

In Re:

Proposed Toxic Pollutant	}	
Effluent Standards for	}	FWPCA (307) Docket No. 1
Aldrin/Dieldrin et al.	}	

WASTEWATER MANAGEMENT SUMMARY FOR
POLYCHLORINATED BIPHENYLS

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MONS 039665

A F F I D A V I T

My name is Kenneth S. Price. My address is: 2504 Pond Street, Urbana, Illinois, 61801. I am an Environmental Consultant in the firm of Clark, Dietz and Associates-Engineers, Inc. with home offices in Urbana, Illinois. I am a Registered Professional Engineer in the State of Illinois. I am a native of Indiana and since the receipt of my Bachelor of Science in Civil Engineering Degree from Purdue University in 1964, I have devoted my life to the study, teaching, and practice of water and wastewater treatment specializing in the area of industrial waste treatment. I received Master of Science in Civil Engineering and PhD Degrees from Purdue University specializing in Environmental Engineering, in 1966 and 1968, respectively. During my graduate study program, I was a full-time instructor in the Environmental Engineering Department for approximately 2 years.

From 1968 to 1970 I was Captain in the U. S. Army Medical Service Corps serving as the Post Sanitary Engineer and Assistant Preventive Medicine Officer at Fort Huachuca, Arizona.

From 1970 to 1973, I was an Environmental Engineer in the Water Quality Research Group, Research and Development Department, Union Carbide Corporation, South Charleston, West Virginia. In this position, I conducted basic and applied research related to the control and treatment of petrochemical wastewaters. In addition, I provided technical service to the customers of the

MONS 039666

Union Carbide Corporation with respect to the handling and treatment of wastewaters containing petrochemicals. During this same period, I was an Adjunct Assistant Professor of Civil Engineering at the Kanawha Valley Graduate Center of West Virginia University. In this position, I taught courses on water treatment and physical-chemical treatment of industrial wastewaters. I have published papers related to biological treatment of petrochemical wastewaters and the measurement of the biodegradability and acute aquatic toxicity of petrochemicals.

In my current position, I am principally responsible for the development of treatment processes for industrial wastewaters. During the past year, I have reviewed all available technical information on Polychlorinated Biphenyls in the environment and prepared an internal report on the handling and disposal of equipment contaminated with PCB's. I am also Technical Director of Laboratory Services for Clark, Dietz & Associates.

I am a member of the American Society of Civil Engineers, Water Pollution Control Federation, the American Water Works Association, and Sigma Xi. I am presently serving as the Chairman of the Industrial Waste Practices Committee, Environmental Engineering Division, American Society of Civil Engineers.

WATER MANAGEMENT SUMMARY FOR POLYCHLORINATED BIPHENYLS

Introduction

Polychlorinated biphenyls have in the past been employed primarily as dielectric fluids in the manufacture of capacitors and transformers. In addition, PCB's have been used as plasticizers for paints, inks, copying papers, adhesives, and sealants. PCB's have also been employed in formulating pesticides,

as industrial fluids for heat transfer and hydraulic applications, as cutting oils, as lubricating oils, and as vacuum pump oils. The sole domestic producer of PCB's, Monsanto Industrial Chemicals Company, has indicated voluntary discontinuance of the sale of PCB's for all uses except in the manufacture of capacitors and transformers. However, there are no restrictions on the importation of the PCB's and PCB containing materials from producers outside of the United States. Therefore, in developing the proposed effluent discharge standard for PCB's the assumption has been made that PCB's may continue to be employed in all of the previously cited areas.

This report will present a discussion of the control and/or treatment techniques which will most probably be required to meet the proposed effluent discharge limitations. The subject areas to be considered are summarized in the following outline:

- A. Control Measures Applicable to All Industrial Operations Involving the Use of PCB's
- B. Control Measures Related to Specific Industrial Operations Involving PCB's
 - (1) Manufacture of PCB's
 - (2) Capacitor and transformer manufacturing
 - (3) Recovery and regeneration facilities
 - (4) All other manufacturing, formulating, and processing operations involving the use of PCB's and constituting point sources of discharge.
 - (5) Ultimate disposal operations.

- C. Potential Treatment Systems for the Removal of PCB's from Wastewater
- D. Comments on Costs of Implementing Control and Treatment Programs
- E. Comments on Time Requirements for the Implementation of Effective Discharge Control Measures

Control Measures Applicable to All Industrial Operations Involving PCB's

Without regard to the type of facility being considered, certain operations are required which present the potential for loss of PCB's to the local environment and subsequent contamination of water. Examples, of such operations include loading and unloading transport vehicles and containers, cleaning transport vehicles and containers, storage of PCB's in tank farms, cleaning storage vessels, transferring PCB's to and from storage facilities, and the disposal of contaminated or "off-grade" PCB's or PCB containing formulations. With the exception of cleaning operations there would appear to be no need for the introduction of water into these operations. Control measures to prevent the loss of concentrated organic materials are, of course, not foreign to industrial operations and have been employed in the petroleum industry, the petrochemical industry, etc. The basic philosophies followed in such control measures include minimizing the potential for accidental spills and leaks, containment of unavoidable spills and leaks, and exclusion of water from those areas in which

spills, leaks, etc. are unavoidable. Specific examples of the measures which should be employed to prevent accidental losses of PCB's are enumerated below:

1. Operations involved with loading and unloading transport vehicles represent potential sources of minor losses due to spills in connection and disconnection of transfer lines, leaks in transfer lines, leaking pumps, etc. These minor losses should be contained through the use of drip pans, collection sumps, etc. Accidental contamination of rainwater could be avoided by enclosing these operations. All storm waters originating outside of the enclosed area should be routed around such enclosures. Curbing and diking should be employed to prevent accidental spills from leaving the enclosures. Loading and unloading operations also represent the potential for major losses of PCB's through overfilling, improper closure of valves, etc. Liquid level alarms, instrumentation including valve positioning indicators etc., collection bibs and sumps, and operator education represent the best control measures for preventing major losses during loading and unloading operations.
2. Transport vehicles employed for the carriage of PCB's should be dedicated to that service. Dedication of transport vehicles reduces and potentially

eliminates the need for cleaning of such vehicles. When cleaning is unavoidable, solvent cleaning with the contaminated solvents subsequently being incinerated should be considered. When the use of water in cleaning operations cannot be avoided, the actual volumes of water employed should be minimized with the use of numerous small washings rather than large volume flushing.

3. PCB storage tanks and vessels should also be dedicated to that service. Drum storage areas should be enclosed and curbed; there should be no floor drains in the drum storage area. Overpacks which can be employed to contain leaking drums should be available. Accidental spills in the diked storage area should be picked up using absorbent materials and the use of water for cleaning in this area should be avoided. Large tanks employed for the storage of PCB's should at a minimum be diked with the diked volume being sufficient to hold the entire contents of the tank. Although it would be unusual on the basis of current practice, it would also be wise to consider enclosing tank farms employed for the storage of PCB's to prevent accidental contamination of rainwater. At a minimum, storm water originating in the PCB tank farm should be segregated from storm waters which have a low potential of

becoming contaminated with PCB's. Vapors originating from PCB storage tanks may condense and be deposited around a tank storage area. Such accumulations could subsequently result in the contamination of storm water, therefore, positive control on the vapors from PCB storage tanks should be considered. Such control measures might include an inert gas blanket on storage tanks, routing all vapors through the properly designed incinerator to destroy PCB's or manifolding all tanks and routing off-gases through a central activated carbon adsorption system.

4. Transfer lines, pumps, etc. employed to move PCB's from storage facilities to the use point in manufacturing operations should be readily accessible to permit proper maintenance and routine inspections for leaks. It would be desirable to have such transfer lines located in a pipe gallery and again enclosed to prevent the contamination of storm water. Drip pans, sumps, etc. should be liberally employed to contain accidental losses and leaks of PCB's. Emptied drums should either be decontaminated through solvent washing or forwarded to disposal firms equipped to incinerate drums contaminated with hazardous materials.
5. Pure PCB's or concentrated organic formulations containing PCB's which have for one reason or another become contaminated with undesirable materials should either be regenerated and reused or destroyed through

Incineration.

With the possible exception of enclosing tank farms employed for PCB storage, virtually all of the measures cited above could be categorized as standard operating procedures for many industries. The proposed effluent discharge standards for PCB's will undoubtedly make stringent application of those principals and practices a necessity. However, these measures will also represent very cost effective means of reducing the total volume of water, particularly storm water, which might require terminal treatment.

Control Measures Related To Specific Industrial Operations Involving PCB's

Manufacture of PCB's. The sole U. S. Manufacturer of PCB's is the Monsanto Industrial Chemicals Company. Its plant, located at Sauget, Illinois, produces PCB's by chlorinating biphenyls in cylindrical contact towers using either iron filings or ferric chloride as a catalyst. A byproduct of the chlorination reaction is hydrogen chloride which is absorbed in scrubber water. The crude products, the desired characteristics of such are controlled by predetermined chlorination exposures, are purified by distillation under carefully controlled conditions of temperature and pressure. The electrical resistivity of the product is regulated by mixing the product with Fuller's Earth at elevated temperatures and then filtering through paper to achieve the desired characteristics.

Potential sources of water contaminated with PCB's which could originate from the PCB manufacturing operations can be

summarized as follows:

1. Waters employed in the scrubber system for the capture of the byproduct hydrogen chloride can become contaminated with PCB's due to volatilization of PCB's from the contact tower and through minor process upset. The scrubber waters are neutralized and reportedly contained in a closed reactor loop system. Blow down from the scrubber water system can contain PCB's. Non-contact cooling waters can become contaminated with PCB's through minor leaks in heat exchange equipment.
2. Water employed to flush PCB's from the floor of the production area in the event of spills or leaks.
3. Water employed for the cleaning of transport vessels.
4. Storm water falling on the PCB production area; the manufacturer believes that this contamination results primarily from the accumulation of PCB's which occurred prior to the initiation of a rigorous in-plant control program.

In a presentation to the Standards and Water Quality Information Advisory Committee (1) Monsanto detailed additional control measures employed in their manufacturing facility. These control measures are summarized in the following numbered items:

1. Drainage is directed to trenches and piping and then to one of two 3000-gallon settling basins for the containment of accidental spills. Small quantities of PCB's collected in the settling basins are later pumped to drums for ultimate disposal.
2. Rupture disc lines and atmospheric vents have been routed through catch basins or redirected to the settling basins. This measure insures containment of PCB's in the event that rupture does occur.
3. Storage tanks are blanketed with nitrogen to eliminate tank "breathing".
4. Mist eliminators have been installed in vapor lines.
5. Sewers have been altered to prevent build-up of PCB's in the system and to allow monitoring of the effluent from a manufacturing unit.
6. Operator education has been conducted to insure a high level of "housekeeping". Operator responsibilities include checking for leaking pumps on every shift, reporting and documenting leaks to insure corrective actions, emptying drip pans into scrap PCB drums, using "Floor Dry" to absorb any PCB's and minimizing the volume of water used if flushing of PCB's to the settling basin is required, and insuring that all sampling drums/scrap PCB drums are transferred to the ultimate disposal area.

7. A special incinerator has been installed for the ultimate disposal of concentrated PCB's employing temperatures at or above 2000° F. Drainage in the disposal area is also routed to a 10,000 gallon basin for the containment of PCB's.

Even with these control measures, Monsanto indicates that their current effluent discharge would not meet the proposed PCB discharge limitations. Therefore, terminal wastewater treatment facilities for the removal of PCB's would be required.

Capacitor and Transformer Manufacturing. Polychlorinated biphenyls have been employed for many years as dielectric fluids in capacitors and transformers. Their use in these applications is primarily related to their superior dielectrical properties and particularly with regard to transformers, their low fire hazard rating. In reviewing all potential uses of PCB's, the Interdepartmental Task Force on PCB's (2) concluded that the use of PCB's in capacitors and transformers should be continued since suitable substitute materials were not available at the present time. A publication by the National Electrical Manufacturers Association, (NEMA) (3) presents "Proposed American National Standard Guidelines for Handling and Disposal of Capacitor and Transformer-Grade Askarels Containing Polychlorinated Biphenyls." Wilmot (4) presents a survey of production techniques employed in manufacturing capacitors containing PCB's. In reviewing these publications, the following numbered potential

sources of PCB containing wastewaters was developed:

1. Bulk shipment, receiving, and transfer of PCB's. Implementation of the previously described control measures for these types of operations could potentially eliminate and should certainly minimize the volume of PCB contaminated waters released from these operations.
2. Steam jet vacuum systems condensates. Preconditioning steps employed in preparing PCB's for use in capacitors and transformers include heating and the application of vacuum for the degasification and demoiaturizing of the PCB's. In addition, the impregnation process employed in manufacturing capacitors can employ the application of heat and a vacuum for these same purposes. PCB's volatilized during these operations can contaminate steam employed in vacuum jet systems. The volume of contaminated water can be reduced by employing other than vacuum jets for the development of a vacuum (i.e. substitution of a rotary or piston type vacuum pump). The small volume of water vapor condensate contaminated with PCB's resulting from PCB demoiaturizing procedures should be captured and disposed of through incineration.
3. In some instances water/detergent type washers are apparently employed to clean capacitors following impregnation and sealing. This source of PCB contaminated wastewater could be eliminated through the application of solvent washing techniques.

4. Control of PCB's in all other operations associated with manufacture of capacitors and transformers should permit the elimination of PCB contaminated wastewaters. The measures recommended in the NEMA report essentially center around good housekeeping to include containment of accidental spills, dry cleaning methods, and ultimate disposal of concentrated PCB's or concentrated organics containing PCB's via incineration. The NEMA report should be consulted for detailed discussion of the recommended control measures. The only other control measure which could be recommended at this time would include the application of activated carbon adsorption systems on all local exhaust ventilation systems employed to control PCB levels in the work environment. Exhausts from such control systems can result in the contamination of roofs and plant site ground which subsequently results in the contamination of storm water.

In summary, it would appear the control measures to prevent the loss of PCB's to water and ultimate disposal of PCB contaminated solids and organic liquids through incineration would represent the best approach to achieving compliance with the proposed PCB effluent discharge limitations. If the recommended control measures are found to be too restrictive for normal production operations, terminal treatment systems could be employed as required to permit compliance with the proposed discharge limitations.

Recovery and Regeneration Facilities. I am unaware of any

specific facilities constructed for the sole purpose of recovering and regenerating PCB's. As previously indicated, capacitor and transformer manufacturing facilities may pre-condition or recondition (regenerate) PCB's from capacitors and transformers which fail to pass quality control checks. If facilities have or will be constructed for the redistillation and recovery of PCB's from PCB containing formulations, it is believed that the control measures, etc. discussed for the manufacture of PCB's would be equally applicable.

All Other Manufacturing, Formulating and Processing Operations Involving the Use Of PCB's and Constituting a Point Source of Discharge. This broad category includes facilities using PCB's as plasticizers for paints, inks, copy paper, adhesives or sealants, in pattern, waxes for investment casting, and in industrial fluids for heat transfer, hydraulic fluid, vacuum pump oil and cutting oils. The general control measures for preventing the loss of PCB's to water from handling, storage and transfer operations are again equally applicable to these uses of PCB's. Manufacturers employing PCB's for any of these applications should review their operations and determine if water contamination can be avoided in their specific cases. Where water contamination is believed to be unavoidable, these manufacturers are confronted with two choices. The first and most satisfactory alternative from the viewpoint of positive prevention of PCB contamination of water would be substitution of other materials for PCB's. The report by the Interdepartmental Task Force on PCB's contains detailed discussions of potential

substitute materials for PCB's in many of these applications. The second alternative would be to weigh the benefits of the continued use of PCB's in applications where water contamination is unavoidable against the capital and operating investments to permit terminal treatment of contaminated wastewaters such that compliance with discharge limitations on PCB's can be attained.

Ultimate Disposal Operations. The general control measures, previously presented, are equally applicable to ultimate disposal operations with regard to the prevention of accidental losses and contamination of storm water, etc. Monsanto in its numerous presentations, the NEMA report, and others have justifiably indicated that the best means of ultimate disposal of liquid PCB's and organic concentrates containing PCB's is through high temperature incineration. The NEMA report includes a section describing existing commercial disposal operations with the capability of incinerating PCB contaminated solid wastes. Since water scrubbing is required to capture HCl generated in the incineration of PCB's the major consideration of ultimate disposal operations would be to insure that incineration facilities are so operated as to result in the complete destruction of PCB's.

Since the various landfilling procedures, subsurface injection, etc., really only represent control techniques rather than destruction of PCB's, these means of disposal of PCB's should be avoided if at all possible. However, it should be noted that landfill disposal of small capacitors may be the

only satisfactory means of disposal currently available.

POTENTIAL TREATMENT SYSTEMS FOR THE REMOVAL OF PCB'S FROM WATER

General. As previously indicated, polychlorinated biphenyls are only slightly soluble in water. Therefore, the first and most obvious means of removing gross quantities of PCB's from water would be through gravity separation. In some instances, this treatment unit might also serve to contain large volume spills of PCB's and prevent overloading of subsequent treatment facilities or direct discharge to a receiving stream. The use of this type of treatment device has already been cited by Monsanto. If particulate materials contaminated with PCB's are associated with the wastewater, such a treatment unit might also remove these solids.

The available data on solubility of PCB's in water is somewhat contradictory. Baque, et al. (5) performed studies which indicated the equilibrium solubility of Aroclor 1254 was approximately 56 ppb. In comparing their results with the work of Zitko, who obtained solubilities in the range of 0.3 to 3. ppm, Baque, et al. suggested that the high values obtained by Zitko might have been due to the presence of foreign materials in the "fresh water" employed in Zitko's studies. These statements suggest the possibility that chemical treatment (i.e. pH adjustment or coagulant addition) might improve the separation of PCB's from water. To my knowledge, this possibility has not been examined. Zitko's results might also indicate that the presence of other organic

materials increases the solubility of PCB's in water. In any case, It is obvious that gravity separation techniques, with or without chemical additions, could not reduce the concentration to a level less than the solubility of PCB's in water.

Based on a review of all available literature and to the best of my knowledge, treatment systems for the removal of PCB's from water (beyond gross separations in gravity clarification devices) are not currently in operation. Therefore, industries confronted with the removal of trace quantities of PCB's from water will have to resort to the use of available treatment technology the applicability of which is supported only by laboratory data.

Adsorption. Activated carbon adsorption has been widely used in the past to treat wastewaters for the removal of organic materials. Hague, et al presented data which indicated that Aroclor 1254 could be adsorbed in various organic containing soils. More recently Hager and Rizzo⁽⁶⁾ presented data relative to the adsorption of Aroclor 1242 and Aroclor 1254 on activated carbon. The data presented are in the form of adsorption isotherms based on the removal of these Aroclors from pure water at initial concentrations of approximately 50 parts per billion. The results obtained indicate that it should be technically feasible to achieve effluent concentrations at least as low as 1 ppb employing activated carbon adsorption. It should be noted that data of this type are not adequate for final design of carbon adsorption facilities to treat waste waters containing PCB's. However, these data verify the basic technical feasibility

of such a treatment system. Since the type and quantities of other contaminants associated with PCB's in a given waste stream could significantly influence the design of carbon treatment systems, pilot tests are required in virtually every instance to develop precise design parameters.

It should be noted that the data by Hager and Rizzo illustrate another interesting point with regard to the removal of PCB's from wastewater. In preparing a standard sample for the adsorption isotherm test, concentrations of approximately 100 parts per billion were initially prepared. Subsequent fine media filtration resulted in a reduction of the PCB concentrations to approximately the 50 parts per billion range. Interestingly, this residual PCB level following filtration corresponds quite closely to the maximum solubility of PCB's in water (in particular Aroclor 1254) as reported by Hague, et al. However, the other technical point raised by this observation (i.e. the removal of PCB's via fine media filtration) is that fine media filtration might be employed following gravity clarification and proceeding activated carbon adsorption as another potential PCB removal step. It is noted that the maximum allowable discharge concentration for PCB's in the proposed effluent discharge limitation is 280 parts per billion. Therefore, it is conceivable that fine media filtration alone might put certain PCB using industries in compliance.

The report by Hager and Rizzo goes into some detail on the meaning of adsorption isotherm tests and the additional steps

required in developing design parameters. Their report is attached as Exhibit A and additional discussions will not be given here. One technical point not covered by Hager and Kizzo is the potential difficulty in regenerating activated carbon which has been employed for the removal of PCB's from wastewater. First, the destruction of PCB's requires temperatures in excess of 2,000° F. which is higher than the normal temperature employed for the regeneration carbon. The normal regeneration temperature is approximately 1800° F. and should be sufficient for volatilization of PCB's from the activated carbon, however, an after-burner to create sufficiently high temperatures for the complete destruction of PCB's might be required. In addition, the generation of HCl might require special construction materials and, of course, would require off gas scrubbing which is normally employed with carbon regeneration in any case.

Extraction. The analytical technique employed for the measurement of PCB's requires the extraction of PCB's from water employing hexane. Extraction techniques have only been employed to a limited extent in the treatment of wastewaters. However, this observation presents another potential technique for the removal of trace quantities of PCB's from wastewaters.

Membrane Separation. The previously cited example of fine media filtration for the reduction of PCB levels in wastewaters also suggests that any of the various membrane processes currently employed for the treatment of wastewater might also be applicable to the removal of PCB's from wastewater. Membrane processing actually only results in concentrating materials therefore

ultimate disposal of the concentrates would still be required. Therefore, membrane separation would seem to be a less practical and potentially more expensive process in this instance.

Other Treatment Techniques. Chemical oxidation and the use of surface active agents to foam separate PCB's from water might represent potential treatment techniques. No data are available to specifically indicate the applicability of either process. Biological treatment is not applicable.

Summary. It would appear that the most promising treatment sequence for removing PCB's from water would include gravity separation, possibly followed by filtration, and final removal of PCB's via activated carbon adsorption. PCB concentrates obtained from the gravity separation could either be regenerated or destroyed via incineration. Fine media filtration, in this case, would probably imply the use of diatomaceous earth or some similar material for the physical filtration of PCB's from the water. Spent diatomaceous earth would have to be incinerated to insure that the environment did not become contaminated with this material. The final treatment step would be activated carbon adsorption. If in-plant control measures etc. had reduced the volume of water at a given installation to a sufficiently low level, it is conceivable that the most economical system would be to incinerate the exhausted carbon rather than attempt regeneration. If larger volumes of water were being treated and therefore larger quantities of carbon exhausted, regeneration of the carbon might result in the lowest operating

cost. Regeneration could be accomplished with on site regeneration facilities comprising a spent carbon transport system, a regeneration furnace (either multiple hearth or rotary kiln) with the special appurtenances previously indicated, and a regenerated carbon transport system. Alternatively, off site regeneration services are offered by the Calgon Corporation.

It should be noted that although the basic technology for the systems cited above are available, laboratory and pilot tests would be required for each specific installation in order to develop exact design parameters.

COMMENTS ON COSTS OF IMPLEMENTING CONTROL AND TREATMENT PROGRAMS

In-Plant Control Measures. The previously cited in-plant control measures could be implemented by as simple a technique as sealing existing floor drains in certain operations where PCB's are employed. On the other hand, extensive revisions of entire sewer systems might be required at other installations. Process modifications to permit substitution of alternative materials for PCB's or to eliminate the use of water in certain operations, might require extensive revisions of equipment. Or, at the opposite extreme, measures of this type might be implemented immediately by simply removing PCB's and substituting on a one to one basis an alternate material. The point being made here is that the types and extent of revisions required are so variable that no reasonable generalization of the costs involved can be made.

Costs for the disposal of scrap PCB's will, of course, be highly variable dependent on the control measures employed to prevent accidental spills and losses of PCB's. Incineration can reportedly be accomplished for \$.03 per gallon by Monsanto at its plant in Sargent, Illinois. This cost is based on customer delivery of pure liquid PCB's in customer owned containers. One contract waste disposal firm, Rollins Environmental Services, Inc., quotes a price of \$.07 per gallon for RES pickup and disposal of PCB's at its Logan Township, New Jersey plant. This cost can vary depending on transport distances.

Terminal Wastewater Treatment. The costs involved in the terminal treatment of wastewaters will also be dependent on the success of in-plant control measures in reducing the volume of contaminated waters. Therefore, perhaps the best approach to summarizing potential costs for wastewater treatment would be to present ranges of unit costs per thousand gallons of wastewater treated in the proposed treatment scheme. Anticipated ranges of treatment costs for gravity clarification, diatomaceous earth filtration, and activated carbon adsorption are presented in Appendix A.

The following comments are offered regarding the use of the listed treatment costs:

1. Cited values for gravity clarification represent only those costs directly associated with that specific unit. Additional costs would be associated with inlet and outlet piping and the disposal of any PCB's actually

collected in the unit. The magnitude of costs for ultimate disposal via incineration have been previously presented.

2. The cost for diatomaceous earth filtration is primarily based on the nominal usage rate of diatomaceous earth for the filtration of water. Since this process has not actually been evaluated for the removal of PCB's, an accurate prediction of the DE use rate cannot be made. In addition, this estimate would not include the cost for ultimate disposal of the contaminated diatomaceous earth.
3. The ranges of costs for activated carbon adsorption are those reported by Hager and Rizzo. The actual costs for this type of system will, of course, vary with the volume of wastewater to be treated, and the actual effluent PCB concentration desired.
4. Since proper in-plant control will minimize the volume of wastewater to be treated, most of the systems requiring terminal treatment for the removal of PCB's will probably be relatively small on a volume flow basis. Therefore, the cost per thousand gallons of wastewater treated will probably be toward the high side of the ranges cited.

Time Requirements for the Implementation of Effective Discharge Control Measures

The normal progression of events in the implementation of a wastewater management program is as follows:

- 1) Implementation of in plant control measures to eliminate all unnecessary materials losses and to reduce the volume of wastewater,
- 2) Evaluation of wastewaters remaining following the implementation of in plant control measures, and the performance of necessary laboratory and pilot studies to develop design parameters for terminal treatment systems,
- 3) Design of required treatment facilities,
- 4) Construction of treatment facilities,
- 5) Start-up of treatment facilities.

Precise elapsed time estimates for the completion of the indicated steps are difficult to prepare for a generalized case. However, with the possible exception of those operations in which alternate materials can be substituted on a one to one basis for PCB's, it seems quite improbable that implementation of the required programs could be completed within the stipulated one year following the adoption of the proposed PCB discharge limitations.

In the case of the sole domestic producer of PCB's, it appears that the recommended in-plant control measures have already been instituted. Therefore, a reasonable projection of the minimum time required for installation of terminal treatment would include approximately 6 months for pilot studies, 6 months for facilities design, and 12 months for construction.

and start up. The indicated ~~total elapsed time~~ would then be approximately 24 months. Considering the current shortage of major basic construction materials it does not seem that even with extreme efforts this elapsed time could be reduced to much lower than 18 months.

With regard to manufacturers of capacitors and transformers employing PCB's, it should be noted that the required in plant control measures have been well documented by the report prepared by the National Electrical Manufacturers Association. The extent of implementation of these recommendations by the manufacturers is unknown. If such measures have not already been implemented it is quite probable that an additional 17 to 18 months could be required for a total of 36 to 42 months for the start-up of terminal treatment facilities if required. If in plant control measures are already in force, the minimum time requirement would again appear to be in the range of 18 to 24 months.

In essence, it is believed that the proposed one year time limitation for implementation of required control programs is too short to be realistic. In addition, it is believed that if such time limitations were stringently enforced, improperly designed and constructed facilities could result which would in turn create more long term difficulties in achieving the desired control on the discharge of PCB's.

References:

- (1) Polychlorinated Biphenyl (PCB), A presentation to the Effluent Standards and Water Quality Information Advisory Committee, EPA, by Monsanto Industrial Chemicals Company, November 29, 1973.
- (2) "Polychlorinated Biphenyls and the Environment", by the Interdepartmental Task Force on PCBs, Washington, D. C., May, 1972.
- (3) Proposed American Material Standard Guidelines for Handling and Disposal of Capacitors and Transformer-Grade Asphalts Containing Polychlorinated Biphenyls by National Electrical Manufacturers Association, January 25, 1974.
- (4) Wilnot, P. L., "Chlorinated Diphenyl Capacitors - A Survey of Production Technique", Electrical Review, October 28, 1955.
- (5) Hogue, K., Schmiedding, D. W. and Freed, V. H., Environmental Science and Technology, 8:139 (1974).
- (6) Hager, D. G. and Rizzo, J. L., "Removal of Toxic Organics from Wastewater by Adsorption With Granular Activated Carbon, Unpublished. A presentation to an EPA Technology Transfer Session on Treatment of Toxic Chemicals, Atlanta, Georgia, April 19, 1974.

APPENDIX A

Anticipated Cost Ranges For PCB Contaminated Wastewater Treatment

Treatment Process	Total Annual Cost \$/1000 Gal. ⁽¹⁾
Clarification ⁽²⁾ (w/o chemical addition)	0.01 - 0.04
Diatomaceous Earth ⁽³⁾ Filtration	0.10 - 0.15
Activated Carbon Adsorption	
On-site Regeneration	2.05 - 29.50 ⁽⁴⁾
Off-site Regeneration	1.15 - 11.00 ⁽⁵⁾

⁽¹⁾ Includes annual capital (10 yr. at 10%) and M & G costs.

⁽²⁾ Range affected primarily by economy of scale based on flow rate.

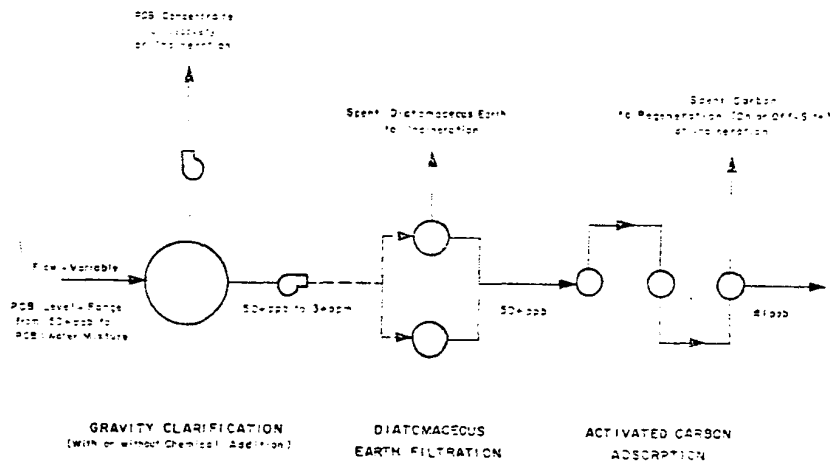
⁽³⁾ Assumes 1.0 lb. DE/1000 gallons; does not include disposal costs for spent DE.

⁽⁴⁾ Excluding single high value, range \$2.05-5.00/1000 gallons.

⁽⁵⁾ Method of annualizing capital costs unknown.

MONS 039693

GRAPH 30117 AND ASSOCIATED INFORMATION



SCHEMATIC REPRESENTATION OF A
POTENTIAL WASTEWATER TREATMENT SYSTEM
FOR REMOVAL OF PCBs

APPENDIX II

EXHIBIT A

MONS 039694

REMOVAL OF TOXIC ORGANICS FROM WASTEWATER BY
ABSORPTION WITH GRANULAR ACTIVATED CARBON

by

D. G. Hager

and

J. L. Rizzo
Calgon Corporation
(A Subsidiary of Merck & Co., Inc.)

PREPRINT: Not for Publication

This paper has been prepared for presentation to an
Environmental Protection Agency Technology Transfer Session
on Treatment of Toxic Chemicals, Atlanta, Georgia, April 19, 1976.

MONS 039695

SUMMARY

1. A recently completed adsorption study indicates that most of the EPA proposed dissolved organic toxic chemicals can be removed from water by activated carbon (Benzidine was not tested).
2. Other chemically similar (aromatic, non-polar, high molecular weight) contaminants, such as OSHA defined carcinogens and the chemicals under examination by the EPA for inclusion on the toxic chemicals list are also predicted to be adsorbable from wastewater by activated carbon.
3. Full-scale granular activated carbon installations are currently removing toxic or biologically refractive contaminants from wastewater, and the exhausted carbon is being reactivated for reuse.

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MASTERMATERIALS FOR TOXIC ORGANIC CHEMICALS
REPORT NO. 039697

Prologue

During the early 1800s, a missionary traveling through Southeast Asia came upon a village with a very unique marital situation - every married man had nine wives. Being a world traveler, the missionary was not surprised by polygamy, but he did wonder about the number nine. Finally, when his curiosity got the best of him, he mustered enough courage to ask one of the tribesmen the purpose of nine wives.

"It is very simple," replied the man. "Our nearest clean water supply is nine miles away, and it requires one person a whole day to walk the distance both ways. It also takes nine trips to secure enough water to satisfy the needs of a family for one day. Since water-carrying duties are performed by our women, it becomes a practical matter to have nine wives."

Introduction

Through the ages man has shown that he will adapt his social habits to the quest for clean water. Civilizations such as Egyptians, Romans, Greeks, and yes, even our early colonists, took care to protect and cleanse water supplies. And many of these peoples used charcoal to purify both water and medicines.

Although the adsorption process was known in ancient times, it was not until the 20th century that we began to use powdered carbon on a grand scale for the removal of tastes and odor-causing constituents from drinking water. Then, during World War I, powdered carbon was tried in gas masks to protect troops from toxic vapors used in chemical warfare. As powder, however, the carbon was not practical because the product was dirty, so granular carbons were developed.

Following World War II, carbon adsorption found applications in sugar decolorization, solvent recovery, and liquid and gas purification. Later, the adsorption process was shown to be technically sound and economically attractive for the removal of refractory and toxic dissolved organics from waste streams.

Adsorption systems have been proven to be more efficient due to their ability to handle toxic wastes such as insecticides, herbicides, other chlorinated hydrocarbons and phenol. Scientists in many countries including Russia,^{1,2} Switzerland³ and the United States,^{4,5,6,7} agree on this point, and their work is cited in the literature.

An example of the use of an adsorption system to correct a health hazard was experienced in Ohio in 1971 when a 5-acre state park lake was deliberately poisoned with 1.8 pounds of endrin⁸. To eliminate the hazard posed by the lake, both to human and aquatic life, the entire body of water was pumped through an adsorber containing granular carbon. Analyses showed the contaminated water contained up to 10 ppb endrin, while the carbon-treated effluent showed the endrin content to be below detectable limits. The spent carbon was thermally reactivated, and the endrin destroyed.

In another case, a railway spill of 25,000 gallons of carbolic acid threatened the Polaris River. Again, activated carbon was employed to remove the compound from the runoff entering a feeder creek, thereby protecting drinking water supplies downstream. And, during another emergency caused by an accidental spill of acrylonitrile in Ohio, carbon was employed in a potable water treatment plant to prevent the possibility of the chemical entering the drinking supply.

Although these examples illustrate the utility of carbon adsorption in specific instances, the questions posed today are: Which toxic organic chemicals give us immediate concern? Why? And can granular activated carbon remove them from our waste streams?

The Federal Water Pollution Control Act requires that EPA publish a list of toxic pollutants and establish effluent standards for such pollutants. The statute specifically provides that the standard can be an absolute prohibition of discharges. The list can be added to whenever the EPA finds other pollutants that meet the statutory criteria of "toxic pollutants." Thus far, the EPA has proposed effluent guidelines for the following toxic pollutants: aldrin, dieldrin, benodanil and its salts, cadmium and all cadmium compounds, cyanide and all cyanide compounds, DIB, DDE and DDT, endrin, mercury and all mercury compounds, polychlorinated biphenyls and toxaphene. With the exception of mercury, cadmium and cyanide, these chemicals are organic in nature and have cyclic structures (Figure 1). Additional toxic pollutant lists published in the future may include those shown in Figure 2.⁹

In addition to these lists, the administrators of the Occupational and Safety Health Act (OSHA) have listed 14 compounds as carcinogenic to humans or animals (Table 1).¹⁰ These compounds also have cyclic structures and are similar to those appearing on the EPA list (Figure 3).

According to Irma West of the California State Department of Health, the long range or indirect effects that toxic organic chemicals can have on the environment have been most disturbing. The most widely used pesticides, the chlorinated hydrocarbons, are concentrated by living matter in the aquatic environment. An increasing buildup of the pesticide may occur in each link of the food chain. However, the amounts tolerated before noticeable effects occur vary with the particular animal species and the pesticide. Some species can tolerate larger amounts, but sooner or later, they are affected by decreased fertility and eventually death.¹¹

Although most attention to this type of buildup is focused on lower forms of animals such as shellfish and other marine life, it is a fact that DDT and its metabolite DDE have been found in all samples of human fat tested for these chemicals (Table 1).¹²

Much research is being conducted to determine the effect of toxic organic buildup in the human body. However, the complex nature of the task will undoubtedly require many years to develop clear-cut conclusions. On the other hand, we do know that many of these chemicals attack the central nervous system and liver when taken in large amounts.¹² And, as little as 0.04 ounces (20 mg/kg) of a chemical such as dieldrin can be considered a large amount when we take into account that this dose can kill a 170-pound man.¹³

To eliminate the threat of toxic organic chemicals as a potential health hazard then, we must take precautionary measures to keep them under control. And, as mentioned previously, the use of granular carbon can help to achieve that goal.

Adsorption Problems Study

The technical literature includes numerous laboratory studies regarding the viability of adsorption for removal of many of the EPA proposed toxic chemicals from wastewater—plus many other potential contaminants used in commerce for pesticides and organic chemical intermediates applications. These researchers have examined a variety of types of activated carbon under many water conditions. The results are invariably the same. These compounds are removed from water very effectively by adsorption in the presence of other organic chemicals. This is not surprising as carbon adsorption is favored by higher molecular weight, non-polarity and limited solubility of the contaminants, most of which characterize the proposed toxic chemicals process.

A laboratory isotherm study was recently completed to evaluate the removal of organic chemicals on the EPA list of toxic pollutants by a commercial-grade of granular activated carbon which has had considerable use in the U.S., Japan and Europe in numerous municipal and industrial wastewater treatment systems. The laboratory procedures were standard adsorption isotherm techniques described in the literature and specifically delineated in Addendum 1 and Addendum 2. Analytical testing for the concentration of contaminants followed EPA recommended procedures.¹⁴

A laboratory adsorption isotherm testing procedure is a reliable technique to ascertain feasibility of adsorption treatment. This testing procedure specifically indicates:

1. The effluent levels of contaminant concentration obtainable by adsorption treatment.
2. The weight of contaminant that will be adsorbed by the adsorbent at the contaminant concentrations studies.

On the other hand, the laboratory test is not used to determine the necessary contact time for granular carbon beds to effect the desired reduction. This determination is usually performed in small pilot carbon beds under dynamic hydraulic flow conditions -- also, a well-established procedure reported in the literature.

Since the solubility in water of the proposed toxic chemicals is limited,^{15,16} it is critical to prepare the standard isotherm test samples by filtration through a fine filter to remove the insoluble fraction (Addendum 1 and 2).

Data on removal of DDD, DDT, DDE, endrin, aldrin, dieldrin, PCB's (Arochlor 1247 and 1254), and toluene is shown in summary form in Figures 4, 5, 6 and 7. Benzidine is not shown because its inclusion on the OSHA list of carcinogens prevented its inclusion in this study.

In each instance, the fine filtration step ahead of adsorption substantially reduced the concentration of contaminants from the initial 100 ppb levels. In the tests on the PCB mixtures (Figure 6), the samples indicated a high degree of insolubility, and thus filtration alone reduces the initial concentrations to levels proposed by the EPA guidelines. Other isomers of the PCB family may be less insoluble, and adsorption appears to effectively reduce the soluble fraction to very low concentrations.

Many of the Isotherm results plotted in Figures 4-7 do not reach the lower effluent limits proposed in the effluent guidelines because of difficulties in testing techniques associated with these very low concentrations. However, Isotherm data can be reasonably extrapolated beyond the data provided by the analytical techniques. Based on the data shown in Figures 4-6, experience with granular carbon systems indicates that the carbon adsorption process can be designed to meet treatment objectives proposed by the EPA.

Isotherm test data for toxaphene is not entirely conclusive, and the tests should be repeated to eliminate interferences and to assure the use of optimum adsorption conditions. Toxaphene is reported by Baron to be adsorbable on activated carbon.⁵

The data shown in Figures 4-7 and in Addendum 1 and 2 suggest the following conclusions of this adsorption isotherm study:

1. Adsorption on activated carbon is an effective treatment process to meet proposed EPA effluent objectives for toxic organic chemicals.
2. Weight pickup of the various contaminants at the very low concentrations tested varied between 0.5 and 10% by weight of carbon.
3. Fine media filtration removes substantial amounts of insoluble components in commercial-grade chemicals found on the proposed toxic chemical list.
4. Analytical testing of the wastewater will require exacting procedures and techniques to assure meaningful results on the carbon-treated wastewater.

The results of this isotherm study are consistent with a broad-range isotherm study recently completed on 227 samples of industrial effluents in which carbon adsorption is shown to be effective for 76% of the wastewaters tested.¹⁷

Full Scale Design Examples

The adsorption isotherm study previously described provides only a cursory view of adsorption's potential for removing toxic organic chemicals from waste streams. However, numerous companies have proceeded far beyond an isotherm test procedure to the installation of full-scale systems. Some have been in operation for a number of years, while others have more recently been put into service.

Each system is comprised of three basic functional components:

1. The adsorption treatment of the wastewater
2. The carbon reactivation equipment
3. The carbon/water transport arrangement

Adsorptive Treatment of the Wastewater

The adsorbers hold the granular activated carbon beds through which the wastewater flows. They can be designed for pressure or gravity flow to achieve the desired contact time of the water with the carbon. Suspended solids and space considerations also must be considered in the adsorber configuration. Flow rates usually fall under 10 gpm per square foot of carbon bed surface area. Contact times for industrial wastewater mixtures usually are in excess of 60 minutes, which is about twice the time employed for purification of domestic sewage. When suspended solids are present, they will be filtered out on the carbon bed. This dual purpose of carbon beds can be usefully employed as long as the adsorbers are designed to accommodate periodic backwashing and bed-cleaning procedures, such as air scour and/or surface wash.

A well-designed water distribution or underdrain will insure good backwashing performance as well as an even distribution of the water. Well

established filtration design practices can be effectively employed in carbon bed design systems. Keep in mind, however, that the carbon beds must be periodically removed via water slurry and obstructions to the flow of carbon from the adsorber should be avoided in adsorber design.

Carbon beds are normally in excess of 10 feet deep and usually fall into one of four basic configurations:

1. Moving beds
2. Beds in series
3. Beds in parallel
4. Expanded beds

The type of configuration selected depends on a number of variables -- principal among them are -- total water flow and suspended solids and degree of contaminant reduction desired. These and other factors have been discussed in other papers on this subject.^{17,18}

Reactivation of the Granular Carbon

Thermal oxidation is employed to reactivate the exhausted carbon for reuse. Either multiple hearth furnaces or rotary kilns are employed for reactivation of the exhausted carbon. The size of the thermal reactivation equipment is based on the carbon exhaustion rate, i.e., pounds of carbon exhausted per thousand gallons of wastewater treated, and the weight of contaminant on the carbon. Excess capacity is designed into the thermal reactivation unit to allow for variances in carbon use rate due to changes in the wastewater flow and organic loading.

The exhausted granular activated carbon is heated to 1600-1800°F to effect volatilization and oxidation of the dissolved organic contaminants. Oxygen in the furnace is normally controlled at less than 1% to effect selective oxidation of contaminants over activated carbon. A 5% loss of activated carbon per reactivation cycle is an acceptable bench mark upon which granular

carbon system economics may be based. In addition, the reactivation equipment should include an afterburner and/or air scrubber to reduce the possibility of air pollution.

Granular carbon is transported between the adsorbers and the reactivation equipment by water slurry. Various pumping designs can be employed including centrifugal and diaphragm pumps as well as movement using either hydraulic or pneumatic pressure. The transport piping should include flush ports and wide radius bends. About one to three pounds of carbon per gallon of water are used, depending upon distance and elevation considerations.

Materials of Construction

Special consideration should be given to the selection of materials of construction used in the adsorption system from two standpoints:

1. Galvanic Corrosions — any tendency toward galvanic corrosion due to water characteristics, such as conductivity and pH, will be enhanced in granular carbon beds. Tanks or adsorbers holding granular carbon under water made from mild steel should be lined or constructed of cement or reinforced synthetic resins/plastics.

Carbon/water slurry piping, which experiences only periodic exposure, is usually exempted from any special corrosion considerations.

2. Erosion — periodic replacement of the carbon beds can cause lining failures at exit ports in carbon tanks and adsorbers. Special grades of stainless steel are usually employed for such wear points.

FULL-SCALE INDUSTRIAL INSTALLATIONS

Tables 3 and 4 summarize data from industrial granular activated carbon systems purifying wastewater that is toxic or biologically refractive. Table 3 includes those installations which include on-site thermal reactivation, while Table 4 summarizes data from installations where the carbon is transported to central reactivation facilities. The data is, of necessity, not detailed because most industrial dischargers classify such information as confidential.

The flow rates shown in Tables 3 and 4 vary considerably because of the point of application at each plant. In some cases, the total plant effluent is being treated. In others, only specific waste streams are being treated by adsorption. The latter point of application normally is beneficial from a total cost viewpoint, as there is usually less contaminated water (smaller treatment system) and higher contaminant concentrations (greater use of the carbon before reactivation).

Comparison of Table 3 and Table 4 on total costs indicates similar costs per 1000 gallons regardless of the carbon reactivation system being on-site or reactivation being performed on a service basis. While the total annual costs appear to be similar, there would be appreciably less initial investment at each treatment site and less space requirements if the reactivation system can be obviated by a reactivation service.

Total annual costs shown in Table 3 range from \$1 to \$20 per 1000 gallons. Similarly, total costs in Table 4 range from \$1.15 to \$11 per 1000 gallons. These ranges are clearly in excess of costs normally associated with domestic sewage or biodegradable industrial wastewater treatment. This can be attributed not only to the type and severity of the contaminant problems being handled

by carbon, but also due to the fact that there are no additional costs associated with granular carbon treatment. Biological treatment costs estimates often reflect only the wastewater treatment components while neglecting the associated sludge treatment, handling and disposal.

CONCLUSION

Adsorption by activated carbon is an effective method to reduce EPA proposed toxic chemicals to EPA proposed discharge guidelines. A number of full scale granular carbon installations have demonstrated reliable and economic treatment of wastewaters containing toxic or biologically refractive contaminants. Granular carbon treatment has been employed on total plant effluents as well as specific in-plant waste streams. Granular carbon reactivation can be performed economically at the treatment site or central reactivation facilities on a service basis.

MONS 039708

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and

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TABLE I

LIST OF CARCINOGENS

2-Acetylaminofluorene
4-Aminodiphenyl
Benzidine (and its salts)
bis-Chloromethyl ether
3,3'-Dichlorobenzidine (and its salts)
4-Dimethylaminoazobenzene
Ethyleneimine
Methyl Chloromethyl ether
4,4'-Methylene(bis)-2-chloroaniline
alpha-Naphthylamine
beta-Naphthylamine
4-Nitrodiphenyl
N-Nitroso dimethylamine
beta-Propiolactone

TABLE 2

DDT PLUS DNE IN HUMAN TISSUE (mg)

<u>AGE</u>	<u>SEX</u>	<u>BLOOD</u>	<u>BRAIN</u>	<u>KIDNEY</u>	<u>LIVER</u>	<u>PROTEIN</u>	<u>FAT</u>	<u>TOTAL</u>
48	M	0.230	0.30	0.005	2.0	4.0	290	300
40	M	0.079	0.06	0.05	1.0	2.0	69	72
41	F	0.053	0.04	0.03	0.2	0.4	41	42
76	F	0.012	0.02	0.02	0.2	0.7	21	22

MONS 039713

TABLE 3

TOXIC OR REFRACTORY INDUSTRIAL WASTEWATER TREATMENT
GRANULAR CARBON INSTALLATIONS (ON-SITE REACTIVATION)

(Partial Listing)

PLANT	FLOW MILLION GAL/YEAR	TOXIC OR REFRACTORY CONTAMINANTS		TYPE OF THERMAL ON-SITE REACTIVATION	CAPITAL COSTS* (\$000)	DIRECT OPERATING COSTS 1000 \$/YEAR**
		AVERAGE INFLUENT	EFFLUENT OBJECTIVE			
A ¹⁹	6	10,000 mg/l TOC	400 mg/l TOC	Multiple Hearth	350	500
B ²⁰	180	370 mg/l phenolics	10 mg/l phenolics	Multiple Hearth	1,300	2
C	70	300 mg/l phenolics	1 mg/l phenolics	Kiln	450	1
D ²¹	50	100 mg/l phenolics	1 mg/l phenolics	Multiple Hearth	300	1
E	550	Color	Color removal	Kiln	---	---
F	1100	Color	Color removal	Multiple Hearth	---	---

* = Includes engineering, construction, adsorption system and reactivation equipment

** = Direct operating costs and do not include depreciation or cost of capital invested.

TABLE 4

TOXIC OR REFRACTORY INDUSTRIAL WASTEWATER TREATMENT
GRANULAR CARBON INSTALLATIONS (CENTRAL REACTIVATION)

PLANT	FLOW MILLION GALLONS PER YEAR	TOXIC OR REFRACTORY CONTAMINANTS		EFFLUENT OBJECTIVE	TOTAL ANNUAL COSTS (MILL. DOLLARS)		
		AVERAGE INFLUENT			ADSORPTION TREATMENT**	REACTIVATION***	TOTAL
A*	128	Phenolics TOC	10 mg/l 250 mg/l	0.1 mg/l	0.95	0.80	1.65
B*	18	Phenolics TOC	40 mg/l 300 mg/l	0.1 mg/l	4.00	2.10	6.10
C*	163	Phenolics TOC	100 mg/l 600 mg/l	0.1 mg/l	0.05	0.60	1.15
D	11	TOC	900#/Day	60#/Day	3.50	3.45	6.95
E*	26	TOC	275 mg/l	Specific Toxicity Tests	4.35	2.45	6.80
F*	84	Color TOC	800 mg/l	Color Removal	1.50	0.25	1.75
G	55	Phenolics TOC	1700 mg/l 3000 mg/l	0.1 mg/l	1.00	2.00	3.00
H	55	TOC	1000 mg/l	Specific Toxicity Tests	2.00	9.00	11.00

* = Filtration Treatment also

** = Includes: Capital, Maintenance, Insurance & Utilities

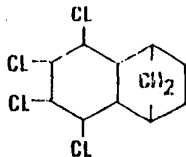
*** = Includes: Reactivation Capital, Transportation, Reactivation Utilities & Make-Up Carbon

MONS 039715

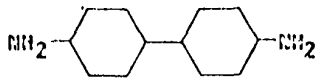
Figure 1

EPA PROPOSED LIST OF TOXIC ORGANIC CHEMICALS

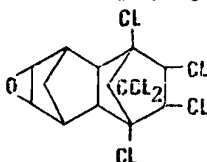
ALDRIN $C_{12}H_8Cl_6$



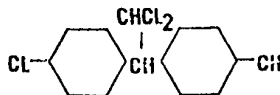
BENZIDNE $C_{12}H_{12}N_2$



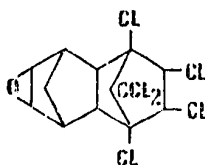
D,ELDRIN $C_{12}H_8Cl_6$



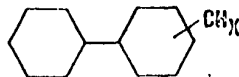
DDE (TDE) $C_{14}H_{10}Cl_4$



ENDRIN $C_{12}H_8Cl_6O$



POLYCHLORINATED BIPHENYL
(210 isomers)



TOXAPHENE $C_{15}H_{12}Cl_8$



DDTC $C_{14}H_8Cl_5$

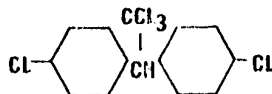
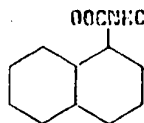
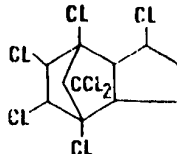


Figure 2
TOXIC ORGANICS UNDER EPA EXAMINATION
 (Partial List)

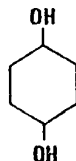
SEVIN $C_{12}H_{11}NO_2$



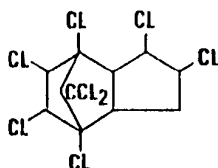
HEPTACHLOR $C_{12}H_5Cl_7$



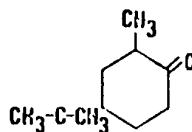
HYDROCORTISONE $C_{21}H_{30}O_5$



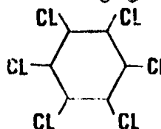
CHLORDANE $C_{10}H_6Cl_8$



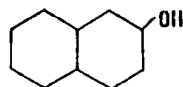
CAMPHOR $C_{10}H_{16}O$



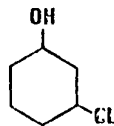
LINDANE $C_6H_6Cl_6$



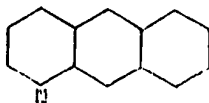
NAPHTHOL $C_{12}H_8O$



O-CHLOROPHENOL C_6H_5ClO



ACRIDINE $C_{13}H_9Cl_6$



PARATHION $C_{10}H_{14}NO_5PS$

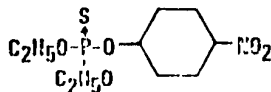
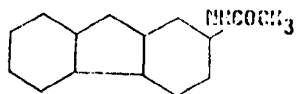


Figure 3
CARCINOGENS
 (Partial List)

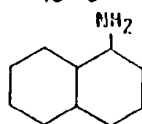
2-ACETYLAMINOFLOURENE

$C_5 H_{13} NO$



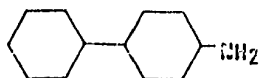
ALPHA-NAPHTHYLAMINE

$C_{10} H_9 N$



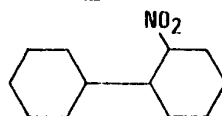
4-AMINODIPHENYL

$C_{12} H_{11} N$



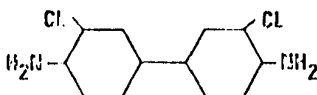
4-NITRODIPHENYL

$C_{12} H_9 NO_2$



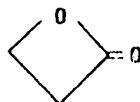
3,3'-DICHLORO BENZIDINE

$C_{12} H_{10} Cl_2 . 2 CHCl$



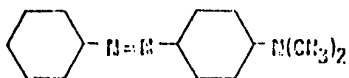
PROPIOLACTONE

$C_3 H_4 O_2$



4-DIMETHYLAMINOAZOBENZENE

$C_{14} H_{15} N_3$



ETHYLENIMINE

$C_2 H_5 N$

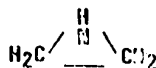


Figure 4

SIMPLIFIED ADSORPTION SUMMARY

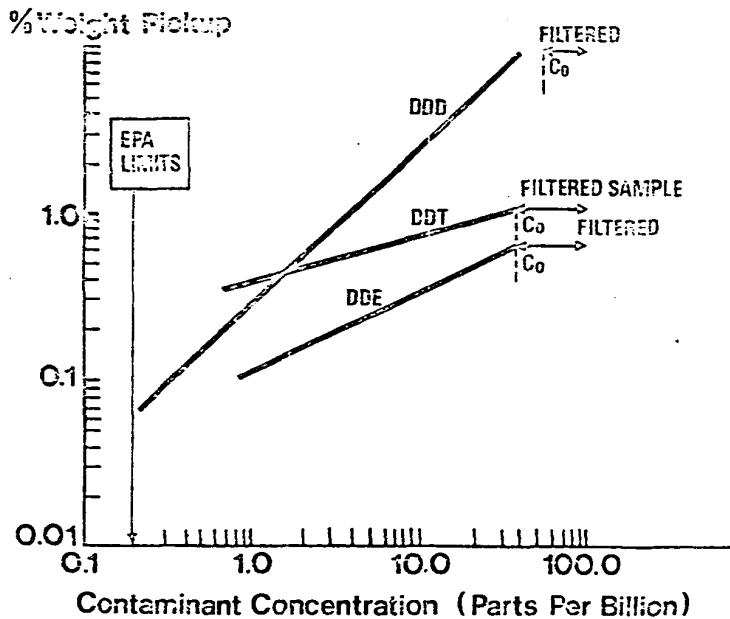


Figure 3

SIMPLIFIED ADSORPTION SUMMARY

% Weight Pickup

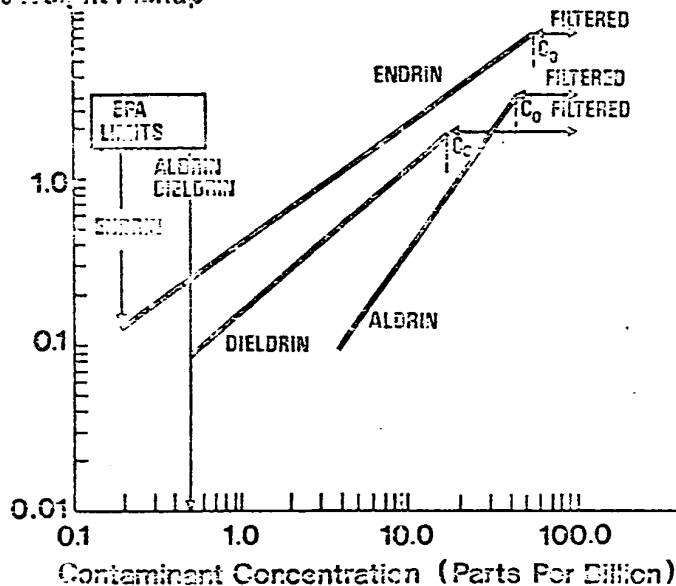
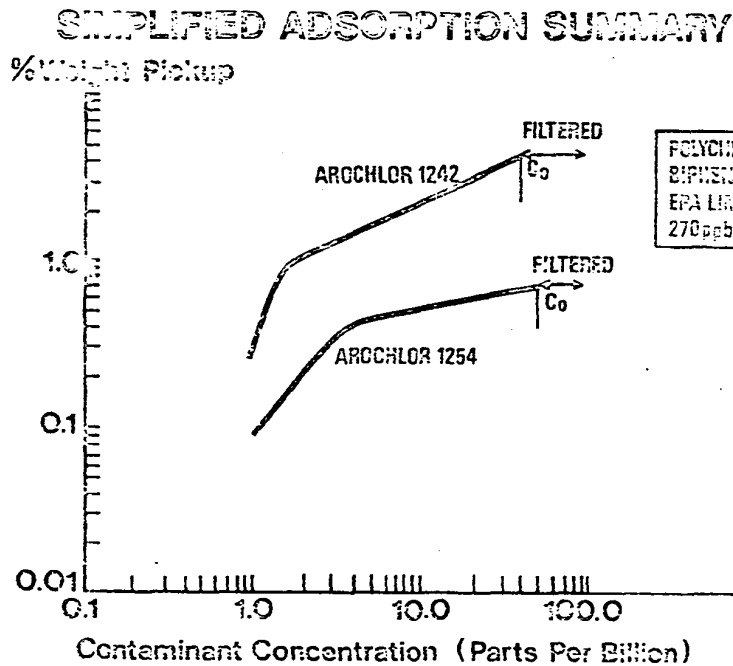


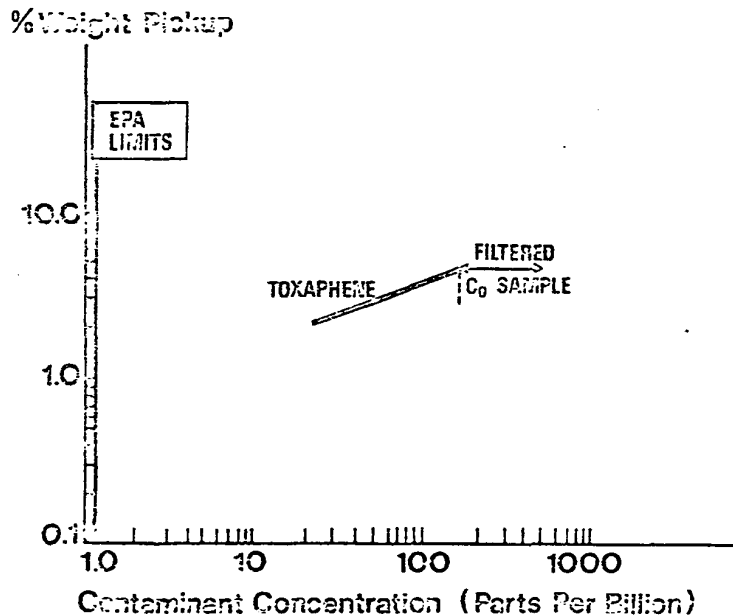
Figure 6



MONS 039721

Figure 7

SIMPLIFIED ADSORPTION SUMMARY



Addendum 1

TOXIC CHEMICAL ISOTHERM AND ANALYSES PROCEDURE

Adsorption isotherms were run on aldrin, dieldrin, endrin, DDD, DDE, DDT, toxaphene and Arochlor 1242 and 1254. The first seven are pesticides, and the last two are mixtures of PCB's containing 42% and 54% chlorine by weight. Stock solutions of each compound, except toxaphene, were prepared in acetone at 100 mg/l. Toxaphene was made up at 1000 mg/l. Filtrasorb[®] 300 (FS-300) activated carbon was used throughout. Carbon was added from a stock suspension of 1 g or 2 g of pulverized FS-300 per liter of distilled water.

Isotherms of aldrin, dieldrin, endrin, DDD and Arochlor 1242 and 1254 were prepared by the following method. Exactly 1 ml of stock pesticide or PCB solution was added to seven flasks, each containing slightly less than 1 liter of distilled water. Measured volumes of the 2 g/l carbon stock solution was added to each flask to give carbon concentrations of 0, 2, 5, 10, 25, 50 and 100 mg/l. The total volume of each flask was 1000 ml. After four hours agitation on a wrist shaker, each solution was filtered through 0.45 micro-millipore pads and stored in a refrigerator in quart amber glass bottles with Teflon-lined caps until analyzed.

The same isotherm procedure was followed with DDE, DDT and toxaphene, except the carbon stock as 1 g/l and carbon dosages were 1, 2.5, 5, 12.5, 25 and 50 mg/l. Also, only 0.5 ml of toxaphene stock solution was added to each flask.

A nickel 63-electron capture gas chromatograph was used for analysis. All samples were extracted and concentrated approximately 100 times before analysis. The method is described in the 1971 EPA report, "Methods for Organic Pesticide Analysis in Water and Waste Water."

Addendum 2

ANALYTICAL LABORATORY RESULTS

CARBON DISC-95 (-27.1)	RESIDUAL (ppb)							ARACHLOR 1242	ARACHLOR 1254
	ALDRIN	ENDRIN	DIELDRIN	DDT	DDO	DDE	TOXAPHENE		
Control	46	62	19	41	56	38	155	45	49
1.0	--	--	--	41	--	34	147	--	--
2.0	25	15	6.3	--	6.9	--	80	7.3	37
2.5	--	--	--	21	--	29	--	--	--
5.0	15	3.4	2.4	3.7	3.7	12	31	1.5	17
10.0	12	1.5	1.1	--	2.2	--	2.7	1.1	4.2
12.5	--	--	--	<1	--	3.3	--	--	--
25.0	6.3	0.56	--	--	0.45	1.1	--	--	1.6
50.0	4.4	0.22	--	--	0.35	0.9	--	--	1.2

MONS 039724