INDUSTRIAL HYGIENE SURVEY
LAND AND MARINE ENTERPRISES
ABRASIVE BLASTING DIVISION
HARVEY, LOUISIANA

Date of Survey:
February 16-20, 1981

Survey conducted by:
Harry M. Donaldson
Michael King

Report prepared by:
Harry M. Donaldson
LLoyd E. Stettler
January, 1982

Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226

PLANT VISITED:
Land and Marine Enterprises
P. O. Box 968
Abrasive Blasting Division
Harvey Louisiana 70059

EMPLOYER REPRESENTATIVES:
Otis T. Logue, President
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UNION:
None

PURPOSE OF VISIT:
To monitor the abrasive blasting of new steel using a coal slag abrasive blasting agent (Stan-Blast)

ACKNOWLEDGEMENTS:
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STANDARD INSDUSTRIAL CLASSIFICATION OF PLANT:
1629

Abstract

NIOSH is interested in studying the potential health hazards of workers engaged in out-of-doors abrasive blasting. This paper reports a study at a facility where coal slag containing less than 0.5% free silica was used to remove rust from new steel prior to painting. The blasters wore double respiratory protection which consisted of a disposable 3M type mask as well as an air supplied helmet. Since blasters wore this double respiratory protection, minimal exposure to slag dust was assumed. To check this assumption, a calculation was made using the heaviest respirable dust sample, and the analysis of blasting slag to calculate the operator's potential exposure to toxic elements assuming no respiratory equipment was worn. This calculation shows that there would essentially be no exposures above the TLV for any of the toxic elements present with the exception of free silica. Of course without respiratory protection the nuisance dust standard would be greatly exceeded.

Since ancilliary workers are at least 100' from the blasting operation, and since dust generating by blasting tends to fall rapidly to the ground, area samples indicate that these workers are exposed to less than 1/10% of the nuisance respirable dust standards of $5\ Mg/m^3$.

During the survey it was noticed that some blasters consistently generated more dust than others. Recommendations by NIOSH that these blasters probably needed more training was accepted by the company who engaged the services of a blasting expert to instruct workers in proper blasting techniques.

Introduction

NIOSH is interested in studying the potential health hazards of workers engaged in out-of-doors abrasive blasting, using currently available abrasive blasting agents. This paper reports the results of an industrial hygiene survey conducted at Harvey, Louisiana where coal slag was used as the abrasive blasting agent to clean rust off new steel prior to its being painted. Respirable airborne dust generated was collected outside the man's respiratory protective equipment and analyzed for respirable net weight and iron. The use of respiratory equipment and protective clothing was observed and reported upon. Chemical analysis of the bulk slag was performed. Airborne dust samples, also collected on nucleopore filters, were examined by electron microscopy, and results are reported herein.

Background

In the latter part of the 19th century, steel came into general use as a material for fabrication of large structural items such as ships, bridges, railroad cars, etc. These steel structures upon being exposed to the weather were prone to corrode and required a protective coating to prevent rusting. Both the initial and the periodic maintenance of these structures require that the surface be cleaned of rust and loose paint in order to obtain a surface capable of accepting a new protective coating. The usual method of preparing thse surfaces has been by abrasive blasting with silica sand.

In studying the incidence of silicosis in the 1930's Mereweather[1] discovered that most workers in the dusty trades were prone to silicosis and that the average employee worked in these industries for 40.1 years and the average age at death was 54.1 years. However, he found one group, the sand blasters, who on the average worked for only 10.3 years and whose average age at death was 40.7 years.[1] With the recognition of this hazard, Great Britain in 1950 banned the use of silica sand as an abrasive blasting material.[2] This was followed by efforts to restrict the use of sand for abrasive blasting purposes in other European countries. It should be noted that though Great Britain and other European countries have banned the use of sand as an abrasive blasting material, the use of silica sand is still permitted in the United States.

Research was performed in Germany and other European countries to find satisfactory low percent free silica substitute abrasive blasting materials.[3] In considering candidate materials as substitutes for sand three properties were sought: (1) the material should contain less than 1% in free silica, (2) the material should possess good abrasive properties, and (3) the material should be economically competitive with sand.

In 1966 Gesell[3] reported results of the test work on several types of waste mineral slags. These included copper slag, chrome slag, glass, etc. These tests were conducted to determine the physical properties of these substitute abrasive blasting agents. Toxicological testing was not included.

In the Unites States it is estimated that sand is used as an abrasive blasting material in about 90% of the out-of-doors abrasive blasting operations. About 10% of the blasting materials used are slags which contain one to two percent free silica. The most widely used low silica abrasive blasting materials are coal slag (wet bottom boiler slag) and primary copper slag. A few lesser known low silica slags such as a secondary copper slag and a nickel slag are also used as abrasive blasting agents. Their chemical composition is described in an AIHA journal article now in press.

Coal slag results from burning a powdered coal with a low melting point ash content in a special type of utility boiler. The molten ash drops to the bottom of the boiler as a viscous liquid which flows into water where it frits to form a material which can be crushed and classified to acceptable grades with size ranges suitable for abrasive blasting. This coal slag usually contains less than 0.5% free silica* and 1.0 to 10 ppm of Be. Traces of other toxic materials such as Pb, As, Cr, etc., are also present. See Appendix A for analysis of the coal slag used in this study in addition to analysis of a competitive coal slag. This comparison indicates that the composition of both slags are similar.

Description of Facility and Blasting Operation

The abrasive blasting yard at Land and Marine Enterprises in Harvey, Louisiana covered about five or six acres backed up to a Mississippi River Levee. In addition to the blasting area, there was a small office building, and a large tall building which housed cranes and other lifting equipment. This building also contained a locker room, a wash room, shower facilities, and a lunch room. At the rear of this building a separate room houses an air compressor which supplies air used for abrasive blasting at approximately 120 pounds per square inch. Air from this source is also bled off to supply the blasting helmets after having first passed through a charcoal filter.

Adjacent to the blasting yard is six or seven acres which houses Land and Marine's main offices and storage buildings. The company's main business is abrasive blasting on oil rigs in the Gulf of Mexico, and they supply crews for such work on a contract basis. The company is also engaged in supplying parts for abrasive blasting equipment such as slag pots, hoses, nozzles, fittings and air compressors. In addition, they supply air supplied blasting helmets, protective clothing and other safety items. They also supply spray painting equipment, and other miscellaneous hardware.

The total number of people employed by the company is about two hundred, but for the purposes of this survey, February, 1981, we were interested only in the 20-25 employees who worked at the blasting yard at Harvey, Louisiana. During the survey, new steel (which included pipes, beams, boat bumpers, etc.) was blasted with the coal slag described above (Stan-Blast), to remove rust and to prepare the surface to accept paint. Though the yard employes about 20-25 men, no more than five were engaged in blasting activities at any one time in the yard, and at times during the survey, only one or two were doing this work. Others waiting for equipment to be moved by cranes or lift trucks were doing maintenance work, or had office jobs.

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* Limit of detection of analytical method is 0.5% free silica. Stan-Blast used in this study contains less than 0.5% free silica.

Stan-Blast was applied through a hose and nozzle with an air pressure of approximately 120 pounds at the compressor. The blasters were outfitted with adequate safety equipment which consisted of abrasive resistant clothing, gloves, ear protectors, air supplied helmet and shoes. The workers are given a complete pre-employment physical, which included a chest x-ray.

The blasting helmet worn is supplied with filtered air from the main compressor. The flow of air, which is filtered through carbon before entering the helmet, can be regulated by the blaster should the noise level be too high.

Under this air supplied helmet the blaster also wears a 3M disposable mask which gives further protection from dust which might infiltrate the helmet, during periods when the helmet sight piece must be opened. The helmet is attached to a device forming a turtle neck seal at the man's neck to keep out dust. This turtleneck is attached below to a poncho which protects the upper part of the blaster's body from the force of the abrasive blasting material hitting against him.

Sampling methods

Personal respirable samples were collected on each blaster to measure the quantity of respirable dust to which he was potentially exposed. The sampling was conducted by drawing dust laden air at a rate of 1.7 liters/minute through a nylon cyclone (10mm, dia.) then through a preweighed M-5 37 mm filter, using a Dupont P-4000 pump. The pump was attached to the blaster's belt and the filter assembly fastened to his collar. The workers normally performed blasting over a period of one to six hours each day. This was because of interruption due to rain or waiting for equipment to move the material being blasted. At the end of the blasting period, the samples were removed and length of work time noted. In the laboratory, the filters were reweighed to determine the net weight of respirable dust, and were then analyzed for iron content by disolving in nitric acid followed by atomic absorption spectrophotometry. The iron analysis was run to determine whether most of the dust was from slag or from iron oxide (rust) removed during the blasting period.

Short term nucleopore filters for electron microscopic examination were also collected on each blaster. However, not until the filters were attached to the workers back instead of to his collar was it possible to collect samples suitable for electron microscopic analysis. The filter time on these samples varied and they had to be removed when by inspection it was judged that the filter had sufficient dust to permit electron microscopic examination, and not too much to interfere with the electron microscopic examination. The samples were obtained for the purpose of determining particle size characteristics and particle identification.

Area samples both respirable and nucleopore were also taken. These were collected at the fence line which was about 80 feet from the blasting area and also at 150 feet down wind from the blasting area.

In addition, bulk samples of the coal slag used in the blasting were collected in bottles, and a complete chemical analysis was run except for free silica, an estimate of which was obtained by electron microscopy. (See Appendix A).

Discussion of results
The results of the personal respirable samples collected show that without respirable protection devices, the workers would be exposed to levels of respirable dust ranging from 1.08 mg/m^3 to 72.7 mg/m^3 as shown in Table I. This dust included iron oxide (rust) blasted from the steel as well as dust from the coal slag. The iron analysis in the respirable samples was run to determine whether the majority of the dust was from slag or iron oxide. Iron oxide proved to be a minor part of the respirable dust collected.

The yard covers 5 or 6 acres. Results of general area samples collected at the fence line (80 feet from the blasting area) and 150 feet from the blasting area in Table II show relatively low levels of respirable dust. The fence line samples ranged from 0.37 mg/m^3 of respirable dust to 0.45 mg/m^3 respirable dust. Samples taken on the property 150 feet down wind of blasting ranged from 0.19 mg/m^3 to 0.39 mg/m^3. This indicates that much of the dust falls out in the blasting yard.

The coal slag used in this study is thought to be representative of coal slag in general though the quantity of the chemical constituents vary somewhat depending on the source of coal burned. An analysis of the slag used is compared with the analysis of a competitive coal slag in Appendix A and the slags are very similar. Both contain about the same amount of beryllium 7-10 ppm.(4) The silica content present as silicates appears to be somewhat higher in the slags used in the survey but the lead content was lower (4 ppm vs. 15 ppm) than in the competitive slag.

Since analysis of the abrasive blasting slag used showed the presence of small amounts of toxic metals in the slag, the respirable sample of the slag dust collected while blasting which possessed the greatest amount of dust (72.7 mg/m^3) was used to calculate from the analysis of the bulk slag the quantity of these elements likely to be present in the air and to compare the results with their respective TLV's (1981), and OSHA Standards. (Table 1)

TABLE 1

Estimated Exposures (Exclusive of Respiratory Protection)
and Comparison to Existing Standards

ELEMENT	TLV	OSHA STD.	ESTIMATED EXPOSURE TO CONTAMINANT
Pb	150 ug/m^3	200 ug/m^3	0.3 ug/m^3
Be	2.0 ug/m^3	2.0 ug/m^3	0.5 ug/m^3
Ni	1000 ug/m^3	1000 ug/m^3	10 ug/m^3
Co	100 ug/m^3	100 ug/m^3	40 ug/m^3
Cr	500 ug/m^3	1000 ug/m^3	43 ug/m^3
SiO_2	100 ug/m^3* (resp.)	100 ug/m^3** (resp.)	145 ug/m^3

* Equivalent TLV (Resp.) - 1981 TLV Booklet P. 52

** Calculated from formula $\frac{10}{\% SiO_2 + 2}$ = mg resp. dust (use %SiO_2 = 100%)

7

The above results are constructs of concentrations likely to be found under the "worst case" conditions. They should not be construed as measurements of actual exposure. However, these results do indicate that potential exposures to respirable free silica (exclusive of respiratory protection) in excess of the TLV could occur. With similar assumptions, i.e. a free silica content of 2000 ug/g of slag, an eight hour exposure to respirable slag dust greater than 50 mg/m^3 would result in an exposure to free silica of greater than the TLV of 100 ug/m^3.

Nucleopore Samples

Of the 15 samples collected on one micro pore size, 37 mm dia. Nucleopore filter paper at a rate of 1.4 l/m, some as personal and others as area samples, the loadings on only four of these 15 samples were suitable for analysis by electron microscopy. These loadings have to be judged by inspection, and it was not until the samples were placed on the man's back instead of on his collar that acceptable samples were obtained, which consisted of three personal and one area sample. The personal samples usually ran one half hour to one hour. The area samples ran somewhat longer, and were collected whenever it was judged that they had the proper dust loading.

Electron microscopy in Table I, Appendix B shows partical sizing of several fields and a breakdown into general chemical types. The particle diameters reported ranged from 0.21 micron to 1.80 micron. These particles are all respirable and for practical purposes may be considered to range mostly between 0.5 and 1.50 microns.

Table II gives a "percent of particles containing specified Element". It should be noted that no beryllium is shown since the electron microscope probe can identify only those elements above atomic No. 11 (sodium). (Be has an atomic number of 4 and cannot be detected by this method). It should be noted that major constituents of these particles were Al, Si (as silicate), Ca, and Fe.

Table III - A condensed particle type summary, gives the number and percent of particles of different types. Most important is that in these samples particles were found ranging from 0.96 to 1.8% in the samples which were considered to be free silica. It is possible that the free silica particles which averaged 1.3% could have resulted from stirring up sand from the ground which was a residue from blasting with sand in previous operations.

Conclusions

Much dust resulted from abrasive blasting with coal slag at Land and Marine Enterprises. However, the blasters were equipped with a double protective respiratory system. This consisted of a disposable 3M type respirator worn over nose and mouth and a carbon filtered air supplied helmet fastened to a turtleneck type garment.

Though much dust is generated in the blasting operations, it rapidly falls to the ground. Non blasters working in the yard usually work at least 100' from the blasting operation and receive minimal dust exposure. For example dust measured at the property line, 80' from the blasting operation is shown

8<

on Table II to be 0.45 $\mu g/m^3$ or approximately one tenth of the nuisance dust standard of 5 Mg/m^3. Other area samples collected where men are working showed lower values.

Since respirable dust measurements were high in the vicinity of some operations, a theoretical calculation of exposures based on the analyses of toxic elements in the bulk slags were run which indicated that with potential respirable dust exposures as high as 72 mg/m^3 essentially all exposures to toxic elements would be below the current TLV's. This calculation however has no relation to operator exposure since as noted above the operators were supplied with double respiratory protection devices which essentially eliminates operator dust exposure. If, however, better work practices were employed, and if relatively comparable slags are used, dust generation could be lowered considerably.

Recommendations

After it was pointed out to the company that a few employees were consistently generating larger quantities of dust than were other blasters, they engaged the services of an expert abrasive blaster to train blasters in proper blasting techniques. It is recommended that this practice be continued as needed.

Based on the results of this survey, it is recommended that additional surveys be conducted at operations using other different types of slag used for abrasive blasting. Exposures which should be considered include free silica, and various toxic trace metals.

TABLE I
PERSONAL SAMPLES BZ's - RESPIRABLE DUST
LAND & MARINE ENTERPRISES, HARVEY, LA.
FEBRUARY 16-20, 1981

Operation	Sample #	Sample Time (min.)	Sample Rate 1.7 l/m (total liters)	Wt. of Resp. Sample (Mg)	Mg/m^3 Respirable dust	Mg Fe on Sample
Blasting Angle Iron	3202	227	386	2.17	5.62	0.220
Blasting 2"-8" Pipe	3197	250	426	1.49	3.51	0.094
Blasting Flanged Pipe 6"-8"	3203	270	459	2.17	4.73	0.120
Blasting Clamps and Gears	3205	150	225	0.76	3.38	0.110
Blasting Clamps and Gears	3195	270	459	1.31	2.86	0.094
U Clamp Blasting	3194	180	306	3.28	10.7	0.280
Blasting Pipe 1"-4"	3191	150	225	1.21	5.38	0.025
Blasting Pipe	3189	330	563	0.61	1.08	0.055
Blasting Angle Iron	3200	150	225	3.79	16.8	
Blasting Small Pipe	3196	65	111	0.54	4.86	0.068
Blasting Angle Iron	3190	150	225	16.37	72.7	1.200
Blasting Boat Bumper	3198	130	221	0.62	2.81	0.040
Blasting Pipe	3192	130	221	0.25	1.13	0.025
Blasting Pipe (standing on top of)	3185	120	204	11.16	54.7	0.750
Blasting Pipe (pumps on only short time)	3182	60	102	1.55	15.2	0.130
U Clamp Blasting	3201	N.G. - filter holder cracked				

TABLE II

AREA SAMPLES - GA's - RESPIRABLE DUST
LAND & MARINE ENTERPRISES, HARVEY, LA.
FEBRUARY 16-20, 1981

Operation	Sample #	Sample Time (min.)	Sample Rate 1.7 l/m (total liters)	Wt. of Resp. Sample (Mg)	Mg/m^3 Respirable dust	Mg Fe on Sample
Feb. 20 - Downwind - Fence Line	3186	210	357	0.14	0.39	0.012
Feb. 17 - Downwind of Blasting 150' (direction of wind varies)	3188	480	816	0.14	0.17	0.023
Feb. 19 - Downwind of Blasting 80' by Fence Line	3199	750	1275	0.58	0.45	0.058
Feb. 19 - Downwind of Blasting 150'	3184	750	1275	0.24	0.19	0.023
Blank	3183			0.03		< 0.012

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APPENDIX A

Analysis of coal slag used on survey compared with the analysis of a competitive coal slag.

CHEMICAL ANALYSIS OF STAN-BLAST VS. COMPETITIVE COAL SLAG

Element	Stan-Blast ug/g	Competitive (5) ug/g Coal Slag
Na	3430	3520
Mg	6248 (0.62%)	10500 (1.05%)
Al	10000 (1.0%)	10800 (1.08%)
Si	200000 (20.0%)	169000 (16.9%)
Ca	13300 (1.3%)	63000 (6.3%)
Mn	130	730
Fe	39400 (3.9%)	138000 (13.9%)
Cu	6	52
V	70	160
Zn	39	126
Mo	2.0	28
Co	70	29
Pb	4	15
As	1.1	33
Be	7.2	9.7
Ni	14	65
Cd	9	<0.08
Cr	60	121
Sn	11	16
Ag	7	0.08
Ba	100	1590 (0.16%)
Hg	3	<0.02
Se	1.1	2
B		3.20
SiO_2	<5000*	<2000

* Limit of detection by analytical method 0.5% SiO_2

APPENDIX B

Microscopic examination of dust generated by the blasting of unpainted steel with coal slag.

DEPARTMENT OF HEALTH & HUMAN SERVICES

Memorandum

Date June 22, 1981

From Chief, Biophysical and Particulate
Measurements Section, TSB

Subject Particle Size and Chemical Analyses of Filter Samples
Collected at Harvey, Louisiana (1-9278387)

To Research Industrial Hygienist, Industrial
Hygiene Section, Industry-Wide Studies Branch, DSHEFS
(ATTN: Harry Donaldson)
Through: Director, DSHEFS
Director, DBBS
Chief, Technical Support Branch

Fifteen filter samples collected at Harvey, Louisiana, during the week of February 17-20, 1981 were submitted for particle size and individual particle chemical analyses. The loading on four of the fifteen filters was suitable for these analyses. The loading on the rest of the filters was too heavy for analyses.

The four filters (N3186, N3195, N3200, and N3202 - your labels) were mounted on carbon planchets carbon coated, and examined in an ISI-Super III A scanning electron microscope equipped with a KEVEX 7000 x-ray analysis system and a LeMont Scientific Model DA-10 image analysis system. Over 1000 particles for each of these filters was sized and analyzed for 31 different elements by this system. The results of these analyses are summarized in Tables I-III. The diameters listed in Table I are the median circular area equivalent diameters.

The analyzed particles were classified according to their qualitative chemistry by the image analysis system. This system uses a specially constructed chemical definition file for this classification. A copy of this file is attached to one of the attached computer printouts. The principal particle types encountered in these samples were those considered slag (blasting agent) and iron oxides (surface being blasted). There were several different types of particles which were considered slags. The principal slag particle (Macro Class 2) was composed of Ca, Fe, Al, Si and in some cases K. A second class of slag particle (Macro Class 3) was similar but also contained varying amounts of S. The remaining slag particles (Macro Classes 4-7) were primarily composed of Fe, Al, and Si with varying amounts of S. These particles were divided into groups based upon the relative abundance of Fe and S. Two types of particles were found whose major component was Fe (Classes 9 and 11). These particles were considered to have come from the surface being blasted which was rusty iron. In general these iron containing particles were smaller than the slag particles.

6-30-81

A small number of particles which contained only Si as a major component were found in each sample. These particles are considered Free Silica. Three particle types; slags, those arising from the surface being cleaned; and Free Silica account for over 90% of the particles analyzed for each filter (see Table III). I suspect that many of the remaining particles also are derived from the slag but have slight variations in chemistry which would not allow them to be placed in the slag category by the image analysis system. Each of the attached computer printouts contain a further classification for these miscellaneous particles.

If you have any questions concerning this work, please call.

Lloyd E. Stettler

Lloyd E. Stettler, Ph.D.

Attachments:
Tables I-III
Computer Printouts

TABLE I

PARTICLE SIZE AND CHEMISTRY DATA

Particle Types	N 3186 Number	N 3186 Median Diameter (μm)	N 3195 Number	N 3195 Median Diameter (μm)	N 3200 Number	N 3200 Median Diameter (μm)	N 3202 Number	N 3202 Median Diameter (μm)
1. All Types	1020	0.95	1046	0.84	1030	0.63	1031	0.72
2. No x-rays	2	1.07	1	0.15	0	-	1	1.39
3. Slag (Ca, K)	480	1.50	710	0.98	631	0.72	616	0.84
4. Slag (Ca, K, S)	148	0.86	44	0.68	46	0.74	17	1.13
5. Slag (<50% Fe)	70	0.54	17	0.49	13	0.33	52	0.47
6. Slag (S,>50% Fe)	27	0.42	3	0.43	11	0.50	7	0.92
7. Slag (>50% Fe)	5	1.13	10	0.21	8	0.31	14	0.58
8. Slag (S,>50% Fe)	9	0.68	2	0.38	1	0.35	1	1.46
9. K(Fe) Al Si	4	0.58	8	1.07	12	0.58	16	0.67
10. Fe (Oxides)	83	0.64	101	0.64	163	0.58	167	0.64
11. Fe Silicate	10	0.24	8	0.71	3	0.30	5	0.43
12. Fe Rich	81	0.57	67	0.61	88	0.45	59	0.48
13. Free Silica	14	1.19	10	0.58	11	0.52	19	0.50
14. Fe Sulfide	8	0.58	9	0.55	2	0.47	9	0.64
15. Silicate (Al<Si)	11	1.27	7	0.79	6	0.52	10	0.71
16. Silicate (Al>Si)	5	0.64	5	0.64	1	0.97	7	0.35
17. Si Rich	8	0.58	13	1.13	10	0.38	8	0.43
18. Ca (Oxide/Carb)	0	-	1	1.80	0	-	2	1.07
19. Ti (Oxide)	0	-	0	-	0	-	2	0.21
20. Ca Sulfate	2	1.07	3	0.35	0	-	0	-
21. Miscellaneous	53	0.69	27	0.64	24	0.47	17	0.43

TABLE II

PERCENT OF PARTICLES CONTAINING SPECIFIED ELEMENT

	SAMPLE			
Element	N 3186	N 3195	N 3200	N 3202
Na	0	0.38	0.39	0
Mg	0.10	0.48	0.29	0.10
Al	79.8	81.8	75.2	73.1
Si	94.2	96.9	94.7	88.6
P	0.78	0.38	0.10	0.39
S	31.2	10.4	13.6	8.54
Cl	0.69	2.87	6.70	1.94
Ag	0	0.10	0.1	0.19
K	45.3	58.1	54.8	41.8
Ca	65.6	77.1	70.0	63.1
Ti	5.39	1.15	2.04	0.68
Cr	0.49	0.38	0.49	1.36
Mn	0.59	0.76	0.10	0
Fe	94.9	96.4	97.6	94.5
Ni	0	0.19	0.10	0
Cu	0	0	0.68	0.68
Zn	0.10	0.29	0.10	0
Pb	0	0.10	0	0.1
As	0	0.10	0	0

TABLE III

CONDENSED PARTICLE TYPE SUMMARY

	N 3186		N 3195		N 3200		N 3202	
Particle Type	Number	%	Number	%	Number	%	Number	%
Slag (Σ3–8)	739	72.4	786	75.1	710	68.9	707	68.6
Surface being cleaned (10 + 12)	164	16.1	168	16.1	251	24.4	226	21.9
Free Silica	14	1.4	10	0.96	11	1.1	19	1.8
Others	103	9.52	82	7.8	58	5.6	79	7.7