

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

New Bedford  
4.1

REGION I

DATE: April 7, 1988



SUBJ: Trip Report from WES on G.E. Program review

SDMS DocID 000200169

FROM: Frank Ciavattieri *FC*  
New Bedford Harbor Project Manager

TO: Addressees

Attached for your information is a copy of a trip report prepared by Tommy Myers of the Waterways Experiment Station concerning the General Electric PCB program review held on February 19, 1988. The conclusions set forth in the memo are consistent with our previous findings.

Attachment: As noted

|             |                 |                  |
|-------------|-----------------|------------------|
| Addressees: | Sig Stockinger  | EBASCO           |
|             | Allen IKalainen | E.C. Jordan      |
|             | Doug Allen      | E.C. Jordan      |
|             | Charlie Bering  | EPA              |
|             | Dorothy Allen   | EPA              |
|             | Leroy Folmar    | EPA-Narragansett |
|             | Helen Waldorf   | MA DEQE          |
|             | Judy Pederson   | MA CZM           |
|             | Dick McGrath    | Battelle         |



DEPARTMENT OF THE ARMY  
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS  
P.O. BOX 831  
VICKSBURG, MISSISSIPPI 39180-0631

March 28, 1988

REPLY TO  
ATTENTION OF

Environmental Laboratory

Mr. Frank Ciavattieri  
U.S. Environmental Protection Agency  
Region I, Waste Management Division (HAN)  
JFK Federal Building  
Boston, Massachusetts 02203-2211

Dear Mr. Ciavattieri:

I am enclosing a Memorandum For Record, 16 Mar 88, subject: Trip Report, Polychlorinated Biphenyl Degradation Research by General Electric Company -- Program Review, Boston, MA, 19 Feb 88 (encl 1). This memorandum was prepared by Mr. Tommy E. Myers as requested by your office. The memorandum was circulated internally to researchers at the U.S. Army Engineer Waterways Experiment Station interested in the New Bedford Harbor Superfund Site. Copies have also been furnished to Messrs. Kevin Mayberry, U.S. Army Engineer District, Omaha, Dave Mathis, U.S. Army Corps of Engineers, Dredging Division, and Mark Otis, U.S. Army Engineer Division, New England.

If you have any questions, please contact Mr. Tommy Myers, (601) 634-3939, or Mr. Danny Averett, (601) 634-3959.

Sincerely,

Robert W. Whalin, PhD, PE  
Technical Director

Enclosure

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## MEMORANDUM FOR RECORD

SUBJECT: Trip Report, Polychlorinated Biphenyl Degradation Research by General Electric Company — Program Review, Boston, MA, 19 Feb 88

1. The U.S. Environmental Protection Agency (USEPA) requested that Mr. Tommy Myers attend the subject program review for the purpose of assessing the potential impact of research conducted and sponsored by General Electric Company (GE) on dredging and dredged material disposal alternatives for the New Bedford Harbor Superfund Site, MA. Five presentations were made describing recent results from studies conducted or sponsored by GE. The first four presentations focused on biodegradation of polychlorinated biphenyls (PCBs) and the last one described surfactant extraction of PCBs from soil. A synopsis of each presentation prepared from notes taken during the presentations and other materials made available at the meeting is provided below.
2. Bioremediation of PCBs on Soil, Dr. Ronald Unterman. Dr. Unterman gave an overview of laboratory studies and field work on biological treatment of PCB-contaminated soils. Aerobic bacterial degradation of PCBs under laboratory conditions has been clearly demonstrated. Eight strains of PCB-degrading bacteria have been isolated with varying degradative ability and PCB congener selectivity. The two strains with the broadest PCB-degradative ability are LB400 (Pseudomonas putida) and H850 (Alcaligenes eutrophus). Detection of metabolites such as chloroacetophenones and chlorobenzoic acid indicate that destruction of the PCB molecule is possible. Laboratory tests involving spiked soils show as much as 50 percent alteration in 2 days.
3. In the field tests, suspensions of LB400 and nutrients were sprayed on prepared plots at a former racing drag strip where PCB oils were used for dust control. Repeated applications of LB400 were made during the summer of 1987. Appropriate control plots were setup and sprayed with nutrient solution. Degradation rates in the field were much lower than in the laboratory indicating that repeated applications and site management in terms of nutrient amendment and cultivation will be required to achieve the reductions observed in laboratory studies.
4. Genetic Studies of PCB Biodegradation, Dr. Frank Mondello. Dr. Mondello presented some very interesting recombinant DNA work. The DNA fragments that encode PCB metabolism in LB400 were isolated and successfully cloned in E. coli DNA using a plasmid vector. First generation recombinant strains were developed with PCB degradation capabilities equivalent to LB400. Recombinant DNA research will continue with emphasis on improved "copying" and "expression" characteristics in higher order generations. Enhancement factors of 100 to 10000 may be possible using recombinant techniques to improve copying and expression.
5. The recombinant DNA work has the potential of developing bacterial strains with the degradation rates needed to make large scale biological treatment systems feasible. The development of strains that are more tolerant of swings in temperature and other environmental conditions is also possible. Even if recombinant strains are never used outside of laboratory research, the

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recombinant DNA work is important because it improves our understanding of the location, structure, and expression of the genes responsible for PCB degradation in indigenous microorganisms and, potentially, our ability to manipulate these microorganisms.

6. PCB Alterations in the Environment, Dr. John F. Brown, Jr. Dr. Brown's presentation focused on in situ reductive dechlorination of PCBs in Hudson River sediments. Chromatograms showing shifts in congener distributions from higher to lower chlorinated congeners indicated dechlorination. Selected analyses of other sediments were also discussed including analysis of sediment samples from New Bedford Harbor. Before discussing GE's in situ biotransformation research, Dr. Brown listed the major published works in the general area of PCB biodegradation. Of particular interest was the listing of the work by Mike Mullins at the USEPA Large Lakes Research Station (LLRS), Grosse Ile, MI. (Mullins, M. D. et al. 1984. "High Resolution PCB Analysis: Syntheses and Chromatographic Properties of all 209 PCB Congeners," Environmental Science and Technology, Vol. 18, pp 468-479.) The congener specific analytical procedures developed by Mullins et al. (1984) is the basis of Brown's work on shifts in congener distributions. In Brown's opinion, the impact of Mullins' work has not been fully realized. (A modest inter-laboratory quality control/quality assurance activity between the LLRS and WES was recently initiated. Since Mullins is widely recognized as the authority on PCB analysis, it is important that the recent interaction between WES and LLRS be maintained and perhaps expanded.)

7. Until recently, it was believed that the more heavily chlorinated PCB congeners did not undergo significant biodegradation. Reductive dechlorination of PCBs in sediments polluted with the more heavily chlorinated Aroclors (1254 and 1260) has been confirmed. The evidence for reductive dechlorination of PCBs in in-place sediments is the decline in the levels of the hexa-, penta-, tetra-, and most trichlorobiphenyl congeners present, and corresponding increases in the levels of the mono-, di-, and certain minor trichlorobiphenyls. The agents responsible are believed to be anaerobic bacteria.

8. Evaluation of data from different sediments showed different congener depletion patterns indicating that different populations of anaerobic bacteria utilize different dechlorination pathways. Thus far, four major PCB congener depletion patterns have been identified. Analysis of sediment samples collected from mudflats in the Acushnet River estuary (New Bedford, MA) indicates that the original Aroclors have undergone two types of dechlorination designated as H and H'. The data indicate PCB degradation in the upper estuary and insignificant PCB degradation in the lower estuary. The differences in PCB-degradating biological activity between upper and lower estuaries is consistent with information from other sites that suggests that a relatively high level of PCB in the sediments is required for the initiation of biological dechlorination. It is argued that PCB-dechlorinating anaerobes are able to successfully compete with the other resident anaerobes by virtue

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of their ability to use PCB as a terminal electron acceptor. This competitive advantage is lost when the initial PCB levels are too low.

9. Laboratory Studies of PCB Dechlorination by Anaerobic Microbial Communities, Dr. Ronald Unterman. Dr. Unterman reported anaerobic dechlorination of PCBs in laboratory experiments using batch cultures of Hudson River sediments. Eighty percent degradation in 16 weeks has been measured. The anaerobes appear to do a better job on the more heavily chlorinated congeners than do aerobes. Experiments are now being conducted to determine the potential of aerobic/anaerobic biofilm reactors for biodegradation of PCBs.

10. PCB Extraction Engineering Studies, Dr. John McDermott. Dr. McDermott presented information obtained in bench-scale investigations of surfactant extraction of PCBs from soil. Surfactant selection was based on performance and biocompatibility. Biocompatibility is a factor in surfactant selection because surfactant extraction is anticipated to be an intermediate step for the development of a bioreactor for soil cleanup. (In situ biodegradation using applied bacterial suspensions may not be feasible for PCB-contaminated clays with low hydraulic conductivity.) Nonionic (Triton X-100) and anionic (Surco 233) surfactants have been investigated. Performance of the anionic surfactant was better than that of the nonionic surfactant due to low adsorption of the anionic surfactant onto the soil, leaving more of the surfactant in solution to solubilize PCBs. Desorption was very fast, requiring about 20 minutes to reach 80 percent of the equilibrium value. Four batch extractions were required to lower the sorbed concentration of Aroclor 1260 from 1000 mg/kg to 41 mg/kg. These results were obtained using a montmorillinite clay spiked with PCB, a liquid to solids ratio of 4/1, and surfactant concentrations in the liquid phase of less than 2 percent by weight. Solids-liquid separation following extraction was accomplished using centrifugation. Calcium chloride precipitation was used to remove PCB from the supernatant. Supernatant PCB concentrations following precipitation were on the order of 1 ug/L.

11. A field process flow chart would probably involve the following: excavation, screening, multistage PCB extraction using counter-current flow, solids-liquid separation using centrifugation, precipitation of PCB from the liquid phase using calcium chloride, and polishing using carbon adsorption. Alternative liquid/solids separation processes include sedimentation and filtration. Neither of these alternatives look real good. Liquid/solids separation using sedimentation in thickeners may be too slow to be feasible at field scale because clays dispersed with a surfactant settle very slowly. Filtration may not be feasible because clay particles quickly blind filters. Centrifugation is workable, but costly. Alternatives to calcium chloride precipitation for supernatant cleanup include biodegradation, selective adsorption, and liquid/liquid extraction. Biodegradation, while a long range goal, is not currently feasible because an Aroclor 1260 biodegradation system is not available. Selective adsorption by resins was investigated but a resin with high capacity and selectivity for PCBs was not found. Liquid/liquid

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extraction is feasible if the surfactant is not recycled. However, extraction into an organic liquid is not consistent with the long term goal of biodegradation.

12. Application of GE Results to New Bedford Harbor. The GE studies show that PCBs are not as resistant to biodegradation as once thought, and PCB biodegradation is probably occurring to some extent in practically all contaminated sediments, including the sediments in New Bedford Harbor. Although bacterial strains capable of degrading the heavily chlorinated PCB congeners have not been isolated yet, the studies of anaerobic batch cultures and in situ sediments indicate that all the PCB congeners are probably biodegradable. Thus, biodegradation of even the most chlorinated PCBs in New Bedford Harbor is a possibility.

13. The studies on in situ biodegradation of sediment bound PCBs are not sufficient, however, for reliable estimation of in situ biochemical decay rates or half-lives. In situ biochemical decay rates are needed to evaluate the significance of biodegradation and to project how long it will take the estuary to self-clean by natural processes. GE's research has focused on comparing relative proportions of congeners in commercial PCB products (Aroclors) to congener distributions in sediments. Shifts in relative proportions, however, are not sufficient to calculate biochemical decay rates because depletion and shifts in congener distributions can result from a variety of physical/chemical processes, such as differential adsorption, volatilization, hydrolysis, photo-oxidation, and solubilization during and after discharge of Aroclors to the estuary. (The physical/chemical properties of PCB congeners differ by orders of magnitude.)

14. Resuspension/deposition and subsequent differential adsorption, hydrolysis, photo-oxidation, volatilization, and solubilization also affects the temporal distribution of PCBs. Because the upper estuary is a deposition area, temporal differences in surficial sediments are impacted by run-off and tides. It is not clear from the limited information available that spatial and temporal variability have been given adequate consideration.

15. For the above reasons, a reliable in situ biochemical decay rate cannot be obtained from the available information. Because reliable decay rates are not available, the significance of biodegradation is difficult to assess. The potential for natural cleanup can be put in perspective by using the half-life of 7 years mentioned by Dr. Brown during his presentation. Disregarding problems inherent in sampling and unknowns relating to physical/chemical phenomena and assuming first order decay, the time required for biodegradation to reduce a sediment PCB concentration of 2167 mg/kg (the concentration in the mid-range concentration composite sample from New Bedford Harbor) to 50 mg/kg (the cut-off for regulation of disposal under the Toxic Substances Control Act) is approximately 38 years, almost two human generations. Since rapid removal of PCBs from New Bedford Harbor sediments by in situ biodegradation has not been demonstrated, it would not be prudent to use the existing information on biodegradation as a basis for selecting the no-action alternative.

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16. A better way of obtaining biochemical decay constants would be to incubate sediment under controlled conditions representative of in situ temperature, moisture, and oxidation-reduction potential. Such a test can be conducted by collecting sediment, mixing the sediment anaerobically, and then holding the sediment for periodic analysis. The sediment should be anaerobically mixed prior to each sampling to rehomogenize the sediment. This approach would overcome many of the problems that limit application of the GE results to New Bedford Harbor. Physical movement of sediment bound PCB by currents would be eliminated. Volatilization and photo-oxidation could be controlled or eliminated. Anaerobic mixing of the sediment before sampling would eliminate or minimize problems related to the spatial variability that affects field sampling. In addition to providing reliable rate constants, this approach could also provide information on shifts in congener distributions and the appearance of metabolites. Testing of replicate 5 gallon batches of sediment should be adequate for these purposes.

17. Scale-up of laboratory systems for aerobic PCB biodegradation to in situ field systems for contaminated soils is not yet possible and significant research and development must be accomplished before such systems are available. This work is not directly applicable to New Bedford Harbor sediment. A bacterial strain for anaerobic PCB degradation has not been developed, and the problems with a delivery system for anaerobic PCB-degradating bacteria to sub-aqueous sediments have not been addressed.

18. The recombinant DNA work is very exciting and promising. However, it will be years before the products of this research are ready for field trials. Even then, there will be public resistance to using recombinant organisms that may prevent field scale applications.

19. Surfactant extraction of PCBs has been investigated in bench-scale studies. This technology should be included in the evaluation of treatment alternatives for dredged material from New Bedford Harbor.

20. Summary. Much of the research reported at the subject program review is not directly applicable to the New Bedford Harbor Superfund site. The information on PCB biodegradation in in-place sediments is adequate to show that biodegradation of PCBs is occurring in New Bedford Harbor sediments, but the information is not adequate for making a reliable estimate of the time required for cleanup by natural processes.

*Tommy E. Myers*

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CEWES-EE-S

16 Mar 88

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