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OCCUPATIONAL, ENVIRONMENTAL, AND PUBLIC HEALTH IN SEMIC: A CASE STUDY OF POLYCHLORINATED BIPHENYL (PCB) POLLUTION

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Abstract: The story of Semic, a small town in Yugoslavia with a factory using PCBs in the manufacture of capacitors, resembles the environmental histories of scores of locales where the health and environmental effects of industry went unrecognized for an extended period. What has made Semic outstanding is the introduction of a positive treatment for affected workers. This report describes events surrounding utilization of the detoxification treatment developed by Hubbard. This procedure reduced both the body burdens and the symptoms of treated workers while no such improvements occurred in a control group of untreated workers. Our findings support the use of health screening and detoxification treatment when dealing with individuals affected by toxic exposures.

Introduction

Facing the environmental issues of the 21st century involves both prospective and retrospective approaches to environmental safety and protection. The lingering effects of past industrial practices must be ameliorated while monitoring the effects of current endeavors. At the core of these issues are the occupational and environmental impacts of activities essential to industry. The lessons of the Love Canal, Mexico City, Minamata, and Bhopal are only beginning to be appreciated. To these we add the story of Semic, a small town in Yugoslavia with a large factory manufacturing electrical products for export.

The technological and institutional responses to occupational and environmental pollution problems often undergo the following sequence:

Functional Responses	Institutional Responses
Discovery	Denial
Initial assessments	Damage control
Interim clinical and technological interventions	Identification of a culprit, litigation, revenge, blaming victim
Cleanup	Temporary fixes while searching for the ultimate solution
Restitution	Conflicts over efficiency and equity
Monitoring, post-audits, and sustainable remedial measures.	Guarded disclosures of information.

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Throughout, attention to long-term economic viability and short-term remedial costs is accompanied by concerns over liability and regulation.

This paper examines this sequence of events in the framework of the environmental pollution in Semic. We focus on detoxification of workers exposed to polychlorinated biphenyls (PCBs) and other chemicals. Our conclusions, which may be refined as a result of further analyses, are based on converging evidence from Semic and other industrially contaminated sites.

Background

The Republic of Slovenia lies in the northwest section of Yugoslavia, bordering Italy, Austria and Hungary. It has become, at a price, the economically strongest republic of the state and has contributed significantly to the 1987 national GNP per capita of $ 2,480. However, both costs and benefits have sometimes been borne inequitably. Predictably, environmental costs fall into this category.

In 1961, Semic was a settlement located near a single water-well supplying some 500 inhabitants in the karstic southeast region of Slovenia. This agrarian area had seen a substantial pre- and post- World War II emigration to the United States. A political goal of economic self-sufficiency of the region was therefore adopted. This began with the introduction of a factory producing small and large electrical capacitors, giving employment to approximately 1,300 workers. Within a decade, the settlement became a town of 2,000 inhabitants. Increasing immigration has resulted in a community of about 5,000 inhabitants with a semi-agrarian way of life. A distinguishing feature of this area is the presence of a half-nomadic Gypsy minority.

The capacitors produced at this factory had polychlorinated biphenyls of the Aroclor 1242 and 1254 types as the main impregnating substances. The PCBs were imported from West Germany, France and the United States. Other lipophilic (fat soluble) chemicals were also used in the production line, with a frequent introduction of new compounds. A complete listing of the chemicals utilized was not accessible but it is known that trichloroethylene (TCE), polychlorinated naphthalenes, epoxides, neoprene, and the chemicals necessary for metal spray-painting and gas welding were extensively utilized. Adverse health effects from chronic exposure to these chemicals are known to occur (Aviado, 1977; Bowman, 1977; Fawcett and Wood, 1982; Lin et al., 1988; McCunney, 1988; Van Duuren et al., 1963).

The original technology and the devices utilized at the factory were maintained for some twenty years. Protective equipment — working suits, leather aprons, working boots, and gas masks — was seldom replaced. The available rubber gloves deteriorated within days and were eventually replaced by cotton products, hardly a suitable alternative. The discomfort and inconvenience experienced by workers attempting to meet the high production demands of this plant precluded a regular, full-time use of gas masks in the steaming halls where capacitors, held in large vats, were immersed in impregnating substances maintained at 120° C. Production demands also resulted in a casual separation of working and eating areas.

In addition to this direct occupational exposure, PCBs and other waste products were burned daily in open fires in the factory yard and used in the heating system of the factory. This resulted in exposure of both workers and residents of the community to the pyrolytic products of these chemicals (Buser, 1985; Kashimoto et al., 1981; Kimbrough, 1980; Weber and Schlatter, 1981). As in other cases (Fishbein and Wolff, 1987; Knishkowy and Baker, 1986), familial exposure was the norm. Workers brought home their working suits soaked with oily chemicals to be laundered over the weekend. In addition, school children of the workers obtained regular daily meals at the factory mess for a symbolic fee.

Surplus PCB barrels and products were stored in nearby barns and some farmers used the oily substance as a covering for the floors of barns and hoghouses. Truckloads of empty barrels and rejected products unfit for recycling were dumped in naturally occurring basins. During twenty-four years some 70 tons of PCBs were dumped into these sites. At the bottom of the socioeconomic scale, gypsies added to the spillage of PCBs by disassembling the dumped products on-site to redeem the copper wiring.

In sum, in Semic as elsewhere around the world, PCBs and other compounds were treated like water. Their effects, being cumulative, were observed only after time and concentration thresholds had been reached.

Discovery and Initial Response

Early in 1983, sporadic reports of disfigured and dwarfed fish with skin ulcers and tumors, odorous oil slicks in the river, and deformed plants and fruits in the factory yard (Figure 1) were dismissed as "coincidental" occurrences. At the same time, geological preparations for a new water supply disclosed a dump site situated above the proposed water source, this source having been intended to provide sufficient and affordable water to the region through the turn of the century. Greasy, oil-soaked limestone was found to extend well beneath the water table.

Public concern over possible long-term health effects due to PCBs absorbed from this water prompted authorities in 1984 to terminate work on the new water system, to start a new project to supply water from distant sources, and to initiate environmental and cross-sectional health surveys.

Eight major dump sites were located. By determining airborne PCB levels, as recovered from pine tree needles, and PCB levels in the downstream river sediment, it was estimated that contamination had spread over some 50 square kilometers, potentially exposing at least 3,000 residents.

PCB contents were measured in various fish species along the river (Table I). The PCB content in one 4-year-old trout, measured at 116 mg/Kg (the FDA tolerance limit is 2 mg/Kg), is among the highest reported in the world.

TABLE I

PCB LEVELS IN VARIOUS SAMPLES*

Samples		PCB Content	Units
FISH (FDA Permissive Value 2 mg/Kg)			
Trout (weight unknown) in 1985		116.0	mg/Kg
Pike	1.6 Kg in 1986	4.1	mg/Kg
Tench	1.3 Kg in 1987	34.0	mg/Kg
Whiting	0.4 Kg in 1987	26.0	mg/Kg
RIVER SAMPLES IN 1983/84			
River Headwaters (below dump)		0.2 - 0.6	ug/L
Sediment at Headwaters		1,500 - 55,000	ug/L
River Water 3 Km Down Stream		0.35	ug/L
Sediment 3 Km Down Stream		2,400	ug/L
FOOD (FDA Permissive Values)			
Milk	(1,500)	400 - 3,600	ug/Kg
Eggs	(3,000)	300 - 6,000	ug/Kg
Pork Fat	----	50 - 1,200	ug/Kg
Beef	(3,000)	1,600 - 3,000	ug/Kg
Poultry Meat	(3,000)	300 - 18,000	ug/Kg

* Data taken from Brumen et al., 1984; Herlander, 1986; Jugovic, 1987.

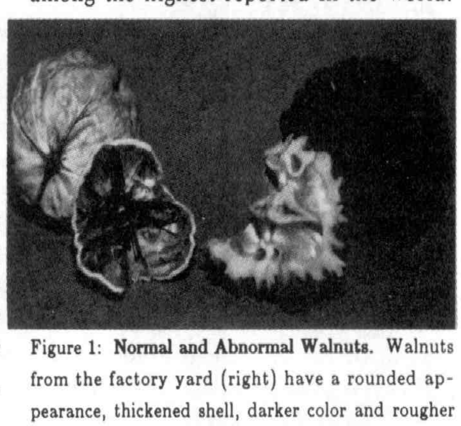

Figure 1: **Normal and Abnormal Walnuts.** Walnuts from the factory yard (right) have a rounded appearance, thickened shell, darker color and rougher exterior when compared to normal nuts (left).

The highest river water PCB content, taken in summer 1983, was 600 nanograms/liter (ng/L) at the artesian source of the river, some 4 Km from the plant. This exceeds by 600 fold the US EPA limit of 1 ng/L for drinking water. The corresponding stream flow rate was 800 L/sec. On a dry weight basis, river sediments at the source contained up to 55 mg/Kg of PCBs. (Brumen et al., 1984; Herlander, 1986; Jugovic, 1987)

Due to the region's karstic limestone geological structure and resultant lack of surface water, residents distant from the river depended on rain water as their main source for drinking. Water was collected from roofs into hand-dug cisterns. The PCB content in the water of these cisterns was 3 to 4 times that permitted by the US EPA. After the cisterns were scrubbed with 70-80 percent ethanol, the PCB content was reduced to the 1 ng/L level. (Herlander, 1986)

As a consequence of the widespread contamination, water was supplied to the inhabitants by tank-trucks until 1988, when a new pipeline brought fresh, clean water from a source 80 kilometers (50 miles) distant. (Pucelj, 1987)

In the food chain, milk, eggs, pork, beef, and poultry were found to contain high amounts of PCBs (Table I). A 1984 order mandating slaughter of these animals was met with reluctance, and their subsequent confiscation with only partial reimbursement caused public outcry. It took more than a year to settle disputes and remedy the damage caused by these actions.

The use of contaminated waters for fishing, bathing, drinking, and watering was banned, and private mills and water-powered saws were shut down in 1984. The financial losses to the owners, resulting from these restrictions, were not reimbursed.

At the impregnating hall, PCB air concentrations exceeded by up to 5.2 times the 8 hour MPC (Maximal Permissive Concentration) of 1 mg/m^3, and TCE levels were 1.6 times higher than the respective MPC of 250 mg/m^3 (ACGIH, 1986; Crnivec et al., 1986).

The factory stopped using PCBs in 1985, temporarily switched to castor oil, and subsequently used a Japanese product with the brand name "PXE" (Pucelj, 1987). Within a year, a double-walled concrete landfill of 300 m^3, with plastic wall lining and underground safety drains, was erected on the factory yard. The surface layers of the eight major dump sites were excavated to a depth of 60 cm (two ft.) and the material trucked to the landfill, along with other discarded products. This part of the clean-up was concluded in 1987.

Health Consequences

In 1984, the University of Ljubljana, Institute of Occupational, Traffic, and Sports Medicine, and the Committee of Public Health of the Republic of Slovenia initiated a two-year cross-sectional health assessment survey of 284 adults from six villages along the river and within 5 km of the factory. In addition to the 122 males and 162 females of this group, the study included all pregnant and breast-feeding women, and 60 children under 10 years of age from these villages. From the group of 284 adults, a random sample of 62 men and 55 women was selected for further evaluation. As a separate item, this study also evaluated the health status of 21 male workers from the factory impregnating halls (Crnivec et al., 1986).

The mean PCB serum level in residents was 52 micrograms/liter (ug/L), ranging from 5 to 132 ug/L, which is approximately ten times higher than the mean for an unexposed group in Slovenia. The average daily amount of PCBs absorbed by the residents was estimated to be 0.46 milligrams. This exceeds by up to 90 times the proposed action levels for an unexposed population (Crnivec et al., 1986; Landrigan, 1980).

No acute toxic effects, increased prevalence of cancers, or congenital birth defects were detected. However, biochemical abnormalities indicating carbohydrate intolerance and derangements in the metabolism of lipids were evident. Changes found in the histology and ultrastructure of liver biopsy samples obtained both from children and adults were consistent with other published cases of PCB exposure (Landrigan, 1980; Maroni et al., 1981; Nishizumi, 1970).

In accordance with the underlying political objectives leading to the construction of the factory, workers kept their jobs for prolonged periods. The average length of employment at the factory was ten years, and that of direct exposure to PCBs was eight years. The mean PCB level in serum was 430 ug/L, ranging from 22 to 2,200 ug/L (Table II). As found elsewhere (Brown and Jones, 1981; Buser, 1985; Chase et al., 1982; Maroni et al., 1981; Safe, 1984), the range of PCB levels was wide and increased in proportion to the length of employment.

No increased prevalence of cancers was found in these workers. This group did, however, have an enhanced number of cases reporting infertility (Harris et al., 1985). Acute exposures to PCBs were associated with an uncomfortable flu-like syndrome, chloracne eruptions, and, as elsewhere (Kimbrough, 1987; Safe, 1984), serum PCB levels of 1000 ug/L or more.

Biochemical abnormalities found in the workers included elevated enzyme levels (alkaline phosphatase, serum aspartate aminotransferase, serum alanine aminotransferase and g-glutamic transferase) on "liver function tests", elevated serum lipids (LDL lipoproteins and triacylglycerols), and either carbohydrate intolerance or overt diabetes. Microscopic changes of liver structure were also found. These chemical and morphological changes were similar to those found in inadvertently exposed residents. In none of the groups under study did the abnormalities correlate with the PCB levels.

A pattern of nonspecific symptoms was noted in the majority of the examined persons. When prior medical evaluations were retrieved from several medical institutions, it was noted that the appearance of these symptoms had preceded public awareness of environmental contamination. The onset of complaints in residents, and especially workers, occurred several years before the health survey was initiated.

Clinical complaints reported by the cross-sectional survey as most frequent were diffuse headaches, loss of mental acuity, concentration disabilities, nervousness, sleep disturbances, eye problems (in particular conjunctivitis and light sensitivity), chloracne eruptions and skin rashes, chronic respiratory, gastrointestinal and neurological disturb-

TABLE II

SUMMARY OF CLINICAL OBSERVATIONS FROM 1984 HEALTH SURVEY*

SERUM PCB LEVELS (Mean values and ranges)		
Residents	(n = 117)	52 ug/L (5 - 132 ug/L)
Workers	(n = 21)	430 ug/L (22 - 2,200 ug/L)
CLINICAL OBSERVATIONS		
Carbohydrate Intolerance and Diabetes		
Lipid Metabolism Derangements		
Abnormal Liver Function Tests		
Liver Histology Alterations		
Infertility		
SIGNS AND SYMPTOMS		
Chloracne Eruptions		
Central Nervous System Symptoms		
Diffuse headaches		
Loss of Mental Acuity		
Concentration Disabilities		
Nervousness		
Sleep Disturbances		
Chronic Respiratory, Gastrointestinal, and Neurological Disturbances		
Eye Problems		
Swelling of Limbs and Joint Pains		

* Data taken from Crnivec et al., 1986.

ances (as paresthesia and unexplained pains), joint pains and edematous swelling of the limbs (Table II). Though present for some time, the self-rated severity of symptoms in individual patients fluctuated considerably over their history and symptom severity also varied between patients.

Notable observations derived from this survey were that: (i) No spontaneous remission of symptoms was reported and (ii) medical treatments directed to particular complaints did not alleviate the problems.

Structural Chromosome Aberrations and Political Consequences

In late 1985, an abnormally high percentage of structural chromosome aberrations (SCAs) was found in a female worker, from the Semic factory, who was admitted to the University Medical Center of Ljubljana, Medical Department of Gastroenterology, for evaluation of her symptoms (presented later herein). This result prompted the selection of a group of residents and one of factory workers for further evaluation. Similar SCA levels were found in both groups (Table IIIa).

SCAs are usually caused by either irradiation or chemical agents. Radiation was ruled out as no unusual radiation exposure was documented in this area. Even the subsequent Chernobyl event was not reported to have caused chromosomal damage in western Europe (Sternglass, 1986). Thus, a chemical origin was suspected.

The presence of SCAs in an otherwise normal population may signal consequences such as increased cancer incidence, higher spontaneous abortion rates and birth defects (Hassold, 1986; Hsu, 1982; Kaye et al., 1985; Lundgren et al., 1988; Natarajan et al., 1986). Significant amelioration is possible if the noxious factor is removed; most affected persons are able to repair this type of DNA damage within a year (Cherry, 1983).

The evaluation of SCAs was included as part of our study in 1987. Although only seven of the eleven studied had had evaluations in 1986, a marked trend towards normalization was apparent (Table IIIb).

In 1985 it had been assumed that the SCAs could be related to elevated PCB levels, although PCBs had not previously been linked to this phenomenon. However, PCB levels were still elevated in 1987, while the SCAs were not. Considering the elevated body burdens and the long half-life of halogenated hydrocarbons (Kashimoto et al., 1981; Kimbrough, 1980; Safe, 1984; Weber and Schlatter, 1981), they could

TABLE III

STRUCTURAL CHROMOSOME ABERRATIONS (SCAs)

(A) IN 55 RANDOMLY SELECTED INHABITANTS FROM SEMIC IN 1986

GROUP	Normal (1-3% sca)	Borderline (4-10% sca)	Abnormal (>10% sca)	Total
Males	2	18	12	32
Females	1	12	5	18
Children	0	2	3	5
Total	3	32	20	55

(B) IN PATIENTS UNDERGOING DETOXIFICATION TREATMENT WITH ANALYSES IN BOTH 1986 AND 1987

PATIENT	% SCA in 1986	% SCA in 1987
P.F.	40	3
B.H.	34	8
S.N.	14	3
S.J.	12	2
R.B.	10	3
H.M.	6	6
P.S.	4.5	3

not be the causative agents. This led to the conclusion that a less persistent chemical was probably the source of the SCAs previously detected.

In 1986, after the discovery of chromosome damage in Semic, the University Medical Center Ad Hoc Committee in Ljubljana had proposed monitoring of SCAs in both workers and residents of the area and an expanded environmental screening program. When a normalizing trend was suggested by the evaluation of workers in our 1987 study, this proposal was reduced by the Public Health authorities to a voluntary screening of all newly-wed pairs planning a family, and to an uncontrolled periodic screening of workers chosen by the factory officials.

These decisions were reported by the local news media, which amplified the extant polarization between the residents and the local governing bodies over the contamination issue.

The Solvency Problem — Who Pays ?

The liability for environmental damage was ascribed by the Court for Commercial Affairs to the factory and its Director General in 1987, resulting in what many considered to be an inadequate penalty. Factory officials agreed to pay a substantial part of the costs of the original environmental survey, the new pipeline and landfill, monitoring of the residents and medical examinations of the workers. They refused to pay for continuous follow-up evaluations of the residents. The ensuing dispute became a public controversy.

Expenses from the initial cross-sectional health survey, although financed only in part by the community, surpassed the town's yearly budget for public health services. As the issue became more publicized, concern mounted over possible health effects from the chemicals. Consequently, an increasing number of individuals requested medical examinations.

The country's socialized medical system allows patients an initial free choice of institutions but does not grant a patient the right to a second opinion. The patients, therefore, chose to go to the University Medical Center of Ljubljana for detailed evaluations. The staggering costs of continuing medical evaluations, coupled with the increasing inflation rate, created a debt that will be carried forward into the next decade. Since new resources could not be provided from the Republic's meager health budget, the demands voiced by the residents and the steady influx of bills for ongoing medical evaluations were met with strong opposition by the factory management, the community health service and the community officials.

A local ad hoc medical committee was formed to evaluate cases where damage from chemical contamination was alleged. Its purpose was to screen these cases prior to their evaluation at specialized institutions. However, the residents perceived the committee to be biased and were unwilling to follow this procedure.

To fully appreciate the response of this community, it is helpful to understand its recent history. This region is known as the birthplace of The Resistance in World War II. The death toll in this region during the war was very high. Additionally, the Republic of Slovenia was constituted in this locale in 1945. When residents recalled their contributions of the past, given to ensure a prosperous future, the feeling of being considered "expendable" in the polluted present generated protests. A representative made several demonstrative visits to governmental offices, including that of the vice president of the Republic Slovenia, to demand that the region be included in the disaster assistance plan of the Republic.

One Step Forward

The controversy was heightened when the government rejected proposals to proclaim the region a natural disaster zone. Mistrust of authorities was intensified by reports of the treatment and subsequent recovery of an occupationally exposed female worker, previously dismissed by the plant physician as a malingerer.

This particular woman had been employed at the factory since 1967. Throughout her employment she was exposed to the variety of chemicals used at the plant. In addition, she had direct exposure to PCBs for nine months in 1983, manually checking approximately 20,000 capacitors per day for leakage. She rarely wore protective equipment.

This non-smoking and non-drinking woman, aged 35, was healthy prior to the onset of an increasing number of symptoms in 1969. Severe abdominal cramps with visible bloating, extreme fatigue, muscle aches and weakness with joint swelling, recurrent chloracne eruptions and enhanced skin pigmentation were her major clinical complaints. She first noticed a steady daily breast discharge which increased to approximately 50 mL/day of bluish-green fluid in 1975. Exploratory surgery in 1984, performed during a severe attack of abdominal cramps, revealed mesenterial lymph node inflammation. The removed appendix was histologically normal. A liver biopsy performed at the University Medical Department of Gastroenterology in 1985 revealed light and electron microscopy changes consistent with those reported in cases of chronic PCB exposure.

No underlying disease compatible with this patient's clinical picture could be found after repeated medical, endocrinological and surgical evaluations at the University Medical Center of Ljubljana. The diagnosis of chronic occupationally related PCB intoxication was proposed in 1985.

A recently published treatment (Schnare et al., 1984), aimed at reducing levels of toxic chemicals, was suggested by her attending physician at the University Medical Department of Gastroenterology, Ljubljana, and approved by the institutional Review Board. Detoxification by the Hubbard method (Hubbard, 1980), mobilizes and removes lipophilic (fat-soluble) compounds. It had been successfully applied to patients contaminated with PCBs and other toxicants and was regularly delivered at two centers in California.

Treatment in Los Angeles was approved by the Committee of Public Health of the Republic Slovenia, which covered half of the travel and other expenses, the balance being paid by the factory. The patient and her physician (one of the authors, Z.T.) went to Los Angeles for further evaluation and treatment. The cost of treatment was borne by a U.S. non-profit organization.

At pretreatment, this woman's PCB content in fat was 102 mg/Kg, her serum level was 512 ug/L and her breast discharge contained 712 ug/L PCBs. The detoxification treatment mobilized and induced the elimination of the PCBs. At post-treatment, PCB levels in fat were lowered by 60 percent and serum levels

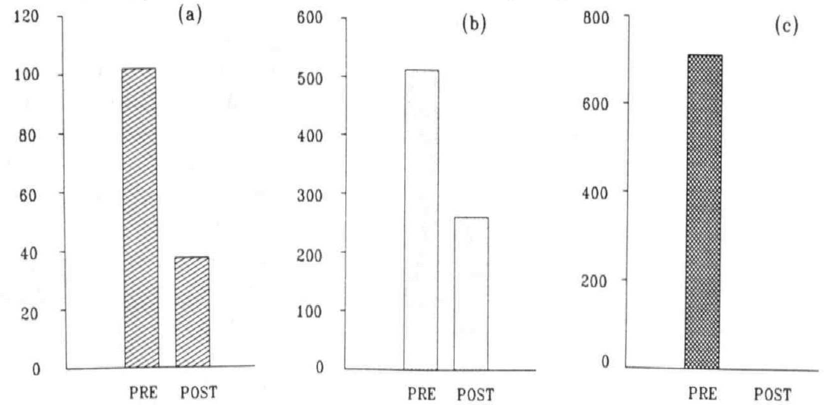

Figure 2: **PCB Body Burden Reductions by Detoxification Treatment in Female Worker.** Pre = Pretreatment, Post = One week post-treatment. (a) Fat, (b) Serum, and (c) Breast Discharge.

were lowered by 34 percent (Figure 2). PCBs are generally expected to have half-lives measured in years, whereas these reductions were effected in less than one month. (Tretjak et al., in preparation)

During treatment her severe symptoms subsided and the breast discharge, which had persisted for over ten years, ceased. Her attending physician and two U.S. specialists who were monitoring her clinical condition confirmed substantial improvements in her clinical profile. The patient was elated by the effects of this treatment.

Responses

From the beginning, both individual and institutional responses to the unfolding events in Semic could have been predicted. They fit the model presented in the introduction to this paper.

Upon return to Semic in 1986, this woman openly discussed her elevated PCB levels, her marked recovery, and her views on the local contamination. Residents thus became aware of the personal effects caused by this contamination event.

Public disputes were heightened by extensive and frequently sensational news reporting. One television program in particular, aired in 1987, evoked a vision of outrageous death tolls due to incurable disease caused by PCBs and suggested an imminent catastrophe. These predictions were supported by dramatic interviews with affected residents and workers. Public outcry increased with a demand for clarification of the issues.

These events evoked a stern response from Republic politicians who rallied behind the community officials. They discouraged protest and demanded that the residents act with "common sense".

The treated woman was discharged disgracefully from the Communist party and publicly declared "irresponsible". Factory officials, supported by political authorities, repeatedly summoned her for cross-examinations over remarks she had allegedly made. Both of her children, aged 10 and 12, were harassed at school after they ceased eating lunches at the factory and ate their own food (presumably uncontaminated), purchased in a distant town. She was prematurely retired as a handicapped, occupationally diseased patient. To enhance her discomfort, her rent allowance had to be claimed in person each month at the factory.

This ongoing stress, accompanied by constant quarrels with former co-workers and neighbors over the contamination issue, forced this woman into solitude. A year after treatment, these pressures and the added trauma of an unexpected miscarriage resulted in extreme depression and a nervous break-down.

Nevertheless, the potential of the detoxification program to produce clinical improvements and body burden reductions was appreciated. The coordination of further medical actions was assigned to the University Medical Department of Gastroenterology, which had organized the treatment of this worker. It was agreed to conduct a pilot study under the supervision of a medical board to determine the feasibility of the treatment procedure for occupationally exposed workers.

The study initially proposed included a large number of tests and controls. While their value was not disputed, severe budget restrictions precluded full implementation of the study design. In addition, the program necessitated the cooperation of local medical authorities with the somewhat alienated citizens. Establishing a bond of trust between these factions was complicated by ongoing efforts to downplay the importance of contamination in the Semic area.

These obstacles were overcome by two avenues. (1) Costs were reduced by abbreviating the project plan and (2) friction between different parties was mitigated by support from senior medical representatives within the Republic and the active involvement of outside researchers: Pacific Toxicology Laboratories in Los Angeles determined polychlorinated biphenyl (PCB) levels in serum and fat, while the Institut für Toxikologie, University and Technical Faculty of Zurich analyzed several blood samples for polychlorinated dibenzofuran (PCDF) and dibenzo-*p*-dioxin (PCDD) content. Associates of the Foundation for Advancements in Science and Education in Los Angeles were engaged to deliver the detoxification program.

Inclusion of these organizations helped to overcome the mistrust held by the area's residents. As a consequence, individuals repeatedly volunteered for participation. In addition, the commitment of unbiased researchers tended to mollify those objecting to the work on vested interest grounds. Limited resources did confine the study to a small number of participants — eleven individuals were treated rather than the 40 intended in the preferred plan.

This study is unique in that it represents the first controlled study of this detoxification treatment on a group of people who had accumulated high amounts of PCBs. Initial findings confirmed excessive levels of PCBs in both residents and workers in this region. Symptoms from the study participants were marked. Treatment reduced both PCB and PCDF levels, improved the immune response, and significantly alleviated the symptoms, consistent with the success of the earlier treatment of the female worker. No such improvements were observed in the control group. Details of this work are presented in Appendix A.

Conclusions

The story of Semic follows a script which could be drawn from almost any of the increasing number of occupational and environmental pollution incidents. The sequence of events, aimed at cleaning up the environment, ensuring economic viability of the region, and preventing a reoccurrence of the incident, followed the course outlined in the introduction.

To this scenario, we add a new tool. Detoxification is demonstrated to be a positive medical intervention, capable of markedly aiding the occupationally exposed, symptomatic, worker. This treatment has been shown to be equally beneficial in cases involving inadvertently exposed individuals (Root et al., 1985; Schnare et al., 1984).

Our suggestions for sites where toxic materials and their by-products are in evidence focus on environmental and occupational health issues. Surveillance and amelioration should include an immediate well-designed cross-sectional survey of the community and a longitudinal survey of the affected population, followed by patient screening and, where indicated, detoxification treatment. In our opinion, the value of such measures to the workers and the affected community outweighs the costs.

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Appendix A

Pilot Study Summary: Detoxification of Occupationally Exposed Workers

The goal of the study was to assess the overall clinical value of the detoxification treatment for individuals exposed to PCBs and related chemicals. Eleven workers with readily identifiable symptoms were selected for treatment from a group of twenty-four male volunteers. The remaining thirteen served as a control group.

For these twenty-four participants, the clinical picture, standard biochemical tests, and the PCB and PCDF levels in serum and fat were taken 1 to 4 days before treatment began and compared to these same measurements on the day of treatment completion (approximately one month later), and at a four month follow-up presentation. The treated workers also had a skin test to assess the status of their cell-mediated immune system before and after treatment.

For comparative purposes the PCB levels were determined in thirteen women from Semic (9 factory workers and 4 residents), a farmer residing 24 Km (15 miles) from the town, and in four unexposed individuals not residing in the polluted area.

During the study no complications were encountered which could be attributed to either the tests or the treatment.

i) Body burdens

Total PCB, in our study, represents the sum total of 18 reliably detected low and high chlorinated congeners. Concentrations of these PCBs in both serum and fat were elevated in all persons from the polluted region. In contrast, for the unexposed individuals, both fat and serum PCB levels were well in the range we all acquire due to the ubiquitous presence of these compounds (Chase et al., 1982; Kimbrough,

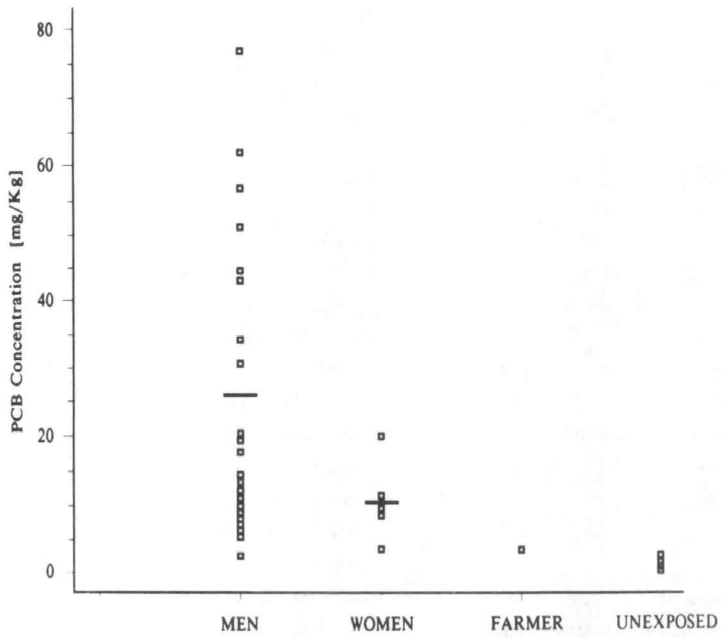

Figure A-1: **PCB Levels in Fat at Initial Evaluation.** PCB concentrations in fat of participants in the 1987 pilot study are presented. (—) Mean concentration for group. Men = male factory workers (n = 22), Women = female residents of Semic (n = 5), Farmer (n = 1), Unexposed = unexposed individuals (n = 4).

1980; Lawton et al., 1985; Sahl et al., 1985). The PCB concentrations in serum and fat for the persons participating in this study are given in Table A-I and fat values are shown in Figure A-1.

No difference could be determined between the PCB levels in the small samples of occupationally exposed and inadvertently exposed women from Semic. PCB levels in the farmer living distant from Semic were in the lower range of the exposed group (Figure A-1).

PCB levels in the twenty-four exposed workers were the highest. As noted in the 1984 health-survey study (Crnivec et al., 1986) and similarly reported by others (Kimbrough, 1980; Lawton et al., 1985; Safe, 1984), the ranges of PCB levels found in these workers overlapped with those of the inadvertently exposed residents (Figure A-1). Fat levels correlated well with the length of direct exposure to PCBs.

The PCBs in persons from Semic had a distinct pattern of congener distribution, including enhanced levels of the less highly chlorinated isomers and one hepta-chloro biphenyl (2,3,5,6,2',3',4'- CB), while unexposed persons from outside Semic had a different pattern with only traces of these PCB congeners. This pattern was especially evident in serum. The PCB pattern from the farmer is interesting in that it includes the less highly chlorinated congeners found in samples from Semic residents. (Figure A-2)

ii) Detoxification

The detoxification program mobilizes and removes fat-stored xenobiotics. It is a medically supervised regimen involving exercise, sauna sweat-out, and nutritional supplements within a regular daily schedule. A detailed description has been published elsewhere (Hubbard, 1980).

iii) Post-Treatment Evaluations of PCB and PCDF Levels

The treated patients were selected based on initial severity of symptoms. It was, therefore, not surprising that some of these patients had organic diseases in addition to chemical exposure. For the purposes of data evaluation, the treated patients were divided into those exhibiting symptoms only (7 patients) and those with both symptoms and organic disease (4 patients). The diseases present in these four patients — diabetes mellitus; peptic ulcer disease; biliary stones; and prostatitis with calcifications and irritable bowel syndrome — necessitated that their detoxification programs be individually adjusted. Their outcomes might also have been influenced by the addition of other treatments indicated by their respective clinical problems during detoxification.

Following treatment, the PCB levels in fat for six of the seven patients without organic disease had decreased by an average of 20.5 percent, representing a statistically significant reduction (Figure A-3a; Table A-I). Samples from one of these patients were lost. In the four treated patients with organic disease, the PCB levels had decreased by an average of 7.9 percent, a statistically non-significant change.

In the control group, one patient was excluded due to an acute exposure to PCBs while assisting in cleanup operations. At the time of the post-treatment evaluation, PCB levels in the remaining twelve workers of the control group were higher than their initial levels by a statistically non-significant 1.3 percent (Figure A-3b and Table A-I).

A follow-up evaluation was done four months after the conclusion of the treatment program. The mean PCB levels in fat for both groups were elevated some 15 percent at this time, with the levels for

TABLE A-I
POLYCHLORINATED BIPHENYL LEVELS IN THE PILOT STUDY GROUP

GROUP			Mean PCB Concentrations[+] Serum	Fat
Unexposed Persons		(n= 4)	3.8	0.9
Farmer		(n= 1)	9.3	2.7
Women	(all)	(n=13)	68.8	---
"	(with fat)	(n= 5)	65.8	9.9
Workers	(all)	(n=22)[*]	168.7	25.6
Workers - Control (n=12)				
Pretreatment			139.8	22.4
Post-treatment			179.4	23.1
Follow-up			183.8	27.4
Workers - Treated (n= 6)[&]				
Pretreatment			139.4	20.9
Post-treatment			80.3	14.5
Follow-up			168.7	16.7

[+] Serum concentrations in ug/L, fat in mg/Kg.
[*] One control patient, with serum at 913 and fat at 74, was excluded due to excessive ongoing exposure. The sample from one treated patient was broken.
[&] Six treated patients without organic disease.

the treated group still less than initially measured (Figure A-3). The explanation that this was solely due to renewed exposure may be discounted; this magnitude of increase would not be expected in a group where long-term exposure is the probable source for high body burdens. Samples had been analyzed in two batches due the project's requirement for interim reports; one immediately after the conclusion of the treatment, the other after the follow-up evaluations. The parallel increase in PCB measurements at follow-up is probably due to the variance between batch analyses found in this type of work (Holden, 1988).

The Institut für Toxikologie, University and Technical Faculty of Zurich, offered to analyze some samples for PCB, polychlorinated dibenzofuran (PCDF) and dibenzo-p-dioxin (PCDD) content. Levels of these compounds were determined for six treated patients. PCDF and PCDD levels were at the limits of detection considering the available sample quantities.

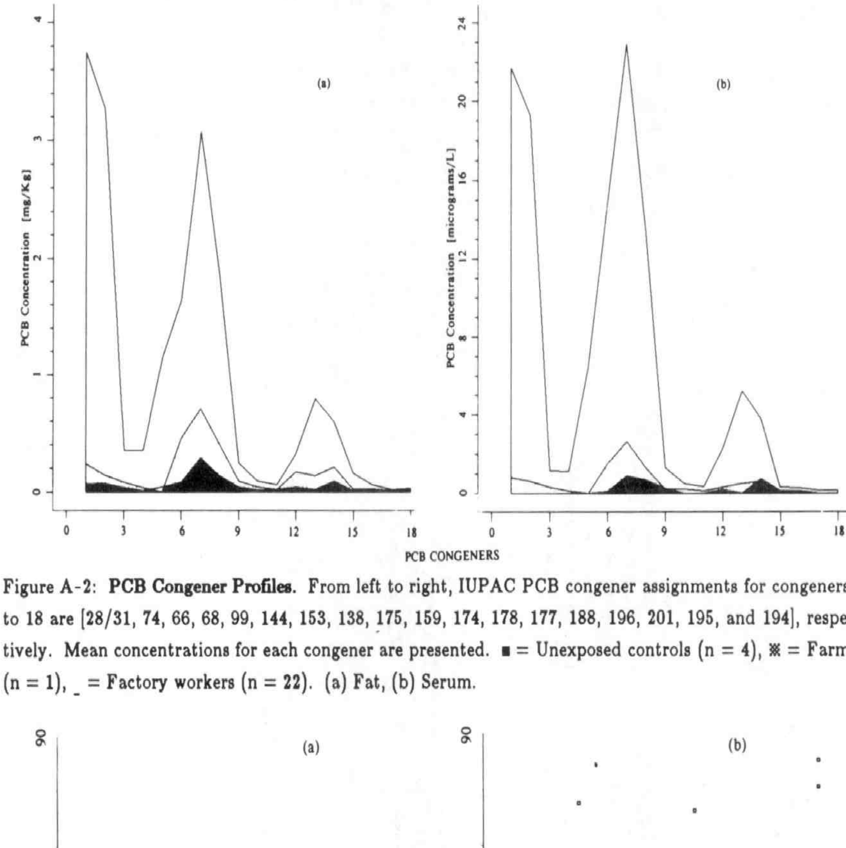

Figure A-2: **PCB Congener Profiles.** From left to right, IUPAC PCB congener assignments for congeners 1 to 18 are [28/31, 74, 66, 68, 99, 144, 153, 138, 175, 159, 174, 178, 177, 188, 196, 201, 195, and 194], respectively. Mean concentrations for each congener are presented. ■ = Unexposed controls (n = 4), ※ = Farmer (n = 1), _ = Factory workers (n = 22). (a) Fat, (b) Serum.

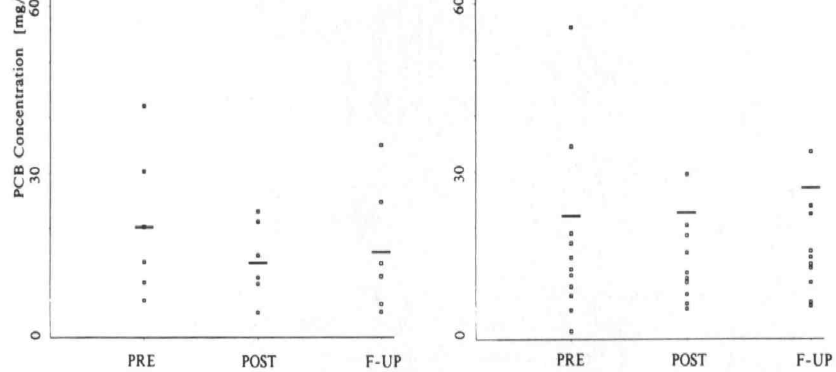

Figure A-3: **Changes in PCB Levels in Fat During Pilot Study.** Pre = Pretreatment; Post = Post-Treatment; F-up = Follow-up. (—) = Mean concentration for group. (a) Treated Patients (n = 6), (b) Untreated Controls (n = 12).

The initial PCB concentrations in whole blood determined at this laboratory were comparable to those obtained in serum by the U.S. laboratory. Dibenzo-p-dioxin levels were below the level of detection (less than 0.2 picograms/g).

The mean initial PCDF values (given as the sum of 2378 TCDF, 12378 PeCDF, 23478 PeCDF and 123478 HxCDF congeners) were slightly elevated, having an average content of 1.43 picograms/g (pg/g), ranging from 0.26 to 1.69 pg/g. The post-treatment concentrations were lower, with an average content of 0.59 pg/g. At follow-up, the mean PCDF content in this group was 0.86 pg/g.

iv) Clinical improvements

The treatment resulted in a marked improvement in symptoms of the patients while the clinical picture of the control group remained unchanged (Figure A-4). Though both PCB levels and the severity of symptoms were high prior to treatment, the amelioration of symptoms in the treated group was greater than anticipated given the level of PCB reduction. This suggests that elimination of other accumulated chemicals might have accounted for some of these improvements.

The skin tests for cellular hypersensitivity in the treated patients revealed an abnormally low immune response at initial evaluation. At the post-treatment evaluation, however, these patients showed a normalization of their immune response (Tretjak et al., in preparation).

v) Discussion

Initial evaluations of our patients showed that inadvertently exposed adult residents in Semic have accumulated PCBs and possibly other xenobiotics in sufficient quantities to reach the range of occupationally exposed workers (Figure A-1). Extrapolating, younger persons and breast-fed children may have accumulated similar amounts of these compounds. Even if no further exposure occurs in their lifetimes (an unlikely event), the current chemical burdens could endanger these individuals' health (Jacobson et al., 1985; Rogan et al., 1980; Skaare et al., 1988; Spyker, 1975).

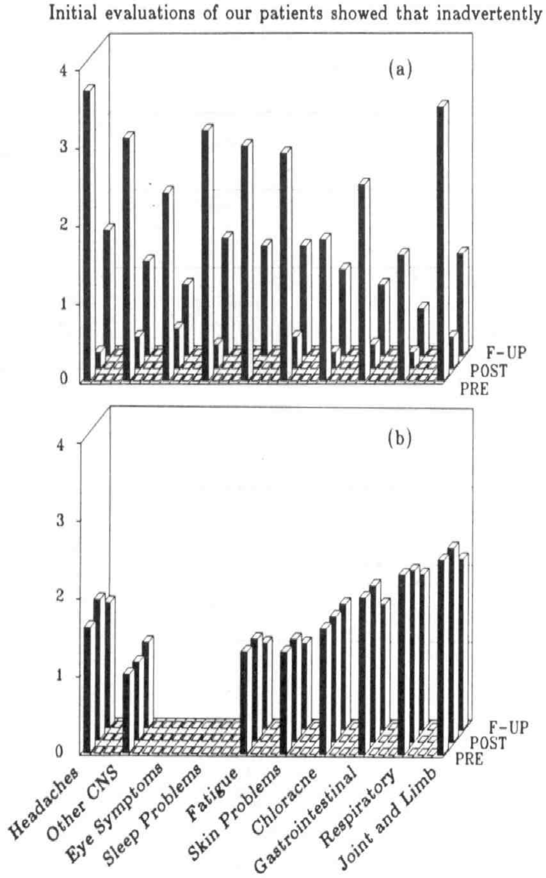

Figure A-4: **Changes in the Self-Rated Severity of Symptoms During the Pilot Study.** Patients rated severity of symptoms on a scale of 0 to 5 [0 = none, 1 = slight, 2 = mild, 3 = moderate, 4 = severe, and 5 = very severe]. Pre, post, and F-up as for Figure A-3. Mean values for each assessment period are plotted. (a) Treated Patients (n=11), (b) Untreated Controls (n = 12).

Second, a distinct gas chromatographic pattern of PCB congeners was found to be characteristic for exposed persons of the polluted region (Figure A-2). The identification of enhanced levels of congeners specific to this pattern in the farmer, who had not lived in Semic and had never traveled there, supports the conclusion that the PCB contamination was extensive. Since the congener pattern found in Semic differs markedly from the pattern present in samples of unexposed persons, it may serve as a fingerprint of this polluted environment.

It should be noted that the array of chemicals utilized in this industrial setting complicates assessment of the causation of health effects. Clinical improvements in the treated patients were more pronounced than the reductions in PCBs, suggesting that other chemicals were co-causative agents. In order to determine which chemicals might be causative agents within the myriad of compounds used, it would be necessary to assess comprehensive body burdens in these workers, and, more importantly, to understand the interactions of these chemicals within the biological context. The latter alone is a research project of some magnitude.

Regardless, in cases where a chemical cause of symptoms is anticipated, detoxification is warranted. Our study showed that detoxification reduced body burdens of accumulated chemicals and improved both the clinical picture and the immune status.

Appendix B

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