DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service
Centers for Disease Control
and Prevention (CDC)

Memorandum

Date: March 27, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program RMF
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 1 R03 OH003796-01.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications

Woolf, AD, Flynn, E: Workplace Toxic Exposures Involving Adolescents Aged 14 to 19 Years. Arch Pediatr Adolesc Med 154:234-239, Mar 2000

Title: Adolescent Toxic Exposures in the Workplace
Investigator: Alan D. Woolf, M.D.
Affiliation: Children's Hospital
City & State: Boston, MA
Telephone: (617) 355-5187
Award Number: 1 R03 OH003796-01
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Abstract:
While previous studies describe injuries to young adolescents occurring in the workplace, few focus on exposures to toxic substances. Yet low skill, entry-level jobs obtained by adolescents may pose the particular hazard of such exposures. Frequently, cleaning agents, solvents, paints and/or other chemicals are used by adolescents in these jobs to carry out their assigned tasks. Prevention of such incidents requires more information about their frequency and severity. However, job-related poisonings involving adolescents less than 18 years of age are unlikely to be reported either to federal or state agencies. Poison control centers sometimes get called about such toxic exposures and might serve as a resource for the surveillance of such injuries.

This study investigated toxic exposure incidents in the workplace involving adolescents less than 18 years, using a national database provided by poison control centers. The purpose was to describe the frequency and severity of such poisonings, the agents involved, and any variation by geography or over time. An analysis of occupational toxic exposures occurring in the United States between 1993-1997 was performed using the Toxic Exposure Surveillance System (TESS) database compiled by the American Association of Poison Control Centers. Contingency tables with the Chi square statistic were used to test bivariate associations. A linear regression of proportions was performed to investigate the trend over time in the frequency of such poisonings. Multiple logistic regression analysis was used to compare the severity of exposures between regions of the country.

Of 301,228 United States workplace toxic exposures occurring over this 5 year period, 8,779 (2.9%) involved adolescents less than 18 years of age. Males (63.9%) predominated; such toxic exposures were more commonly reported during the summer months (38.2% of all exposures occurred during June, July, and August), between the hours of 3-9 p.m. (45.7% of all calls), and as frequently during weekends as weekdays. The most common agents involved were: alkaline corrosives (13.2%), gases and fumes (12.1 %), cleaning agents (9.7%), bleaches (8.3%), drugs (7.4%), acids (7.1 %), and hydrocarbons (6.9%). In the majority of cases few symptoms developed and the patient could be managed at the workplace or at home (60.0%); however 37.0% of these children were assessed in a hospital emergency department and 3.0% required at least a brief hospitalization. In 14.2% of cases, the toxic injuries sustained were rated as moderately severe and 0.3% resulted in life-threatening symptoms; there were 2 deaths. Linear

regression analysis of weekly proportions suggested that the frequency of occupational exposures occurring among adolescents versus exposures among adults increased over time (r2=0.03; p=0.003). More exposures overall were recorded in Southern states (32.5%) than other regions of the country, although a greater proportion of the severe exposures were reported from Central states (17.6%) compared to other regions of the country (mean=14.5%; p=0.001).

This study found adolescent workplace toxic exposures to be a significant public health concern, accounting for almost 3% of all occupational toxic exposures reported to U.S. poison control centers. Such injuries more often involved males and more frequently occurred during evening hours and during summer months. Agents most often implicated were noxious gases and fumes, caustic chemicals, cleaners and bleaches. While many exposures were medically trivial, some required evaluation in a health care facility or hospitalization. A significant number of severe injuries were attributable to dermal or eye exposures to caustic substances. These adolescent toxic exposures were more common in Southern states but more severe in the Midwest region of the United States. The proportion of exposures involving teens increased from 1993-1997 in all sections of the United States, relative to occupational poisonings involving adults. This trend may reflect an increasing number of such exposures, an increasing number of adolescents working, and/or an increased utilization of poison control centers.

This study also confirms the usefulness of poison control center-derived data in describing and monitoring workplace exposures involving adolescents that might not be reported elsewhere. These are sentinel events that suggest an even larger underlying problem involving business establishments that employ children. Further study is needed to define more precisely the circumstances surrounding such toxic exposures, the determinants of which adolescents at high risk, and the preventive strategies needed to avert some of these injuries.

Publications

Woolf, AD, Flynn, E: Workplace Toxic Exposures Involving Adolescents Aged 14 to 19 Years. Arch Pediatr Adolesc Med 154:234-239, Mar 2000

ADOLESCENT OCCUPATIONAL TOXIC EXPOSURES IN THE WORKPLACE

Final Report on National Institute of Occupational Safety and Hygiene NORA Grant # R03 OH03796-01.

Date: March 31, 2000

Principal Investigator: Alan Woolf, M.D.,M.P.H.[*,***]

Coinvestigator: Anjali Garg, B.S.[∞, ***]

Coinvestigator: Hillel Alpert, M.P.H.[**]

Coinvestigator: Samuel Lesko, M.D.,M.P.H.[^]

Institutions: Harvard Medical School[*], Harvard School of Public Health[∞], Boston's Children's Hospital[*], Boston University School of Medicine[^], Vital Sciences Inc[**], and the Massachusetts Poison Control System[***], all in Boston, Massachusetts 02115

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LIST OF ABBREVIATIONS

AAP – American Academy of Pediatrics

AAPCC – American Association of Poison Control Centers

CPSC – Consumer Product Safety Commission

OSHA – Occupational Safety Health Administration

TESS – Toxic Exposure Surveillance System

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SIGNIFICANT FINDINGS

1. There were 301,228 occupational toxic exposures reported to United States poison control centers between 1993-97, of which 8779 (2.9%) involved adolescents 12-17 years of age, 19,521 (6.5%) involved young adults 18-20 years old, 255,574 (84.8%) involved adults, and 17,354 (5.8%) were of unknown age.
2. The most common months for adolescent occupational toxic exposures were July and August.
3. The most common times of day for these events were 3-9 p.m., accounting for almost 45% of all reports.
4. Males were over-represented as victims of these toxic exposures almost 2:1 over females. Toxic exposures involving males resulted in more severe adverse medical effects than those involving females.
5. In 20% of these exposures, the adolescents remained without symptoms. Over 50% could be managed outside of a health care facility at their home or on the job. Another 47% were treated in an emergency department and released; 2.2% required hospitalization and there were 2 deaths recorded.
6. The most common agents involved in adolescent toxic exposures were: gases and fumes, alkaline and acid agents, bleach, hydrocarbons, cleaners, pesticides, soaps, chemicals (not otherwise specified), and medications.
7. Only 13.2% of the adolescent exposures resulted in moderate to severe medical injuries. The most common agents involved in exposures resulting in a severe toxic effect were: gases and fumes, alkaline and acid agents, and hydrocarbons. Other

predictors of severity included: the route of exposure (dermal exposures, eye , and inhalations were more severe).

8. A disproportionately high number of toxic exposures occurred in the Midwest compared with other regions of the United States; a disproportionately high number of exposures resulting in severe medical effects occurred in the South.

9. The proportionate frequency of adolescents with toxic exposures in the workplace appeared to be rising compared with that of adults over the time span of 1993 to 1997.

USEFULNESS OF FINDINGS

Poison center generated data represents a valuable source of national surveillance defining occupational toxic exposures that involve young adolescents. By determining the effectiveness of Poison Control Center operations as a mechanism for surveillance of adolescent occupational exposures through a range of populations and services configurations, this study informs the national debate concerning the vulnerability of children in the workplace to toxic injury and gives evidence-based arguments being developed in the pursuit of national consensus-building. Of all occupational toxic exposures reported to U.S. poison control centers between 1993-97, almost 3% involved adolescents 12-17 years old. Such injuries most often involve males exposed to fumes, caustics, cleaners or bleach. Many such exposures were judged as resulting in moderate to severe injury, although only 3% of cases required hospitalization; there were 2 related deaths.

This report also uncovered the fact that caustics account for a significant number of such toxic exposures, often dermal exposures or eye splashes. Such injuries are preventable by wearing protective clothing and safety glasses or goggles. Appropriate orientation and safety precautions would be helpful to adolescents engaged in work involving cleaners, solvents, caustics, and other chemicals. Moreover this study provides evidence which could be used to communicate to small businesses and other teen employers their need to comply with the worker 'right to know' regulation of adolescent workplace experiences.

Finally this study found a disturbing increasing trend in the relative frequency of such toxic exposures among adolescents vs. adults. The proportion of occupational toxic

exposures among young adolescents appeared to be increasing between 1993-97. This finding needs to be further investigated. There could be many reasons for the trend. It could be that more adolescents are gainfully employed in a tight labor market, giving them more opportunities to become victims of a toxic exposure. It could also be that the same tight market is causing employers to ask teens to perform different tasks on the job, involving chemicals more frequently, because they do not have enough experienced adults who formerly would do such work. A increase in frequency could also be explained by improved familiarity of the population with the services offered by poison control centers, such that families and health care professionals are utilizing them more and reporting toxic exposures more often than in past years.

Adolescent occupational exposures to toxins are an important but under-recognized injury category; poison control center data can be used to fill in gaps in surveillance for this type of worksite-associated injury.

PRESENT & FUTURE PUBLICATIONS

A manuscript describing the pilot study of Massachusetts adolescent occupational toxic exposures was published in the Archives of Pediatric & Adolescent Medicine in March, 2000 and is attached to this report. Two other manuscripts describing the study are in preparation:

1. Descriptive study of adolescent occupational toxic exposures
2. Study comparing occupational toxic exposures between adolescents vs adults

The results of the national study were presented in part at the meeting of the National Congress of the American Association of Clinical Toxicologists (NCAACT) in La Jolla, California, held on October 1-5,1999. Two abstracts describing the research were published in the Journal of Toxicology Clinical Toxicology (1999; vol 5). Abstracts describing portions of the work are also submitted for the national meetings of the NCAACT to be held in September 2000, and the fall meeting of the American Academy of Pediatrics, to be held in October 2000. This will allow wide dissemination of the results of this work to health professionals concerned with poisoning prevention and also those charged with safeguarding the health of adolescents.

ABSTRACT

Background

While previous studies describe injuries to young adolescents occurring in the workplace, few focus on exposures to toxic substances. Yet low skill, entry-level jobs obtained by adolescents may pose the particular hazard of such exposures. Frequently cleaning agents, solvents, paints and/or other chemicals are used by adolescents in these jobs to carry out their assigned tasks. Prevention of such incidents requires more information about their frequency and severity. However job-related poisonings involving adolescents less than 18 years of age are unlikely to be reported either to federal or state agencies. Poison control centers sometimes get called about such toxic exposures and might serve as a resource for the surveillance of such injuries.

Objective

This study investigated toxic exposure incidents in the workplace involving adolescents less than 18 years, using a national database provided by poison control centers. The purpose was to describe the frequency and severity of such poisonings, the agents involved, and any variation by geography or over time.

Methods

An analysis of occupational toxic exposures occurring in the United States between 1993-97 was performed using the Toxic Exposure Surveillance System (TESS) database compiled by the American Association of Poison Control Centers. Contingency tables with the Chi square statistic were used to test bivariate associations. A linear regression of proportions was performed to investigate the trend over time in the frequency of such

poisonings. Multiple logistic regression analysis was used to compare the severity of exposures between regions of the country.

Results

Of 301,228 United States workplace toxic exposures occurring over this 5 year period, 8,779 (2.9%) involved adolescents less than 18 years of age. Males (63.9%) predominated; such toxic exposures were more commonly reported during the summer months (38.2% of all exposures occurred during June, July, and August), between the hours of 3-9 p.m. (45.7% of all calls), and as frequently during weekends as weekdays. The most common agents involved were: alkaline corrosives (13.2%), gases and fumes (12.1%), cleaning agents (9.7%), bleaches (8.3%), drugs (7.4%), acids (7.1%), and hydrocarbons (6.9%). In the majority of cases few symptoms developed and the patient could be managed at the workplace or at home (60.0%); however 37.0% of these children were assessed in a hospital emergency department and 3.0% required at least a brief hospitalization. In 14.2% of cases, the toxic injuries sustained were rated as moderately severe and 0.3% resulted in life-threatening symptoms; there were 2 deaths. Linear regression analysis of weekly proportions suggested that the frequency of occupational exposures occurring among adolescents versus exposures among adults increased over time (r^2 0.03; p=0.003). More exposures overall were recorded in Southern states (32.5%) than other regions of the country, although a greater proportion of the severe exposures were reported from Central states (17.6%) compared to other regions of the country (mean 14.5%; p=0.001).

Discussion

This study found adolescent workplace toxic exposures to be a significant public health concern, accounting for almost 3% of all occupational toxic exposures reported to U.S. poison control centers. Such injuries more often involved males and more frequently occurred during evening hours and during summer months. Agents most often implicated were noxious gases and fumes, caustic chemicals, cleaners and bleaches. While many exposures were medically trivial, some required evaluation in a health care facility or hospitalization. A significant number of severe injuries were attributable to dermal or eye exposures to caustic substances. These adolescent toxic exposures were more common in Southern states but more severe in the Midwest region of the United States. The proportion of exposures involving teens increased from 1993-97 in all sections of the United States, relative to occupational poisonings involving adults. This trend may reflect an increasing number of such exposures, an increasing number of adolescents working, and/or an increased utilization of poison control centers.

This study also confirms the usefulness of poison control center-derived data in describing and monitoring workplace exposures involving adolescents that might not be reported elsewhere. These are sentinel events that suggest an even larger underlying problem involving business establishments that employ children. Further study is needed to define more precisely the circumstances surrounding such toxic exposures, the determinants of which adolescents at high risk, and the preventive strategies needed to avert some of these injuries.

Occupational toxic exposures involving adolescents are an under-recognized hazard in the United States. Poison control center experience can be used to fill a gap in the surveillance of such injuries.

Body Of Paper

Young adolescents in America are fully involved as workers with part-time, seasonal, or full-time jobs. More than 5 million American children and adolescents are legally employed and another 1-2 million are employed in violation of provisions of the Fair Labor Standards Act (FLSA). [1] Child labor is resurgent in the United States due to a variety of factors, including increased immigration, the increased need for family income, a robust economy and employers' increased needs for unskilled help, and social acceptability of work among adolescents and their desire for disposable income. [2-4]

Cross-sectional studies of injuries related to child labor frequently do not itemize information about toxic exposure, although some have pointed out the higher injury risk to adolescents working under stress in the service industry of fast-food and full-service restaurants, citing solvent and chemical exposures, caustic burns, and other hot liquid burns among the particular health hazards.[5] Schober[6] reviewed compensation award claims in 24 states concerning work-related injuries to minors; of almost 24,000 injuries in the 3 years of study, there were 722 claims involving liquids, 995 involving food products, and 5840 in an 'other' category that could have involved toxic exposures but were not analyzed in detail. An analysis of 37,400 injuries among 14-17 year olds reported to the Consumer Product Safety Commission (CPSC) and the Occupational Safety and Health Administration (OSHA) over a 6 month period included 3553 burns, of which 14.8% were from exposure to caustic liquids.[7] A Massachusetts study of workers' compensation injury claims among adolescents reported 29 of 2551 injuries were due to chemical burns.[8] In a review of NY State workers' compensation awards to adolescents 14-17 years old from 1980-83, Belville et al included 49 teens with chemical burns

(28.6% permanently disabled) and 17 cases of poisoning (11.8% permanently disabled) among the 9656 reports.[9]

Such data may seriously undercount the number of toxic exposures since many adolescent jobs are not covered by workers' compensation and many poisonings occurring in small, unmonitored businesses would go unreported to OSHA. While workmen's compensation claims, Occupational Safety Health Administration (OSHA) reports, and other sources provide some information, they often do not include injuries that might be sustained by children less than 18 years old and/or those adolescents working in small businesses, homes, and other establishments, for which mandatory reporting regulations do not apply or are not enforced. Blanc has estimated that the incidence of occupational illness in the United States may be 3-5 times higher than that captured from these incomplete sources.[10]

Poison control centers in the U.S. can collect data on product safety and perform surveillance activities with relevance to occupational toxic exposures.[11-15] These agencies submit patient-related data annually to the American Association of Poison Control Centers (AAPCC), a non-profit organization concerned with setting high standards for poisoning control and prevention. A pilot study in Massachusetts revealed 269 adolescent occupational toxic exposures were reported to a single poison control center over a 6 year period.[16] The objective of the current study was to extend the scope of the surveillance so as describe the types, severity, and trends over time of adolescent workplace toxic exposures occurring in the United States, as documented in data collected nationally by the AAPCC.

Methods

a. TESS Database

A secondary analysis of 1993-97 Toxic Exposure Surveillance System (TESS) data-set maintained by the AAPCC was performed. The number of poison control centers participating in the TESS database was 64 centers in 1993 (covering 70% of the United States population)[17] , 65 in 1994 (covering 83% of the population)[18], 67 in 1995 (covering 83% of the population)[19], 66 in 1996 (covering 93.5% of the population)[20], and 67 in 1997 (covering 91.1% of the population)[21]. Occupational toxic exposures in the United States were identified by the site of the incident (the workplace) or by the circumstances given by the caller as a reason for the exposure (occupationally-related). Exposures were stratified by age and toxic agent(s) involved.

The TESS database has been operational since the early 1980's. Elements within the database were expanded in 1993 to add additional details with respect to the symptoms experienced by patients. At the same time, the list of management options was increased to include specific antidotes and other treatment strategies. A guide of rules and protocols for coding decisions is uniformly used by poison control centers to reduce variation in the coding of data. [22] Variables of interest available to the present study within the database include:

a. Date & Time of Call
b. Poison Center Identity – gives geographical location of the poison control center to which the original exposure call was placed
c. Site Of Exposure – limited to the workplace, for the purposes of this study

d. Site Of Caller – includes whether call to poison control center originates from the home, school, workplace, or other site

e. Age & Gender Of Patient

f. Circumstances – include the determination as to whether the exposure was the result of an intentional or unintentional poisoning, an adverse effect of the proper use of a product, intentional misuse of a product, or a suicide attempt

g. Toxin – includes provision for two separate identified toxins

h. Route Of Exposure – ingestion, inhalation, dermal, ocular, parenteral routes

i. Initial Triage & Disposition – whether patient remained at home or was seen in a health care facility

j. Symptoms – arranged by body system (e.g. cardiac, pulmonary, nervous system) and symptoms (e.g. irritation, rash, shortness of breath, etc.)

k. Medical Interventions – includes specific antidotes and supportive measures

b. Groupings Of Toxic Agents, Outcomes, Seasons & Geographical Areas

For certain analyses, toxins implicated in the exposure were classified into 18 broad descriptive categories:

Cleaners (not including bleach)	Stings & Bites
Acids	Plants
Alkali	Hydrocarbons
Pesticides/Rodenticides	Foreign Bodies
Herbicides	Refrigerants (Freon)
Bleaches	Drugs
Paints, Inks, Dyes, Paint Thinners	Glues/Pastes

Miscellaneous Chemicals	Soaps & Detergents
Fire extinguishers	Gases & Fumes

Examples of how these individual products were grouped into the larger categories are shown in Table 1.

Medical outcomes defined previously by the American Association of Poison Control Centers[22] include:

No Effect - The patient developed no symptoms as a result of the exposure.

Minor Effect - The patient exhibited some symptoms, but they were minimally bothersome to the patient. The symptoms resolved rapidly.

Moderate Effect - The patient exhibited symptoms which were more pronounced, more prolonged, or of a more systemic nature than minor symptoms but were not life threatening. Usually some form of treatment was indicated.

Major Effect - The patient exhibited some symptoms that were life threatening or resulted in significant residual disability or disfigurement.

Not Followed, Judged as Nontoxic Exposure - The patient was not followed because the substance was judged to be non-toxic.

Not Followed, No or Minimal Medical Effects Possible - The patient was not followed because the exposure was likely to result in only minimal toxicity.

Unable To Follow, Judged as a Potentially Toxic Exposure - The patient was lost to follow-up and the exposure was significant and may have resulted in toxic manifestations with a moderate, major, or fatal outcome.

Other data elements were transformed as follows in order to facilitate analysis:

Season: months were regrouped into winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November)

Geography: States were grouped by region according to poison control center catchment area as follows:

NORTHEAST: MA, NH, RI, NY, NJ, CT, PA

SOUTH:MD,VA,GA,FL,AL,TX, NC, WV, TN, DC, KY, LA, DE

CENTRAL: OH, IN, IL, IA, KS, MI, MN, MO, ND, SD, WI, NE

WEST: CA, AZ, CO, NM, OR, WA, UT, NEV, ID, MON, WY

During the years of study, Maine, Vermont, Mississippi, Arkansas, South Carolina, Oklahoma, Alaska and Hawaii cases were not reported to TESS and so are not included in this analysis.

c. Exclusions

Those cases in which only information was sought, without evidence of a human toxic exposure, were excluded from the study. The analysis reported here was limited to records concerning children between 12-17 years of age, although a coincident validation study included cases outside of this age range.

d. Validation Study

A sample of 900 medical records of the 72 poison control centers was ascertained by a computer-generated random selection based on medical record number. The original paper records were then solicited from participating poison control centers in the United States. Nine relevant variables were compared: agent type, age, exposure site, caller site, reason for the call, route of exposure, duration of effect, and outcome. The original

medical records returned from participating poison control centers were redacted according to written AAPCC guidelines [22] by a trained research assistant who was unaware of the coded electronic choices entered into TESS. The data from the original medical records were compared with those previously entered into the TESS database. The extent of correlation with each comparison was assessed using the kappa statistic.

Thirty-five (35) of 72 poison control centers (45%) participated in sending 453 cases (50%) for analysis. Of these, 31 records could not be interpreted. There were 422 cases (93.2%) with all variables available. Table 2 gives the percent agreement and kappa coefficients of agreement. Of all nine route categories combined, 3757 of 3798 observations were in agreement. The intraclass correlation coefficient was 0.77 for age, for example.

Of those case variables with discrepancies, only outcome showed a percentage agreement of less than 80% and a kappa less than 0.666. Those variables were investigated in greater depth to determine what the mismatches in choices were. Table 3 presents the most common mismatches.

e. Statistical Methods

STATA v.6 for microcomputers (College Station, Texas) was used for data analysis. Contingency table analyses with the X statistic were used to test bivariate associations. A two-tailed alpha was set at 0.05 to establish statistical significance. A linear regression of proportions was performed to investigate trends over time in the frequency of such poisonings. Multiple logistic regression analysis was used to compare the severity of exposures between regions of the country. A separate validation study

(manuscript in preparation) of the TESS database confirmed exposure types and circumstances.

This study was approved by the committee on clinical investigation at Children's Hospital, Boston. It was also authorized by the board of directors of the American Association of Poison Control Centers.

Results

Figure 1 shows the flow of the data assessed in this study. There were 301,460 occupational exposure cases reported to TESS in 1993-97, of which 232 cases were invalid and excluded from the study. Another 17,354 cases were excluded because of incomplete age information and 275,095 were outside the inclusive age criteria. This left a total of 8,779 poisonings (2.9% of the total) among children 12-17 years of age, which formed the basis for further analysis. Total cases rose in each of the first four years under study to a peak of 1993 exposures reported in 1996, then falling slightly to 1858 reports in 1997.

We performed a separate analysis of the contribution of each poison control center to the TESS database over the study period. Of 75 poison control centers who submitted data in at least one of the five years under study, 17 centers (23%) had at least one year of missing data and five centers (6.7%) submitted data for only one out of the five years. Those poison control centers participating in all five years showed year-to-year consistency in the number of cases reported.

Age & Gender

Figure 2 shows the trends in the number of cases reported to poison control centers, by gender and year, for 8758 cases (in 21 cases, gender was not specified). Males

predominated, accounting for 63.9% of the exposure incidents. Figure 3 presents the age-related data. The median age of the sample was 16 years old; however 287 cases (3.3%) involved 12 year olds and 2093 cases (23.8%) involved adolescents under the age of 16 years. Table 4 shows gender differences related to the toxic agents involved in the exposures. Workplace exposures among both groups commonly involved alkali, gases and fumes, cleaners, and acids. However females were more likely to suffer toxic exposures involving medications (10.5% vs. 5.7%; $p \leq 0.001$) and were less likely to suffer toxic occurrences involving hydrocarbons (3.7% vs. 8.8%; $p \leq 0.001$).

Season, Time of Day, Site of the Caller

Adolescents were most likely to suffer toxic exposures during the summer months (38.2% of the total occurred in June, July, August); exposures were reported during weekends as frequently as during weekdays. 25.0% of these incidents occurred between 6-9 p.m.; another 20.7% occurred between 3-6 p.m. The initial call to the poison control center was made from the home in 41.7% of cases and from the workplace in 28.3%; 23.3% of the initial calls to poison control centers were made from a health care facility.

Trend in Frequency

Linear regression analysis of weekly frequencies demonstrated a trend toward a proportionate increase in exposures among this age group from 1993-1997 (r^2 0.21, $p<0.001$) relative to those of adults 21 years or older, whose proportionate frequency fell during the same period of time (r^2 0.13; $p=0.003$). This comparison of the two trends can be seen in the graph shown on Figure 4.

Toxic Agents

Figure 5 gives the frequencies of some of the toxic agents involved in these exposures, by route of exposure. In this determination, only the first agent entered into the record (if there was more than one agent involved) was counted per incident and the 18 categories of toxins were collapsed into the 10 specific categories that were most frequently specified and a 'miscellaneous chemicals' and 'others' categories. The most common adolescent exposures were to alkaline corrosives (13.2%), gases and fumes (12.1%), cleaning agents (9.7%), bleaches (8.3%), drugs (7.4%), acids (7.1%), and hydrocarbons (6.9%).

A second toxic agent (e.g. bleach + ammonia) was implicated in the exposure in 862 (9.8%) of the adolescent cases. As shown in Figure 5a, there were no clear trends in the frequencies of toxic agents involved in these exposures from year to year.

Route of Exposure

Of the 8779 cases, 34.9% involved toxic inhalations, 26.8% were ocular exposures and another 23.6% were skin exposures. There were 19.3% oral ingestions; 2.4% involved bites or stings. In 0.7% of incidents, a parenteral route was reported; in 0.3% the patient aspirated a toxin. In 0.7% of cases, the route of exposure was unclear. More than one route of exposure (e.g. a chemical splashed both in the eyes and on the skin) was reported in 7.7% of cases. As shown in Figure 5 ocular splashes and dermal exposures comprised a common route of exposure for many toxins encountered by adolescents in the workplace. Over 71% of the exposures to alkaline agents, 71% of exposures to cleaners, 71% of exposures to soaps and detergents, and 55% of exposures to acids involved dermal or ocular splashes. Exposures to bleach included a number of

inhalations (39%) and ocular contacts (41%), with a smaller number of dermal exposures (11.5%) and ingestions (15.3%).

Symptoms of Toxicity & Management

In 7176 (81.7%) of the incidents, adolescents reported that they developed some symptoms as a result of the exposure incident. Ocular or dermal irritations were the most commonly reported symptoms (25.9% and 12.5% of all reported symptoms respectively). Other dermal symptoms were also common, including erythema (7.2%), burns (7.1%), swelling or edema (2.6%). Respiratory or throat symptoms were also common, with 9.5% of adolescents reporting coughing or choking, 6.7% reporting throat irritation, 4.7% reporting dyspnea, and 2.6% reporting chest pain. Gastrointestinal complaints included nausea (11.6%), vomiting (7.3%), and abdominal pain (2.8%). Headache (8.8%) and dizziness (6.0%) were also frequently reported. Therapies were offered in 81.1% of all cases. These included dilution or irrigation (57.8%), fresh air (19.8%), oxygen (3.2%), antihistamines (1.2%), bronchodilators (1.3%), intravenous fluids (1.2%), and other therapies (19.2%).

Triage

As shown in Figure 1, 50.7% (4451 of 8779) of these toxic exposures were managed on site (either at the workplace or at home). Another 47% of patients were treated and released from the emergency department of a health care facility; less than 2.2% (189 patients) required admission to the hospital.

Severity

The outcomes in 8.4% of the cases were coded as resulting in no toxic effect or were deemed to be nontoxic incidents by poison center staff. In 65.8% of cases only

minor injurious effects were the reported or expected outcome of the incident. However in 13.5% of cases, the toxic exposures resulted in injuries coded as a moderate or major effect, with another 6.6% coded as having potential for toxicity, but the poison center staff were unable to contact the patient for follow-up information. In 5.6% of cases the symptoms reported were judged to be unrelated to a toxic exposure. Severity varied by the toxic agent involved, as shown in Table 5 and Figure 6. The highest percentage of cases with severe injury outcomes involved alkaline products (27.6% of the total resulted in moderate or major toxic outcomes), acids (20.7%), glues and pastes (19.0%), herbicides (17.6%), gases and fumes (17.4%), cleaners (16.8%), pesticides (15.6%), miscellaneous chemicals (15.4%), soaps and detergents (15.4%), and bleach (13.6%). Many of the more severe injuries from workplace exposures among adolescents involved dermal or ocular splashes, or inhalation-related injuries.

Severity of injury from adolescent workplace toxic exposures did not vary significantly either by season or year. However 16.4% of the males with toxic exposures suffered severe injuries vs. 13.85% of females (X^2 8.87; p=0.003). Table 6 shows the results of multivariate analyses in the associations between selected variables and the outcome of moderate or major severity. There were no associations found between severity and the month, day, or year of occurrence. However those toxic exposures that did not involve the oral route were more than twice as likely to be more severe (odds ratio 2.63; 95% CI 2.14 to 3.24) and those that occurred in the morning (OR 1.34; 95% CI 1.17 to 1.54) and involving males (OR 1.08; 95% CI 1.03 to 1.13) also resulted in more severe toxic effects.

Of those cases in which clinical symptoms were reported, the duration of the effects lasted <2 hours in 34.3% of cases and one day or less in 80.9%.

Geographic Variations

Table 7 shows the distribution of workplace toxic exposures by age across four different geographic regions in the United States. The most toxic exposures during this five year period were reported from the South (32.5% of the total) and the least from the Northeast (12.7%) ($p<0.001$). Midwest states reported more toxic exposures among 16 and 17 year olds than any other sections of the country; whereas more toxic exposures involving 12-15 year olds were reported from states in the South.

Figure 7 shows the percentages of males involved in adolescent workplace exposures and the percentages of toxic exposures causing severe medical injury, given by region of the United States. Males predominated in adolescent workplace poisonings occurring across the United States, particularly in the Midwest where they comprised two-thirds of the exposures. Although more toxic exposures were reported from states in the South, comparatively more severe exposures occurred in the Midwestern states, where poison control centers reported that 17.6% of 1877 toxic exposures had a severe medical outcome, as opposed to 15.8% in the West, 14.5% in the Northeast, and 13.5% in the South (Pearson X^2=16.57, df=3, p=0.001). Multivariate analysis, adjusting for other variables (year, month, day of the week) , revealed that living in the Midwest region of the United States was associated with a greater risk of moderate or major injury from an adolescent workplace toxic exposure (17.6% vs. 14.5%) (Pearson X^2 16.5564; p=0.001).

Figure 7 also shows regional variations in the type of toxic agent involved with such exposures. There was considerable consistency in the agents that ranked among the

most frequent associated with toxic injuries throughout the country, with caustics, cleaners, bleach, gases and fumes, drugs, and hydrocarbons all over-represented in the data. The highest percentage of exposures in the West, Midwest, and Northeast involved alkaline agents, whereas those in the South more often involved exposures to gases and fumes ($p<0.001$). Toxic exposures to plants accounted for 5.8% of incidents reported from the South, but were not among the seven most frequent agents reported elsewhere. Hydrocarbons accounted for more exposures in the Northeast than elsewhere, and cleaners and bleach ranked higher among frequent agents implicated in the West. Figure 8 shows the regional differences in toxic agent frequencies among the entire 18 categories of toxins (representing 88% of the total, the remainder being due to an 'other' category). Comparative differences between regions is evident, with herbicides responsible for more of the toxic exposures in the Midwest and paints, dyes, inks, and thinners being more frequently implicated in the Northeast. Exposures to gases and fumes and plants were more frequent in the South, while the West demonstrated a higher percentage of exposures to alkaline agents, cleaners, bleach, and biting or stinging animals.

Figure 9 shows for each region of the country the percentage of exposures reported to have severe medical outcomes (not including those exposures that might have resulted in severe injury but could not be followed up by poison control centers) by year. Trends were apparently over time only in the Midwest, where the percentage of severe injuries steadily dropped from 22.5% in 1993 to 13.3% in 1997. By contrast, the frequency of severe injuries in the Northeast rose from 10.9% of exposures in 1993 to 15.6% by 1997.

Figure 10 explores the trends in all adolescent workplace toxic exposures over time. An analysis using linear regression of monthly proportions of adolescent workplace exposures, relative to workplace toxic exposures among all ages, shows a gradually rising trend all regions, most pronounced in the Midwest (R^2 0.1195; p=0.007).

Deaths

There were 2 reported deaths, both of which involved exposures to caustic agents. In one, a 13 year old male was taken to the emergency department after inhaling acid fumes while at work. He experienced respiratory arrest, coma, and cardiac arrest, and did not respond to cardiopulmonary resuscitation. The other involved a 16 year old male who swallowed an alkaline corrosive agent which he thought was a beverage while he was working laying bricks at a construction site. The potassium hydroxide mixture was in a milk jug that he obtained from the back of a truck. He vomited, aspirated and developed respiratory arrest. He also suffered oral and esophageal burns, chest and abdominal pain, pneumonia, and suffered a cardiac arrest. Despite intensive medical support, including artificial ventilation and vasopressors, the patient succumbed. No information about the specific circumstances of the workplace was available in either case.

DISCUSSION

This study supports a role for poison control centers in the United States in conducting surveillance of occupational toxic exposures among adolescents. The proportion of work-place toxic exposures occurring among adolescents reported here (2.9%) is similar to the proportion reported previously (3.8%) in the pilot study conducted by the Massachusetts poison control center.[16] The findings reported here extend the observations, to include more information about gender differences, severity,

regional differences, and trends over time regarding adolescent workplace toxic exposures.

The risk factors associated with agents of injury and both the physical and social environments to which adolescents are exposed in the workplace are incompletely understood.[23,24] According to Baker *et al*, the first step in ascertaining determinants of risk should be to implement surveillance (i.e. using poison control center data) so that we can then actively intervene to prevent these conditions.[25] The male predominance in the current study could be explained by their greater participation in part-time employment, although estimates of adolescent employment probably undercount participation by both males and females making it difficult to speculate about employment rates between the sexes. Observations that males were over-represented in those toxic exposures resulting in severe injuries also suggests differences in the categories and types of jobs in which they are employed. Since circumstances and identification of the workplaces involved in these reports were not specified in the data, such differences are speculative at best. However if males are more likely to be employed in construction, automotive, agricultural and landscaping work, and painting activities, then this could account for their exposure to more potent toxins such as caustics, hydrocarbon solvents, pesticides and herbicides, and heavy metals, paints, and thinners respectively.

The most frequently involved toxic agents were in many cases also those accounting for the highest percentage of severe injuries: caustics (acids and alkalis), gases and fumes, cleaning compounds, bleaches, pesticides, and soaps and detergents deserve the particular attention of public health officials, because of their frequent use by adolescents, their inherent toxic potency and because precautions can be taken to prevent

such mishaps. Significantly many of the poisoning incidents described in this report involved dermal exposures and/or ocular splashes, exposures that can be prevented by the appropriate use of barrier clothing, gloves and goggles.

There were two deaths reported in this study; both involved ingestion of caustic liquids, in one case a solution of potassium hydroxide swallowed when mistaken for a beverage. There are other reports of adolescent deaths from work-site toxic exposures.[26,27] In a review of 104 work-related deaths in children reported to OSHA, 4 teens died while exposed to chemicals: 2 were asphyxiated while sniffing trichloroethane on the job, 1 was asphyxiated while sniffing nitrous oxide, and 1 was killed in an explosion after he lit a cigarette while using a lacquer thinning chemical.[28] There are few systematic fatality studies of such injuries in the United States. In one investigation of North Carolina medical examiner's cases from 1980-89, Dunn and Runyan discovered 71 children aged 11-19 years who died from on-the-job injuries, including 5 who died from a poisoning.[29] An analysis of the National Traumatic Occupational Fatalities surveillance system from 1980-89 discovered 20 deaths from poisoning in male 16 and 17 year olds, for a rate of 0.28 deaths per 100,000 full-time equivalents.[30] Some poisoning fatalities are reported to poison control centers during the follow-up of active cases. Many others, both hospital and out-of-hospital deaths, are not reported because it is not mandatory and there is no perceived need by the health professionals at the scene for a consultation. Previous studies have documented the incompleteness of poison control center adult fatality reporting.[31] Thus this study can comment only descriptively on the two fatalities in the data-set.

The voluntary, passive nature of reporting to poison centers make them less reliable sources of information concerning poisoning-related workplace deaths involving adolescents.

We noted some variations between sections of the country with regard to the frequencies and types of toxic exposures occurring among adolescents. It is unclear why such toxic exposures should be a more prominent problem in the South or why more severe injuries related to such exposures are a problem in the Midwest. One might speculate that regional differences in the number of youth employed, the types of jobs they obtain, and their orientation to safety aspects of the work could account in part for such variation. For example, pesticides seemed a more prominent cause of injury in the Southern states. Whether or not this reflects a greater percentage of adolescents working on farms or in agricultural or horticultural industries should be further investigated. Many farm injuries among minors may have previously gone unreported;[32] Wilk notes the theoretical risk to children working on farms in the use of toxins such as caustics and pesticides in agricultural activities.[33] Yet there was also remarkable similarities between regions of the United States with respect to such aspects as the most frequent agents involved, the predominance of males, and the trends towards increasing frequencies of these workplace toxic exposures over time.

There are some limitations to this study, which dictate that the results be interpreted with caution. Comparisons from year to year should be valid, since the catchment areas and poison control centers contributing cases remained relatively consistent during the years 1993-1997. The number of poison control centers contributing data increased only slightly during this time period (from 64 to 66 reporting centers)

although the catchment areas reported increased from 70% in 1993 to more than 90% of the United States by 1996 and 1997. Such changes should not have affected the quality of the data.

Coding errors could affect the accuracy of the data; however, our validity study found good concordance between data recorded in the original record and that in the TESS file. This study confirmed the accuracy of many of the variables routinely reported from the TESS database. Most had greater than 80% agreement and kappa values within an acceptable range (>0.80). There was a lower correlation only for the Outcome variable. When this was investigated in detail, much of the discrepancy appeared between labeling a case as either no effect or a minor effect on the patient vs. an unknown effect. These mismatches point out the ambiguity in coding choices at this level of precision. While clear rules are given in the coding handbook furnished by the AAPCC, how they are applied may differ from poison control center to center and specialist to specialist. However such ambiguity mostly included minor choices – the difference between the outcome of 'minor effect' and 'unknown effect, probably nontoxic' is probably of negligible clinical importance.

Calls to poison control centers are acceptable as evidence of the standard of medical care administered to a poisoned patient. Nevertheless such calls are entirely voluntary; TESS reporting is a passive surveillance system and no toxic exposures have mandatory reporting to the AAPCC or to individual poison control centers. Health care providers may choose not call a poison control center if they know how to manage the patient, or if the injury from the toxic exposure is judged by them to be relatively minor. Poison control center calls reflect the poisoning experience of a select population and

undercount the true incidence of poisoning exposure; the call frequency cannot be considered a true population-based incidence rate

Adolescent toxic exposures that do not result in symptoms may not be reported to poison control centers, either because the exposure is unappreciated or managed by the family or health care facility without the perceived need for consultation. Adolescents who are exposed to toxic chemicals may not attribute their symptoms to the exposure or may misdiagnose themselves as suffering from some other ailment. Their physicians may fail to take an appropriate medical history to uncover the toxic exposure or otherwise fail to diagnose the etiology of the medical symptoms correctly. Adolescents who have acute, subacute or chronic exposures associated with symptoms may also be managed by health care professionals with only discretionary consultation to a poison control center. In practice, poison control centers are more likely to be consulted for perceived emergencies and acute poisonings than for those repetitive exposures presenting with more indolent symptoms. Thus underreporting of such occurrences is expected. Finally adolescent toxic exposures to carcinogens, teratogens, fertility-lowering chemicals, or other agents whose adverse effects are only apparent after long latency periods – in some cases, years or decades – will likely never come to the attention of a poison control center.

While cases are labeled by exposure site at the time of the original telephone call, there is no element specifying the occupation involved or the type of work effort undertaken at the time of the injury. Bresnitz has previously pointed out the inadequacies of documentation and the questionable quality of recommendations of poison control center staff regarding their management of occupational toxicity cases.[13,14] Improved staff training and improved documentation of the circumstances surrounding

occupational toxic exposure calls could improve the overall quality of surveillance of poison centers in this area.

Many in public health have called for further investigation of adolescent occupational injuries.[34-37] The fact that an adolescent works, the type of job held and the number of hours worked are among those factors correlated with higher injury risk and other detrimental effects on the teenager.[38-40] There is a relative lack of experiential scientific data concerning teen occupational toxic exposure, even when investigations look at relevant industries. For example Rossignol linked work-related burns (including chemical burns) to food preparation/consumption activities, motor vehicle repair and maintenance, and the use of flammable liquids, but did not include the adolescent work-force in the investigation, even though these industries are important entries for teenagers.[41] The theoretical risks of known hazardous agents in certain occupations, such as solvents and lead in automotive repair shops, formaldehyde and dyes in the garment industry, asbestos and lead in construction abatement projects, solvents used in T-shirt imprinting, benzene in gasoline, and pesticides and nicotine on farms are cited in numerous reviews concerning adolescent occupational injuries.[42-44] The present study addresses the gap in knowledge of adolescent workplace exposures.

The Institute of Medicine has called for the use of 'ambulatory services' databases to improve the monitoring of adolescent occupational injuries.[45] Under 'right to know' legislation, teens should be advised about potential toxicities of the products they are using at work.[46] They should be oriented to safe practices necessary when using such chemicals and advised of precautions to avoid toxic exposures.[47] Information about occupational exposure surveillance activities of poison control centers can be useful to

policy makers --federal, state, and local government as well as private sector, to assist: (1) in making judgments about whether specific interventions (e.g., clinical, educational) aimed at defined target populations (e.g., younger children, those exposed to solvents, etc.) are efficient compared to well-specified alternatives, (2) in setting priorities within the field of poison prevention by providing information on the relative vulnerability of various target populations, and (3) in setting priorities more broadly within public health and medicine by providing information on the relative effectiveness of poison control centers at surveillance for sentinel occupational toxic events compared to other selected programs and databases aimed at injury surveillance, prevention and control. Further prospective studies are needed concerning the determinants underlying children's vulnerability to injury from toxic exposures in the workplace.

Conclusion:

Poison center generated data represents a valuable source of national surveillance defining occupational toxic exposures that involve young adolescents. By determining the effectiveness of Poison Control Center operations as a mechanism for surveillance of adolescent occupational exposures through a range of populations and services configurations, this study informs the national debate concerning the vulnerability of children in the workplace to toxic injury and gives evidence-based arguments being developed in the pursuit of national consensus-building.

Adolescent occupational exposures to toxins are an important but under-recognized injury category; poison control center data can be used to fill in gaps in surveillance for this type of work-site associated injury.

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Table 1: Examples of Specific Substances Within 18 Toxic Agent Categories

Toxic Agent Category	***Examples of Specific Products***
Acids	Hydrofluoric acid, muriatic acid, battery acid
Alkali	Alkaline corrosive, potassium hydroxide, sodium hydroxide
Bleaches	
Cleaners	Industrial cleaners, non-bleach disinfectants, drain cleaners, ammonia cleaners, bathroom cleansers
Drugs	Acetaminophen, caffeine, nicotine, salicylate, vitamins
Fire Extinguishers	
Freon	Refrigerants
Gases & Funes	Carbon monoxide, hydrogen sulfide (sewer gas)
Glues/Pastes/Putty	Adhesives
Herbicides	
Hydrocarbons	Gasoline, kerosene, diesel fuel, xylene
Inks, Dyes, Paints, Paint Thinner	Paints, paint thinner, methylene chloride, varnish, lacquers
Misc Chemicals	Bromine, copper, mercury, rhodium
Other Toxins	
Pesticides	Organophosphates
Plants	
Soaps & detergents	Anionic/cationic detergents, dishwashing soap
Stings & Bites	Fish stings, spider bites

Table 2: Agreement between variables from 422 cases of poisoning from the TESS database

Variable	Number Accurate	Percent Agreement	Kappa
Age	**370**	**88.5**	**0.862**
Exposure Site	364	89.7	0.332
Reason	355	83.4	0.723
Substance	339	82.5	0.813
Caller Site	357	92.9	0.898
Route-Ingestion	413	97.9	0.953
Route-Inhalation	410	97.2	0.926
Route-Aspiration	422	100.0	1.000
Route-Ocular	409	96.9	0.914
Route-Dermal	416	98.6	0.957
Route-Bite or Sting	422	100.0	1.000
Route-Parenteral	422	100.0	1.000
Route-Other	421	99.8	0.666
Route-Unknown	422	100.0	1.000
Duration of Effect	351	96.8	0.857
Outcome	250	61.5	0.514

Table 3: Specific Choice Discrepancies Among the Variables: Exposure Site, Reason, Substance, and Outcome

Variable	Total Mismatches	Mismatch Choices	N (%Total)
Exposure Site	**53**	**Workplace/Residence**	**28 (6.6%)**
		Workplace/Blank	17 (4.0%)
		Workplace/Other	07 (1.7%)
Reason	65	Occupation/Environment	19 (4.5%)
		Occupation/General	15 (3.6%)
		Intended/Unintended Misuse	11 (2.6%)
Substance	79	Substance	79 (18.7%)
Caller Site	52	Residence/Blank	16 (3.8%)
		Workplace/Blank	13 (3.1%)
		Residence/Workplace	07 (1.7%)
Duration of Effect	79	≤1 Day/Blank	35 (8.3%)
		Blank/Zero	22 (5.2%)
Outcome	147	No Effect-Minor Effect	
		Not Followed, Minor	

Table 4: Most Frequent Agents Involved In Workplace Exposures Among Adolescents, By Gender

Toxic Agent	***% Male***	***% Female***	***p Value***
Other Toxins	23.5	22.5	
Alkali	13.6	12.6	
Gases & Fumes	11.5	13.0	
Cleaners	9.0	11.0	
Bleach	7.4	9.8	
Drugs	5.7	10.5	$\leq$0.001
Acids	7.8	6.1	
Hydrocarbons	8.8	3.7	$\leq$0.001
Pesticides, Rodenticides	4.5	3.6	
Plants	3.3	2.2	
Stings & Bites	2.6	2.5	
Soaps & Detergents	2.5	2.6	
Totals	100.2	100.1	

Table 5: Agents Most Often Involved In Severe Adolescent Workplace Toxic Exposures

Toxic Agent	*N*	*% Severe*	Route (%)*				
			Ingestion	Inhalation	Ocular	Dermal	Other
Alkali	1033	27.6	7.02	16.14	42.46	44.91	0.70
Acid	575	20.7	5.88	38.66	22.69	36.13	0.84
Glues/Pastes	100	19.0	0.00	21.05	26.32	57.89	0.00
Herbicides	108	17.6	5.26	52.63	26.32	52.63	5.26
Gases & Fumes	900	17.4	2.55	92.36	6.37	1.91	0.00
Cleaners	791	16.8	5.26	17.29	61.65	24.81	0.00
Pesticides	295	15.6	8.70	63.04	19.57	45.65	0.00
Misc Chemicals	162	15.4	0.00	56.00	24.00	36.00	0.00
Soaps & Detergents	208	15.4	9.38	0.00	59.38	40.63	0.00
Bleach	656	13.6	2.25	42.70	47.19	12.36	0.00

**More than one route may be involved, so that the total routes may add to >100%*

Table 6: Predictors of Severe Toxic Exposure Cases Among Adolescents, 1993-97

Predictor	*Odds Ratio*	*P value*	*Lower 95% C.I.*	*Upper 95% C.I.*
Route Not Ingestion	2.63	<0.001	2.14	3.24
Dermal Route	1.16	0.037	1.01	1.34
Route Not Bite or Sting	2.33	0.002	1.37	3.98
Morning vs. Evening	1.34	<0.001	1.17	1.54
Male vs. Female	1.18	0.014	1.03	1.35
Year of Age	1.08	0.005	1.02	1.13

In bivariate analyses, the month, day of the week, year, other routes of exposure were not statistically significant.

Table 7: Age Distribution of Exposures by Geographic Region of the United States

Age (Years)	***Northeast***	***South***	***Midwest***	***West***	***Totals***	*p*
Number of exposures	1,112	2,850	2,587	2,230	8,779	<0.001
% 12 years old	5.6	61.7	18.8	13.9	100	<0.001
%13 years old	9.6	52.7	23.7	14.1	100	<0.001
%14 years old	10.2	44.0	29.1	16.7	100	<0.001
%15 years old	12.6	34.6	32.1	20.8	100	<0.001
%16 years old	12.5	30.2	31.0	26.3	100	<0.001
%17 years old	13.9	28.3	29.1	28.8	100	<0.001
% Total Cases	12.7	32.5	29.5	25.4	100	<0.001

FIGURE 1

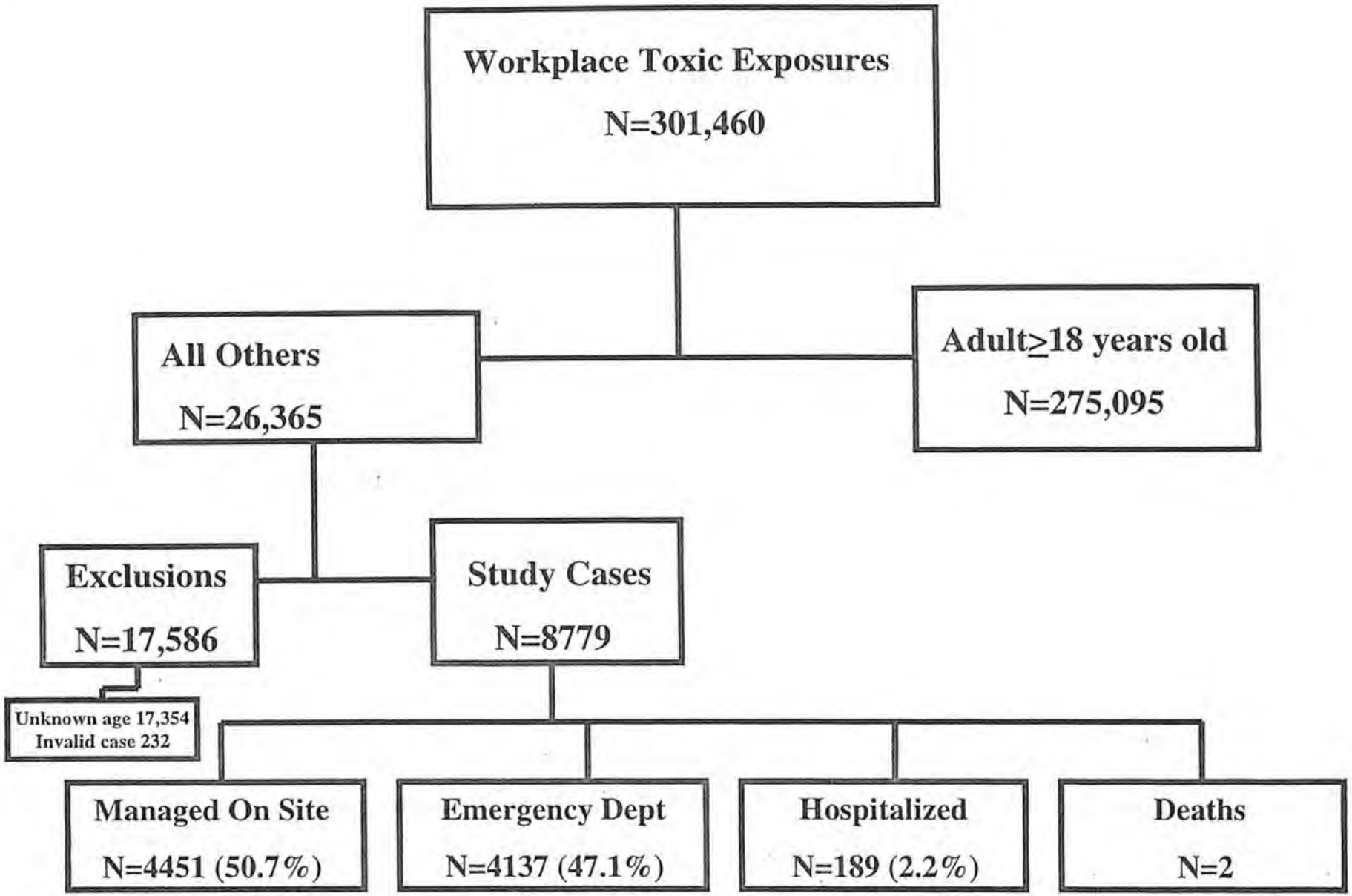

Workplace Toxic Exposures
N=301,460
All Others
N=26,365
Adult≥18 years old
N=275,095
Exclusions
N=17,586
Study Cases
N=8779
Unknown age 17,354
Invalid case 232
Managed On Site
N=4451 (50.7%)
Emergency Dept
N=4137 (47.1%)
Hospitalized
N=189 (2.2%)
Deaths
N=2

FIGURE 2

Adolescent Occupational Toxic Exposures in the United States, by Gender and Year

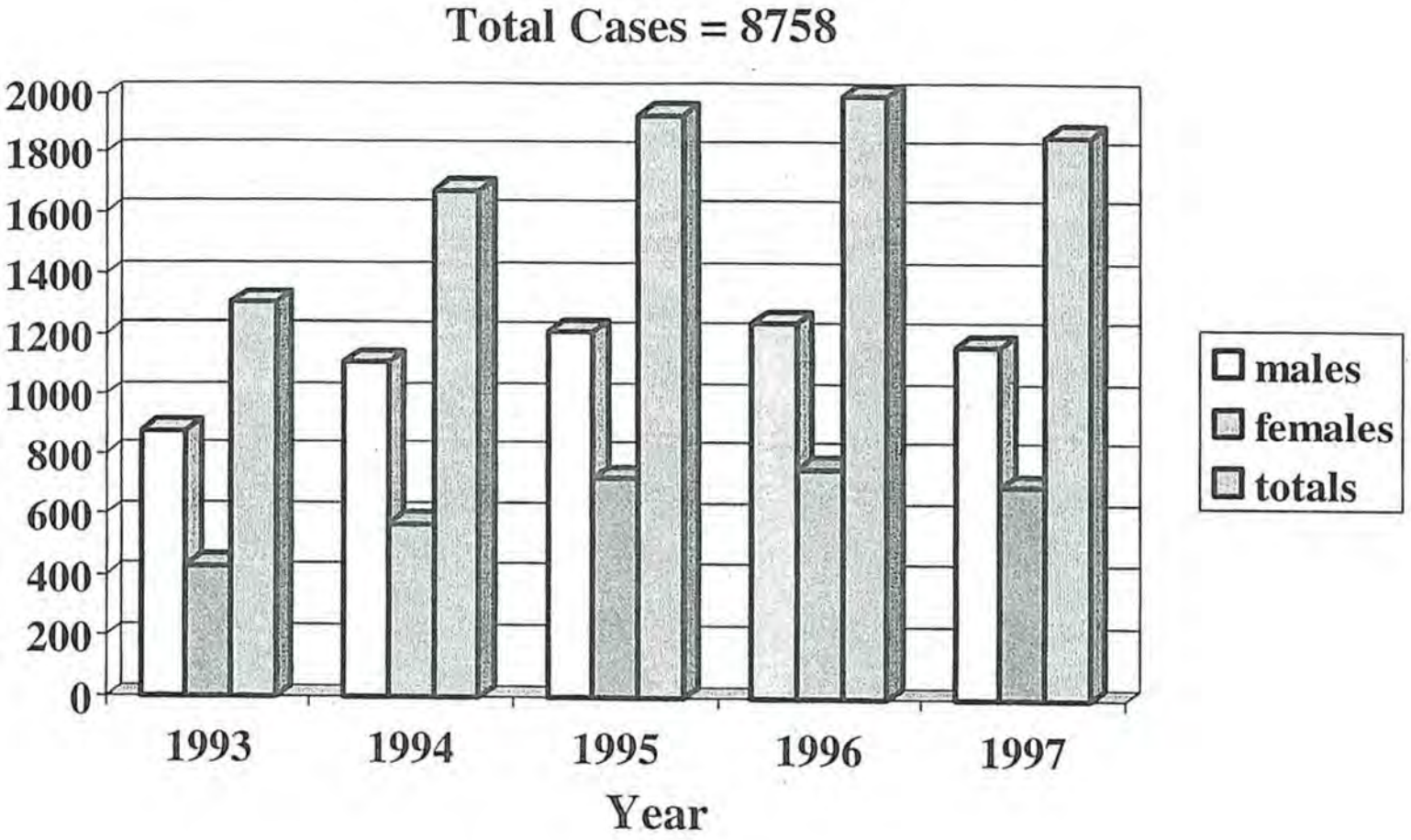


FIGURE 3

Adolescent Occupational Toxic Exposures in the United States from 1993-97, by Gender and Age

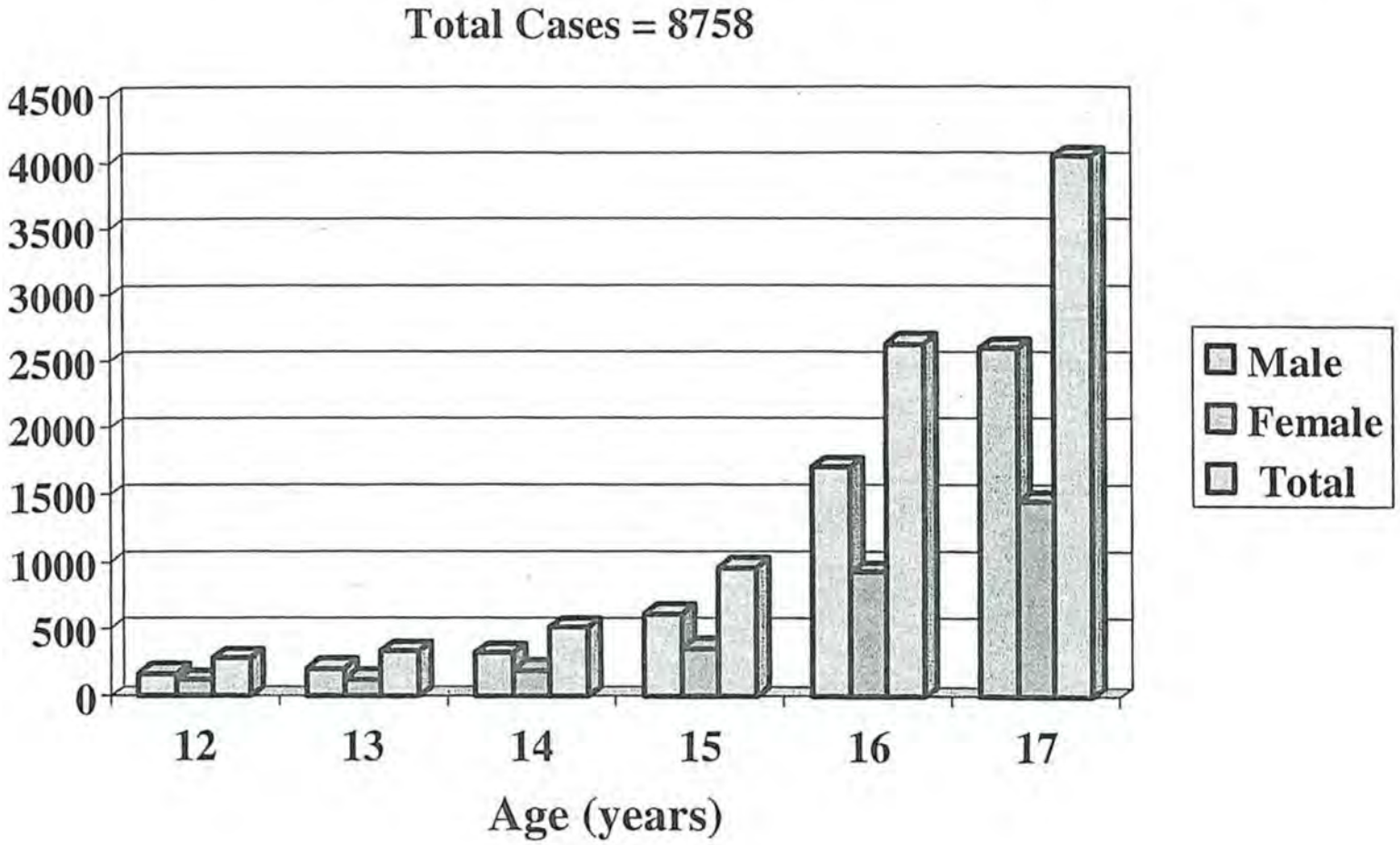


FIGURE 4A

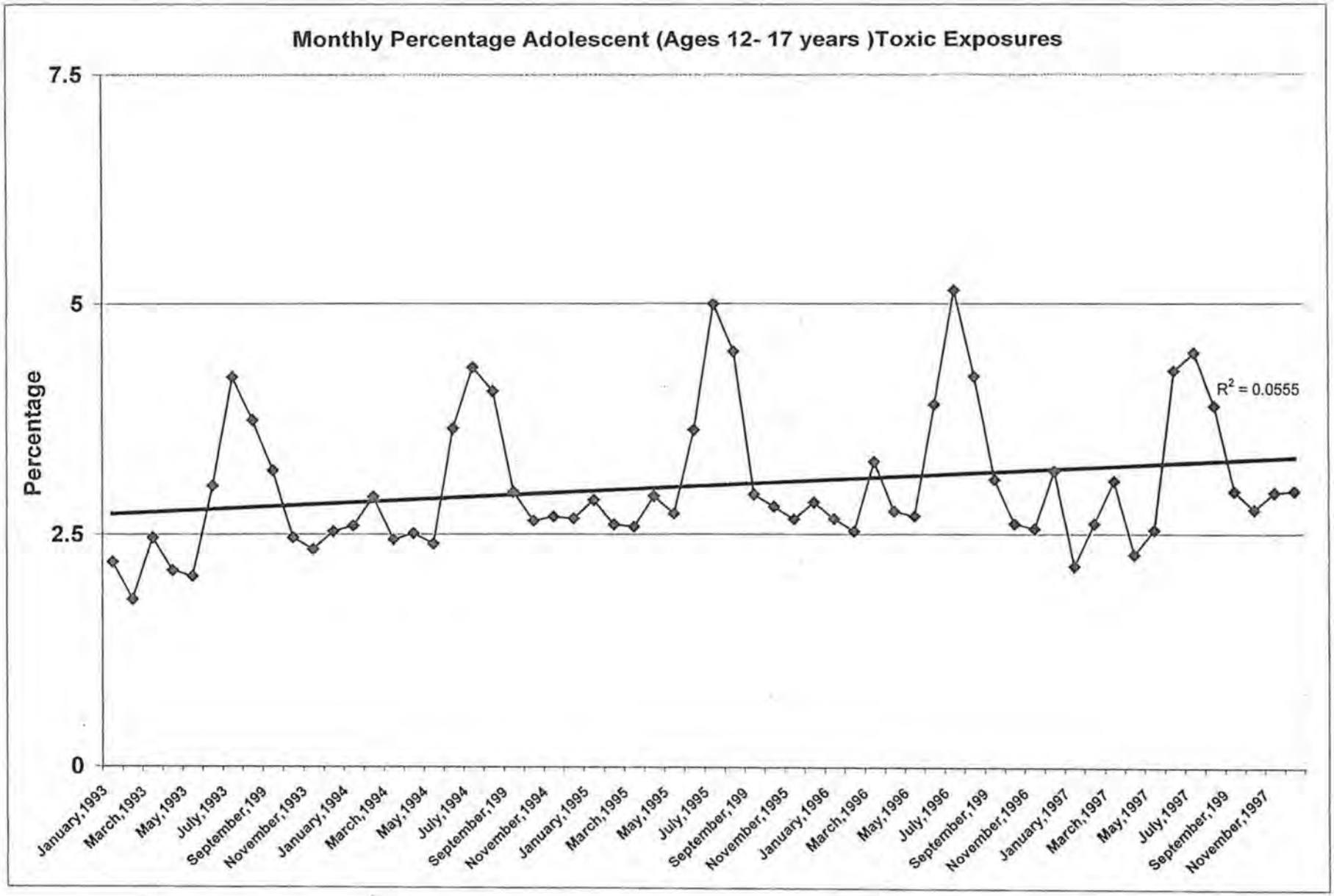

Monthly Percentage Adolescent (Ages 12- 17 years)Toxic Exposures
Percentage
7.5
5
2.5
0
R^2 = 0.0555
January,1993
March,1993
May,1993
July,1993
September,199
November,1993
January,1994
March,1994
May,1994
July,1994
September,199
November,1994
January,1995
March,1995
May,1995
July,1995
September,199
November,1995
January,1996
March,1996
May,1996
July,1996
September,199
November,1996
January,1997
March,1997
May,1997
July,1997
September,199
November,1997

FIGURE 4B

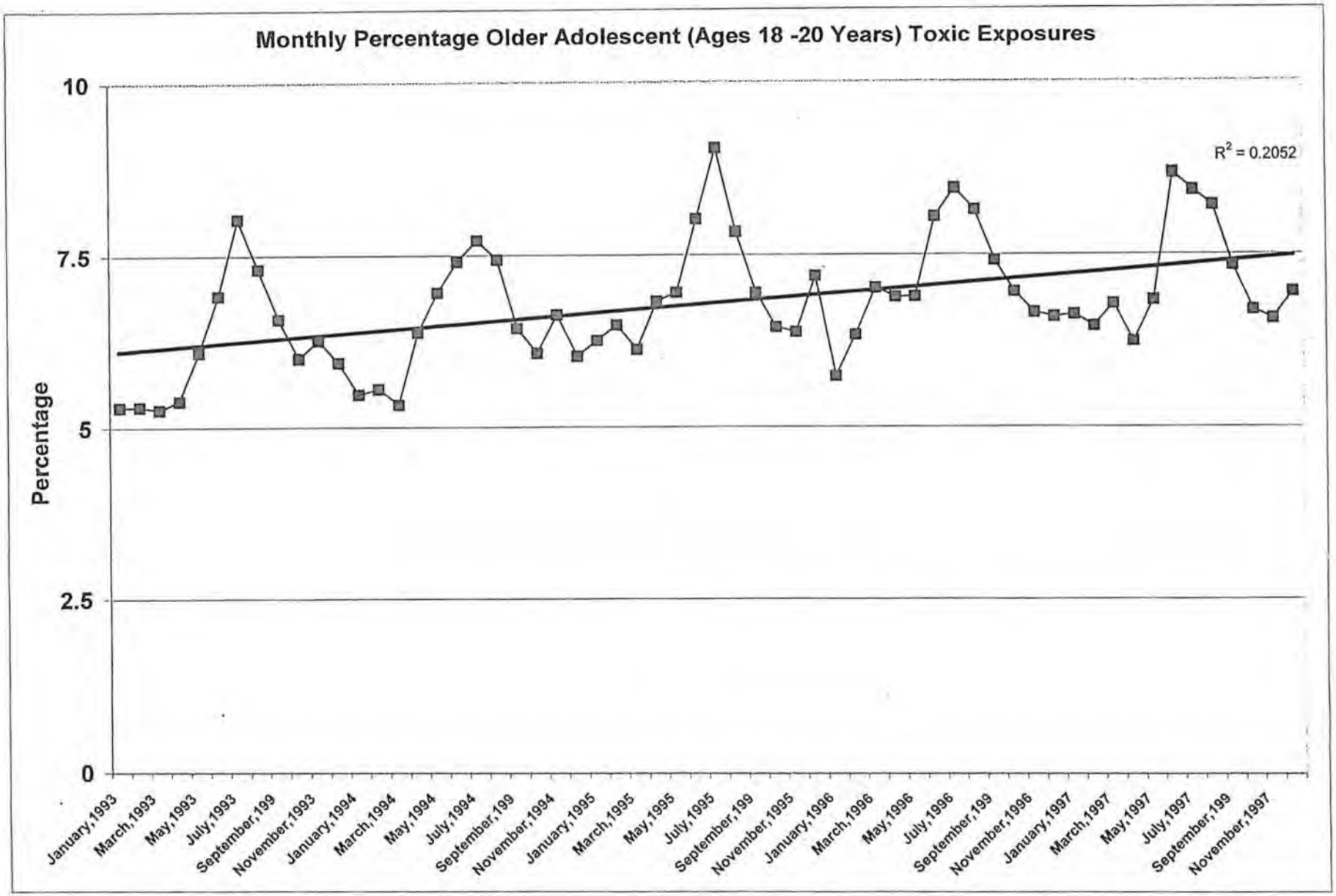

Monthly Percentage Older Adolescent (Ages 18 -20 Years) Toxic Exposures
Percentage
10
7.5
5
2.5
0
R^2 = 0.2052
January,1993
March,1993
May,1993
July,1993
September,199
November,1993
January,1994
March,1994
May,1994
July,1994
September,199
November,1994
January,1995
March,1995
May,1995
July,1995
September,199
November,1995
January,1996
March,1996
May,1996
July,1996
September,199
November,1996
January,1997
March,1997
May,1997
July,1997
September,199
November,1997

FIGURE 4c

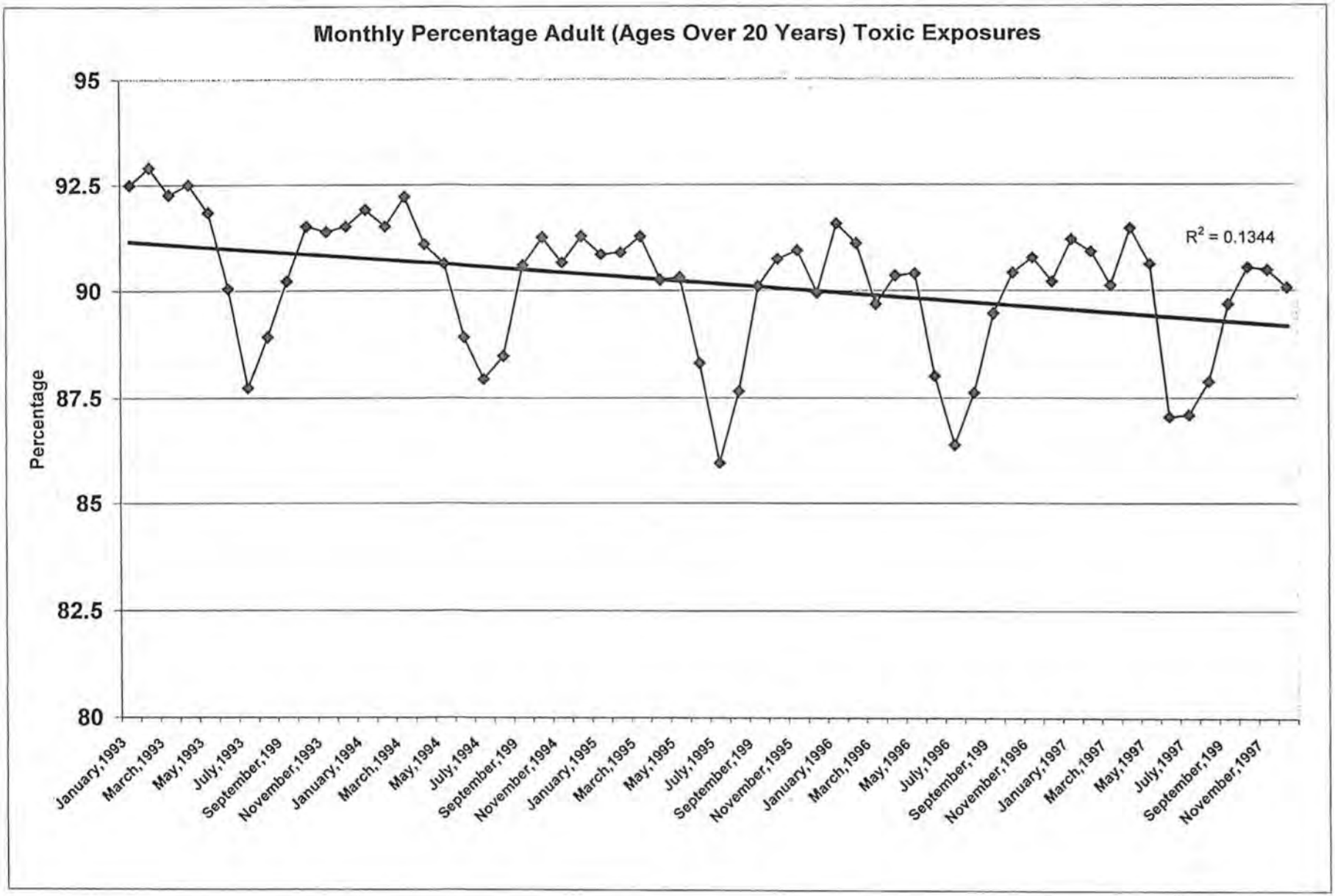

Monthly Percentage Adult (Ages Over 20 Years) Toxic Exposures
Percentage
95
92.5
90
87.5
85
82.5
80
R^2 = 0.1344
January,1993
March,1993
May,1993
July,1993
September,199
November,1993
January,1994
March,1994
May,1994
July,1994
September,199
November,1994
January,1995
March,1995
May,1995
July,1995
September,199
November,1995
January,1996
March,1996
May,1996
July,1996
September,199
November,1996
January,1997
March,1997
May,1997
July,1997
September,199
November,1997

FIGURE 5

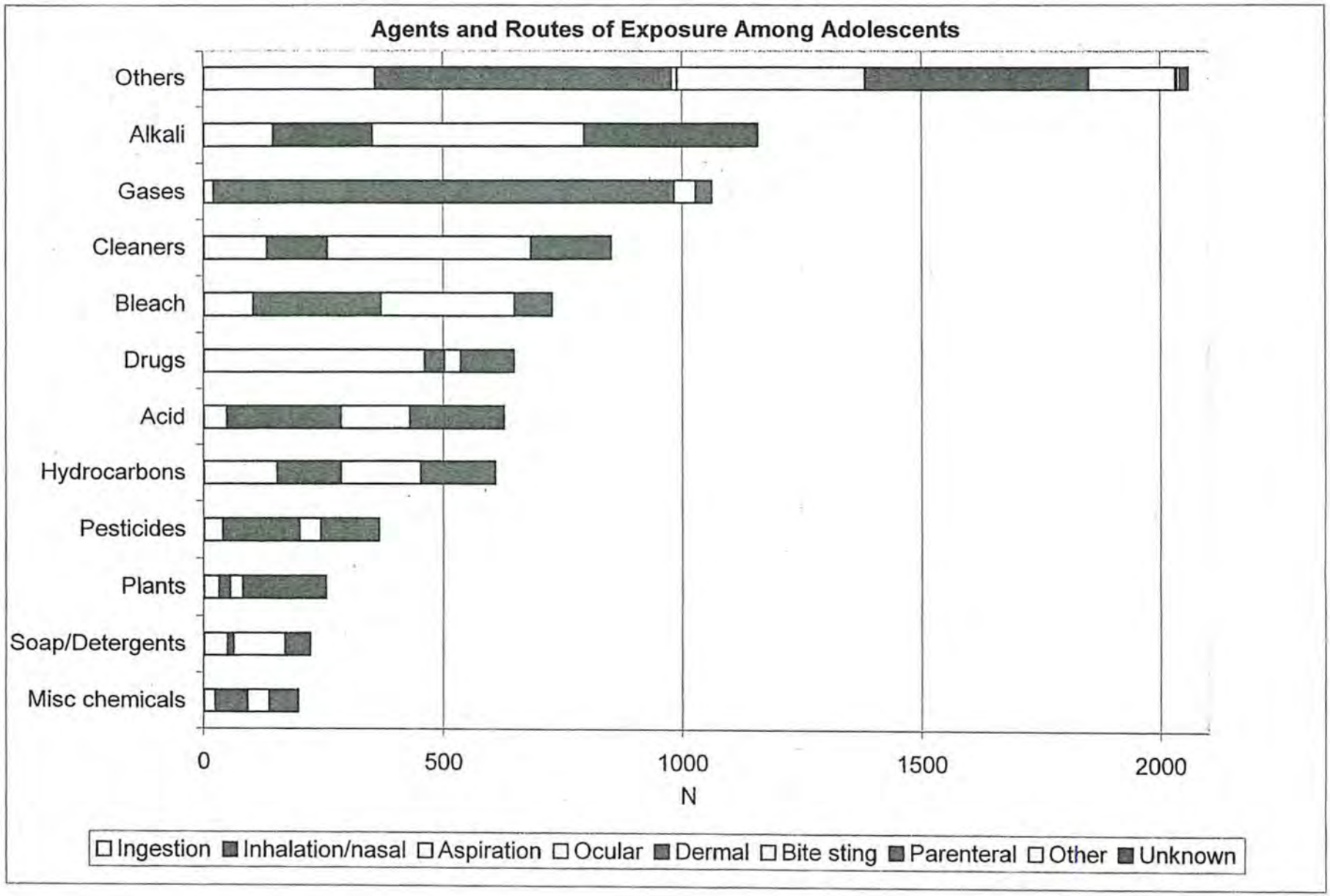

Agents and Routes of Exposure Among Adolescents
Others
Alkali
Gases
Cleaners
Bleach
Drugs
Acid
Hydrocarbons
Pesticides
Plants
Soap/Detergents
Misc chemicals
0
500
1000
1500
2000
N
Ingestion
Inhalation/nasal
Aspiration
Ocular
Dermal
Bite sting
Parenteral
Other
Unknown

FIGURE 5A

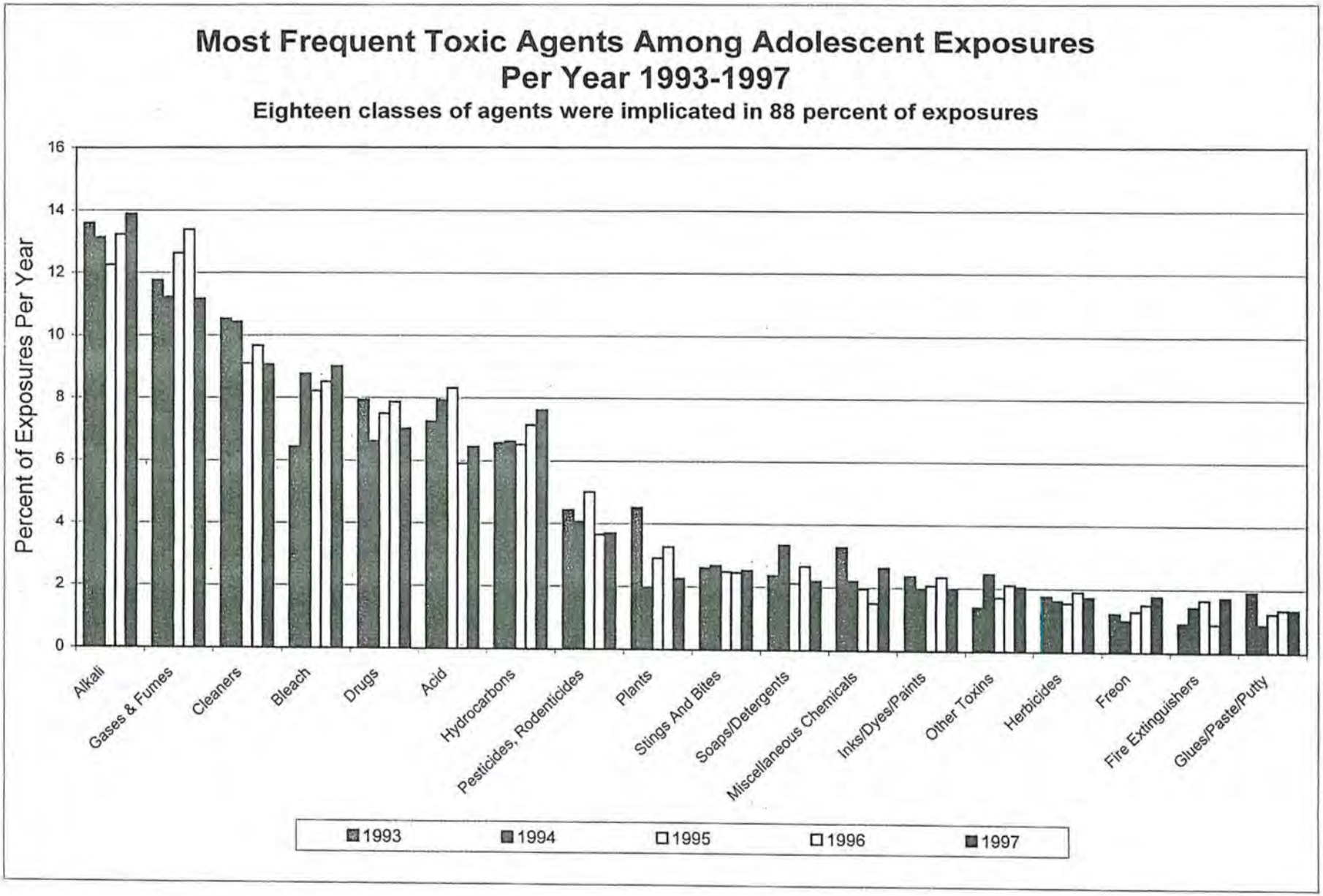

Most Frequent Toxic Agents Among Adolescent Exposures
Per Year 1993-1997
Eighteen classes of agents were implicated in 88 percent of exposures
Percent of Exposures Per Year
16
14
12
10
8
6
4
2
0
Alkali
Gases & Fumes
Cleaners
Bleach
Drugs
Acid
Hydrocarbons
Pesticides, Rodenticides
Plants
Stings And Bites
Soaps/Detergents
Miscellaneous Chemicals
Inks/Dyes/Paints
Other Toxins
Herbicides
Freon
Fire Extinguishers
Glues/Paste/Putty
1993
1994
1995
1996
1997

FIGURE 6

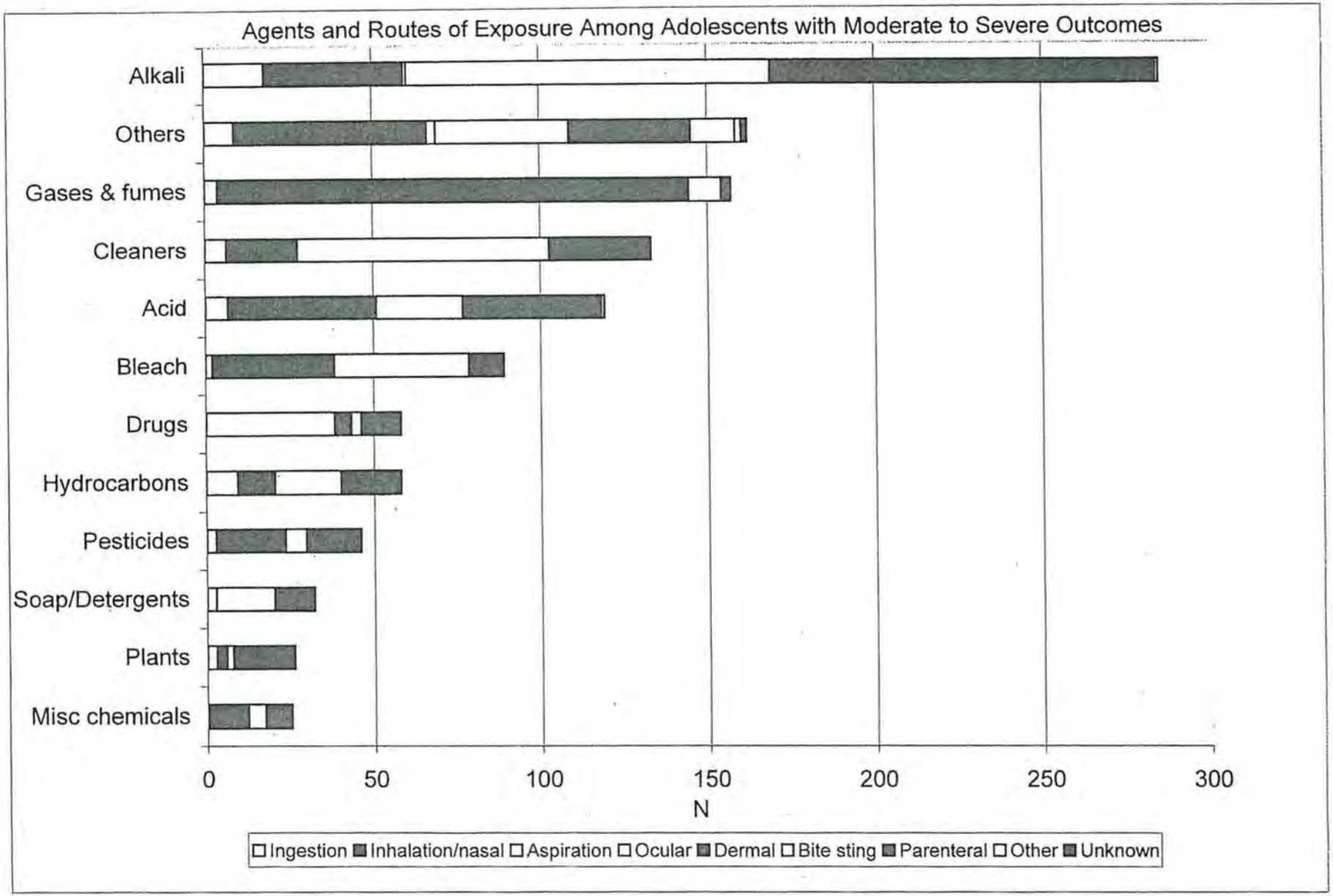
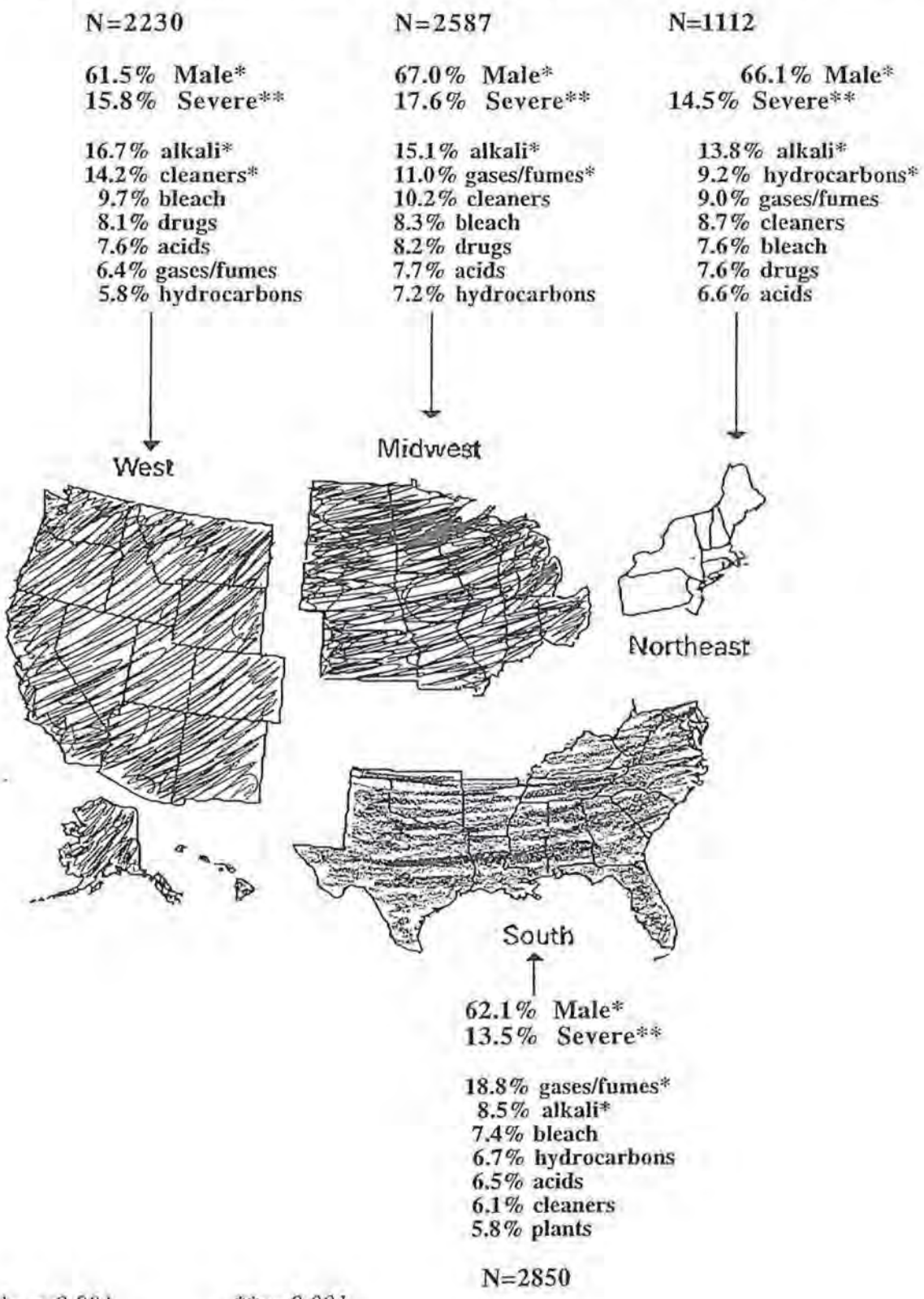

Agents and Routes of Exposure Among Adolescents with Moderate to Severe Outcomes
Alkali
Others
Gases & fumes
Cleaners
Acid
Bleach
Drugs
Hydrocarbons
Pesticides
Soap/Detergents
Plants
Misc chemicals
0
50
100
150
200
250
300
N
Ingestion
Inhalation/nasal
Aspiration
Ocular
Dermal
Bite sting
Parenteral
Other
Unknown

FIGURE 7

7

Figure 8: Distribution of adolescent workplace toxic exposures according to region of the United States; by gender, severity, and toxic agent type



*$p < 0.001$ **$p=0.001$

FIGURE 8

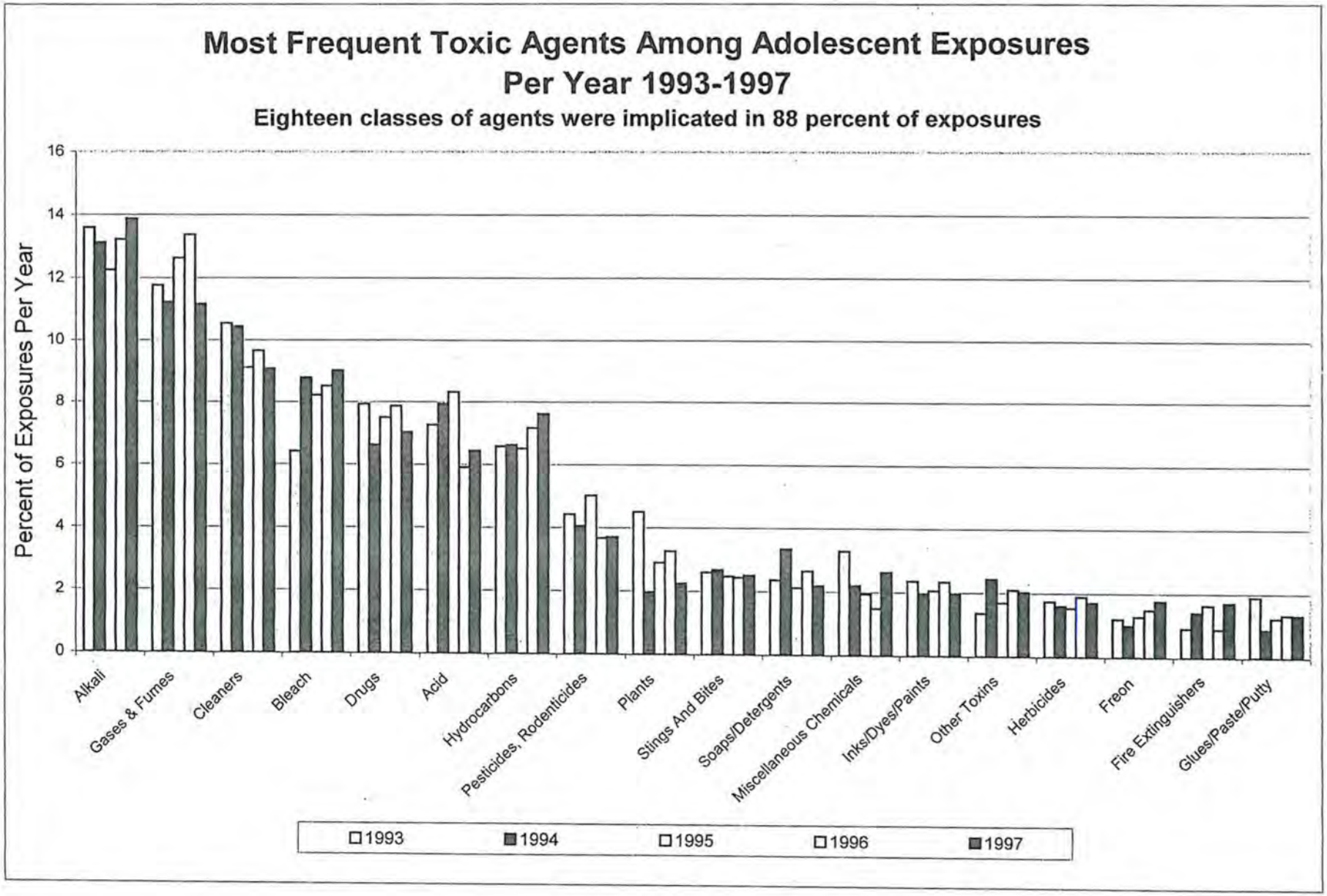
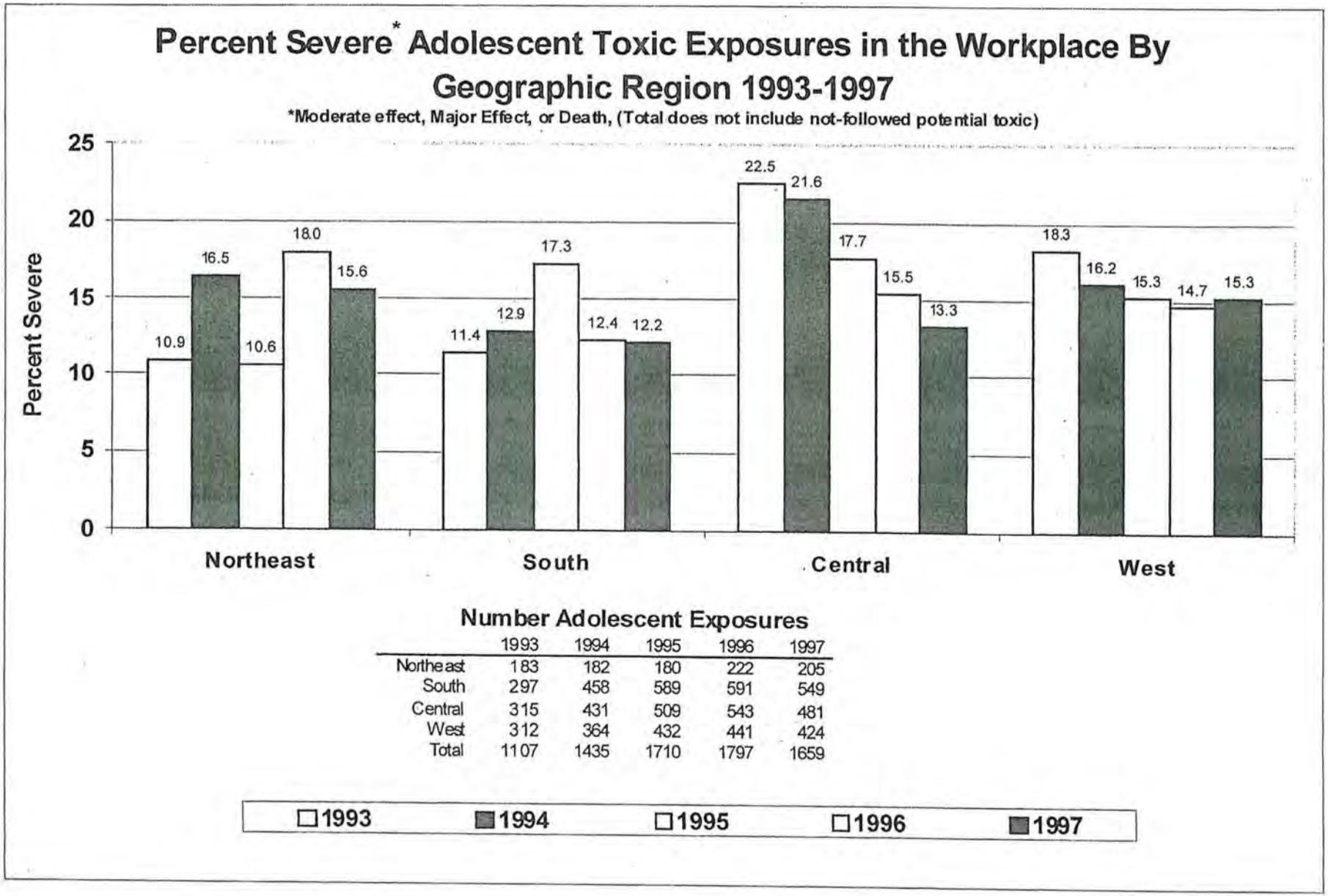

Most Frequent Toxic Agents Among Adolescent Exposures
Per Year 1993-1997
Eighteen classes of agents were implicated in 88 percent of exposures
Percent of Exposures Per Year
0
2
4
6
8
10
12
14
16
Alkali
Gases & Fumes
Cleaners
Bleach
Drugs
Acid
Hydrocarbons
Pesticides, Rodenticides
Plants
Stings And Bites
Soaps/Detergents
Miscellaneous Chemicals
Inks/Dyes/Paints
Other Toxins
Herbicides
Freon
Fire Extinguishers
Glues/Paste/Putty
1993
1994
1995
1996
1997

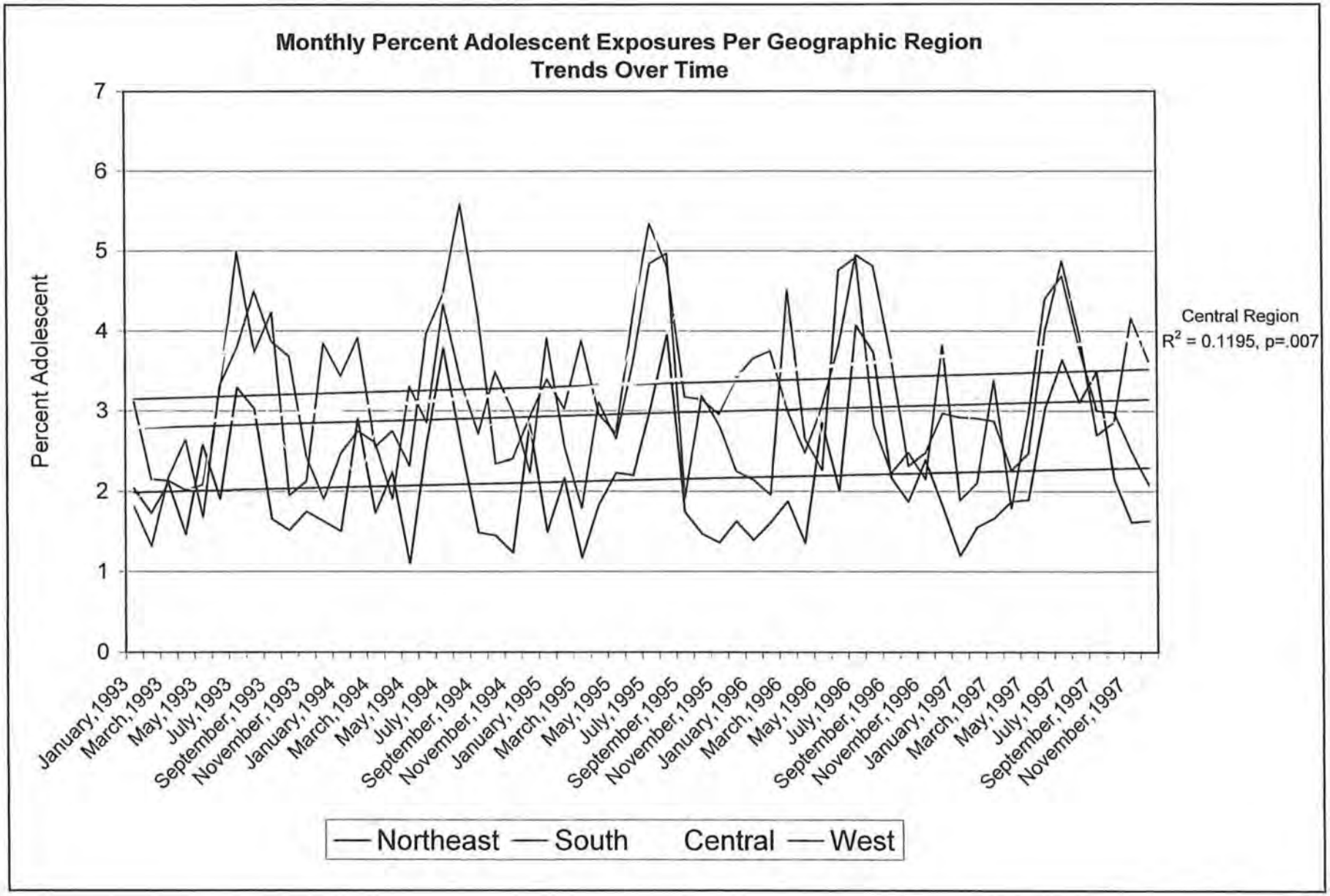
FIGURE 9



Number Adolescent Exposures

	1993	1994	1995	1996	1997
Northeast	183	182	180	222	205
South	297	458	589	591	549
Central	315	431	509	543	481
West	312	364	432	441	424
Total	1107	1435	1710	1797	1659

FIGURE 10


Monthly Percent Adolescent Exposures Per Geographic Region
Trends Over Time
Percent Adolescent
0
1
2
3
4
5
6
7
January,1993
March,1993
May,1993
July,1993
September,1993
November,1993
January,1994
March,1994
May,1994
July,1994
September,1994
November,1994
January,1995
March,1995
May,1995
July,1995
September,1995
November,1995
January,1996
March,1996
May,1996
July,1996
September,1996
November,1996
January,1997
March,1997
May,1997
July,1997
September,1997
November,1997
Central Region
R^2 = 0.1195, p=.007
Northeast
South
Central
West

Workplace Toxic Exposures Involving Adolescents Aged 14 to 19 Years

One Poison Center's Experience

Alan D. Woolf, MD, MPH; Elizabeth Flynn, BA

Background: While many previous reports describe injuries to adolescents in the workplace, few focus on toxic substance exposures among such injuries. Yet low-skill, entry-level jobs pose a particular hazard of toxic exposure owing to the frequent use of cleaning agents, solvents, and/or other chemicals in carrying out assigned tasks.

Objective: To analyze the types and severity of adolescent occupational toxic exposures.

Design: Secondary analysis of calls to a single regional poison control center (PCC).

Setting: Massachusetts PCC poisoning consultations between 1991 and 1996.

Subjects: Children aged 19 years or younger reporting toxic exposures occurring in the workplace.

Results: Of 7024 occupational toxic exposures recorded by the PCC in the 6 years of study, 269 incidents (3.8%) involved adolescents aged 14 to 19 years (median age, 18 years; 124 aged 14-17 years and 145 aged 18-19 years; 65% were male). The most frequently involved agents were cleaning compounds (27.8%); paints, solvents, and glues (9.0%); caustics (8.7%); hydrocarbons (8.7%); and bleaches (7.3%). Of 88 cases (32.7%) in which a worksite was identified, food services (30.7%), automotive services (14.8%), and general retail stores (12.5%) were the most common locations. One hundred fifty-six patients (58.0%) were triaged to an emergency department; 7 were hospitalized. Forty-three subjects (16.0%), 18 who were between the ages of 14 and 17 years and 25 who were aged 18 or 19 years, were judged to have moderate to severe injuries. There were no deaths.

Conclusions: This study confirmed the usefulness of PCC surveillance as a source of information about adolescent toxic exposures occurring in the workplace. The occupational toxic exposures reported here most commonly involved cleaning agents, solvents, paints, caustics, and bleach used in those entry-level jobs most frequently filled by adolescents. We conclude that occupational toxic exposures are an underrecognized adolescent injury, and that PCC experience can be used to fill a gap in the surveillance of such workplace-associated events.

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Editor's Note: Now these are classic examples of poisoning adolescents against work.

Catherine D. DeAngelis, MD

From the Department of Pediatrics, Harvard Medical School; the Department of Medicine, Children's Hospital; and the Massachusetts Poison Control System, Boston.

As many as 4 million children and adolescents are legally employed in the United States; an additional 1 to 2 million are suspected to be employed in violation of the Fair Labor Safety Act.[1] A recent report from the Institute of Medicine (Washington, DC) on adolescent work injuries observed that as many as 80% of high school students hold jobs during some part of the school year.[2] Injuries suffered by children and adolescents in the workplace have long been recognized as an important public health problem. As many as 64 000 work-related injuries among children and adolescents are treated in emergency departments annually, which projects to an estimated 200 000 such injuries occurring in the United States.[3]

In reviewing adolescent workplace injury types, many authors cite a theoretical risk to adolescents of exposure to toxic agents such as solvents, hot liquids, and grease (from fast-food or full-service restaurants),[4] benzene, lead and pulmonary sensitizers (from gas stations and automobile repair shops),[5] or pesticides and nicotine (used in agricultural jobs).[5,6] Yet there are few data defining the number of incidents involving youth exposed to toxins in the workplace. There are anecdotal reports of adolescent deaths from toxic ex-

MATERIALS AND METHODS

We analyzed computer-coded telephone records of toxic exposures reported to the Massachusetts Poison Control System, Boston, from 1991 to 1996. Only those records involving adolescents aged 14 to 19 years and in which the site of the toxic exposure was coded as the worksite were included. Cases were excluded if the written record could not be found. Because we were interested only in those toxic injuries specific to a worksite, if the record indicated that this was a suicide attempt, then the case was excluded. Each medical record was retrieved and reviewed for information regarding the patient's age and sex, the toxin involved, the site, time, and circumstances (if available) of the exposure, any related symptoms or signs of toxic effects, triage to health care, disposition, and medical outcome. In cases in which the type of worksite was not noted, but the correct telephone number of the worksite was recorded, sites were called to classify the type of worksite.

For certain analyses, toxins implicated in the exposure were classified into 14 larger descriptive categories. **Table 1** gives examples of how individual products and chemicals were sorted into these 14 categories. Medical records were reviewed for notations about the circumstances of the poisoning. Worksites were classified into 10 industry sectors (**Table 2**). Medical outcomes defined previously by the American Association of Poison Control Centers[20] include the following:

- No effect: The patient developed no symptoms as a result of the exposure.
- Minor effect: The patient exhibited some symptoms, but they were minimally bothersome. The symptoms resolved rapidly.
- Moderate effect: The patient exhibited symptoms that were more pronounced, more prolonged, or more systemic in nature than minor symptoms but were not life-threatening. Usually some form of treatment was indicated.
- Major effect: The patient exhibited some symptoms that were life-threatening or resulted in significant residual disability or disfigurement.
- Not followed up, judged as nontoxic exposure: The patient was not followed up because the substance was judged to be nontoxic.
- Not followed up, no or minimal medical effects possible: The patient was not followed up because the exposure was likely to result in only minimal toxic effects.
- Unable to follow up, judged as a potentially toxic exposure: The patient was lost to follow-up and the exposure was significant and may have resulted in toxic manifestations with a moderate, major, or fatal outcome.

This research was approved by the Committee on Clinical Investigation at Children's Hospital, Boston, Mass.

Table 1. Toxins Involved in Accidents in the Workplace Among Adolescents

Category	Examples
Cleaners (not including bleach)	Industrial cleaners, disinfectants (nonbleach), ammonia cleaners, drain cleaners, glass cleaners, bathroom cleaners
Caustics	Corrosives (alkaline), potassium hydroxide, sodium hydroxide, hydrofluoric acid, muriatic acid, battery acid
Automotive products	Antifreeze, oil, ethylene glycol
Pesticides/herbicides/ fertilizers	Insecticides, fertilizers, garden fungicide
Bleach	Hypochlorite bleaches
Paints, glues, and solvents	Adhesives, paints (including lead paint), paint thinner, wood sealer, turpentine
Miscellaneous chemicals	Copper, bromine, chlorine, rodium, mercury
Biologicals	Fish stings, spider bites, mold, spoiled food
Building and construction products	Fiberglass, asphalt, tar, fluorescent lightbulbs
Hydrocarbons	Gasoline, kerosene, xylene, diesel fuel
Refrigerants	Freon, refrigerants
Drugs	Caffeine, nicotine, acetaminophen, aspirin
Cosmetics	Nail polish remover, nail glue, aloe vera
Unknown/miscellaneous	Other chemicals, no substance found

posures in the workplace.[7-9] In a review of North Carolina medical examiners' cases between 1981 and 1989, Dunn and Runyan[10] reported that 5 of 71 childhood deaths on the job were related to poisoning. An analysis of the National Traumatic Occupational Fatalities surveillance system from 1980 to 1989[11] discovered 20 deaths from poisoning in male adolescents aged 16 or 17 years, a rate of 0.28 deaths per 100 000 full-time equivalents.

A few studies of morbidity related to adolescent occupational injuries refer obliquely to toxic exposures. In a Massachusetts investigation of 2551 adolescent workers' compensation claims, 29 claims were related to chemical burns.[12] A similar New York study of 9656 workers' compensation claims included 49 adolescents with chemical burns and 17 cases of poisoning.[13] Several studies of adolescent workers presenting to emergency departments with injuries sustained on the job include numerous cases of chemical burns and scalds from grease, deep fat fryers, or hot water.[14-16] In a study of 1361 work-related injuries suffered by adolescents and treated in one emergency department in Dunedin, New Zealand, during 1990 to 1993, there were 27 cases of chemical burns to the eye.[17] Among 37 405 adolescent injuries reported by emergency departments to the Consumer Product Safety Commission's National Electronic Injury Surveillance System (Washington, DC) in a 6-month period, there were 4629 burns, 3553 of which were sustained in the service industry. Of these 3553 burns, 14.8% were from exposure to caustic liquids.[18]

The databases currently recommended for surveillance with regard to adolescent workplace injuries include workers' compensation records, the Annual Survey of Occupational Injuries and Illnesses, hospital discharge data, the Census of Fatal Occupational Injuries, the National Electronic Injury Surveillance System, and the National Traumatic Occupational Fatalities System.[19] All of these sources of data are likely to

Table 2. Workplace Injuries Categorized by Industry Sector

Site	No. of Injuries by Age Group, y			Categories of Toxins
	14-17	18-19	14-19 (%)	
Food services	17	10	27 (30.1)	12 Cleaning products 3 of Each: bleach, hydrocarbons 1 of Each: automotive products, miscellaneous chemicals, construction products, drugs, refrigerants 4 Miscellaneous/unknown
Automotive services	5	8	13 (14.8)	5 Hydrocarbons 4 Automotive products 1 of Each: caustics, cleaners, paints, and glues 1 Miscellaneous/unknown
Retail trade-general merchandise	4	7	11 (12.5)	2 of Each: biological, caustics, drugs 1 of Each: cleaners, pesticides, refrigerants 2 Miscellaneous/unknown
Miscellaneous/unknown	4	5	9 (10.2)	3 Hydrocarbons 1 of Each: biologic, paints, and glues 4 Miscellaneous/unknown
Health services	1	7	8 (9.1)	5 Cleaners 1 of Each: drug, pesticide 1 Miscellaneous/unknown
Recreational services	3	4	7 (8.0)	1 of Each: biologicals, bleach, cleaners 4 Miscellaneous/unknown
Retail trade-food/bakery/dairy	2	4	6 (6.8)	2 Cleaners 1 of Each: miscellaneous chemicals, hydrocarbons, pesticide 1 Miscellaneous/unknown
Construction/painting	1	2	3 (3.4)	3 Paints, glues, and solvents
Agriculture	1	2	3 (3.4)	1 of Each: construction products and hydrocarbons 1 Miscellaneous/unknown
Hotel services	0	1	1 (1.1)	1 Caustic
	38	50	88 (100)	

undercount toxic exposure involving adolescents because (1) death from an occupational toxic exposure is very rare, (2) many injured adolescents do not self-refer to the emergency department, (3) many adolescents are not eligible for or will not file a claim for workers' compensation, (4) small businesses (or private residences) where adolescents often work may not be required to report such injuries, (5) businesses that are required to report injuries may not enforce this rule, or (6) a toxic exposure in the workplace may not be recognized as the cause of an adolescent's symptoms or death.

The objective of the current study was to define the frequency, circumstances, and medical severity of adolescent occupational poisonings and toxic exposures occurring in Massachusetts by using a novel database. If such incidents are detectable as "sentinel events," then it might be possible to use the existing health care network not only to manage cases, but also to define high-risk groups and direct population-based preventive interventions.

RESULTS

Of 7024 occupational exposures reported to the poison center in the 6-year study period, we identified 313 poison center cases involving adolescents aged 14 to 19 years (**Figure 1**). Of these, 44 cases did not meet our inclusion criteria (in 33 cases, no medical record could be found, 2 cases were duplicates, and 9 cases were misclassified and no drug or toxin was involved). Thus, 269 cases (3.8%) of occupational toxic exposures and poisonings among adolescents aged 14 to 19 years were entered into the analysis. Of those adolescents, 124 were younger (aged 14-17 years) and 145 were older (aged 18 or 19 years).

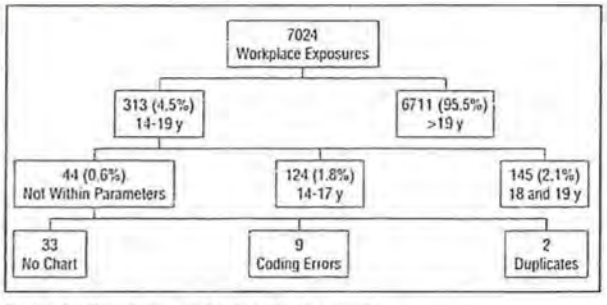

Figure 1. *Flow diagram of data collection results.*

Figure 2 gives the age and sex distribution of the 269 cases. The median age was 18 years old; 66% of the victims were male.

TOXIC AGENTS

There were 288 individual toxic agents (in 19 of the cases, the adolescent was exposed to more than 1 substance) involved in these exposures. **Figure 3** presents the relative frequencies of exposures to different types of toxins, subdivided by route of exposure. Nonbleach cleaning products (27.8%) were most commonly involved; many of these contained upper-airway irritants such as ammonia. Other common substances included paints,

glues, and solvents (9.0%), caustics (8.7%), hydrocarbons (8.7%), and bleach (7.3%).

WORKSITE

In one third of the cases (n = 88), the worksite was identified and was confirmed by a follow-up telephone inquiry. Table 1 identifies the worksites involved in these exposures. Food services had the most toxic exposures (30.7%); more than half of the food service sites were fast-food restaurants. Automotive services and other retail stores were other common sites of exposure.

SYMPTOMS AND SIGNS OF TOXIC EFFECTS

Figure 3 shows frequency of these poisonings defined by the category of toxin involved as well as the route of exposure (inhalation, ocular, dermal, or a combination of routes). The most common routes of exposure included inhalations (27.5%), ocular splashes (27%), skin contamination (21.1%), and ingestions (18.2%). Symptoms often included irritation of the eyes and throat, in cases of exposure to simple irritants such as bleach, ammonia, and cleaning agents. Patients also complained of temporarily impaired vision, nausea, and/or dizziness related to exposure to solvents, bleach, or cleaning agents. Skin burns were frequently the result of exposure to caustics.

SEVERITY AND OUTCOME

One hundred fifty-six (58%) of these adolescents referred themselves to a health care facility or were triaged there by the poison center for further evaluation of their injuries. Forty-three incidents (15.9%) involving 48 separate toxins were coded by a poison center staff member as having had an injury outcome of moderate or major severity. As **Figure 4** shows, almost half of these severe injuries involved caustics or cleaning compounds. However, only 7 (2.6%) of 269 adolescents required short periods of hospitalization for observation and there were no deaths.

COMMENT

This study confirms that toxic exposures occur with some frequency among adolescents aged 14 to 19 years working in a variety of occupational experiences; 3.8% of all toxic exposures in the workplace reported to one poison control center in a 6-year period involved children aged 19 years or younger. Almost half of the injuries involved cleaners, bleaching agents, or caustics. It is likely that both food and health service establishments use strong cleaning agents such as bleach or ammonia to sanitize workspaces and equipment, and adolescents come into contact with these substances during

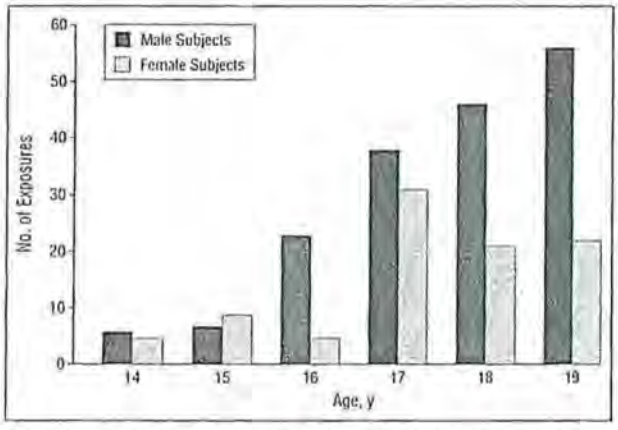

Figure 2. *Age and sex of 269 subjects who reported toxic exposures that occurred at the worksite.*

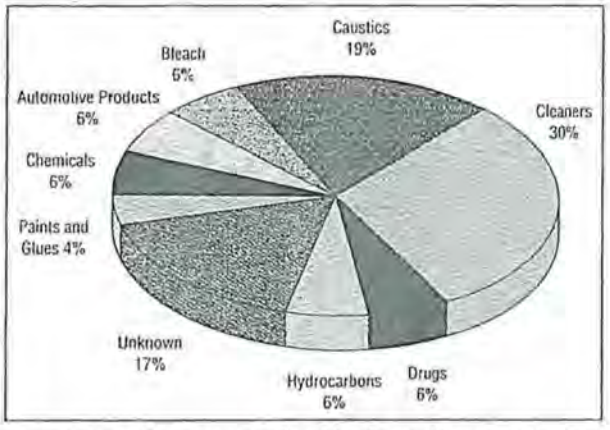

Figure 4. *Forty-eight toxins producing 43 injuries rated in severity of medical outcome as either moderate or severe.*

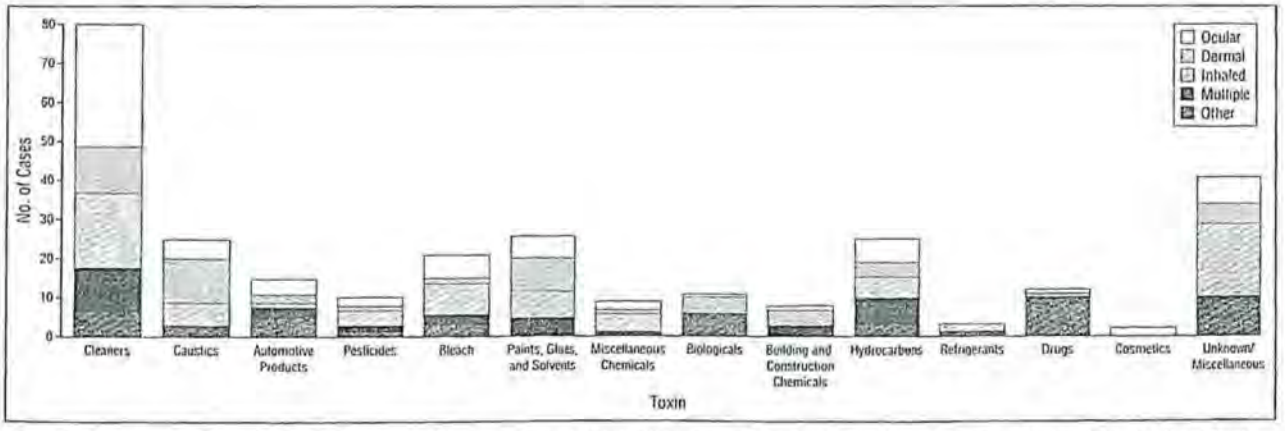

Figure 3. *Chemical agents involved in 288 adolescent toxic exposures, by route of exposure. The category "miscellaneous" is not further defined in the dataset.*

routine cleaning tasks. Other frequently involved substances included automotive products, paints, and glues. Adolescents find often work in automobile repair shops, which commonly use hydrocarbon-based solvents, oil, benzene-containing gasoline, and degreasers in their operations. Part-time work for painting or remodeling contractors can account for the exposure of adolescents to paints, thinners, and other toxic chemicals such as asbestos. Such work may also inadvertently expose them to contact with lead-containing dust from older painted surfaces.

Why are these adolescents at high risk for injury from a toxic exposure on the job? Entry-level jobs with minimal skill requirements are those most commonly secured by adolescents. Such jobs pose a particular hazard of toxic exposure owing to the frequent use of cleaning compounds, solvents, caustics, and/or other chemicals in carrying out assigned tasks. Because many of these jobs may be in small businesses or homes, they may not be carefully regulated by governmental agencies. Adolescents involved in part-time or seasonal work may not be adequately trained for the tasks they do and may not receive important safety information about toxic solvents, pesticides, or cleaners they are using. Although parents and adolescents are warned by such child advocacy groups to carefully consider safety issues when securing work, such issues are likely to be assigned a lower priority in the family's decision-making when jobs for which the youth can qualify are limited. Risk-taking behaviors within the context of adolescent perceptions of personal safety may influence vulnerability to workplace injuries. Further, adolescents may be motivated by their achievement of an "adult status" activity (ie, employment) and disregard their personal safety to please an employer.

Many of the cases reported here included children younger than 18 years whose work experience falls under the regulations of the Fair Labor Safety Act. There have been recent increases in detected child labor violations and a general relaxation in the enforcement of child labor laws.[1,21-24] Violation of the restriction on total working hours per week may contribute to an adolescent's fatigue, making him or her more susceptible to making a mistake when working with hot oil, a corrosive compound, or another agent.[24] Whether any of the toxic exposures described in this report occurred in violation of the Fair Labor Safety Act is unknown.

There are limitations in this study and the results should be interpreted cautiously. Poison control centers remain a voluntary reporting system; therefore one cannot derive population-based injury rates from such a database and it is likely that our data underestimate the true incidence of adolescent occupational toxic exposures and poisonings. Similarly, it is difficult to assess how much risk may be age-related. While the frequency of such injuries among children aged 14 years was low, the average number of months on the job for this group is probably much lower than that of older adolescents.

In some cases, the nature of the toxic product involved in the event was incompletely characterized. This could have led to a misclassification bias related to product category. For example, if the substance involved was described only as a "cleaner" and its major ingredient (sulfuric acid) was not identified, then the exposure would have been categorized as a "cleaner" when it also could have been classified as a "caustic." While we created exclusive categories for the toxins, some overlap exists—for example, an automobile engine cleaner containing both a corrosive and a hydrocarbon-based solvent could be classified in 4 different categories.

The retrospective nature of the data also constrained our ability to discover details about the circumstances of the injury. Time-motion studies of adolescents in the workplace have been recommended by others[23] and could uncover exactly how adolescents are working with chemicals and what precautions they commonly take.

While it was assumed that many of the exposures resulted in no injury or medically trivial effects, not all calls were followed up to verify this. The amount of time lost from school or work owing to these injuries was not available in the poison control center records. Finally, the results of this study may not be generalizable to other parts of the United States. Massachusetts is largely a manufacturing and technology-oriented state, and injuries to adolescents from pesticides and other agricultural toxins are less likely here than in other states.

The recent Institute of Medicine report recommended that the National Institute for Occupational Safety and Health (Washington, DC) develop and implement a plan for monitoring work-related injuries among workers younger than 18 years.[2] Poison control center data could help achieve such a worthy objective. In some instances, even if the acute injury to the adolescent is medically trivial, these sentinel events may expose unsafe work practices or the use of hazardous chemicals that may be outmoded and unnecessary to the performance of the job. Toxic exposures with latent manifestations, such as reproductive effects, would likely not be uncovered by this surveillance, which emphasizes largely acute symptoms and signs.

These findings should encourage further research into adolescent occupational exposures. Prospective studies could better define the determinants underlying these injuries such that preventive regulations or interventions could be guided by more informed public policy. It seems evident that many of the poisonings we described could have been prevented with prior training, attention to the hazards inherent in some of these products, use of appropriate protective gear, and a better orientation at the worksite. Adolescents should be notified of potentially hazardous substances they are being asked to work with and should be trained to use the products safely. Proper supervision of the employee in the setting in which the hazardous chemical is being used is also of utmost importance.

CONCLUSIONS

Adolescent occupational exposures to toxins are an important but underrecognized injury category; poison control center data can be used to fill in gaps in surveillance for this type of workplace-associated injury.

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Corresponding author: Alan D. Woolf, MD, MPH, Massachusetts Poison Control System, 300 Longwood Ave, Boston, MA 02115.

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