers were operated in series during a treatment cycle. At sample point C, two Mattson-Garvins and two AGI-30 impingers were placed above the compactor and operated as treated waste was dumped and compacted. On the first day of testing, two non-spiked tests were performed, one on each of the two autoclaves. On the second day of testing, one spiked test was performed on autoclave number two.

O.4.2 Waste Spiking

Spores of *Bacillus stearothermophilus* were purchased (ATCC 10149, Difco Lot 82388, Detroit, MI) and were aseptically loaded onto 0.2 micron cellulose nitrate membrane filters (Lots 067769201 and 001984A3201, Nalge, Rochester, NY). The filters were placed into sterile 50 x 9 mm petri dishes and dried at 40°C for two to four hours. The petri dishes were then capped and stored in zip-lock bags until testing. They were shipped to and from the facility in insulated coolers. Six filters were randomly checked for spore count and viability before shipping and use in the field. Six randomly chosen filters were sent to the facility as field controls which were checked again for spore count and viability upon their return to RTI laboratories. Spore suspensions as received and those eluted from the filters were quantified by performing serial dilutions in PBDW, plating onto TSA, and incubating at 55°C for 24 hours. The average *B. stearothermophilus* spore count eluted from six filters six days prior to testing was 5.0×10^7 spores per filter. The average *B. stearothermophilus* spore count eluted from six filters two days after testing was 1.3×10^7 spores per filter.

Additionally, spores of *Bacillus subtilis* var *niger* (ATCC 9372, Amsco Lot LG 065B, Apex, NC) were purchased and were aseptically loaded onto 0.2 micron polycarbonate and cellulose nitrate membrane filters (Lots TQC851523C2201 and 067769201, Nalge, Rochester, NY). The filters were placed into sterile 50 x 9 mm petri dishes and dried at 40°C for two to four hours. The petri dishes were then capped and stored in zip-lock bags until testing. They were shipped to and from the facility in insulated coolers. Six filters were randomly checked for spore count and viability before shipping and use in the field. Six randomly chosen filters were sent to the facility as field controls which were checked again for spore count and viability upon their return to RTI laboratories. Spore suspensions as received and those eluted from the filters were quantified by performing serial dilutions in PBDW, plating onto TSA with actidione , and incubating at 35°C for 24 hours. The average *B. subtitis* var *niger* spore count eluted from six filters six days prior to testing was 2.3×10^7 spores per filter. The average *B. subtitis* var *niger* spore count eluted from six filters two days after testing was 4.5×10^6 spores per filter.

For the autoclave spiked run, ten petri dishes with filters of *B. stearothermophilus* and ten with filters of *B. subtilis* var *niger* were placed open faced on top of each of five loaded waste bins for a total of fifty filters of each organism in the treatment load.