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Time of Exposure Based on Biological Monitoring

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Abstract

There are two biological exposure indices that represent exposure to elevated levels of mercury. One is based on total inorganic mercury in urine; the second is based on total inorganic mercury in blood. Retention of mercury in these fluids is different and represents exposures over different relative times. Mercury in urine represents exposure three to six months prior to testing, while the blood test represents exposure during the days prior to testing. In the absence of air monitoring data, biological monitoring can represent exposures to elevated concentrations of this contaminant, and aid in identifying the time of exposure. In this case study, there were two successive employers of a plant, both of which agreed the worker was exposed to high levels of mercury and was experiencing adverse health effects from that exposure. The first owner held coverage with two insurers in succession. The second employer took the position that the worker was exposed while the other owned and operated the plant. Exposure during each period of responsibility was demonstrated.

Production Process

The plant produced a variety of chemicals for the pulp and paper industry, and for local companies. These chemicals included caustic soda and chlorine in various forms and concentrations. A solution of sodium chloride was electrochemically dissociated. Sodium was removed by dissolving in mercury that flowed beneath the brine. As the sodium was removed from the mercury, the mercury was recycled through the process.

This process proceeded in 100 cells that were about 50 feet long and about 3 feet wide. These were housed in two cell rooms that were constructed in 1956 – 1957. At that time, engineering controls for worker safety were not routinely considered in industrial plant design. By the 1980s, the plant had deteriorated and the efficiency of the equipment was affected. There was some investment in the plant in 1987 to repair foundations, floor surfaces, and other improvements in the equipment. However, market conditions changed and hurt the financial condition of the company. As plant efficiency and capacity dropped, leaks and spills became more common, and down time for repairs increased. The plant was shut down in 1994.

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Worker Protection

By 1966, it was becoming apparent to industry that there was a need to protect workers from mercury. Plant management testified that as technology evolved and became available, every reasonable protection was utilized. In 1979, every employee had a hard hat, steel-toe shoes, and half-face respirator. There were also full-face respirators and self-contained breathing apparatus throughout the plant for protection from chlorine gas.

There are indications that government agencies thought there was room for improvement. During April 1988, investigators from the National Institute of Occupational Safety and Health (NIOSH) conducted industrial hygiene and medical evaluations at the plant. In the interim report of that investigation[1], NIOSH reported substantial mercury contamination measured in the laundry room, locker room, first aid room, break rooms, and restrooms in each cell room. Also, half of the workers tested had urine mercury levels greater than 50mg Hg/g creatinine. Cell assembly workers had an average urine mercury level of 311.0 mg Hg/g creatinine. Cell operators had an average urine mercury level of 258.2 mg Hg/g creatinine, and cell foreman had an average urine mercury level of 214.7mg Hg/g creatinine. NIOSH concluded from these data that there "exists an unacceptably high potential for health effects in workers" at this plant. NIOSH interim recommendations included changes in respiratory protection, engineering controls, and work practices. Recommended changes in work practices included:

- Spills and leaks of mercury shall be promptly cleaned up either mechanically or chemically. No blowing or dry sweeping shall be permitted. When vacuum cleaners are used, they shall be equipped with mercury vapor absorbing filters to prevent dispersal of mercury vapors into the work place air.
- No smoking, eating, or drinking shall be allowed in the cell rooms (including the break rooms) and other mercury work area.
- Work and street clothing shall not be stored in the same locker.

Mercury tends to collect and concentrate on worker's clothing. As the work clothes are changed, mercury can be re-entrained in the air to become a significant route of exposure. The data referenced in the letter were not available.

Plaintiff's Job

The plaintiff was hired in 1987, as a temporary worker in the cell room for a special task force that had been hired to upgrade and maintain the equipment in the cell room. In a short time, he was hired as a permanent employee in the labor gang, where he performed janitorial functions, unloaded rail cars, and per-

formed general labor tasks. While in the labor gang, he worked in the laundry room where they laundered work clothes on site. Sometime in 1989, the plaintiff moved into the cell room. When the plant closed in February 1994, he was a laborer repairman within the cell room.

The cell is basically a steel structure with a rubber protective coating on the inside. The coating would last about eight years, and the components would have to be replaced periodically. Because of the corrosive atmosphere and deterioration of the nuts and bolts, sledge hammers were sometimes used to disassemble units. Three or four people typically worked on each cell, and usually more than one cell would be worked on at a time. Production continued in the other cells at the same time.

After production stopped, the first employer began efforts to remediate waste contamination. The workers were called back in about a month and completed physical examinations and the 40-hour Occupational Safety & Health Administration (OSHA) required training for hazardous waste operations.

The plaintiff and several others were assigned to the cell room. The plant was not in operation, but there was mercury in the cells. Each operating cell contained a couple of tons of mercury, 80 to 90 percent of which could be drained out through drain plugs. That work had been completed, but several hundred pounds of mercury remained in each cell. Some disassembly was required to remove the remaining mercury. Initially, there was no additional personal protective equipment (PPE) required.

Regulatory Difficulties

The management of this plant had considerable difficulty with regulatory agencies, particularly the United States Environmental Protection Agency (EPA). While it is clear much data was collected over the years to characterize worker exposure to mercury, EPA seized it all in order to pursue criminal enforcement. The author is not familiar with the details of that investigation. The pubic record describes air and waste issues that are relevant.

On November 30, 1993, Mr. Frederick D. Rowe[2], Georgia Environmental Protection Division (EPD) inspected the plant for compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPS). He reported the following mercury spills:

Cell Room 1 Basement – Seven spills totaling less than 8,050 grams
Cell Room 1 Upstairs – Eighteen spills totaling less than 90 grams
Cell Room 2 Basement – Five spills totaling less than 3,310 grams
Cell Room 2 Upstairs – Twenty spills totaling less than 100 grams

As the mercury evaporates, it leaves a salt shell around the mercury spill. Based on the number and size of the slat shells, Mr. Rowe estimated the spill in Cell Room 2 Basement to be twice the 3.3 kilograms reported above. He also notes that a machine operator was cleaning off cells in the Number 1 Cell Room with a compressed air hose.

As the result of a separate action, EPA issued a Unilateral Administrative Order for Removal Activities (EPA Docket No. 94-15-C), in April, 1994. A December 15, 1994, letter to the owner from the Federal On-Scene Coordinator/Enforcement Officer, required the owner to retain a qualified removal contractor, to replace the contractor the owner had selected; and, further that EPA did not wish to meet with the original contractor again. In that letter, EPA specifically required the use of full-face air purifying respirators for all persons working in the buildings.

The regulatory situation continued to deteriorate and, on February 10, 1995, EPA ordered a work stoppage due to problems concerning worker health and safety monitoring, and compliance with the Site Health and Safety Plan. These were resolved and operations began again within several days. But on March 17, 1995, EPA issued a Notice of Noncompliance with the Order and the Comprehensive Environmental Response, compensation and Liability Act (CERCLA). Ultimately, on February 1, 1996, a second employer took charge of the operation.

Mercury Toxicity[3]

Mercury is readily absorbed through the respiratory tract, intact skin, and the gastrointestinal tract. The respiratory tract and lungs retain most of the elemental mercury inhaled; less than 26 percent of the inhaled amount is exhaled. Dermal absorption of mercury vapors is about 2.2 percent of pulmonary uptake, and therefore is not likely to be a significant factor in biological levels. Of course, handling liquid mercury increases the dermal absorption and can significantly increase the biological levels.

Acute exposure to mercury salts can cause a violent corrosive effect in skin and mucus membranes; and cause nausea, vomiting, abdominal pain, bloody diarrhea, kidney damage, and death within ten days. Chronic exposure results in inflammation of the mouth and gums, excessive salvation, loosening teeth, kidney damage, muscle tremors, jerky gait, spasms of extremities, personality changes, depression, irritability, and nervousness.

Plaintiff Health Assessment

A medical evaluation by physicians at an environmental and occupational medicine consulting clinic concluded the plaintiff's history, physical and lab

analysis indicate chronic mercury toxicity. The report notes [4]:

> Initially, he noticed weight loss as manifested by loose fitting clothes, and that he had squinting of his right eye. He now frequently wears sunglasses to cosmetically cover the squinting in the right eye. He next developed dental pain and has had several teeth pulled over the years due to this. He stated the dentist told him his teeth were rotting from the inside out.
>
> He next developed shakiness, which he believes was in the late 1980's. This had been noticed by others.
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> The Plaintiff admitted joint pain increasing over the last two years, specifically in the left shoulder, left elbow associated with swelling, and both knees; especially at times when he is most active. Joint pain in his left wrist was first documented in his medical records in 1989.
>
> The Plaintiff stated he has occasionally been violent. This was manifested first by an altercation with a fellow employee in June 1992. Another episode occurred, he believes, in the early 1990's, where he saw a police-man stopped in his vehicle on the side of the road. He stopped his car, went over to the policeman and started yelling at him for no reason, then got back in his car and left. In addition, he described mental confusion and problems with memory such as getting in his car to drive home after work and finding himself hours later in a different town, not knowing how he got there. In addition, he had started his car and locked his keys inside, walking back into the plant thinking he had lost his keys, only to discover hours later that they were in his car and had to have his car opened for him. This has happened several times, but he is uncertain as to the time frame of when this first occurred.

The physicians continue that the exposure occurred during the early stages of employment at this facility. They also state the most recent plant operator used the appropriate protection for the plaintiff and there are no data documenting increased intake of mercury at this time and, therefore, his work for the most recent owner probably did not contribute to his symptomatology.

Biological Exposure Indices

The human form can serve as a monitoring instrument for some chemicals. A biological exposure index (BEI) represents the level of determinant which is most likely to be observed in specimens collected from a healthy worker who has been exposed to chemicals to the same extent as a worker with inhalation exposure to the Threshold Limit Value (TLV) [5].

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The BEI for total inorganic mercury in urine is 35mg Hg/g creatinine. Creatinine is used for a concentration base because liquid volume of urine varies with time and amount of fluid intake. Creatine is an amino acid constituent of muscles that stores energy used for muscle contractions. Creatinine is a crystalline end product of creatine metabolism. Comparing mercury to metabolism is a better indicator than concentration in a liquid that is variable.

Mercury concentrates in the gray matter of the brain, in the kidney, and in the liver. Since it takes about six months exposure to reach a steady state, the mercury in urine serves as a reference value representing exposure three to six months prior to sample collection. Mercury concentration in urine remains elevated for approximately 100 days after the end of exposure[6].

The BEI for mercury in blood is 15mg HG/L. There is a good correlation between the blood mercury index and recent exposure. Generally, blood concentrations are affected by exposure over the work week. Thus, the recommendation for sampling at the end of the work week.

When Exposed

Table 1, Mercury BEI Data and Ownership Timeline, lists the available Plaintiff Mercury BEI data and the dates the owners (and insurance companies) assumed responsibility.

The urine test of June 26, 1996 is consistent with blood test of April 3, 1996. Those two data suggest June 5, 1996 is not representative.

The defendant's position was that there was no exposure after February 1, 1996. The data in Table 1 reflect subsequent exposure. The later data appears to be inconsistent. There was a hand written note on the June 5, 1996 report questioning the data. The note was not attributable to anyone and was insufficient for interpretation. That report indicated a value less than the BEI for mercury in urine.

Two other data, the blood sample of April 3, 1996, and the urine sample of June 26, 1996, had values that were greater than the BEI. While the correlation between blood and urine levels seems to be weak generally, it can be partially explained by diurnal fluctuations in the urine mercury index and the six month latent period. Blood concentrations are affected by exposure over the work week. The blood sample of April 3, 1996 indicates exposure above the TLV during the week before. Since April 3, 1996 was a Wednesday, the exposure period represented by that sample includes a weekend. The urine sample of June 26 (84 days later) also indicates an exposure above the TLV for mercury.

Table 1

Mercury BEI Data and Ownership Timetable					
Date	**Blood or Urine**	**Hg µg/L**	**Hg µg/g creatinine**	**BEI**	**Owner/ Insurance Co.**
May 19, 1994	Urine	78	32.23	35	
June 1, 1994	Blood	0		15	
October 28, 1994					ABC/123
May 3, 1995	Urine	26	10.12	35	
May 31, 1995	Urine	35	9.83	35	
June 28, 1995	Urine	34	12.88	35	
August 9, 1995	Urine	36	15.58	35	
August 30, 1995	Urine	49	13.57	35	
October 4, 1995	Urine	56	17.18	35	
October 28, 1995					ABC/456
November 8, 1995	Urine	40	14.76	35	
January 17, 1996	Urine	24	7.77	35	
February 1, 1996					XYZ/789
February 28, 1996	Urine	30	11.32	35	
March 27, 1996	Urine	56	20.97	35	
April 3, 1996	Blood	21		15	
June 5, 1996	Urine	13	3.74	35	
June 26, 1996	Urine	171	38.34	35	

Note:
Owners are identified here as ABC and XYZ.
Insurance companies are identified here as 123, 456, and 789.

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Since mercury in urine remains elevated for approximately 100 days after exposure, and mercury in blood represents exposure in the previous five days, it is reasonable to infer the plaintiff was exposed to mercury at levels comparable to exposures above the TLV sometime between March 19 and April 4, 1996. This was subsequent to February 1, 1996, when XYZ/789 were responsible.

Mercury in urine exhibits a latency period while the kidney accumulates a certain amount of mercury. Therefore, the June 26, 1996 data also suggests exposure to elevated levels of mercury began prior to the end of December 1995.

Based on a description of work practices and the data above, it is likely that the plaintiff was exposed to mercury. In addition to work place exposure, improper changing and handling of coveralls and other clothing probably resulted in additional exposure. His exposure was chronic, as evidenced by medical symptoms. More recent exposure was reflected in biological monitoring data.

Resolution

Within weeks of presenting the above opinion in deposition, the plaintiff's attorney reported the case was resolved in his favor.

References

1. Letter to Plant Manager from National Institute of Occupational Safety & Health, HETA 87-402, NIOSH, Cincinnati, OH, September 1, 1998.
2. NESHAP Inspection of..., Memorandum to Lou Musgrove from Frederick D. Rowe, December 3, 1993.
3. Documentation of the Threshold Limit Values and Biological Exposure Indicies, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1996.
4. Environmental & Occupational medicine Consultation Clinic, Physicians report of medical evaluation, February 28, 1997.
5. 1997 Threshold Limit Values and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1997.
6. Documentation of the Threshold Limit Values and Biological Exposure Indicies, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1996.