

range from 6.8 to 9.0. These values indicate that these compounds should partition into sediments and bioaccumulate even more effectively than the corresponding PCB's.

Acknowledgments

We express our gratitude to the Canada Centre for Inland Waters for supplying the Lake Ontario sediment samples, to the New York State Department of Environmental Conservation for supplying fish samples, and to Paul H. Chen and Ray Kaminsky for their assistance in the synthesis and sample workup procedures.

Registry No. 1, 95998-69-9; 2, 95998-70-2; 3 (Cl₁ isomer), 95998-64-4; 3 (Cl₂ isomer), 95998-65-5; 3 (Cl₃ isomer), 95998-66-6; 3 (Cl₄ isomer), 95998-67-7; 3 (Cl₅ isomer), 95998-68-8.

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Received for review September 20, 1984. Accepted January 22, 1985. This research was supported by the U.S. Environmental Protection Agency under Grant 808961.

Reaction/Removal of Polychlorinated Biphenyls from Transformer Oil: Treatment of Contaminated Oil with Poly(ethylene glycol)/KOH

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■ Polychlorinated biphenyls (PCBs) in transformer oil react with poly(ethylene glycols) and potassium hydroxide under relatively mild conditions. Complete reaction with PEG occurs at 60–120 °C in under 2 h to produce aryl polyglycols, the products of nucleophilic aromatic substitution. The reactants and aryl polyglycol products are insoluble in transformer oil and are easily removed. Process optimization, demonstration of batch and continuous processes, and an engineering evaluation have been completed. The treated oil has been tested for its chemical and electrical properties and meets all the specifications required for reuse.

Introduction

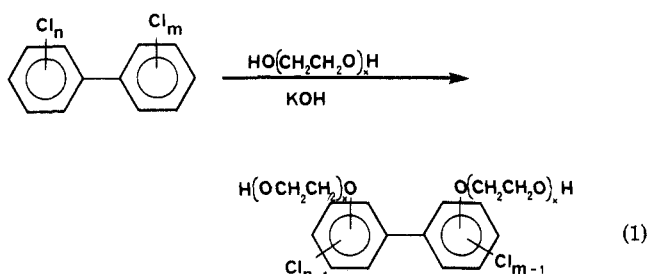
The production of polychlorinated biphenyls (PCBs) began in 1929 and peaked in the late 1960s (1, 2). The

properties of PCBs that led to their widespread utilization in transformers and capacitors are their thermal stability, their flame retardant capability, their resistance to oxidation, reduction, acids, and bases, and their excellent dielectric properties (1, 2). In 1972, the EPA issued a report stating that PCB contamination was ubiquitous and that PCBs represented an unquantified threat to the environment (3). In 1976, Congress passed the Toxic Substances Control Act, which specifically regulates manufacture, use, and disposal of PCB-contaminated materials (4). At the inception of our work, no method existed for removal of PCBs from contaminated oil (Facilities are currently available for burning PCBs or PCB-contaminated fluids. Solvent extraction processes have been patented (5, 6).) At the present time, the only methods available for chemical destruction of PCBs, which permit reuse of the oil, require the use of metallic sodium (7–14). Hence, we undertook a program of research with the goal of identifying a safe, inexpensive, and simple means of

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reacting PCBs in transformer oil that would allow easy disposal of the byproducts and reuse of the transformer oil and that would not involve the use of metallic sodium. We now wish to report realization of these goals, via reaction of PCB-contaminated oils with poly(ethylene glycol) (PEG) and potassium hydroxide.

We have previously reported the phase transfer catalyzed reactions of PCBs with alkanethiolates (15). In that paper, we described the use of PEG's as phase-transfer catalysts (16-20). We have subsequently found that PEG and poly(ethylene glycol) methyl ether (PEGM) can act as both catalyst and nucleophile in reaction with PCBs under basic conditions (21). Reactions occur under mild conditions (10 min to 2 h at 60-120 °C) in nonpolar media such as hydrocarbon solvents or transformer oil (eq 1). This method constitutes an economically attractive scheme for decontamination of PCB-laden transformer oil. The method is tolerant of air, water, and other contaminants and allows nearly quantitative recovery of the dielectric fluid for reuse. The process has been optimized, and batch and continuous operations have been demonstrated. A preliminary engineering evaluation is included herein.



Experimental Section

General. Vapor-phase chromatography was carried out on a Varian 3700 gas chromatograph equipped for auto-injection and flame-ionization detection and coupled with a Spectraphysics SP-4000 computer for data reduction. Separations were performed on a 6-ft 3% OV-17 column (Chrom W). Capillary VPC analyses of PCBs in oil samples were carried out on a Hewlett-Packard 5880A gas chromatograph equipped with a ^{63}Ni electron capture detector, using modified published procedures (22), with a chlorofluorobiphenyl internal standard (23). Gas chromatograph/mass spectrometry (GC/MS) was carried out by using full mass range scans (detection limits ca. 1 ppm) and multiple ion detection (detection limits ca. 5 ppb). All solvents and reagents were reagent grade, used without further purification. A sample of used, PCB-contaminated (ca. 650 ppm of Aroclor 1260) transformer oil was obtained from GE Transformer Division, Pittsfield, MA.

General Procedure for Reactions of PCBs with PEG or PEGM/Base. A 1.00-mL sample of Aroclor 1260 stock solution (1.0 M PCB and 25.00 mg/mL *n*-docosane internal standard in toluene) was diluted to 20 mL with solvent. The required amount of PEG or PEGM was added, along with the base. If solid KOH or NaOH were used, they were ground to a powder before use in a Waring blender. The reaction flask was lightly stoppered and was heated at the temperature shown with vigorous mechanical stirring for the indicated time. Samples were removed periodically, were quenched with saturated NH_4Cl solution, and were diluted with CH_2Cl_2 . VPC analysis provided the results shown. Yields were determined by integration of the entire PCB envelope vs. the internal standard and by comparison to the starting standard, with an accuracy of $\pm 2\%$. Results are summarized in Table I. Product identification has been previously described (21).

Table I. Reaction of Aroclor 1260 with PEG and Base in Toluene/Heptane^a

entry	PEG ^b (equiv)	base (equiv)	temp	time, h	% reaction ^c
1	PEG 300/thiol ^d (7)	KOH (6)	100	2	72
2	PEG 200 (6.7)	KOH (6)	100	1	83
3	PEG 600 (6.7)	KOH (6)	100	1	94
4	PEG 600 (4)	KOH (15)	75	1	21
				2	82
5	PEGM 550 (4)	KOH (15)	75	1	61
				2	90
6	PEG 3400 (1)	KOH (15)	75	1	60
7	PEGM 1900 (2)	KOH (15)	75	1	85
8	PEGM 750 (2)	KOH (20)	75	1	78
9	PEGM 750 (2)	NaOH (23)	75	1	40
10	PEGM 750 (2)	50% NaOH (23)	75	1	16
11	PEGM 750 (2)	KOH (20)	75	1	74 ^e
12	PEGM 750 (2)	KOH (20)	75	1	78 ^f
13	Triton ^g (2)	KOH (8)	75	1	78
14	none	KOH (6)	100	4	0
15	PEGM 750 (2)	KOH (20)	75	1	6 ^h

^a Reaction in 20% toluene/heptane; PCB concentration = 0.05 M (20 000 ppm). All reactions (except entry 15) were mechanically stirred; reagent amounts are equivalent relative to PCB. ^b Numbers following PEG or PEGM are the average mole weight of the polyglycol. ^c Extent of reaction determined by VPC analysis vs. *n*-C₂₂H₄₆ internal standard. ^d *n*-Dodecylthiol and PEG 300 were used in equimolar amounts. ^e Air was bubbled through the reaction mixture. ^f Reaction was carried out rigorously under nitrogen. ^g Triton X-100, a commercial PEG-based surfactant. ^h Reaction was carried out without stirring.

Table II. Reaction of Aroclor 1260 Contaminated Transformer Oil with PEG/KOH^a

PEG (level)	KOH level	temp	time, h	ppm of PCB remaining ^b
PEG 300 (5)	1	100	1	16
			2	0
PEG 300 (1)	1	130	1	47
			2	0
PEGM 750 (3)	3	95	1	60
PEGM 750 (5)	5	95	1	6
PEGM 350 (4)	6	110	1	0
PEGM 550 (4)	6	110	1	0

^a PCB concentration in oil = 650 ppm; all reagent amounts are in weight percent relative to transformer oil; all reactions utilized mechanical stirring. ^b PCB levels by VPC with electron capture detection.

Reactions in transformer oil were carried out in a similar manner but used no solvent or added PCB. Oil contaminated with 650 ppm of Aroclor 1260, PEG, and base were stirred vigorously at 75-130 °C. Reagent amounts for all reactions in oil are in weight percent relative to the oil. After reaction, samples were cooled and filtered through a short pad of Celite on glass wool and were submitted for analysis. Results are presented in Table II.

Preparation of Samples for PCDF and PCDD Analysis. A mixture of 6.10 g of Aroclor 1260 (ca. 17 mmol), 1.08 g of 1,2,4,5-tetrachlorobenzene (50.0 mmol), 30.00 g of PEG 300 (100 mmol), 32.9 g of ground KOH (500 mmol), 50 mL of xylene, and 150 mL of dodecane was stirred at 100 °C, removing samples after 5, 15, and 30 min. The temperature was raised to 120 °C, and a sample was removed after stirring for 1 h. The temperature was finally raised to 150 °C, and a final sample was removed after 2 h. All samples were filtered through a short pad of Celite, washing with CH_2Cl_2 , and were directly analyzed for PCB, PCDD, and PCDF. PCBs were found in the samples re-

Table III. PCB Destruction: Continuous Process Results^a

mode	temp	residence time, ^b min	PCB content, ppm
batch	100	10	<1
continuous	100	10	10
continuous	110	10	<1
continuous	100	15	<1

^aFeed: transformer oil + 500 ppm of Aroclor 1260. Reagents: PEGM 750 (1% by weight relative to oil) and KOH (powdered 85%; 1% by weight relative to oil). ^bAverage residence time at steady state.

moved at 100 °C; tetrachlorobenzene, PCDD, and PCDF were not detected in any sample (detection limit for PCDF and PCDD = 5 ppb).

General Procedure for 1-gal Batch Reactions.

Figure 2 presents the experimental setup and the process sequence employed for the 1-gal batch reaction studies. A 1-gal, jacketed, glass reactor was used. To provide efficient mixing, the reactor was equipped with vertical baffles, two pitched blade turbine impellers, and a recirculation pump. Nitrogen blanketing was maintained over the reactor to prevent oxidative degradation of the oil (which changes from yellow to pink in reaction under air).

The contaminated oil was heated to the desired reaction temperature by adjusting the temperature of the hot oil circulation through the jacket. During this operation and the subsequent reaction, the reactor contents were recirculated through the pump, stirring with the impellers at desired speed. After the desired reaction temperature was attained, required amounts of PEG and KOH were added to the reaction vessel. The reaction mixture almost immediately turned to a brownish black color, darkening further as the reaction progressed. After the desired reaction time, the reactor contents were drained into another vessel and were quickly cooled to 40 °C; this resulted in precipitation of PEG, KOH, and reaction products. The postdestruction oil recovery system consisted of vacuum filtration through a bed of Fuller's earth, water wash of the oil, removal of water by decantation, and then final vacuum dehydration of the oil. The resulting oil (yellow in color) was submitted for PCB analysis and for testing to establish reusability criteria.

Procedure for Continuous Process. Figure 3 presents the experimental setup for the continuous reaction system. In the feed tank (a 4-gal jacketed glass vessel), the oil/KOH slurry was prepared and was heated to the reaction temperature. The reaction vessel was a jacketed 1-gal glass vessel, with an overflow outlet. The reactor used was a continuous stirred tank reactor (CSTR), with continuous feed (oil/KOH slurry and PEG) and continuous withdrawal of the reaction mixture as overflow from the reactor.

A continuous reaction run consisted of carrying out a typical batch reaction sequence in the reaction vessel and introducing the feed (oil/KOH slurry and molten PEG) and collecting the reactor overflow continuously. The feed rates of oil/KOH slurry and of molten PEG were adjusted such that the desired residence time and reagent/oil ratios were obtained. Sampling of the effluent indicated that steady-state operation was achieved in 1–2 h. After the reaction was run continuously for 8 h, samples of the reactor effluent were subjected to postdestruction recovery procedures described above for batch reactions. Typical results are summarized in Table III.

Results

In studying the phase transfer catalyzed reactions of thiolates with PCBs, we were particularly interested in the

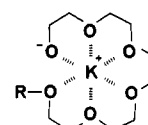


Figure 1. Proposed complexation of potassium poly(ethylene glycol) alkoxide.

use of PEG's as catalysts. PEG's have recently become attractive catalysts (16–20) due to their relatively low cost and their stability and also because of their low toxicity (24, 25). We were pleasantly surprised, therefore, to find that not only were the PEG's superior phase-transfer catalysts but also the reaction of PCBs with PEG's occurred faster *in the absence of thiol*. It appears that the potassium PEG alkoxide can phase transfer itself into the organic phase, via self-complexation (Figure 1). Once present in the organic phase, the PEG alkoxide is a potent nucleophile that can attack the PCB. (Although the reaction of ethylene glycol and NaOH with chlorobenzenes and PCBs at high temperatures has been demonstrated (26), such high nucleophilicity at low temperature was unanticipated.)

We have completed a laboratory evaluation of the reactions of Aroclor 1260 (commercial mixture of PCBs with an average of six chlorines per molecule) in heptane/toluene mixtures and in transformer oil. The results are summarized in Tables I and II. It is clear that reaction proceeds best in the absence of thiol (compare entries 1 and 2, Table I). Several other key points should be made: (1) reaction rate increases with increasing molecular weight of the PEG (entries 2, 3, 6); (2) monomethyl PEG ethers (i.e., PEGM) offer a significant advantage over uncapped PEG's (compare entries 4 and 5); (3) potassium hydroxide is much more efficient than NaOH (entries 8 and 9); (4) water slows the rate of reaction but does not otherwise affect it (entry 10); (5) the presence or absence of oxygen has no effect on reaction (entries 11 and 12); (6) commercial PEG based surfactants such as Triton X-100 [poly(ethylene glycol) nonylphenyl ether] will react with PCBs, but emulsions form (entry 13); (7) efficient stirring is crucial for successful reactions (entry 15).

Reactions of PEG or PEGM with PCBs in transformer oil were somewhat slower than those in solvent. Two reasons for reduction in rate are the lower available concentrations of PCB (650 ppm), and diminished interphase mixing due to the higher viscosity of transformer oil. These problems were overcome, however, when larger scale reactions were engineered (see below). The most efficient reagent on a weight basis is PEGM 350 (average M_n 350). Reaction/removal of PCBs to undetectable levels occurs in 2 h at 130 °C with PEG 300 or at 100 °C with PEGM 350. During a well-mixed reaction, the reaction medium appears homogeneous and black. After reaction, cooling provides clean separation of the transformer oil (light yellow in color) from the glycol/KOH phase. The glycol phase can be either solid or liquid, depending on the molecular weight of the PEG used (M_n > 550 provides a solid phase). All of the reactants and products are contained in the glycol/KOH phase; filtration affords clean oil. Results of laboratory reactions are summarized in Table II.

Product Analysis

The chemistry of the PEG/KOH process involves a simple nucleophilic aromatic displacement reaction of chloride by a poly(ethylene glycol) alkoxide (eq 1). We were surprised to find that nucleophilic displacement occurs under such mild conditions in the absence of an ac-

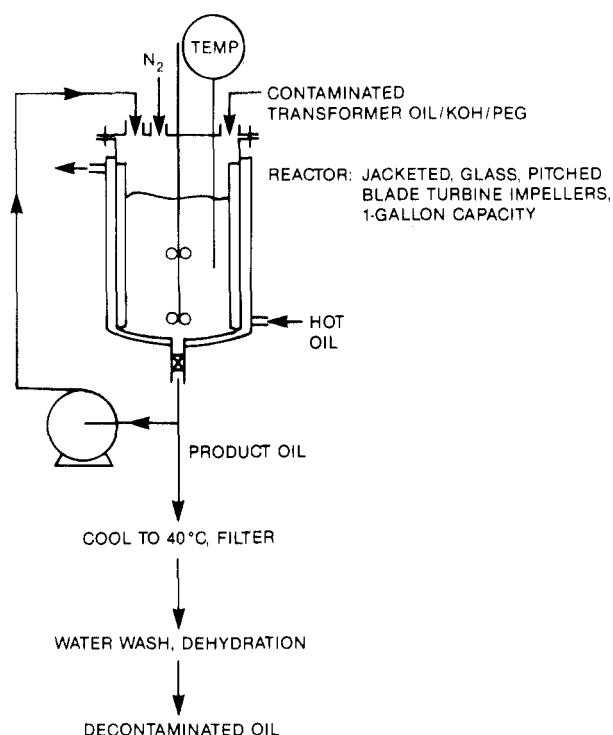
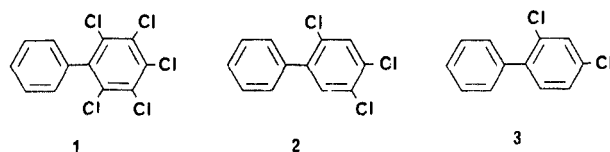


Figure 2. PCB destruction batch process.

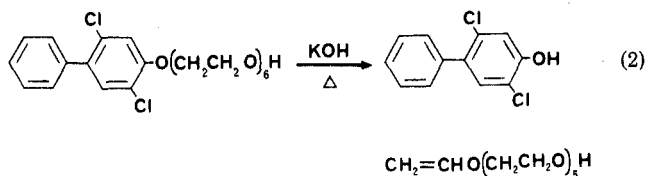
tivating group (such as carbonyl or nitro), since "benzene rings which lack activating substituents generally are not useful substrates for the S_NAr mechanism" (27). Isolation and identification of individual products from reaction with Aroclor 1260 would be extremely tedious, due to the large number of PCB isomers present in commercial mixtures, combined with the presence of several oligomers in PEG or PEGM reactants, and further complicated by

any lack of regioselectivity of the reaction. Thus, we have prepared three pure PCB isomers (1-3) and reacted them



with pure hexa(ethylene glycol), for isolation and identification of the products.

Pentachlorobiphenyl (1) reacted with KOH and hexa(ethylene glycol) at ambient temperature, to afford a mixture of all three possible isomers, with a slight preference for reaction at the para position. Compounds 2 and 3 reacted at 90 °C and also provided mixtures of products, with little regioselectivity. The total lack of regioselectivity in reaction with PEG alkoxides is somewhat surprising, since chlorobenzenes and PCBs react very specifically with thiolates under phase-transfer conditions (15, 28). Further heating of the aryl polyglycol products in the presence of base led to production of polychlorobiphenyl alcohols (eq 2), via elimination of a vinyl-terminated PEG.



Reaction of Aroclor 1260 with hexa(ethylene glycol) at 100 °C afforded a mixture of aryl polyglycols, along with 1-5% polychlorobiphenyl alcohol (yield of polychlorobiphenyl alcohol was approximated by UV). Polychlorobiphenyl alcohols and polyols have been identified as the major PCB metabolites excreted by many animals (29).

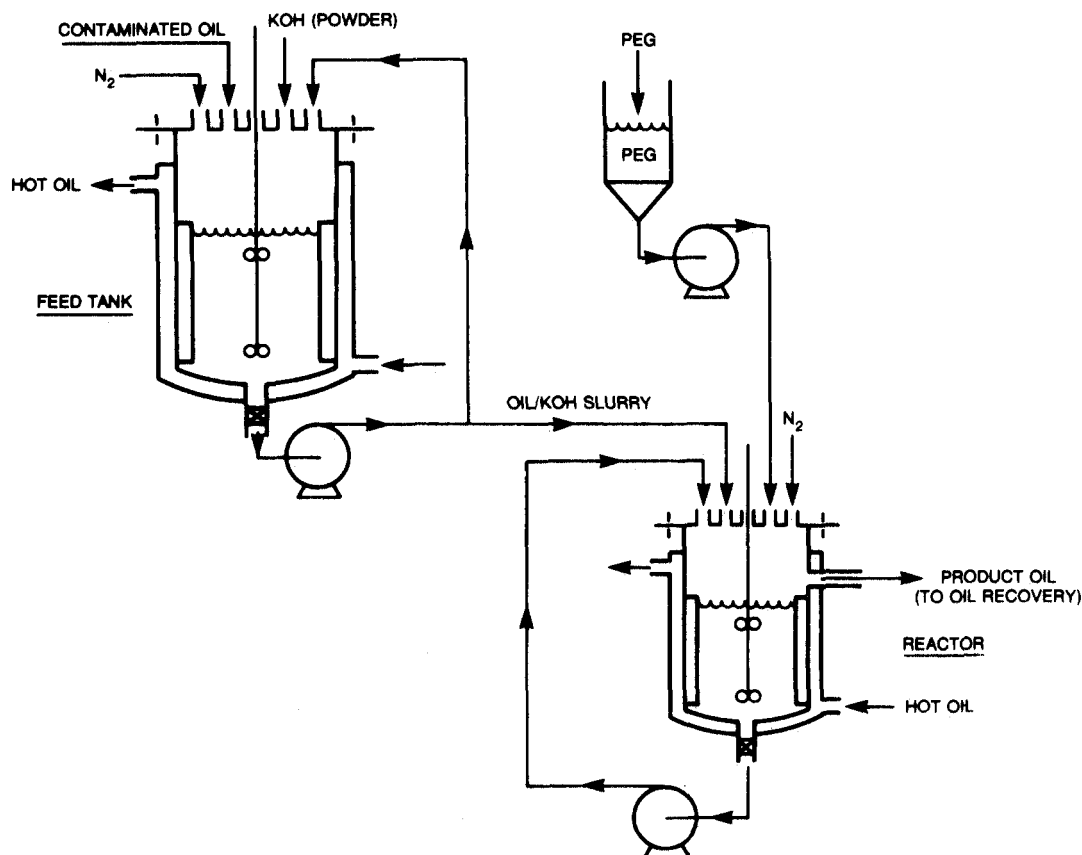


Figure 3. PCB destruction continuous process.

Because polychlorophenols are precursors to polychlorodibenzodioxins (PCDD) (30–32) and polychlorobiphenyl alcohols can be precursors to polychlorodibenzofurans (PCDF) (2, 32–34) we have carried out exhaustive tests for the presence of these compounds. Reactions were carried out in toluene/heptane or xylene/dodecane because lower levels of PCDD and PCDF can be detected in these solvents than in transformer oil. Reactions carried out with 30 000 ppm of PCB and 10 000 ppm of 1,2,4,5-tetrachlorobenzene under either severe conditions (150 °C) or mild partially reacted conditions (100 °C, 5–30 min) showed no PCDD or PCDF to a detection limit of 5 ppb (by GC/MS). PCDD and PCDF are not formed in these reactions for several reasons: (1) temperatures of greater than 270 °C are normally used for (non-copper-catalyzed) diaryl ether synthesis (2, 30–34), whereas our reactions are carried out at much lower temperatures; (2) reactant concentrations are far lower in our examples; literature PCDF and PCDD syntheses (2, 30–34) are normally conducted without solvent; (3) only small amounts (1–5%) of the active intermediate for ether synthesis (i.e., the polychlorobiphenyl alcohol) are typically formed; (4) the aryl polyglycol products should be about 300 times less reactive than starting PCBs (ref 11, pp 584–618) toward a second nucleophilic substitution required for diaryl ether synthesis; finally (5) any PCDD or PCDF that did form could also react with PEG/KOH and be converted to its aryl polyglycol.

We have submitted the product-containing glycol phase from a typical reaction for acute toxicity screening. Aroclor 1260 was reacted with 2% PEG 400 and 4% KOH for 2 h at 100 °C. After cooling, filtration, and neutralization, the glycol phase was submitted. A control experiment was carried out under the same conditions, but without PCBs. The control and test samples gave identical toxicity results. Neither sample was toxic by oral ingestion (maximum dose = 5000 mg/kg; rat); neither sample was toxic by dermal absorption (mouse), and both samples were found to be mild eye irritants (rabbit).

Engineering Evaluation

A laboratory engineering evaluation of the PCB destruction process was carried out to establish the feasibility of the PEG/KOH process, to evaluate the effects of different process parameters, and to obtain scale-up and design data. On the basis of these experiments, optimal design of the commercial operation was established. An attempt was then made to establish the economics of the process.

Effects of different process variables upon the performance of the PCB destruction reaction were studied by using a 1-gal, jacketed, glass, batch reactor (Figure 2). As expected, the following parameters were found to be critical for good reaction performance: reaction temperature, rate of mixing, reaction time, and amounts/types of reagents.

Although the presence of water slows the reaction, a small amount is tolerable, and no predrying of the oil is necessary (the commercially available KOH used for all reactions contained 15% water; additional drying was deemed unnecessary). The rate of dechlorination for individual PCB mixtures was also followed. As expected, it was observed that more stringent conditions were required for dechlorination of lower chlorinated PCBs such as Aroclor 1242 (average of four chlorines per molecule). Runs were carried out with actual used, PCB-contaminated transformer oil and with fresh transformer oil artificially loaded with Aroclors 1260, 1254, and 1242. On the basis of the results of these reactions, optimal process conditions for the complete destruction of PCB present in the oil were

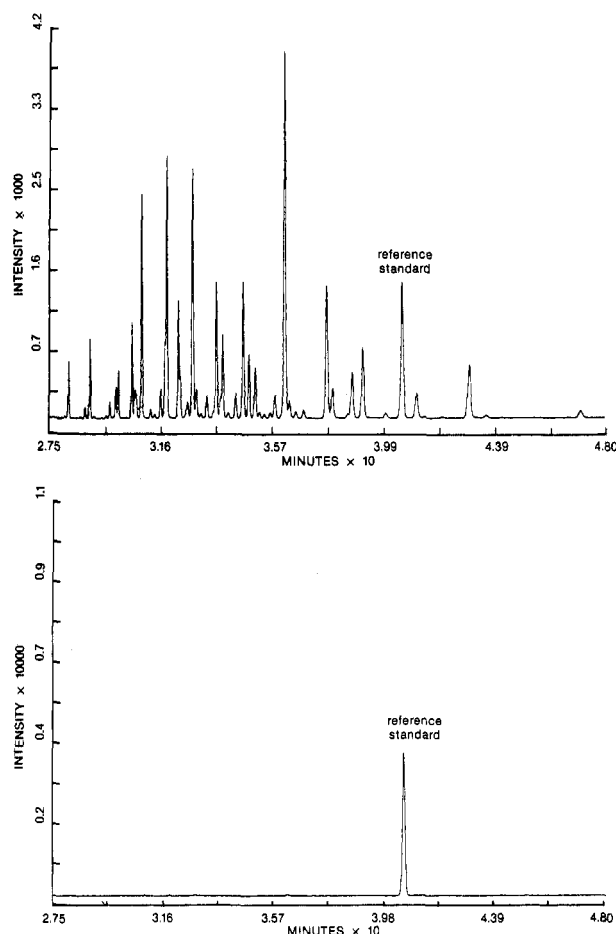


Figure 4. Capillary VPC/EC detection trace of transformer oil contaminated with 1060 ppm of Aroclor 1260 (top trace). After treatment with PEGM 350/KOH (bottom trace). Reference standard is a chlorofluorobiphenyl (23).

determined and are the following:

- (1) *feed*, used transformer oil containing 500 ppm of PCB
- (2) *product*, decontaminated transformer oil (i.e., <1 ppm of PCB)
- (3) *optimum parameters*, PEG 1% (by weight relative to transformer oil) PEGM 750, KOH 1% (by weight relative to transformer oil), powdered, 85%; mixing efficient (Reynolds number > 10⁴; motor hp > 0.6 for the reactor system used); reaction temperature 100 °C; reaction time 10 min

Typically, 97–99% of the transformer oil was recovered. If it is undesirable to operate the PCB destruction process at 100 °C because of oil quality or operation considerations, complete destruction can be achieved by conducting the reaction for a longer period of time at lower temperature (e.g., 45 min at 60 °C).

In a typical reaction, where the reactor contents are cooled and drained, a slight amount of byproduct sludge (dark pasty material consisting of PEG, KOH reaction products, and oil) remains in the reactor. This sludge is quite soluble in water; addition of about 5% water (based on the weight of the reaction mixture) after the reaction is complete dissolves the sludge, leaving the reactor clean for the next batch. There are no adverse effects, however, on the performance of the PCB destruction process if the reactor is used repeatedly without any cleanup between runs.

The PCB destruction reaction has been carried out in a continuous manner. The reactor system used was a continuous stirred tank reactor (CSTR) with continuous

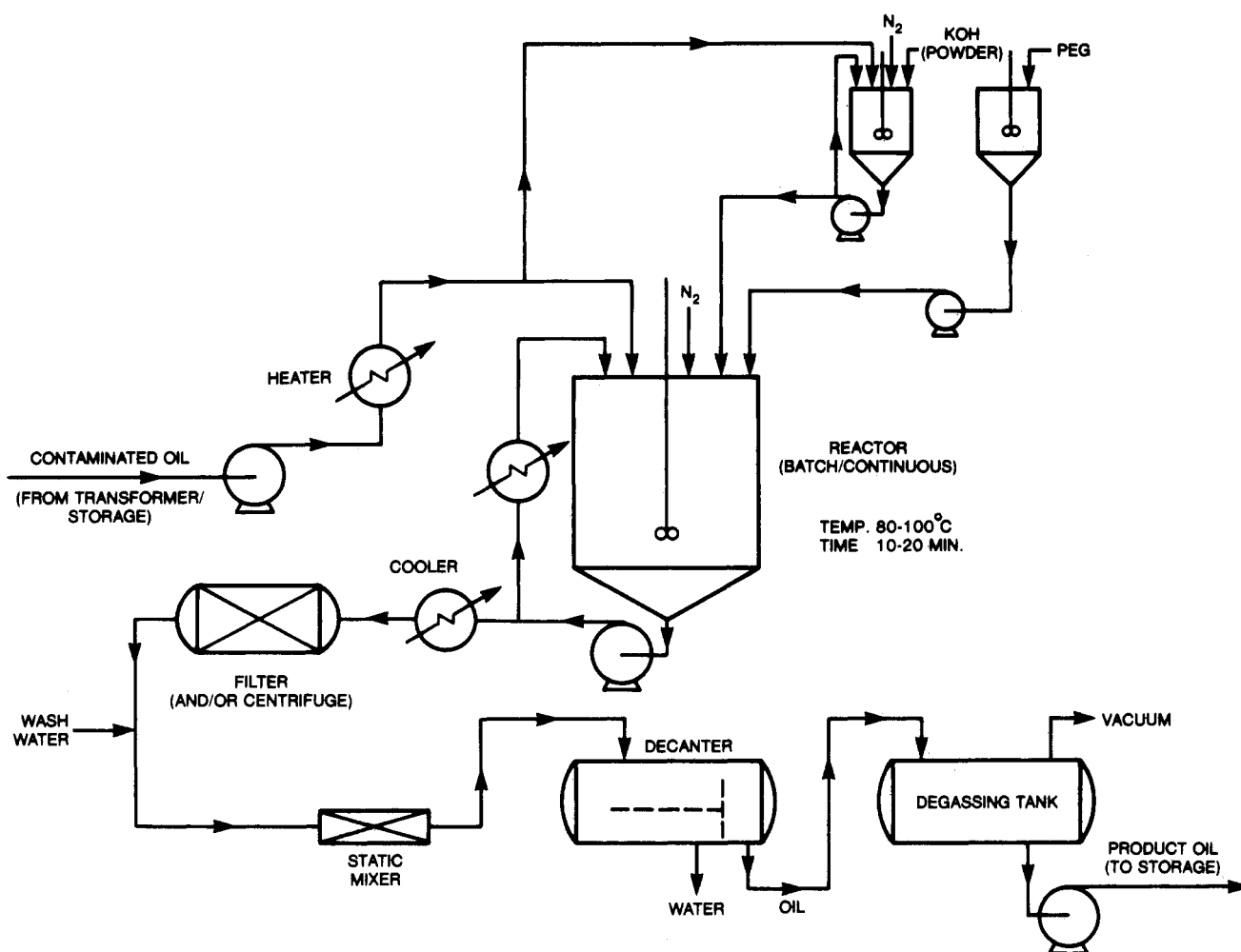


Figure 5. Proposed commercial PCB destruction process.

feed (contaminated transformer oil, PEGM 750, and KOH) and continuous withdrawal of the reaction mixture (as overflow from the reactor), after allowing a certain residence time in the CSTR. Figure 3 represents the experimental design of the continuous reaction system. The continuous reactor system was operated under the optimum conditions determined earlier during the batch experiments. At steady state, the PCB content of the recovered decontaminated oil was 10 ppm. An increase in residence time to 15 min, or an increase in the reaction temperature to 110 °C with a residence time of 10 min, gave completely decontaminated transformer oil (i.e., <1 ppm of PCB; see Table III).

After completion of the PCB destruction reaction, the oil was recovered from the reaction mixture by cooling the mixture, filtering through a bed of Fuller's earth, washing with water, decanting to remove water, and degassing and dehydrating under vacuum. The filtering, washing, and dehydration steps constitute standard treatment of used transformer oil before reuse. Recovered oil samples were tested for reusability by the Transformer Division of General Electric. All the physical, chemical, electrical, and aging properties were found to be adequate, indicating the treated oil to be suitable for reuse (35). Figure 4 shows VPC traces (capillary VPC and electron capture detection) of an oil sample contaminated with 1060 ppm of Aroclor 1260 before and after treatment with PEGM/KOH under optimum experimental conditions.

On the basis of the results obtained from the studies described above, commercial operation was envisaged. The process flow diagram for a commercial operation is pres-

ented in Figure 5. The contaminated oil from storage facilities (or directly from the transformer) is pumped through a heat exchanger to the reactor. The required amounts of molten PEG and ground KOH are also fed into the reactor. The reactor is insulated, which has a circulation loop through a heat exchanger to maintain the temperature of the reactor contents. The reactor could be run in either a continuous or a batch mode. After allowing a certain residence time (or batch reaction time), the reaction mixture is pumped through a heat exchanger to cool the reaction mixture, precipitating the byproducts for filtration. The cooled reaction mixture then passes through a filter bed (and/or a solid/liquid centrifuge) to remove the solids. The recovered oil is washed with water, the water is removed by decantation, and the oil is dehydrated under vacuum. The clean oil is then pumped back into the transformer or storage facility.

The operation as described above is safe and simple, requiring no special controls or precautions. Hence, no major engineering hurdles are envisaged in scale-up or commercialization. One possible concern could be handling of the sludge during operation (e.g., fouling of equipment, sludge filtration or disposal, etc.). However, proper choice of processing equipment should circumvent these problems. A means of safe disposal of the byproduct/glycol phase consistent with regulatory guidelines must also be established. The experience of current decontamination operators (e.g., SunOhio) suggests that operation under regulatory guidelines can be readily accomplished.

A preliminary economic evaluation of the PEG/KOH process was also completed. While a stationary unit would

be more economical, logistics favor a mobile unit. The maximum feasible reactor size on a mobile unit will be about 300 gal. Enough engineering data were collected in the 1-gal laboratory reactor system to scale-up directly to the 300-gal size. Operating costs were calculated by assuming continuous operation of a 300-gal reactor at 900 gal throughput/h over a 7-h day, for 200 days/year, thus decontaminating 1.26 million gallons of oil/year. The economics of the mobile unit indicate the process to be extremely attractive. The chemical reagents PEG and KOH are commonly used and fairly inexpensive (PEG, \$0.60–0.90/lb; KOH, \$0.34/lb) and are used in small quantities. The cost of oil decontamination was estimated to be well below any available alternative disposal costs (e.g., incineration or landfill) and also well below the cost of fresh transformer oil.

Summary

We have developed a safe, simple, inexpensive, and efficient method for destruction and removal of PCBs in transformer oil. Our initial discovery that PCBs will readily react with PEG and KOH under mild conditions has been optimized and engineered into a feasible process. The reaction products have been identified as aryl polyglycols and polychlorobiphenyl alcohols, formed by nucleophilic aromatic substitution. Acute toxicity testing shows no biological activity, other than as a mild eye irritant.

The engineering feasibility of the process has been amply demonstrated. Numerous batch reactions have been carried out in a 1-gal reactor, for optimization of the process conditions. A continuous process has been demonstrated. Samples of the decontaminated oil have been tested for electrical, physical, chemical, and aging properties, and the oil has been deemed suitable for reuse.

Acknowledgments

We thank James C. Carnahan, Robert E. Wagner, and Joanne F. Smith for PCB analyses in oil samples. We also thank Ralph J. May and Woodfin V. Ligon, Jr., for providing GC/MS analyses and Wayne F. Morgan for technical assistance. We acknowledge International Research and Development Corp., Mattawan, MI, for toxicity data.

Registry No. KOH, 1310-58-3; PEG (SRU), 25322-68-3; PEGM (SRU), 9004-74-4; Aroclor 1260, 11096-82-5.

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Received for review September 24, 1984. Accepted February 11, 1985.