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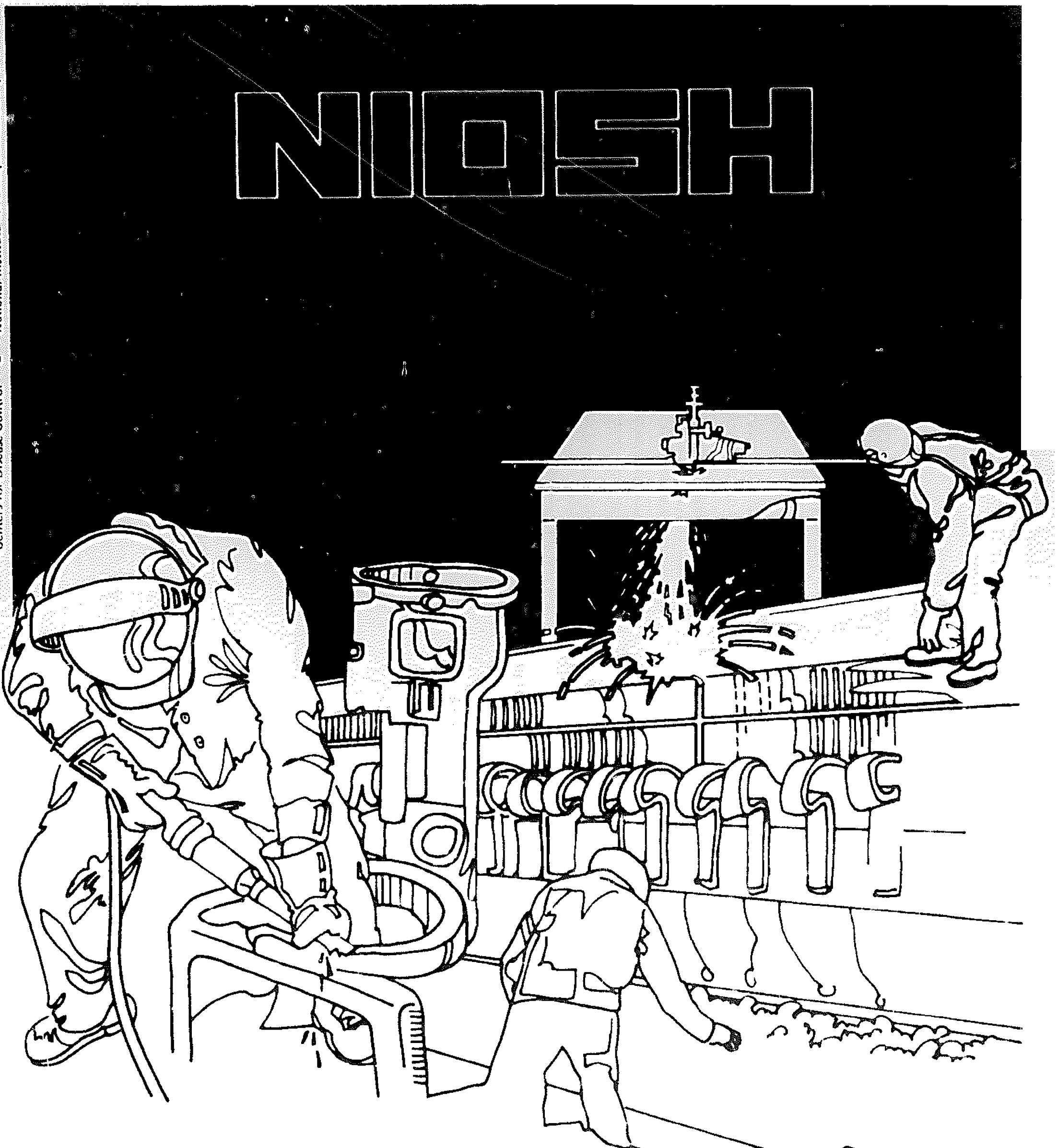

Health Hazard Evaluation Report

HETA 80-009-1383
INLAND STEEL CORPORATION
EAST CHICAGO, INDIANA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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INLAND STEEL CORPORATION
EAST CHICAGO, INDIANA

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I. SUMMARY

In October 1979, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate worker exposure to by-products of the coke-making process at the Inland Steel Corporation's No. 2 coke plant, East Chicago, Indiana. In June and July 1980, NIOSH investigators collected 26 personal breathing zone air samples for measurement of benzene, toluene, and xylene concentrations; administered health questionnaires; and obtained blood and urine specimens from 32 by-products area and nine laboratory workers to determine urine phenol concentrations, red and white blood cell parameters, and concentrations of serum constituents reflective of liver function.

Personal breathing zone air samples showed 60-minute time-weighted average (TWA) air benzene concentrations ranging from 0.16 to 6.0 parts per million parts of air (ppm), with a median of 2.3 ppm. Eight-hour TWA air benzene concentrations ranged from 0.45 to 96 ppm, with a median of 0.99 ppm. Twelve 60-minute samples exceeded the NIOSH recommended standard of 1 ppm for a 60-minute sampling period. One 8-hour sample exceeded the OSHA standard of 10 ppm for an 8-hour TWA. The highest exposures were in a light oil operator, two phenol pumpmen, and a benzol pump tender. Toluene was detected in seven (30%) of 23 samples; concentrations ranged from 0.03 to 10.4 ppm, all well within the NIOSH recommended standard of 100 ppm. Xylene was detected in only one sample, at a concentration of 1.3 ppm, well within the NIOSH recommended standard of 100 ppm. This worker, a light oil operator, also had the highest exposures to benzene and toluene.

Among by-products area workers the most commonly reported symptoms were fatigue (58% of workers), eye irritation (38%), skin burns (34%), nausea (32%), headache (31%), and dizziness (30%). Among laboratory workers, nausea (78%), fatigue (67%), headache (56%), skin burns (44%), dizziness (33%) and eye irritation (33%) were also the most common. One worker had anemia (without neutropenia), and six others had (mostly minor) decreases of single red blood cell parameters. No worker had a decreased neutrophil count. Two workers had two abnormal liver function tests each, and five others each had one abnormal test.

All 32 by-products area workers had elevated urine phenol concentrations. Among by-products area workers, concentrations ranged from 3.7 to 32 mg/g creatinine, with a median of 11 (reference range 1.5 - 2.8). Three laboratory workers had elevated urine phenol concentrations, ranging from 3.5 to 5.0 mg/g creatinine. Urine phenol concentration was not associated with symptoms, blood cell abnormalities, or abnormal

liver function tests, but was highly correlated with air benzene concentration ($p = 0.0004$ by linear regression).

On the basis of the environmental and medical findings of this investigation, NIOSH concluded that at the time of this study (mid-1980) there was a health hazard from over- exposure to benzene in the by-products area of the No. 2 coke plant. Recommendations for reducing benzene fugitive emissions and monitoring worker exposures are contained in Section VIII of this report.

Keywords: SIC 3312 (Blast furnaces [including coke ovens], steel works, and rolling mills), coke oven by-products, benzene, toluene, xylene

II. INTRODUCTION

In October 1979, NIOSH received a confidential request from an authorized representative of employees to evaluate worker exposure to by-products of the coke-making process in the by-products area (by-products building, benzol building, and related areas) and the laboratory of the No. 2 coke plant at the Inland Steel Corporation, East Chicago, Indiana. Workers were concerned about the occurrence of respiratory disorders and high blood pressure.

In January 1980, company officials denied entry to NIOSH investigators. The investigation was delayed until June 1980 because of NIOSH's need to obtain a warrant for entry and a subpoena for medical records. Environmental sampling and medical interviews were conducted June 25-27, and additional medical interviews, testing, and records review July 14-17. NIOSH notified the company and requester of the environmental findings in a letter dated August 28, 1980.

III. BACKGROUND

A. Process Description

Inland Steel is an integrated steel works where all phases of steel production occur, from the receipt of ores and coal to the production of the finished article. An essential process in steel making is the carbonization of coal to form coke, which can then be used in the reduction of iron ore to form pig iron, a major component of all steel.

The carbonization of coal is the heat treatment of bituminous coal in the absence of air, which results in the production of a residue called coke. Also produced during this process are vapors which, when condensed and separated, produce crude coal chemicals commonly referred to as tar, light oil, ammonia liquor, and coke oven gas. These crude fractions are further refined in varying degrees from plant to plant to produce commodity chemicals such as benzene, toluene, xylene, ammonium sulfate, pyridine, naphthalene, anthracene, phenanthrene, creosote, road tars, and industrial pitches, to name a few.[1,2] (See Appendix 1)

At the Inland Steel No. 2 Coke Plant, the hot gas (1200-1500°F) resulting from the carbonization leaves the coke oven and enters a collecting main. At this point it is sprayed with a flushing liquor, the primary component of which is water. The evaporation of the water results in a cooling of the gas. By the time the gas leaves the collecting main it has sufficiently cooled (180°F) to cause the condensation of a majority of the tar components of the gas. This tar, along with the unevaporated flushing liquor, is removed from the system and pumped to large tanks to undergo gravimetric separation. The separated liquor is then recirculated into the cooling system of the collecting main. The tar is pumped into storage tanks until such time as it can be loaded into tank trucks and transported from the area.

The remaining coke oven gas, still under slight negative pressure, leaves the collecting main and enters the primary coolers. This further cooling (75-95°F) results in the condensation of more tar and water. The condensed water is separated from the gas and pumped to the phenol removal plant. The water is mixed with caustic soda in the phenol scrubber, resulting in the precipitation of phenol, which is subsequently removed from the system. The remaining water, high in ammonia content, is pumped to the ammonia still. Before it enters the fixed ammonia section of the still, lime is added to the solution to free the "fixed ammonia" (that which is in the chloride or thiocyanate form). This, along with the "free ammonia" (the carbonic or hydrosulfuric form) remains in the vapor state and will reenter the gas stream at a later point.

The gas leaving the primary coolers is pulled into the by-products building by high speed centrifugal exhausters driven by steam turbines and then pushed through the rest of the system under pressure. Upon leaving the exhausters, the gas enters an electrostatic precipitator, which removes any remaining tar. The gas is then mixed with the vapor returning from the ammonia still and enters the saturator. At this point the gas comes in contact with a solution of sulfuric acid. This results in the precipitation of ammonium sulfate, which is then removed in a slurry, dried in a high-speed centrifuge, and conveyed to a nearby section of the building for temporary storage. The gas then enters the final coolers, and the temperature is lowered (75°F) by direct contact with water such that the precipitation of naphthalene occurs. The water from the cooler is run to a sump, and the naphthalene crystals are skimmed off.

The next step is the recovery of the light oil, which consists primarily of benzene, xylene, and toluene. This occurs as the gas is passed through a countercurrent scrubber and comes into contact with a heavy petroleum wash oil, resulting in the extraction of the light oil. The "enriched" wash oil then undergoes fractional distillation to separate the two oil components. The heavy oil is recirculated back into the scrubber system, and the light oil is stored until it can be transported by tank truck. The remaining gas leaves the countercurrent scrubber, and fifty percent is piped back to the coke ovens for use as a fuel, the balance going into the plant gas system.

B. Job-Descriptions/Locations

1. By-products area

Nine full-time employees are responsible for equipment operation on each of the four shifts in the by-products area of the No. 2 coke plant. Three employees work within the by-products building itself. The exhauster engineer is responsible for starting up the exhausters, monitoring the guages and dials indicative of the operation of these machines, and responding to malfunctions or changes in equipment performance. A majority of the time can be spent in a room with an air conditioning system separate from the rest of the building. At intervals, the engineer is required to leave this room to perform maintenance chores within the by-products building. The saturator monitors the level of the sulfuric acid, operates related pumps, and maintains the equipment and the area. The dryerman operates the two centrifugal dryers, shovels ammonium sulfate that falls to floor back onto the conveyor, and cleans the equipment and area around the operation.

Three by-products pump tenders are responsible for a variety of duties in the area outside of the by-products building. These include maintaining tar levels in the various tanks, operating the pumps used for providing the cooling water for the coke oven gas, operating the ammonia still, and pumping tar from tank to tank. These duties require the employee to move throughout the by-products area, with a significant portion of the time being spent outdoors. Additionally, one individual is responsible for the loading of tar into the tank trucks. During this operation the worker is located in a small room directly above the loading area.

The phenol pump tender operates the pumps for the phenol scrubber, the naphthalene skimmer, and the final cooler, and also operates the crane that moves the ammonium sulfate in the storage area adjacent to the by-products building.

There are two employees working in the benzol building. The light oil operator is responsible for maintaining the temperature on the fractional distillation units. Additionally, he is required to load transport trucks with light oil after it has been separated. During the loading operation, a respirator is made available to the employee upon request. The light oil pump tender operates the pumps related to the absorption process and regulates the flow rates of the various components.

2. Laboratory

The by-products quality control laboratory was moved from the by-products area to a new, distant building during the period between the submission of the hazard evaluation request and the first NIOSH site visit. The new building has modern laboratory equipment and hoods, so the environmental conditions which prompted the request no longer existed in the laboratory.

C. Medical Records

By-products area workers received the medical surveillance procedures specified by the Occupational Safety and Health Administration's coke oven emissions standard (29 CFR 1910.1029). (Laboratory workers were not included in this program; their medical records generally contained only pre-employment examinations and descriptions of injuries and illness.) A review of the medical records of by-products area workers revealed various sporadic test abnormalities and several cases of red blood cell parameters decreasing between 1979 and 1980. While this trend was not sufficiently consistent to document an occupational health effect, it supported the need for NIOSH to include such tests in the health hazard evaluation.

IV. METHODS

A. Environmental

The environmental survey was designed to quantify personal exposures to volatile organic substances at the various jobs throughout the by-products area. Samples were collected near the breathing zones of the employees using battery-powered sampling pumps attached via tygon tubing to a charcoal tube collecting media. Seventeen short-term (approximately 60 minutes) and nine long-term samples were collected. Two of the short-term and one of the long-term samples were replicates. Samples were analyzed for benzene, toluene, and xylene using a modification of NIOSH Method P&CAM 127.[3] The sample location, duration, flow-rate, and other information pertinent to sample collection is contained in Tables 1 and 2. The laboratory was not included in the industrial hygiene survey because there was no longer exposure to the coke-making process.

B. Medical

All available No. 2 coke plant by-products area and laboratory employees participated in the medical study, which included an interviewer-administered symptom questionnaire, measurement of urine phenol concentration (an indicator of benzene exposure), and determination of white and red blood cell counts, blood hemoglobin concentration, hematocrit (packed red blood cell volume), serum bilirubin concentration (an indicator of liver function), and serum concentrations of four enzymes (aspartate aminotransferase [SGOT], alanine aminotransferase [SGPT], alkaline phosphatase, and gamma glutamyl transpeptidase [GGTP]) indicative of liver damage. Urine phenol was measured by NIOSH Method PYCAM 330.[4] The other analyses were done by standard automated techniques.

In addition to the above tests, laboratory employees also had pulmonary function tests. Forced vital capacity (FVC) and one-second forced expiratory volume (FEV_1) were measured with an Ohio Medical Products Model 822 dry rolling seal spirometer attached to a Spirotech 200B dedicated computer. A test was considered adequate for interpretation only if there were three acceptable trials and the two best differed by no more than 5% with respect to both FVC and FEV_1.[5] Predicted values were calculated according to the Knudson equations[6]; the predicted values for Black persons were calculated by multiplying the Knudson predicted values by 0.85.[7]

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH recommended standards, by contrast, are based solely on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

B. Benzene, Toluene, and Xylene[8,9]

Benzene, toluene, and xylene all affect the central nervous system, resulting in such symptoms as headache, vertigo (dizziness) lightheadedness, drowsiness, confusion, and incoordination. Toluene and xylene vapors are irritating to the eyes, nose, and throat, and skin contact with any of the three compounds can result in dermatitis. Inhalation of xylene can cause stomach discomfort, loss of appetite, nausea, and vomiting. Chronic exposure to benzene can cause decreased production of red blood cells, white blood cells, and platelets, resulting in pallor and shortness of breath, impaired ability to fight infections, and bleeding problems, respectively. Benzene can also cause leukemia. Toluene and xylene are not known to have these effects, but commercial-grade toluene is commonly contaminated with benzene. Except when ingested or inhaled in extremely high concentrations (glue-sniffing) none of these three compounds has appreciable liver toxicity.

In order to reduce the risk of leukemia, NIOSH recommended in 1977 that exposure to benzene not exceed 1 part per million (ppm).[10] This criterion, initially a 2-hour TWA, then later a 1-hour TWA as analytical sensitivity improved, was chosen because it represented the limit of analytical reliability.[11] As with other carcinogens, NIOSH recommends that employee exposure to benzene be reduced to the lowest feasible level.[11] NIOSH recommends that exposure to either toluene[12] or xylene[13] not exceed a full-shift time-weighted average (TWA) concentration of 100 ppm nor a 10-min ceiling concentration of 200 ppm. The current OSHA standard for benzene is an 8-hour TWA of 10 ppm, a 10-minute ceiling of 25 ppm, and a maximum peak of 50 ppm. The corresponding OSHA limits for toluene exposure are 200, 300, and 500 ppm. The OSHA standard for xylene is 100 ppm. The ACGIH TLV for benzene is an 8-hour TWA of 10 ppm and a 15-minute short-term exposure limit (STEL) of 25 ppm. The ACGIH TLV's for toluene and xylene are 8-hour TWA's of 100 ppm and 15-minute STEL's of 150 ppm.

VI. RESULTS

A. Environmental

Personal breathing zone air samples showed 60-minute TWA air benzene concentrations ranging from 0.16 to 6.0 ppm, with a mean of 2.3 ppm. Eight-hour TWA air benzene concentrations ranged from 0.45 to 96 ppm, with a median of 0.99 ppm. Twelve 60-minute samples exceeded the eight-hour NIOSH recommended standard of 1 ppm for a 60-minute sampling period. One 8-hour sample exceeded the OSHA standard of 10 ppm for an 8-hour TWA. A complete listing of the environmental results is provided in Tables 1 and 2. In those instances where replicate samples were collected, the average of the two values was used in the summary information.

The highest benzene exposure, the only one exceeding the OSHA standard of 10 ppm, was in a light oil operator (Table 2), who also had, by two orders of magnitude, the highest exposure to toluene, 10 ppm, and the only detectable exposure to xylene, 1.3 ppm. The second highest benzene exposure, 6.0 ppm, was in a phenol pumpman (Table 1). The other six benzene exposures greater than 2.0 ppm were in the light oil operator already mentioned (two short-term samples), a benzol pump tender (2 short-term samples), and two phenol pumpmen (one of whom was mentioned above). Toluene was detected in seven (30%) of 23 samples; concentrations ranged from 0.03 to 10.4 ppm, all well within the NIOSH recommended standard. Xylene was detected in only one sample, at a concentration of 1.3 ppm, and was well within the NIOSH recommended standard. No other significant air contaminants were observed in the analysis. The limit of detection for benzene, toluene, and xylene was 0.001 mg/sample.

B. Medical

Thirty-two by-products area employees and nine laboratory workers participated in the medical study. Except for one laboratory employee, all were men. They ranged in age from 20 to 55 years, median 26, and had worked at their present job from two days to 28 years, median 2.5 years. Seniority at the plant ranged from 1.5 to 33 years, with a median of 6. Thirty (73%) of the 41 participants smoked cigarettes, and another four (10%) were former smokers.

Seven (17%) of the 41 workers thought that they had a work-related health problem: two reported respiratory symptoms, three reported fatigue, one repoprted insomnia, and one reported ringing in the ears. Two workers who reported fatigue were laboratory workers, and the other five each had a different job in the by-products area.

Fatigue was the most commonly reported health effect (reported by 58%) among by-products area workers and the second most common (67%) among laboratory workers (Table 3). Among the laboratory workers, nausea was the most commonly reported health effect (78%). Eye irritation, skin burns, nausea, headache, and dizziness were reported by 30-38% of by-products area workers and (except for nausea) by 33-56% of laboratory workers. Other health effects, including respiratory problems and high blood pressure, were reported by two (22%) or less laboratory workers and by five (16%) or less by-products area workers.

In the by-products area, no more than two workers (6%) had an abnormality of any one liver function test (Table 4). Only one worker had more than one abnormality; he reported occasional nausea and prolonged bleeding following removal of teeth. Two laboratory workers had an elevated GGTP, and one of these also had an elevated SGPT. This latter worker reported no symptoms.

Five by-products area workers had low red blood cell (RBC) counts (Table 4), but in only one case were there other abnormalities of blood cell paramaters: a low hemoglobin concentration and a low hematocrit. This worker reported fatigue. One laboratory worker had a low RBC count, and two others had a high hematocrit. All total white blood cell (WBC) and neutrophil abnormalities, and four of five lumphocyte abnormalities were increased counts. Altogether, 4 (13%) of the by-products area employees and 3 (33%) of the laboratory employees had one or more WBC abnormalities, but none had a decreased neutrophil count, the expected manifestation of benzene bone marrow toxicity.

Compared to the laboratory's reference range, all 32 by-products area workers had an elevated urine phenol concentration (Table 4), ranging from 3.7 to 32 mg/g creatinine, with a median of 11. The by-products area worker with the three abnormal RBC parameters had a urine phenol concentration of 9.6 mg/g creatinine. Three laboratory workers had an elevated urine phenol concentration, ranging from 3.5 to 5.0 mg/g creatinine.

Although the concentration of 5.0 was in the worker with the two abnormal liver function tests, this concentration was less than that of 28 by-products area workers. Of the five by-products area workers with one or more abnormal liver function tests, three had a urine phenol concentration above the median, including the highest concentration. The median urine phenol concentration of the by-products area workers with any of the systemic symptoms potentially associated with benzene toxicity was no higher than the median of those without such symptoms (Table 5).

Ten medical survey participants had one or more air samples taken. Urine phenol concentrations was highly correlated with air benzene concentration (linear regression, r = 0.90, = 4.55, t = 5.8, d.f. = 8, p = 0.0004) (Figure 1), even though the medical survey took place almost three weeks after the environmental exposure. (When a worker had more than one short-term air benzene sample, the mean concentration was used for analysis. With one exception, if the worker had a long-term sample, the result of this test was used instead. In the case of the worker with the benzene exposure of 96 ppm, this concentration was considered a statistical outlier, so the mean of the two short-term samples was used.)

One laboratory worker, a smoker with respiratory discomfort on exertion, had pulmonary function results suggesting minimal airways obstruction. Another, a non-smoker with no respiratory symptoms, had results compatible with mild obstruction and/or minimal restriction.

VII. CONCLUSIONS

The urine phenol data documented universal exposure to benzene in the by-products area, and the environmental sampling showed that a majority of workers had exposures exceeding the NIOSH recommended standard. The high correlation between urine phenol concentration and air benzene concentration measured three weeks previously suggests that the air samples were representative of the individual workers' usual exposures. Since the highest urine phenol concentration in a laboratory worker was 5.0 mg/g creatinine, one could infer from Figure 1 that laboratory workers' exposures to benzene were not excessive.

Since this study was done, the NIOSH laboratory, using improved analytical procedures, reports mean urine phenol concentrations of 10-15 mg/g creatinine in persons not exposed to benzene.[14] (These values are more consistent with a recently published upper limit of 20 mg/liter for persons not exposed to benzene.[15]) While this does not necessarily negate the finding of elevated urine phenol concentrations among by-products area workers or the association between air benzene and urine phenol concentrations found in this study, it means that the numerical values cannot be used as individual or group referent values for future urine phenol determinations, nor can the regression line (Figure 1) be used to determine what urine phenol concentration to use as an indicator of potential escessive exposure to benzene.

The blood tests showed no epidemiologic evidence of occupational liver toxicity, but this effect would not be expected from benzene exposure anyway. There was one case of anemia (without neutropenia), and six other workers had (mostly minor) decreases of single RBC parameters. The data from this study are insufficient, however, to determine whether these represent cases of benzene-related bone marrow toxicity. Neither the questionnaire data nor the pulmonary function test results suggested any pattern of work-related respiratory disease among laboratory workers. Neither the questionnaire data nor the documented exposures provide a basis for suspecting hypertension of occupational etiology. Finally, although fatigue, nausea, headache, and dizziness were frequently reported, these symptoms could not be epidemiologically associated with intensity of benzene exposure. (Some of the symptoms might have been related to the hot work environment, but this study did not address that issue.)

Since the by-products area of the No. 2 Coke Plant consists of what appears to be an essentially closed system, the majority of the employee exposures to benzene and the other organic compounds presumably occurred as a result of "fugitive emissions" in the various work areas. These emissions are usually considered to be the result of leaks in valves, pumps, flanges, and other pieces of equipment used in handling the process stream. Since it is not possible to eliminate benzene from the process, control techniques designed to reduce levels of fugitive emissions should be implemented to reduce worker exposure.

Various references are available which provide in-depth discussions of techniques for identifying and controlling fugitive emissions, and these should be consulted for more detailed information.[16,17,18] In addition, it would be prudent to implement a combined industrial hygiene and medical surveillance program which would identify those employees who are being exposed to benzene and further identify the need for engineering controls and personal protection.

The highest exposure to benzene (96 ppm for a light oil operator) was not verified by additional sampling during the evaluation. However, information suppled to the NIOSH investigators during the survey indicated that previous environmental data for this job, while less than 96 ppm, was still in excess of 10 ppm. Since this exposure is not typical of the other employee exposures in the area, due to the potential for high organic vapor concentrations during loading of tank trucks, it should be separately and thoroughly evaluated to ensure that future exposure is minimized to the greatest extent possible.

VIII. RECOMMENDATIONS

1. State-of-the-art control techniques designed to reduce levels of fugitive emissions should be utilized throughout the by-products area. These should include (a) leak detection and repair programs in which fugitive emissions sources are located and repaired at regular intervals, and (b) preventive programs in which potential fugitive emission sources are eliminated by either retrofitting with specified controls or replacement with leakless equipment.[13]

2. An industrial hygiene survey should be conducted initially, and periodically thereafter, in order to identify those employees and work areas subject to high concentrations of benzene. In the time necessary for their implementation, administrative controls (e.g. removal of employees from areas of exposure when their presence is not essential) and personal protective equipment (e.g. the use of NIOSH/MSHA approved respirators, in conjunction with an adequate respiratory protection program) should be utilized in those instances where exposures are found to be above the NIOSH recommended standard of 1 ppm.

3. An analysis of the current procedures for the loading of light oil should be carried out. Efforts should be made to reduce the exposure of the employee involved in this operation through the use of engineering controls, improved work practices, and personal protective equipment, including appropriate respiratory protection. (According to company representatives, these measures have been implemented.)

4. Workers potentially exposed to benzene should have periodic tests for urine phenol concentration. Slight elevations are difficult to interpret individually, but a high prevalence of elevated urine phenol concentrations in the workforce or a substantial elevation in an individual suggests benzene exposure. A urine phenol concentration in excess of 20 mg/g creatinine indicates potential occupational exposure to benzene. An elevated urine phenol concentration requires no treatment, but it indicates a need for evaluation of the worker's exposure to benzene and appropriate corrective measures. Workers with environmental or biological monitoring data suggestive of chronic or repeated acute benzene exposure should have periodic complete blood cell counts and medical evaluation of any abnormality or substantial change from previous results.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Requester
2. Inland Steel Corporation
3. United Steel Workers of America, Local 1010
4 NIOSH, Region V
4. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Results of Short-Term Personal Breathing Zone Samples
for Benzene, Toluene, and Xylene
Inland Steel Corporation, East Chicago, Indiana
June 26-27, 1980

HETA 80-009-1383

Job Title	Sample Time (min)	Flow Rate (cc/min)	Volume (liters)	Benzene (ppm)
Exhauster	59	53	3.1	1.4
Dryer	62	53	3.3	0.85*
Dryer	62	53	3.3	0.94*
Saturator	59	40	2.4	2.0
Phenol pumpman	67	50	3.4	4.0
Tar/lime tender	57	50	2.8	1.5
Light oil operator	59	50	3.0	2.3
Benzol pump tender	61	50	3.0	2.3
Tar loader	88	50	4.4	0.35
Exhauster	58	53	3.1	1.2
Dryer	52	94	4.9	0.13**
Dryer	52	94	4.9	0.19**
Saturator	52	50	2.6	1.1
Tar/lime tender	48	50	2.4	1.2
Phenol pumpman	58	52	3.0	6.0
Light oil operator	50	50	2.5	5.5
Benzol pump tender	49	50	2.4	3.9
Blank				ND
NIOSH Recommended Standard (60-minute sample)				1.0

In all of the above samples, toluene and xylene were found to be below the level of analytical detection (see Appendix 2).

Abbreviations: ppm = parts of contaminant per million parts of air
ND = none detected, below the level of analytical detection
cc = cubic centimeter

* Replicate samples, mean: 0.90 ppm
** Replicate samples, mean: 0.165 ppm

Table 2

Results of Long Term Personal Breathing Zone Samples
for Benzene, Toluene, and Xylene
Inland Steel Corporation, East Chicago, Indiana
June 26-27, 1980

HETA 80-009-1383

Job Title	Sample Time (min)	Flow Rate (cc/min)	Volume (liters)	Benzene (ppm)	Toluene (ppm)	Xylene (ppm)
Dryer	455	48	22	1.5	0.24	ND
Phenol pumpman	450	53	24	2.4	0.33	ND
Exhauster	458	48	22	0.95	0.24	ND
Benzol pump tender*	436	100	44	0.54	0.06	ND
Benzol pump tender*	436	100	44	0.53	ND	ND
Saturator	448	50	22	0.99	0.11	ND
Tar loader	449	50	22	1.2	0.36	ND
Light oil operator	436	50	22	96	10	1.3
Tar/lime tender	428	50	21	0.45	ND	ND
Blank				ND	ND	ND
NIOSH Recommended Standard**				1.0	100	100

Abbreviations: ppm = parts of contaminant per million parts of air
ND = none detected, below level of analytical detection
cc = cubic centimeter

* Replicate samples; means: 0.54 ppm for benzene, 0.03 ppm for toluene
** 60-minute sample for benzene, full-shift sample for toluene and xylene

Table 3

Health Effects Reported by Medical Survey Participants
Inland Steel Corporation, East Chicago, Indiana
June 26-27, 1980

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	Workers Reporting Health Effect			
	By-products area (32 workers)		Laboratory (9 workers)	
Health Effect	Number	%	Number	%
Fatigue	18	58[A]	6	67
Eye irritation	12	38	3	33
Skin burns	11	34	4	44
Nausea	10	32[A]	7	78
Headache	10	31	5	56
Dizziness	9	30[B]	3	33
Respiratory problems	5	16	1	9
High blood pressure	5	16	1	9
Bleeding problems	4	13	1	9
Sore throat	3	10[A]	2	22
Weight loss	2	6	0	-
Change in color of urine	0	-	2	22
Convulsions	0	-	0	-
No health effects	3	9	0	-

A - One non-respondent to this question omitted from denominator.
B - Two non-respondents to this question omitted from denominator.

Table 4

Blood and Urine Test Results Among Medical Survey Participants
Inland Steel Corporation, East Chicago, Indiana
June 26-27, 1980

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Test	Reference Range[1]	Results outside of Reference Range: By-products area (32 workers) Number	%	Laboratory (9 workers) Number	%
Total bilirubin	0.10-1.70 mg/dl	2	6	0[A]	-
Aspartate amino-transferase (SGOT)	1-70 I.U./l	0	-	0[A]	-
Alanine amino-transferase (SGPT)	0-50 I.U./l	0	-	1[A]	13
Alkaline phosphatase (AP)	10-50 I.U./l	2	6	0	-
Gamma glutamyl transpeptidase (GGTP)	1-40 units/l	2	6	2[A]	25
Red blood cells[2]	4.4-5.9 per ul	5	16	1	11
Hemoglobin[2]	13.3-17.7 g/dl	2	6	0	-
Hematocrit[2]	39.8-52.2%	1	3	2	22
White blood cells	4000-11600 per ul	1	3	2	22
Neutrophils	1650-8330 per ul	1	3	2	22
Lymphocytes	1049-3581 per ul	4	13	1	11
Urine phenol	1.5-2.8 mg/g creatinine[3]	32	100	3[B]	38

1 - The range of results for most health adults. Unless otherwise noted, the reference range used is that of the laboratory perfoming the tests. Abbreviations: mg = milligram, dl = deciliter, I.U. = international unit, ul = microliter, g = gram.

2 - Reference ranges are for adult men; for women the reference ranges for red blood cells, hemoglobin, and hematocrit are 3.8-5.2, 11.7-15.7, and 34.9-46.9, respectively. Source: Williams WJ, Schneider AS. Examination of the peripheral blood. In: Williams WJ, Beutler E, Erslev AJ, Rundles RW, eds. Hematology. 2nd ed. New York: McGraw-Hill, 1977.

3 - Range of concentrations among 12 NIOSH employees without occupational exposure to benzene or phenol.

A - Test could not be done on one blood specimen because of lipemic serum.

B - Phenol concentration could not be calculated for one specimen because of low creatinine concentration.

Table 5

Urine Phenol Concentrations Among By-Products Area Workers
According to Presence of Systemic Symptoms Potentially
Related to Benzene Exposure
Inland Steel Corporation, East Chicago, Indiana
June 26-27,1980

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	Urine phenol concentration, median and (range), mg/g creatinine	
Symptom	Symptom Present	Symptom Absent
Nausea	9.9 (4.1-31)	11 (3.7-32)
Dizziness	11 (3.7-15)	11 (4.1-32)
Headache	8.4 (4.4-15)	12 (3.7-32)
Fatigue	11[A] (3.7-23)	9.1[A] (4.1-32)

A - $p > 0.5$, Wilcoxon rank sum test

FIGURE 1
RELATIONSHIP BETWEEN AIR BENZENE AND URINE PHENOL CONCENTRATIONS, INLAND STEEL CORPORATION, EAST CHICAGO, INDIANA, JUNE - JULY 1980
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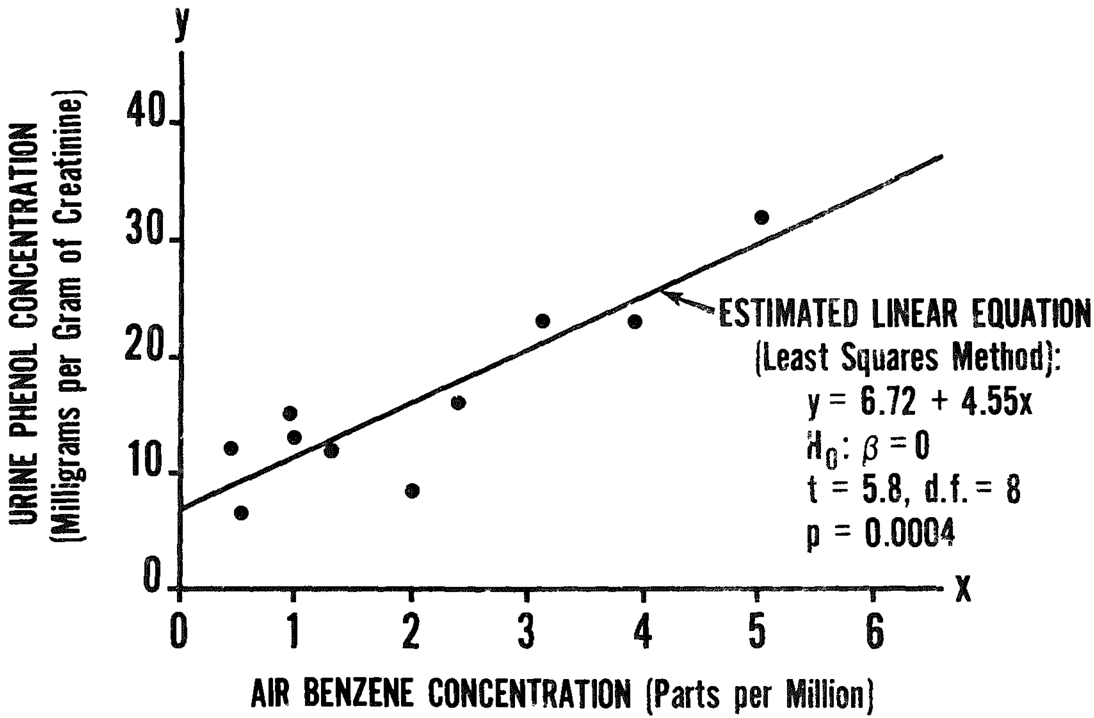

Appendix 1

Typical Yields of Coke and Chemicals from High-Temperature Coal Carbonization*

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Major Substance/Components	Per Cent	Pounds Per Ton of Coal
Coke(including coke breeze)	75	1500
Coal Tar	4	80 (8 gal)
Light Oil		1
Naphthalene Oil		8
Heavy creosote oil		9
Anthracene oil		14
Soft pitch		16
Medium pitch		14
Light Oil	1	22 (3 gal)
Benzene		15
Toluene		3
Xylene		1.5
Other		2.5
Liquor	6	120
Ammonium sulfate		20
Gas	14	280 (10,500 cu ft.)
Hydrogen sulfide		6
Carbon dioxide		18
Nitrogen		8
Hydrogen		32
Carbon monoxide		45
Methane		130
Ethane		11
Ethylene		20
Propylene		3
Light Oil		3
Other(butylene, hydrogen cyanide, etc)		4

*Source: Reference #1 in text.

Appendix 2

Supplement to Analytical Procedure

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The samples were desorbed with 1 ml of carbon disulfide containing 1 ul/ml cymene internal standard and analyzed by gas chromatography according to NIOSH Method P&CAM 127 (modified) using a Hewlett-Packard 5711A gas chromatograph with a flame ionization detector.

A 12' x 1/8" stainless steel column packed with 10% SP-1000 on Supelcoport (80/100) was used at an oven temperature of 100°C (isothermal).

The presence of benzene in all the above numbered samples was confirmed by re-analyzing them on another column. It consisted of a 12' X 1/8" stainless steel column packed with 10% tris (cyanoethoxy) propane on Chromosorb P (80/100) AW. The oven temperature was 120°C (isothermal).

No other significant unknowns were observed in the analysis.

The limit of detection per sample tube was 0.001 mg for benzene, 0.01 mg for toluene, and 0.01 mg for m-xylene.