

Residual Petroleum in Sediments Reduces the Bioavailability and Rate of Reductive Dechlorination of Aroclor 1242

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Residual petroleum hydrocarbons and polychlorinated biphenyls (PCBs) are frequently found together at contamination sites. Intrinsic reductive dechlorination of PCBs at these sites is highly variable. Sediments of Silver Lake (MA), which contain ~6.2% petroleum hydrocarbons, did not support PCB dechlorination in laboratory assays. Removal of petroleum components from Silver Lake sediments by solvent extraction did not alter their inability to support dechlorination. When other sediments known to support PCB dechlorination were inoculated with PCB-dechlorinating organisms and amended with incremental increases of pure petroleum hydrocarbons (0–4 wt %/wt) or 6.2% petroleum hydrocarbons extracted from Silver Lake sediments, a reduction in both the rate and extent of PCB dechlorination occurred. The maximal rate of dechlorination observed in these assays appears to depend singularly on the aqueous-phase PCB concentrations. A single-regression equation relating maximal PCB dechlorination rates to the PCB concentrations in water was developed that accurately described the data presented here and in two previous studies ($R^2 = 0.960$). Petroleum components in sediments appear to provide a sorptive phase that lowers the solution concentrations of PCBs, thus diminishing the bioavailability of PCBs and rate of dechlorination.

Introduction

Because of their widespread use in industrial applications residual petroleum products are often found at sites contaminated with polychlorinated biphenyls (PCBs) (1). Intrinsic reductive dechlorination of PCBs at these sites is often limited or nonexistent. Both commercial PCBs and petroleum exist in the environment as complex mixtures of structurally related compounds. The compounds comprising these mixtures typically have low water solubilities and high sorption coefficients. At relatively low concentrations in the environment (sub ppm), the constituents of these mixtures partition into soil and sediment organic matter where they become immobilized (2). At higher concentrations, both petroleum hydrocarbon mixtures and commercial PCB mixtures may form separate stable nonaqueous phases in soils and sediments (3). These phases may substantially alter the sediment– or soil–water distribution of nonionic organic

contaminants (NOCs), including individual PCB congeners (4, 5).

Although PCBs are generally considered recalcitrant in the environment, they are subject to reductive dechlorination (1). The process of PCB reductive dechlorination replaces chlorines on the biphenyl ring with hydrogen, reducing the average number of chlorines per biphenyl in the resulting product mixture. This reduction is important because the less chlorinated products are less toxic (6, 7), have lower bioaccumulation factors, and are more susceptible to aerobic metabolism, including ring opening and mineralization (8, 9). Although the intrinsic anaerobic reductive dechlorination of PCBs is well documented, the extent and rate of dechlorination varies considerably among sites (1).

It has been suggested that the presence of petroleum hydrocarbons may prevent or limit the process of anaerobic reductive dechlorination of PCBs (1, 10, 11). Physiological and physiochemical factors have been implicated. Light aliphatic hydrocarbons (C_3 – C_8) have a higher water solubilities than higher molecular weight aliphatic hydrocarbons, and this may increase their bioavailability and hence toxicity to bacteria. Light aliphatic hydrocarbons appear to solvate cellular lipids and membranes, altering their permeability or destroying cellular integrity (12). Other contaminants, such as methylated mercury, partition into the hydrocarbon mixture and may be inhibitory or toxic to bacteria which are capable of dechlorinating PCBs (13). Petroleum hydrocarbon co-contaminants provide a major source of carbon that may promote the formation of anaerobic conditions but also result in increased numbers of less diverse microorganisms (14, 15). Under otherwise nonlimiting conditions, these co-contaminants provide a selective advantage to hydrocarbon-utilizing bacteria. The resulting population shift produces a less diverse bacterial community that is less likely to possess the ability to reductively dechlorinate PCBs.

The presence of a residual hydrocarbon phase in soils or sediment has been shown to increase the soil– or sediment–water distribution coefficients of poorly water-soluble organic contaminants (4, 5). Such petroleum-hydrocarbon-based phases have been shown to function as effective partition media for PCB congeners (16). In general, sorption of contaminants by soils and sediments reduces their bioavailability to microorganisms (17–19). In this fashion, the presence of an additional partition phase (e.g., a residual petroleum hydrocarbon phase) may reduce bioavailability, thereby limiting the rate and/or extent of PCB dechlorination.

The objective of this study was to determine whether and to what extent petroleum hydrocarbons inhibit the reductive dechlorination of PCBs in anaerobic sediment slurries. PCB dechlorination was evaluated utilizing non-PCB-contaminated sediments amended with a combination of petroleum hydrocarbons and PCBs as well as sediments from an environmental site (Silver Lake, MA) contaminated with these constituents.

Materials and Methods

PCB-contaminated sediments from Silver Lake (SL) were utilized to evaluate the possible inhibitory effects of residual petroleum hydrocarbons on PCB dechlorination. Petroleum hydrocarbons were removed from the SL sediment by solvent extraction, and the ability of the extracted sediments to support anaerobic reductive dechlorination was evaluated. Also, to establish the effect of solvent extraction itself on the ability of sediments to support dechlorination, Red Cedar (RC) River (Lansing, MI) sediments, which are known to

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support PCB dechlorination, were compared before and after solvent extraction. Samples (20 g) of air-dried SL sediments were extracted with 1,1,2-trichlorotrifluoroethane (CFC) in a Soxhlet apparatus for 12 h and then air-dried for 24 h. Residual CFC was then removed from the extracted petroleum fractions using a rotary evaporator at 27 °C. After the solvent was removed, the petroleum content of the sediment was determined gravimetrically.

Anaerobic reductive dechlorination of PCBs was evaluated utilizing 60-mL serum bottles that contained 10 g of sediment. The bottles were evacuated and refilled with N₂ in a glovebox lock, then flushed with N₂/CO₂ (80:20 vol/vol) using a Hungate apparatus. The bottles were first tested for their ability to maintain strict anaerobic conditions. For this test, inoculum was obtained by shake elution from PCB-contaminated Hudson River (HR) sediments as previously described (20). A 10-mL portion of the HR inoculum was amended with 10 µL of ethanol and added to each bottle. The bottles were sealed with butyl stoppers and aluminum crimp caps and incubated in the dark at 37 °C for 10 days. Headspace gas was then analyzed for methane, and bottles that contained methane (indicating strict anaerobic conditions) were autoclaved for 90 min on two consecutive days. Methane production was determined by gas chromatography utilizing a thermal conductivity detector.

Twenty-four hours after autoclaving, the bottles were amended with 10 mL of inoculum eluted from PCB-contaminated HR sediments and 10 mL of sterile reduced anaerobic minimal media (RAMM) (21). Using sterile anaerobic technique, the butyl stoppers were subsequently removed from the bottles, which were then flushed with filter-sterilized N₂/CO₂ (80:20 vol/vol) and amended with 80 µL of an acetone solution containing 2',3,4-trichlorobiphenyl (2',3,4-CB) to a final PCB concentration of 250 mg kg⁻¹ sediment. Teflon-lined stoppers (The West Company, Phoenixville, PA) and aluminum crimp caps (Wheaton, Millville, NJ) were used to reseal the experimental vessels. The biological controls (negative controls) were autoclaved for 90 min on two successive days prior to adding 2',3,4-CB. All the samples were then shaken by hand for 1 min and then incubated statically in the dark at 25 °C. Sampling for PCB dechlorination activity and methane production took place at 6-week intervals. Prior to sampling, headspace gas (2 mL) was removed via a syringe through the Teflon-lined butyl stopper and analyzed for methane. Each bottle was then opened and, while being flushed with filter-sterilized N₂/CO₂ (80:20 vol/vol), a 2-mL slurry subsample was removed using a sterile disposable 5-mL pipet tip with the bottom 1.5 mm removed to increase the bore diameter. Each bottle was then resealed with a new Teflon-lined stopper and aluminum crimp cap. Dechlorination activity was determined by extraction and analysis of the sediment slurry sample as described previously (20).

The effect of the petroleum components extracted from SL sediments on PCB dechlorination in sediments known to support PCB dechlorination was also evaluated. Extracts were obtained from the SL sediments by Soxhlet extraction as already described. Acetone was added to the extracts (4:1 vol/vol) and the whole was then added to air-dried non-PCB-contaminated HR sediment. The SL petroleum extract was added at a concentration of 6.2% (wt/wt), the approximate petroleum content found in SL sediment. Acetone was then removed by rotary evaporation at 27 °C; this process also served to homogenize the samples. The sediments were then inoculated and incubated as already described except that the slurries contained 2 g of sediment in 28-mL Balch tubes (Bellco Glass Inc., Vineland, NJ); volumes of inoculum and RAMM were reduced 10-fold (20). Sediment slurries were spiked with 5 µL of an acetone solution containing Aroclor 1242 to a final sediment concentration of 250 mg kg⁻¹.

TABLE 1. Dechlorination of 2',3,4-Trichlorobiphenyl in Sediment Slurries^a

treatment	incubation time (weeks)		
	0	6	12
Silver Lake			
not extracted	2.12 ± 0.01	2.07 ± 0.05	2.14 ± 0.09
CFC extracted	2.04 ± 0.05	1.92 ± 0.03	2.04 ± 0.08
autoclaved	2.10 ± 0.02	2.11 ± 0.01	2.12 ± 0.06
Red Cedar Sed.			
not extracted	2.00 ± 0.00	1.35 ± 1.10	1.10 ± 0.04
CFC extracted	2.00 ± 0.06	1.62 ± 0.05	1.34 ± 0.52
autoclaved	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00

^a Data are reported as the average number of *meta* plus *para* chlorines per biphenyl after 0, 6, and 12 weeks of incubation (mean of triplicate samples ± standard deviation).

Treatments included HR sediment amended with SL petroleum extract, unamended HR sediment, and autoclaved HR sediments. Sampling for PCB dechlorination activity and methane production took place at 4-week intervals. The entire contents of tubes were extracted and analyzed as previously described (20).

The petroleum extract of SL sediments may contain other nonpolar compounds that may be toxic or inhibitory to the PCB-dechlorinating microorganisms. To remove this potential complication, PCB dechlorination was evaluated utilizing HR sediments known to support PCB dechlorination amended with pure petroleum hydrocarbons. Vacuum pump oil, comprised primarily of aliphatic hydrocarbons, was used because it is relatively nontoxic, low in sulfur (the presence of sulfur may stimulate sulfur reducers), and does not contain any additives such as detergents, antimicrobial, or corrosion inhibitors that could influence the experimental results. Various amounts of vacuum pump oil dissolved in acetone were added to HR sediments. Once added, the oil-acetone-sediment mixture was homogenized and acetone was removed via rotary evaporator as already described. The total amount of acetone used for each treatment was determined by a 4:1 (vol/vol) acetone:oil ratio for the assay treatment receiving the highest concentration of oil (4%). All assays were set up and sampled in the same manner as already described except that 1 g of HR sediment was added to each tube (instead of 2 g) and the sediments were amended with various amounts of vacuum pump oil (0, 0.25, 1, and 4%, wt/wt) instead of SL CFC extract. Autoclaved sediment slurries served as negative controls, and unamended sediment slurries served as a positive control. A treatment of acetone addition (0% oil), homogenization, and evaporation was used to test the effects of the oil addition process itself. The entire contents of the tubes were extracted and analyzed as described previously (20).

Results

The removal of the petroleum components from the SL sediment did not enable these sediments to support the reductive dechlorination of 2',3,4-CB when inoculated with known PCB-dechlorinating organisms from the HR. This result is indicated by the fact that for added 2',3,4-CB the average number of *meta* plus *para* chlorines per biphenyl did not decrease significantly from 2 during 12 weeks of incubation in either the nonextracted sediment or the same sediment extracted with CFC to remove the petroleum constituents (Table 1). Significant dechlorination of 2',3,4-CB did occur in (nonextracted) RC sediments; the average number of *meta* plus *para* chlorines declined from 2 to 1.1 (Table 1). This decline established the ability of the inoculum to dechlorinate PCBs. Red Cedar River sediment extracted with CFC also supported similar dechlorination rates, but

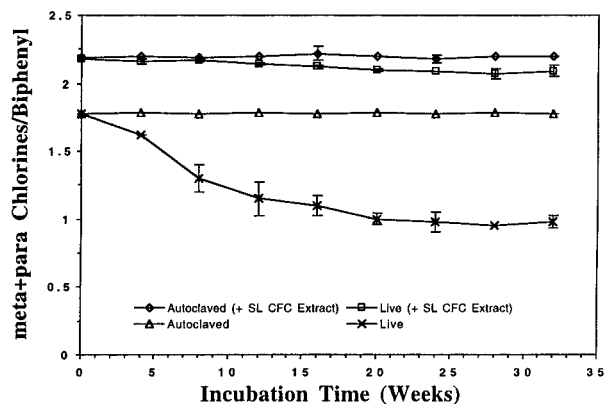


FIGURE 1. Dechlorination of Aroclor 1242 by Hudson River (HR) microorganisms added to sterile anaerobic slurries of upstream (clean) HR sediment amended with 6.2% (wt/wt) Silver Lake (SL) petroleum components obtained by extraction with 1,1,2-trichlorotrifluoroethane (CFC). The higher initial level of *meta plus para* chlorines in the assays amended with SL petroleum extract was the result of coextracted PCB congeners ($\sim 75 \text{ mg kg}^{-1}$ partially dechlorinated Aroclor 1254, see ref 1) from SL sediments. Data plotted are the mean of triplicate samples \pm standard error.

the extent of dechlorination was diminished somewhat as compared with nonextracted sediments. In the CFC-extracted RC sediment the average number of chlorines decreased from 2 to 1.34 *meta plus para* chlorines.

Regardless of the presence or absence of PCB dechlorination activity, methane was detected in the headspace of all nonautoclaved treatments, indicating the activity of methanogens (data not shown). Methane production was highest in the unextracted SL and RC sediments (25 to 30% in headspace, vol/vol). Methanogenic activity was detected in both the CFC-extracted SL and RC sediments but was significantly less than in their unextracted counterparts (5 to 7% in headspace, vol/vol).

Hudson River sediments known to support PCB dechlorination were amended with petroleum components obtained from SL sediments. The effect of the extracted petroleum components on the ability of HR sediments to support PCB dechlorination activity when inoculated with PCB-dechlorinating bacteria eluted from the HR was evaluated (Figure 1). The addition of SL petroleum components at 6.2% acutely inhibited dechlorination of Aroclor 1242, resulting in an overall removal of 0.12 *meta plus para* chlorines/biphenyl as compared with 0.93 *meta plus para* chlorines/biphenyl in the unamended sediment slurries. The addition and removal of acetone alone (used as a carrier for the SL petroleum components in the amended sediment) had no effect on dechlorination (data not shown). Methanogenic activity was detected in all nonautoclaved assays (data not shown).

The effect of pure petroleum hydrocarbons on PCB dechlorination was determined by adding various amounts of vacuum pump oil to HR sediments known to support PCB dechlorination. Diminution in the dechlorination of Aroclor 1242 was dependent on the amount of oil added (Figure 2). The effect was greatest for the highest amount of oil addition (4%) and was still observed, albeit to a lesser extent, at an oil content of 0.25%. The addition of oil at 4% decreased the maximal rate as well as the extent of dechlorination observed by about half. Exposure of HR sediment to acetone in the absence of oil amendments, as well as the homogenization process, had no effect on dechlorination rates or extents.

Discussion

As a result of local industrial activity, SL sediments are contaminated with PCBs (10 to 1200 mg kg^{-1} sediment, PCBs

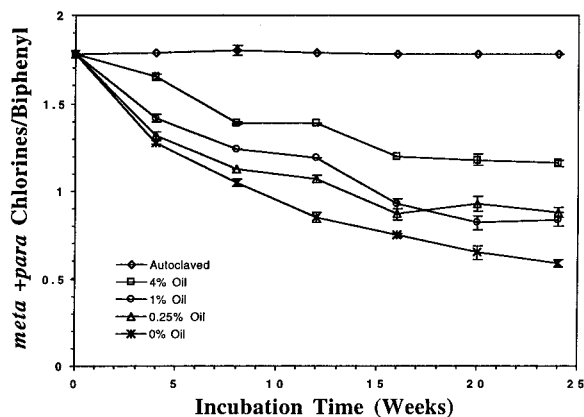


FIGURE 2. Dechlorination of Aroclor 1242 by Hudson River (HR) microorganisms added to sterile slurries of upstream (clean) HR sediments amended with vacuum oil at levels between 0.25 and 4.0% (wt/wt). Data plotted are the mean of triplicate samples \pm standard error.

primarily Aroclor 1254), petroleum hydrocarbons ($\sim 6.2 \text{ wt \%}$), and metals (Cr ~ 550 , Cu ~ 2700 , Ni ~ 300 , Pb ~ 1500 , and Zn $\sim 3800 \text{ mg kg}^{-1}$ sediment; 22). The SL sediments do not support PCB dechlorination in laboratory assays where PCBs and known PCB-dechlorinating organisms are added, despite some historical evidence of minimal *in situ* dechlorination (J). Possible reasons for the lack of dechlorination in SL sediment slurries are the presence of toxic co-contaminants (e.g., metals, petroleum products) or reduced bioavailability due to sequestration of PCBs by residual petroleum phases. Our experiments were designed to elucidate the effects of petroleum components on the dechlorination of PCBs in SL sediments.

Simple removal of petroleum hydrocarbons and associated co-contaminants by solvent (CFC) extraction did not alter the inability of SL sediments to support PCB dechlorination. This result may be due to the elevated concentrations of toxic metals present in these sediments that would not be removed by (CFC) extraction. When noncontaminated RC sediments known to support dechlorination of PCBs were extracted in the same fashion, PCB dechlorination was inhibited, but only slightly compared with nonextracted RC sediments (Table 1). Thus, in the case of CFC-extracted SL sediments, the total lack of PCB dechlorination was not due solely to CFC exposure.

The addition of petroleum components to sediments known to support dechlorination activity resulted in the inhibition of PCB dechlorination. This result was demonstrated in two separate experiments. First, the rates and extents of Aroclor 1242 dechlorination were diminished in RC sediments amended with vacuum pump oil, the effects being greatest at higher rates of addition. Likewise, amending HR sediments with petroleum components extracted from SL sediments (6.2% vol/vol) caused a large decrease in PCB dechlorination activity.

Careful examination of the results presented herein and results from two previous laboratory studies (23, 24) reveal that PCB dechlorination rates in sediment slurries can be related to several factors. In these studies, the solution concentrations of PCBs were altered either by addition of PCBs to the system or by the presence of an anthropogenic sorptive phase (i.e., petroleum) in addition to natural sediment organic matter. Analysis of these results suggests the rates of dechlorination of PCBs may depend in large part on the availability of PCBs to PCB-dechlorinating microorganisms. Several previous studies have indicated that in soil–or sediment–water systems only compounds in the aqueous phase are available to microorganisms (17–19).

TABLE 2. Natural Sediment Organic Carbon Contents, Residual Petroleum Contents, PCB Contents and Partition Coefficients Used to Estimate Aqueous-Phase PCB Concentrations in Experimental Systems

aroclor	PCB content (mg kg ⁻¹)	organic carbon (%)	petroleum fraction (%)	log <i>K</i> _{oc}	log <i>K</i> _{ow}	source
1242	500	3.7	0	5.0 ^a	5.2 ^c	this work
1242	500	3.7	0.25	5.0 ^a	5.2 ^c	this work
1242	500	3.7	1.0	5.0 ^a	5.2 ^c	this work
1242	500	3.7	4.0	5.0 ^a	5.2 ^c	this work
1242/1248/1260	20–3000	3.7	0.0626	5.4 ^{a,b}	6.0 ^{b,c}	Abramowicz et al. (23)
1242	20–800	5.14	0	5.0 ^a	5.2 ^c	Rhee et al. (24)

^a Reference 29. ^b Adjusted for PCB mixture of Aroclor 1242, 1248, and 1260 (7:2:1). ^c Reference 30.

Two processes can alter the aqueous-phase PCB concentrations in sediment–water systems. First, aqueous-phase concentrations of PCBs can be increased in a predictable manner by adding PCBs to the system. The sorbed and aqueous-phase PCB concentrations are defined by the linear partition coefficient (*K*), which can be accurately predicted from the organic-carbon-normalized sorption coefficient, *K*_{oc}, and the fractional sediment organic carbon content (*f*_{oc}) using the following equation:

$$K = K_{oc}f_{oc} \quad (1)$$

The *K*_{oc} values of nonionic organic compounds are known to be relatively invariant among sediment organic matters (25). Second, the presence of anthropogenic organic phases in soils or sediments, in addition to natural organic matter, can also alter the solution concentrations of PCBs. Boyd and Sun (4) demonstrated that residual petroleum hydrocarbon phases in soils and sediments act as partition phases for organic solutes, and that these phases are ~10 times more effective on a unit weight basis than natural organic matter. They found that the linear sorption coefficients for compounds such as pentachlorophenol, toluene, and 2-chlorobiphenyl could be accurately estimated for systems containing both natural organic matter and residual petroleum hydrocarbons utilizing the following equation:

$$K = f_{oc}K_{oc} + f_{oil}K_{oil} \quad (2)$$

where *f*_{oil} is the fractional oil content of the sediment and *K*_{oil} is the oil–water partition coefficient of the solute. Boyd and Sun (4) also found that readily available octanol–water partition coefficients (*K*_{ow}) could be used as an approximation for *K*_{oil} such that

$$K \cong f_{oc}K_{oc} + f_{oil}K_{ow} \quad (3)$$

Previous studies suggest a relationship between aqueous-phase PCB concentrations and dechlorination. The first laboratory study documenting anaerobic microbial PCB dechlorination indicated that the rate and extent of dechlorination was directly dependent on the total PCB concentration (26). Recently, Sokol et al. (27) found that a threshold PCB concentration between 35 and 45 ppm was required for dechlorination. Above that threshold, the rate of dechlorination of Aroclor 1248 was linearly dependent on its total concentration. A survey showed that 93% of environmental sediment samples with PCB concentrations of 100 mg kg⁻¹ or greater were extensively dechlorinated, whereas <63% of samples containing PCB concentrations of 5 to 10 mg kg⁻¹ had undergone similar transformation (28). One possible explanation for the concentration effect is that higher overall PCB concentrations will manifest higher solution PCB concentrations, and it is this latter pool that is available for dechlorination. Reexamination of the studies done by Rhee et al. (24) and Abramowitz et al. (23) also support the relationship between solution concentration and dechlori-

nation rate. In these studies, solution concentrations of PCBs were manipulated by addition of PCBs to the system. Because isotherms describing the sorption of PCBs to soils and sediments are characteristically linear, incremental additions of PCBs to a sediment water system manifest linear increases in both the sorbed and solution phase concentrations as defined by the linear sorption coefficient. The studies of Sokol et al. (27), Rhee et al. (24), and Abramowicz et al. (23) show that increasing the concentrations of total PCBs added to laboratory assays increased the maximal dechlorination rates. In these experiments, the dechlorination rates were a linear function of total PCB concentrations in sediment between a minimum of ~20 to 40 mg kg⁻¹ and a maximum of 800 mg kg⁻¹. Incremental additions of petroleum hydrocarbons to sediment, as described herein, would also result in incremental increases in *K* (eq 2) and concomitant decreases in the PCB solution concentrations, accompanied by an incremental decrease in PCB dechlorination rates.

To analyze the relation between aqueous-phase PCB concentration and rates of PCB dechlorination quantitatively, data from the study described here, where pure petroleum was added to sediments, was pooled with data from the studies of Abramowicz et al. and Rhee et al. (1, 23, 24). Using the partitioning eqs 1 and 3, we estimated the solution concentrations of PCBs in the various experimental systems based on knowledge of *f*_{oc}, *f*_{oil}, *K*_{oc}, and *K*_{ow} (Table 2).

A plot of the estimated solution PCB concentrations versus the maximal dechlorination rates resulted in linear relationships for all three sets of data (Figure 3). Correlation coefficients for the regression lines were 0.996, 0.994, and 0.993 for data from Rhee et al. (24), Abramowicz et al. (23), and the current study, respectively. Multiple linear regression comparisons indicated that slopes of the regression lines for the data of Rhee et al. (24) and Abramowicz et al. (23) were not significantly different (*p* ≤ 0.05) from the oil addition experiment (data presented herein). This result indicates a high probability of similar cause and effect; namely, that aqueous-phase PCB concentration controls bioavailability and hence dechlorination rates. Because the individual regression lines are not statistically different, a single-regression analysis of all the data from the current study and the two previous studies (23, 24) was performed yielding the following equation:

$$MDR = 1.16C_e + 6.37 \quad (4)$$

where MDR is the maximal PCB dechlorination rate (ng-atoms Cl⁻ g sediment⁻¹ week⁻¹) and *C*_e is the estimated aqueous PCB concentration (μg L⁻¹). The *R*² value for this regression equation was 0.960.

The correlation between the maximum rate of PCB dechlorination and aqueous PCB concentration may be a useful tool for estimating PCB biodegradation rates in sediments, including those contaminated with petroleum. For the three independent studies examined, the consistent

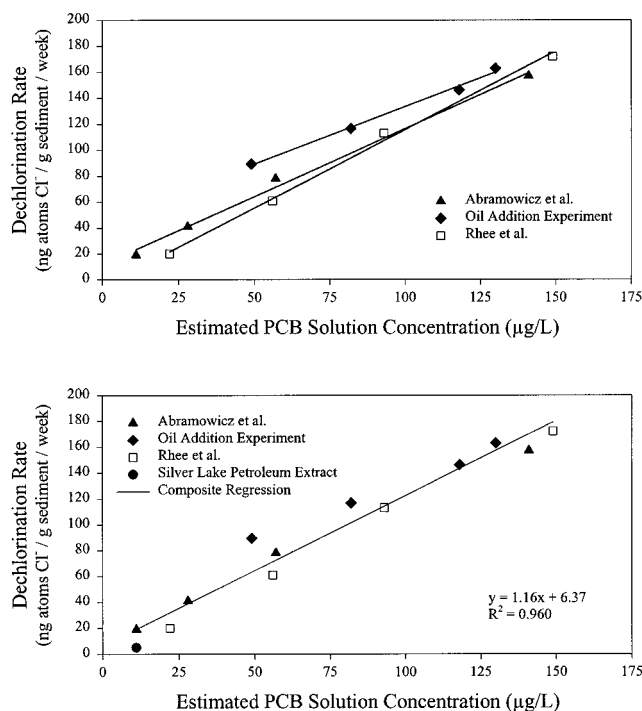


FIGURE 3. Maximum dechlorination rate versus estimated solution concentrations of PCBs plotted for three separate experiments. (A) Multiple linear regression analysis indicates that the data for the oil addition experiment (presented here) is not significantly different ($p \pm 0.05$) from either the Abramowicz et al. (23) or the Rhee et al. (24) experiments. (B) All data in (A) plus the single point generated from the addition of Silver Lake (SL) petroleum extract are included as a single-regression analysis ($R^2 = 0.960$).

ratio of maximal dechlorination rate to aqueous PCB concentrations (i.e. slopes of regression lines) suggests a common mechanism. The diversity of the experiments examined, including use of sediments from different locations with and without anthropogenic bulk petroleum hydrocarbon phases, suggests this predictive relationship may be valid over an extended range of conditions. In these studies, natural organic carbon contents ranged from 3.7% in clean HR sediments to 5.14% in SL sediments. Petroleum hydrocarbon co-contaminants ranged in both residence times (10 days to >20 years) and hydrocarbon contents (0 to 6.2%), and consisted of a residual waste oil mixture as well as a pure petroleum hydrocarbon oil. In addition, these studies utilized total PCB concentrations ranging from 20 to >800 mg kg⁻¹ as well as aqueous-phase PCB concentrations ranging over >1 order of magnitude. However, it is premature to broadly extrapolate these relationships to other sites. In each of the cases studied, the origin of the dechlorinating microbes was similar (eluted from PCB-contaminated HR sediments) and the PCB congener mixture was primarily Aroclor 1242. Other commercial PCB mixtures (e.g., Aroclor 1254 and 1260) and perhaps other PCB-dechlorinating populations may manifest different relationships between dechlorination rates and aqueous PCB concentrations. However, because there are only a few commonly encountered PCB mixtures and PCB dechlorination processes (1), a set of predictive equations for the important combinations, including sediments with petroleum present as a co-contaminant, seems attainable.

Acknowledgments

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