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Prevention of Toxic Environmental Illness in the Twenty-First Century

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Previous introductions of new technologies have frequently resulted in unanticipated occupational and environmental illness. Prevention of such illness in the twenty-first century requires stringent application of two fundamental principles of public health: evaluation of new technologies before their introduction, and surveillance of exposed persons after the introduction of new technologies. Failure to establish these basic preventive mechanisms in advance will inevitably result in the development of new toxic diseases in the twenty-first century.

Introduction

A major challenge to technologic development in the twenty-first century will be to prevent environmental and occupational diseases, which too often accompanied the introduction of new technologies in centuries past.

The catalogue of diseases caused by new technologic developments includes lead poisioning, which occurred in the ancient Greeks and Romans using lead acetate to sweeten wine (*1*); mercury poisoning, present in the Almaden Spanish miners during the Middle Ages (*2*); lead poisoning in Renaissance potters (*3*); black lung in coal miners (*2*); and silicosis in English foundry workers and grinders during the Industrial Revolution (*4*). In the modern era industrial toxic conditions include bladder cancer in dye workers (*5*), phossy jaw in matchmakers (*6*), mesothelioma and lung cancer in asbestos workers (*7*), encephalopathy and neurotoxicity in pesticide manufacturers (*8,9*), leukemia and solid tumors in persons exposed to ionizing radiation (*10*), and leukemia and lymphoma in benzene workers (*11,12*).

Typically, when a new technology is first introduced, it is hailed as safe. No associated disease is seen in the initial months or years following its use; presumably, this is due either to the fact that a latency (incubation) period must elapse before the appearance of illness or that an illness associated with the technology has simply not yet been recognized. When disease associated with a new technology is finally observed, the symptoms associated with high-dose exposure are usually the first to be perceived. Frequently, initial recognition is made by an astute clinician (*13*) who sees a new disease or a new association such as scrotal cancer in chimney sweeps (*14*), angiosarcoma of the liver in vinyl chloride workers (*15*), or lung cancer in workers exposed to bis-chloromethyl ether (*16*). Initial clinical recognition is followed by epidemiologic confirmation and toxicologic corroboration. Additionally, and with increasing frequency, quantitative risk assessment is undertaken and a dose-response relationship is established.

Recent Environmental Diseases in Industry

Two recent examples of environmental diseases that resulted from the introduction of new technologies are the kepone disaster, associated with the manufacture of a new pesticide (*9*), and epidemic neurologic paralysis of the urinary bladder, associated with the introduction of a new catalyst in plastic manufacture (*17*). Details of these two environmental episodes are as follows.

Kepone Episode

Kepone (decachlorooctahydro 1,3,4-metheno-2H-cyclobuta (cd) pentalen-2-one) is a chlorinated hydrocarbon insecticide. It was developed by the Allied Chemical Company in the early 1950s and was registered as a pesticide in 1955. In succeeding years Kepone was made intermittently by Allied Chemical, but in 1973 the company discontinued all production of Kepone and entered into an exclusive production contract with Life Sciences Products Company (LSPC), a newly incorporated firm in Hopewell, VA. From 1974 through July 1975, LSPC in Hopewell was the world's sole producer of Kepone.

On July 11, 1975, an internist in Hopewell sent a blood sample from an LSPC worker with severe tremors to the Centers for Disease Control Toxicology Laboratory for Kepone analysis. The result showed a highly elevated Kepone level of 7.5 parts per million (ppm); the normal

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level is zero. Follow-up field investigations on July 22 and 23 by the Epidemiology Bureau, Virginia State Health Department, revealed massive contamination of the plant site and a high prevalence of unusual illness in workers. Officials of the State Health Department closed the plant on July 24.

To investigate the clinical and epidemiologic features of this outbreak, a listing was obtained from company records of all 148 persons who had been employed at LSPC in the 16 months of its operation (33 current employees and 115 former). One hundred fifty-three (90%) of these employees (all current and 100 former) were located, and a questionnaire was completed for each worker relating to general health, occupational exposure, and possible job-related illness. A brief physical examination was performed on each worker, and a venous blood sample was obtained to determine the Kepone level.

A bizarre neurologic syndrome was found in the affected workers with the average interval between start of employment at LSPC and onset of symptoms being 6 weeks. The two most prominent features were a sensation of nervousness and the occurrence of tremor. In severe cases, tremor was present at rest; in all cases it was increased by using the affected limbs. The hands were chiefly involved, but fine tremor of the head and trembling of the entire body were also noted. The tremor interfered with ordinary activities such as eating, writing, and using simple hand tools. Greatly exaggerated startle responses were noted in persons severely affected.

Visual difficulty, characterized by an inability to fixate and focus, was also a prominent finding. On examination, patients were noted to have bursts of opsoclonus, usually horizontal, but occasionally multidirectional as well. Occasionally, a mild degree of cerebellar ataxia was noted. Personality changes were also observed with the most common being irritability, difficulty with recent memory, and mild depression that occasionally ranged to disorientation.

Epidemic Neurogenic Bladder Dysfunction

On March 28, 1978, the Board of Health in Marblehead, MA, notified the Massachusetts Department of Public Health that 11 workers employed in a factory that produced polyurethane foam automobile seat cushions had been examined at a local hospital emergency room. They complained of urinary difficulties of recent onset. These difficulties included hesitancy in urination, straining to void, decreased force of urinary stream, and increased duration of urination. Several volunteered that they had lost the urge to urinate and voided only once a day or by habit.

The clustering and sudden onset of the patients' illness suggested an occupational etiology. Accordingly, all available workers, symptomatic and asymptomatic, were interviewed. Work practices and plant processes were evaluated. The analysis revealed that a new catalyst, dimethylaminopropionitrile (DMAPN), had been added to the polyurethane on one of the two assembly lines in August 1977, and it was used irregularly until December. From December 1977 through March 1978, both assembly lines at the plant had used the new catalyst.

In the epidemiological analysis, data were obtained on 208 of the 230 plant workers. The first case of bladder dysfunction occurred in August 1977 (shortly after the introduction of DMAPN) in a female mold cleaner who worked close to an area where hot polyurethane foam with the new catalyst was removed from molds. The frequency of subsequent cases increased roughly in parallel with the use of the catalyst.

The highest incidence of bladder dysfunction occurred in assembly line workers. Among the 166 production workers, 104 (63%) had symptoms. No cases occurred among the 42 nonproduction employees. Twenty cases were noted in 36 women production workers (55.6%), and 84 cases in 130 men (64.5%).

Five men and three women were referred for detailed neurologic and urologic evaluation. On neurologic examination, seven of these eight patients had abnormalities affecting the distal lower extremities. Five had a sensory neuropathy and two had a mixed sensorimotor neuropathy. On electrophysiologic testing, one patient had prolonged peroneal latency and reduced evoked muscle action potentials; these findings were corroborated by marked muscle atrophy in the feet. Three patients had a slowing of sural sensory nerve conduction, and one showed a reduced amplitude of the sural nerve action potential. There patients had prolonged sacral latency, and two of the three had evidence by electromyography of partial denervation of the external anal sphincter.

Discussion

An exponential increase has occurred since World War II in developing and producing new synthetic chemicals. During this 40-year period, chemical production capacity has increased worldwide by 350-fold (*18*). More than 1000 new chemical compounds are now produced each year; they are added to the 60,000 pure chemicals and the two million mixtures, formulations, and blends already in commercial use (*19*).

An unfortunate consequence of this widespread introduction of new chemical technologies into the human environment has been the wide occurrence of new occupational and environmental diseases. Such illnesses are highly prevalent in American society today.

Recent data from New York state indicate that occupationally related exposures are responsible each year for 5,000 to 7,000 deaths and for 35,000 new cases of illness (not including work-related injuries) (*20*). The deaths due to occupational disease include 3,700 deaths from cancer (10% of 37,000 cancer deaths in the state each year), and between 1,000 and 2,800 deaths from pulmonary, cardiovascular, renal, and neurologic diseases (1–3% of 95,000 deaths from these causes each year).

Crude national estimates of the burden of occupational disease in the U.S. may be developed by multiplying the New York state data by a factor of 10. New York state contains slightly less than 10% of the nation's workforce, and it includes a broad mix of employment in the manufacturing service and agricultural sectors. Thus, it may be calculated that occupational disease is responsible each year in the U.S. for 50,000 to 70,000 deaths, and for approximately 350,000 new cases of illness.

Several factors account for this high prevalence of environmental and occupational disease resulting from technologic innovation. They are as follows:

- Inadequate evaluation of new technologies before their commercial introduction. Recent data from the National Academy of Sciences indicate that no more than 20% of commercial chemicals have had adequate premarket toxicologic evaluation (*21*). Enforcing the provisions of the Toxic Substances Control Act (*19*) has been a substantial failure.
- Inadequate training of physicians and other health providers in the recognition of occupational and environmental disease. The average physician in training in the United States receives a total of only 4 hr of instruction in occupational medicine (*22*). Consequently, few physicians take adequate occupational histories (*23*) or are skilled in diagnosing occupational and environmental illness.
- Inadequate surveillance of populations exposed to newly introduced technologies.

Unless these continuing multiple failures of prevention are rectified, we must recognize that the introduction of new technologies in the twenty-first century will almost inevitably result in the development of new forms of environmental and occupational illness.

Techniques for preventing diseases caused by new technologies are not new. They were developed in the nineteenth century during the era of sanitary reform in England (*2*). They are proper evaluation of new technologies before their commercial introduction and proper surveillance of exposed persons following the introduction of new technologies.

If these two fundamental mechanisms for the prevention of environmental and occupational illness are established in this century and carefully applied in the next, the risk of new environmental and occupational illness will be reduced. If not, history will repeat itself.

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