BIOACCUMULATION OF ALKYLLEAD COMPOUNDS FROM WATER AND FROM CONTAMINATED SEDIMENTS FROM MUSSELS

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ABSTRACT

Bioaccumulation of alkyllead compounds from water and from contaminated sediments by mussels

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Chemicals in the environment may be accumulated by living organisms to a very high level. The measurement of bioaccumulation can often be used to assess the potential impact of a chemical on the food chain. Since sediment is the ultimate storage sink for pollutants, the availability of these compounds could pose a severe threat to the ecosystem.

Studies on bioavailability have been mostly conducted in water systems without much regard to the underlying sediment. The interactions between water and sediment and the ecological effects of in situ sediment contaminants have been topics of current concern. Alkyllead compounds have been found in sediment, fish and other biota near the lead alkyls production plants in Ontario. While the toxicity and health effects of these compounds to human are not known, their pathways and availability from contaminated sediment in the aquatic system must be investigated. The present study describes the results of laboratory investigations of the bioaccumulation of trialkyllead, dialkyllead and Pb(II) compounds in different organs of freshwater mussels from direct exposure to spiked lake water, and to two contaminated sediments.

Alkyllead compounds are accumulated by mussels. A much higher concentration of trimethyllead is accumulated than triethyllead for the same period of exposure. The highest concentration of trimethyllead is found in the muscle, gills and visceral tissue. There is evidence for the in vivo transformation of the trialkyllead species to dialkyllead and Pb(II) in the muscle tissue by a series of dealkylation reactions. The rates of accumulation are related to the concentrations of alkyllead compounds in water and sediment.

RÉSUMÉ

Bioaccumulation par les moules des composés alkylplomb présents dans l'eau et les sédiments contaminés

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Les organismes vivants peuvent accumuler de grandes concentrations de produits chimiques présents dans le milieu. La mesure de la bioaccumulation peut parfois servir à évaluer l'impact d'un produit chimique sur la chaîne alimentaire. Étant donné que les sédiments constituent le lieu final de stockage de ces polluants, leur présence peut constituer une sérieuse menace pour l'écosystème.

On a effectué la plupart des études de biodisponibilité dans des cours d'eau sans attacher beaucoup d'importance aux sédiments qu'ils renferment. Les interactions entre l'eau et les sédiments ainsi que les effets écologiques des contaminants présents dans les sédiments sont des sujets d'intérêt actuel. On a trouvé des composés alkylplomb dans les sédiments, les poissons et d'autres organismes près d'usines qui produisent des composés alkylplomb en Ontario. La toxicité et les

effets de ces composés sur la santé des humains ne sont pas connus mais leur métabolisme et leur biodisponibilité pour les humains à partir des sédiments contaminés doit faire l'objet de recherches. La présente étude rapporte les résultats de recherches de laboratoire sur la bioaccumulation des composés trialkylplomb, dialkylplomb et de Pb(II) dans les différents organes de la moule d'eau douce exposée directement à des échantillons d'eau de lac dopés et à deux échantillons de sédiments contaminés.

Les moules accumulent les composés alkylplomb. Au cour d'une même période d'exposition, elles accumulent beaucoup plus de composés triméthylplomb que de composés triéthylplomb. La concentration la plus élevée de triméthylplomb se retrouve dans le muscle, les branchies et les viscères. Des résultats indiquent que le muscle pourrait transformer <u>in vivo</u> les composés trialkylplomb en composés dialkylplomb et en Pb(II) grâce à une série de réactions de désalkylation. Le taux d'accumulation est corrélé à la concentration des composés alkylplomb dans l'eau et les sédiments.

EXECUTIVE SUMMARY

Bioaccumulation of Alkyllead Compounds from Water and from Contaminated Sediment by Mussels

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Chemicals in the environment may be accumulated by living organisms to a very high level. The study of bioaccumulation is often useful for the assessment of the potential impact of a chemical on the food chain.

The occurrence of alkyllead compounds in fish and other aquatic biota near the lead alkyl production plants (DuPont at St. Lawrence River and Ethyl Corp. at St. Clair River) was first reported by us. Although the production of lead alkyls has been substantially reduced, the contaminated sediment can still pose a serious threat to aquatic organisms. The present study describes and compares results of laboratory investigations on the bioaccumulation of trialkyllead, dialkyllead and Pb(II) compounds by mussels from direct exposure to solutions and to contaminated sediment.

In the exposure experiments with trimethyllead solution (1 mg/L), the highest concentration was found in the muscle tissue (19.7 ug/g), followed by gills (10.5 ug/g), viscera mass (6 ug/g) and mantle (5.9 ug/g) in a 17-day exposure. Accumulation of triethyllead followed a similar pattern but lower in concentration. Results from laboratory experiments with contaminated sediments agree well with the findings of exposure in alkyllead solutions except the rates are different. In the course of a 52-day sediment exposure experiment, the bioaccumulation rates for triethyllead, diethyllead and Pb(II) from a St. Clair River sediment were 1.96, 0.26 and 2.59 ng/g/day respectively. Evidence was first established in this study for the <u>in vivo</u> transformation of trialkyllead to dialkyllead and to Pb(II) in aquatic organisms.

<u>Management's Implications</u>

The information in this paper will be useful for management for setting up guidelines and regislation for alkyllead compounds. The Food Research Division of National Health and Welfare (Dr. D. Forsyth) is at present working on the occurrence of alkyllead compounds in seafood.

RÉSUMÉ A L'INTENTION DE L'EXÉCUTIF

Bioaccumulation par les moules des composés alkylplomb présents dans l'eau et les sédiments contaminés

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Les organismes vivants peuvent accumuler de grandes concentrations de produits chimiques présents dans le milieu. L'étude de la bioaccumulation est souvent utile pour évaluer l'impact que peut avoir un produit chimique sur la chaîne alimentaire.

Notre équipe a été la première à signaler la présence de composés alkylplomb dans les poissons et d'autres organismes aquatiques près d'usines qui produisent des composés alkylplomb (DuPont sur le fleuve Saint-Laurent et Ethyl Corp. sur la rivière Sainte-Claire). Même si la production des composés alkylplomb a été réduite de façon significative, les sédiments contaminés peuvent encore menacer sérieusement la vie aquatique. La présente étude décrit et compare les résultats des recherches de laboratoire sur la bioaccumulation des composés trialkylplomb, dialkylplomb et Pb(II) par les moules exposées directement à des solutions et à des sédiments contaminés.

Dans les expériences sur l'exposition à une solution de triméthylplomb (1mg/L) qui a duré 17 jours, la concentration la plus élevée a été retrouvée dans le muscle (19,7 ug/g), suivie des branchies (10,5 ug/L), des viscères (6 ug/g) et du manteau (5,9 ug/g). Le profil d'accumulation du triéthylplomb était similaire mais les concentrations étaient plus faibles. Les résultats des expériences de laboratoire sur des sédiments contaminés concordent avec les résultats de l'exposition à des solutions d'alkylplomb sauf que les taux d'accumulation sont différents. Dans une expérience d'exposition à des sédiments contaminés qui a duré 52 jours, les taux de bioaccumulation du triéthylplomb, du diéthylplomb et du Pb(II) présents dans des sédiments de la rivière Sainte-Claire étaient respectivement de 1,96, 0,26 et de 2,59 ng/g/jour. On présente dans cette étude la première évidence d'une transformation in vivo des composés trialkylplomb en composés dialkylplomb et en Pb(II) dans les organismes aquatiques.

Perpectives de gestion

Les résultats que renferme cet article seront utiles aux gestionnaires pour établir des lignes directrices et une législation sur les composés alkylplomb. La Division de la recherche sur les aliments du ministère de la Santé nationale et du Bien-être social (D. Forsyth) fait actuellement des recherches sur la présence des composés alkylplomb dans les fruits de mer.

Bioaccumulation of alkyllead compounds from water and from contaminated sediments by mussels

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Keywords: Bioaccumulation, alkyllead, sediment, mussels

INTRODUCTION

It is well known that chemicals in the environment may be accumulated in living organisms to a very high level. In aquatic systems, sediment is the ultimate storage sink for metallic and organic compounds. Current knowledge of point and diffuse sources to rivers and lakes has indicated that persistent organic compounds are present in surficial sediment layers in nearshore and depositional basins. Thus the bioavailability of these adsorbed compounds could pose a severe threat to the ecosystem.

Studies on bioaccumulation are mainly conducted in water and seldom with regard to the underlying sediment.[1] Recent studies of the bioavailability of pollutants from contaminated sediments and their impact have been the topic of an international conference.[2] Alkyllead compounds, notably tetraalkyllead (R=Me, Et), as a result of anthropogenic input, have been found in fish, sediment and other biota near alkyl lead production plants.[3,4] These compounds are either physically bound to sediment by adsorption or chemically bound by complexation processes. They can become available to biota through leaching or exchange. The lipophilic properties of tetraalkyllead compounds further enhance their partitioning into lipid-containing

organisms. The present study was conducted with two objectives: first, to investigate the direct bioconcentration of different alkyllead compounds from water and from contaminated sediment by freshwater mussels, and secondly, to investigate the possibility of *in vivo* transformation of these compounds through methylation, demethylation, or degradation processes in mussels.

MATERIALS AND METHODS

Indigenous freshwater mussels (*Elliptio complanata*), 6.5-7.0 cm in length, were collected from Balsam Lake, Ontario, for laboratory and field experiments. These mussels were free from contamination by alkylleads.

Glass aquaria (40x20x25 cm, LWH), filled with Lake Ontario water were used for experiments. Mussels were exposed to alkyllead solutions to study the concentrations of these compounds in different organs of the mussels. In these experiments, well-washed, fine white sand was used in each aquarium (ca. 3 cm deep) to provide a bed for the mussels. The tanks were filled with lake water, spiked with solutions of trimethyllead chloride and triethyllead chloride at 1 mg/L (1 ppm) expressed as Pb. The concentrations of the lead compounds in water were checked before and after the experiment by the gas chromatography-atomic absorption spectrometry method[5] to ensure that the test compound was still present at the experimental concentration, and in the designated form. At the 7, 10, 14, and 17th day intervals, three mussels were sacrificed and crudely dissected for analysis of the alkyllead compounds in the following organs: gill, mantle, muscle (adductor muscle and foot), and the visceral mass. After dissection, the organ was

blotted dry with tissue papers, weighed and processed for analysis as described in the following section.

Contaminated sediments used in the exposure experiments were collected by an Ekman grab from the St. Lawrence River off Maitland (DuPont) and from the St. Clair River off Corunna (Ethyl Corporation) near the lead alkyl production plants. The sediments were stored in plastic bags, transported to the laboratory, and stored in a cold room (2-5° C) before use. About 3 kg of the wet sediment was placed in the aquarium and allowed to equilibrate with Lake Ontario water for 7 days before the test mussels were put in. The sediment samples were analyzed for alkyllead compounds before and after the experiments. The overlying water was also analyzed for alkyllead species occasionally in parallel with the mussel analysis.

Both the water and contaminated sediment exposure experiments were conducted under static conditions without agitation or continuous water circulation, except with air bubbling in at mid level to supply the system with oxygen, but not disturbing the sediment. Water levels of the aquarium were maintained by replenishing with distilled water when necessary. The mussels were fed with live algae every three days. During the exposure experiment, two mussels were removed from each of the sediment tanks and the control tank at 3 to 4 days intervals. The mussels were mechanically opened, blotted dry with filter papers, weighed and analyzed individually on a whole mussel basis for alkyllead species according to the techniques given by Chau et al.[6] In this method, the whole mussel was digested in a 20% tetramethylammonium hydroxide (TMAH) solution. After neutralization, the tetraalkyllead, ionic trialkyl-, dialkyllead and Pb(II) compounds were extracted into

a benzene solution containing a chelating agent, sodium diethyldithiocarbamate (NaDDTC), followed by butylation to convert all the ionic alkyllead and Pb(II) species to the tetraalkyl-substituted forms which were determined by a GC-AAS technique. The following alkyllead species were determined: R_4Pb, R_3Pb, R_2Pb, Pb(II) (R=Me,Et). Monoalkyllead species, RPb^{3+}, were not determined because (i) their existence have not been established, (ii) method of determination is not certain for lack of reference substances.

RESULTS AND DISCUSSION

Exposure in Alkyllead Solutions

Mussels exposed to solutions of triethyllead and trimethyllead (1 mg/L) were observed to concentrate these compounds at steady rates with no noticeable physiological or behavioural changes before the 17th day of exposure to triethyllead. The mussels grew normally without loss in body weight. The burdens of trimethyllead and triethyllead in different mussel organs as a function of time are given in Figures 1 and 2 respectively. The concentrations of alkyllead in the various organs were mean values from three individual mussels, with relative standard deviations ranging from 5 to 18% of the mean values. Much higher concentrations of trimethyllead were accumulated than triethyllead for the same exposure period. For trimethyllead, the highest concentration was found in the muscle tissue (19.7 ug/g) followed by gills (10.5 ug/g), visceral mass (6 ug/g) and mantle (5.9 ug/g). The distribution of triethyllead in the organs was in general similar to that for trimethyllead, except the differences among the organs were not as remarkable. Muscle (5.9 ug/g), visceral mass (5.9 ug/g) and mantle (5.7 ug/g) contained the highest concentrations of triethyllead. The rate of

accumulation was in general much higher for trimethyllead than for triethyllead. Whether this is an effect of the alkyl group functionality was not investigated. The in vivo stability of the trimethyllead species as discussed in the subsequent section may explain its high accumulation. It has been shown, however, that marine mussels and dab also accumulated higher concentration of $(CH_3)_3Pb^+$ trimethyllead than triethyllead.[7]

As estimated from the accumulation curves, the concentration factors for trimethyllead and triethyllead by mussels were 8x and 3x respectively over a 14 day exposure period in solutions of 1 ppm of the alkyllead compounds. These concentration factors are relatively low in comparison to those of other aquatic organisms. Bioaccumulation for organometallic compounds, even for those with strongly ionic characteristics, is much higher in the lipid-containing tissue. Mussels and other bivalves usually have lower lipid content than most other fish. This could be the reason for their low concentration factors for the ionic alkyllead compounds. Table 1 summarizes some concentration factors for different species of alkyllead compounds by various aquatic organisms for comparison.

At the 17th day, the triethyllead test solution began to turn turbid. The colloidal particles, soluble in dilute acid, were determined to be lead-containing compounds, probably hydrous lead oxide precipitates, formed due to the slow decomposition of triethyllead. Two mussels died as a consequence of fouling of the solution, and the experiments were terminated. This phenonmenon was not observed in the trimethyllead test solution.

Tetraalkyllead compounds are volatile and only form unstable physical solutions. It is difficult, although not entirely impossible, to maintain test solutions at constant concentrations.[8] Their environmental occurrence is scarce and therefore they were not included in the experiments.

In the course of the exposure experiment, no mussel died before the 17th day, indicating that the concentration causing acute toxicity of alkyllead compounds to mussels may have not been reached. No data are available for acute toxicity of these compounds to freshwater mussels.

Transformation of Alkyllead Compounds

In vivo transformation of alkyllead compounds was observed in the course of the mussel analyses. Using the temporal accumulation of trialkyllead in the visceral mass of the exposed mussels as an example, both diethyllead and Pb(II) species were found to increase as the triethyllead accumulation increased with time during the first 10 days of incubation (Figure 3). Similarly, the dimethyllead and Pb(II) species were also found in the organs of mussels exposed to trimethyllead solution. During this period of time, concurrent analyses of both test solutions did not show the presence of the diethyllead or dimethyllead species except traces of Pb(II) which was always present. It is evident that the dialkyllead and Pb(II) species must have been formed in vivo of the mussels by dealkylation of the trialkyllead species during this time period. It is also shown that more degradation occurred with the triethyllead species than with the trimethyllead such that the accumulated products of dialkyllead and Pb(II) in the mussel organ were much higher in the triethyllead exposure experiments. At the

end of the 17-day exposure experiment, more Pb(II) was accumulated than the diethyllead species, indicating the faster kinetics for the conversion of diethyllead to Pb(II) than that for the conversion of triethyllead to diethyllead. The fact that the higher accumulation was observed for trimethyllead (preceeding section) could well be due to its in vivo stability in comparison to the triethyllead species. Degradation of tetraalkyllead by a series of dealkylation reactions to trialkyllead, then dialkyllead and eventually to Pb(II) have been observed in other biota such as fish[11] and human.[12]

In an dynamic system of accumulation and degradation simultaneously occurring in the mussel, we were not able to obtain mass balance at any stage of the exposure period. Each data point in Fig. 3 was from a different mussel which could bring in a new set of biological parameters different from the previous one. We could only produce evidence to show the presence and increasing concentrations of the degradation products, diethyllead and Pb(II) in the triethyllead exposure experiment, and similarly, dimethyllead and Pb(II) in the case of the trimethyllead exposure. Figure 3 also showed the rapid degradation of the diethyllead species giving rise to the increasing concentration of Pb(II). This did not happen in the trimethyllead exposure experiments.

Exposure in Contaminated Sediment

Results from experiments with mussels exposed to sediment contaminated with alkylleads agree well with the findings of the spiked lake water experiments, except that the uptake rates of alkyllead concentration are different. The rates of bioaccumulation of alkyllead compounds are

obviously related to the concentrations of the alkyllead species in the sediment. For example, St. Clair river sediment contained about 8 times as much Pb(II) and more than 2 times as much tetraethyllead as the St. Lawrence River sediment (Table 2). The rates of bioaccumulation for triethyllead and Pb(II) are 5 times and 14 times faster respectively for mussels placed in St. Clair sediment than those placed in St. Lawrence River sediment. Unlike the bioaccumulation experiments conducted in alkyllead solutions which are simple media, the accumulation experiments with contaminated sediment may be complicated by many other parameters controlling the absorption and desorption of alkyllead compounds from the sediment surfaces. Apart from the differences in the alkyllead loadings of the sediment, the differences in sediment composition, such as organic content, will also play an important role in affecting the bioaccumulation of alkyllead.

In the course of the 52-day exposure, the bioaccumulation rates for mussels for triethyllead, diethyllead and lead(II), from the St. Clair River sediment, as estimated from the slopes of the regressed accumulation curves, were 1.96, 0.26, and 4.87 ng/g/day respectively (Figures 4A,B). For St. Lawrence sediment (Figure 5A,B), the bioaccumulation of alkyllead and Pb(II) species was less pronounced. For triethyllead, the rate was 0.42 ng/g/day which is about one quarter of the rate for St. Clair sediment under identical conditions. For diethyllead, and lead(II), the slopes of the accumulation curves were almost flat but slightly negative. Accumulation was considered zero. This phenomenon may be attributed to the decrease of the concentration of diethyllead in the water of the St. Clair sediment tank from 510 ng/L to below detection, and that of lead(II), from 3530 ng/L to less than

half of its value, after 46 days. In contrast, the diethyllead concentration in the water of the St. Clair sediment tank did not decrease as much, and the concentration of lead(II) was actually increased by 20% after 46 days (Table 2). The release of alkyllead compounds from sediment is a complex process, depending on many parameters such as particle size, organic content, chemical and physical characteristics of the sediment, and chemistry of the overlying water. It is also affected by bioturbation caused by movements of any organisms, in this case, the mussels. The present investigations, however, only aim at assessing the direct bioavailability of alkyllead compounds in contaminated sediments with a view to providing a laboratory basis for interpretation for our continuing *in situ* work using caged mussels in the polluted sites. The investigation of the release mechanism is beyond the scope of this study.

Although tetraethyllead was present in sediment samples collected from both locations (Table 2), it was not found in the exposed mussels. It is possible that tetraethyllead was strongly adsorbed onto the sediment and was not available to the mussels. Alternatively, it may undergo rapid *in vivo* degradation in the mussel to the triethyllead and diethyllead species after accumulation. Such degradations have been previously reported.[11,12] Our earlier work[8] showed that rainbow trout accumulated tetramethyllead from water and the highest concentration was found in the lipid layer of the fish. Unfortunately, only tetramethyllead was determined because methods were not available for the determination of the trimethyllead and dimethyllead species in fish and water at the time of the investigation. We were not able to substantiate the *in vivo* degradation of tetraalkyllead compounds in

aquatic organisms.

Conclusions

Alkyllead compounds are accumulated by mussels, much higher concentrations of trimethyllead being accumulated than triethyllead for the same period of exposure. The highest concentrations of trimethyllead are found in the muscle, gills and visceral tissue. The distribution of triethyllead in organs is slightly different with the highest concentrations in muscle, visceral mass and mantle.

There is evidence for the in vivo transformation of the trialkyllead species to dialkyllead and Pb(II) species in mussel organs by a series of dealkylation reactions. As the dialkyllead species were not detected in either of the trialkyllead test solutions within this time frame, the transformations must have taken place in vivo after accumulation.

The rates of accumulation are related to the concentrations of alkyllead compounds in water and sediment. Higher accumulation is observed with St. Clair River sediment (Corunna) than with St. Lawrence River sediment (Maitland), as reflected by their alkyllead content. As the release of alkyllead compounds from sediment with time is probably not a linear process, the accumulation by the exposed mussels would accordingly fluctuate. The bioaccumulation study can only indicate the trend and a cumulative estimation of accumulation over a period of time.

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Table 1. Concentration Factors for Alkyllead Compounds

Compound	Species	Exposure Conc.	Exposure Time	Conc. Factor	Reference
Me_4Pb	Shrimp	0.01-0.7mg/L	96 hr	20x	(7)
	Mussel	0.05-0.7mg/L	96 hr	170x	
	Plaice	0.02-0.7mg/L	96 hr	60x	
	Rainbow Trout	3.46 ug/L	96 hr	500-934x	(9)
	Rainbow Trout	3.5 ug/L	1 d	100x	(8)
	Rainbow Trout	3.5 ug/L	7 d	760x	(8)
Et_4Pb	Shrimp	0.01-0.2mg/L	96 hr	650x	(7)
	Mussel	0.01-0.2mg/L	96 hr	120x	
	Plaice	0.02-0.2mg/L	96 hr	130x	
	Rainbow Trout:				
	viscera fats	2.5 ug/g	21 d	3189x	(10)
	intestine	2.5 ug/L	21 d	1824x	
	skin	2.5 ug/L	21 d	1500x	
	kidney	2.5 ug/L	21 d	843x	
	brain	2.5 ug/L	21 d	92x	
Me_3Pb	Shrimp	0.2-3.0mg/L	96 hr	1x	(7)
	Mussel	0.1-3.0mg/L	96 hr	24x	
	Plaice	10-50mg/L	96 hr	1x	
	Mussel (freshwater)	1 mg/L	14 d	8x	This work
Et_3Pb	Shrimp	1.0-15.0mg/L	96 hr	2x	(7)
	Mussel	0.1-25.0mg/L	96 hr	10x	
	Plaice	1.0-10.0mg/L	96 hr	2x	
	Mussel (freshwater)	1 mg/L	14 d	3x	This work
	White sucker	0.54 ug/L	##	88x	(3)
Et_2Pb	White sucker	0.14 ug/L	##	375x	(3)

Concentration Factor = conc. of alkyllead compound in animal tissue (ug/kg)/ conc. in water (ug/L); ## - field samples

Table 2. Analyses of sediments and aquarium water in mussel exposure studies.

Compound	sediment (ng/g) starting	sediment (ng/g) 33 day	aquarium water (ng/L) 14 day	aquarium water (ng/L) 46 day
St. Lawrence River sediment				
Et_4Pb	39	98	nd	nd
Et_3Pb	25	35	1100	270
Et_2Pb	21	nd	510	nd
Pb(II)	4050	3131	3530	1610
St. Clair River sediment				
Et_4Pb	90	337	nd	nd
Et_3Pb	28	34	1170	810
Et_2Pb	11	nd	460	150
Pb(II)	23926	29024	6850	8200
Control*				
Et_4Pb	-	-	nd	nd
Et_3Pb	-	-	nd	nd
Et_2Pb	-	-	nd	nd
Pb(II)	-	-	150	460

St. Lawrence River sediment was taken off Maitland; St. Clair River sediment was taken off Corunna.
3 kg of sediment and 10 L of Lake Ontario water were used in each aquarium.
* - 4 kg of well-washed aquarium white sand and 10 L of Lake Ontario water was used in control aquarium; nd - not detected; "-" not analysed.

Fig. 1. Concentration of trimethyllead in different mussel tissues after exposure to a trimethyllead chloride solution (1 mg/L as Pb) for 17 days. Data from average of 3 clams; ■ - muscle, ▲ - viscera, ▽ - gill, ● - mantle.

Fig. 2. Concentration of triethyllead in different missel tissues after exposure to a triethyllead chloride solution (1 mg/L as Pb) for 17 days. Data from average of 3 clams; ■ - muscle, ▲ - viscera, ▽ - gill, ● - mantle.

Fig. 3. Biotransformation of trialkyllead in viscera mass.

Fig. 4A,B. Concentrations of triethyllead, diethyllead and Pb(II) in mussels after exposure to St. Clair River sediment. Data from average of 2 mussels.

Fig. 5A,B. Concentrations of triethyllead, diethyllead and Pb(II) in mussels after exposure to St. Lawrence River sediment. Data from average of 2 mussels.

Figure 1

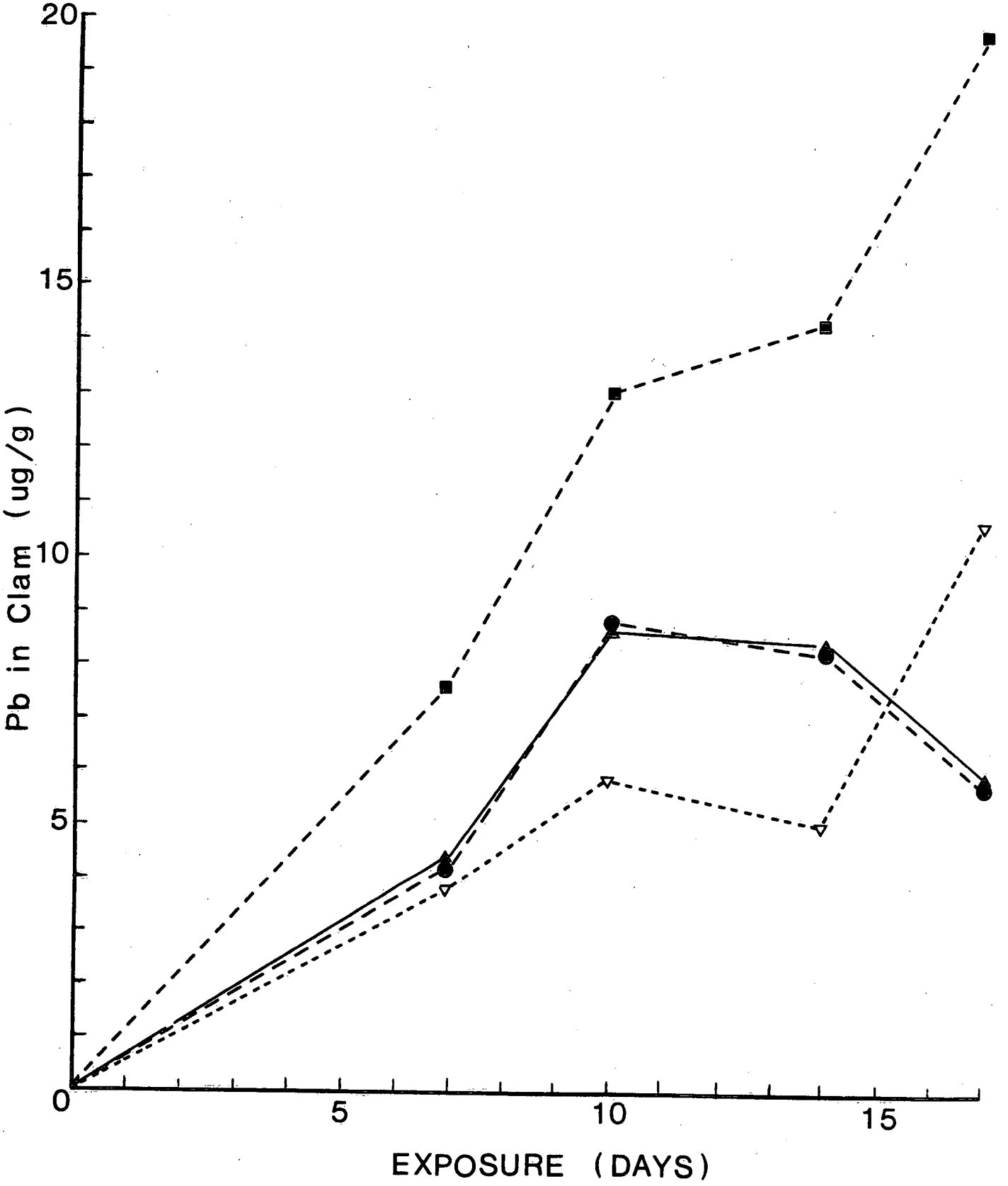


Figure 2

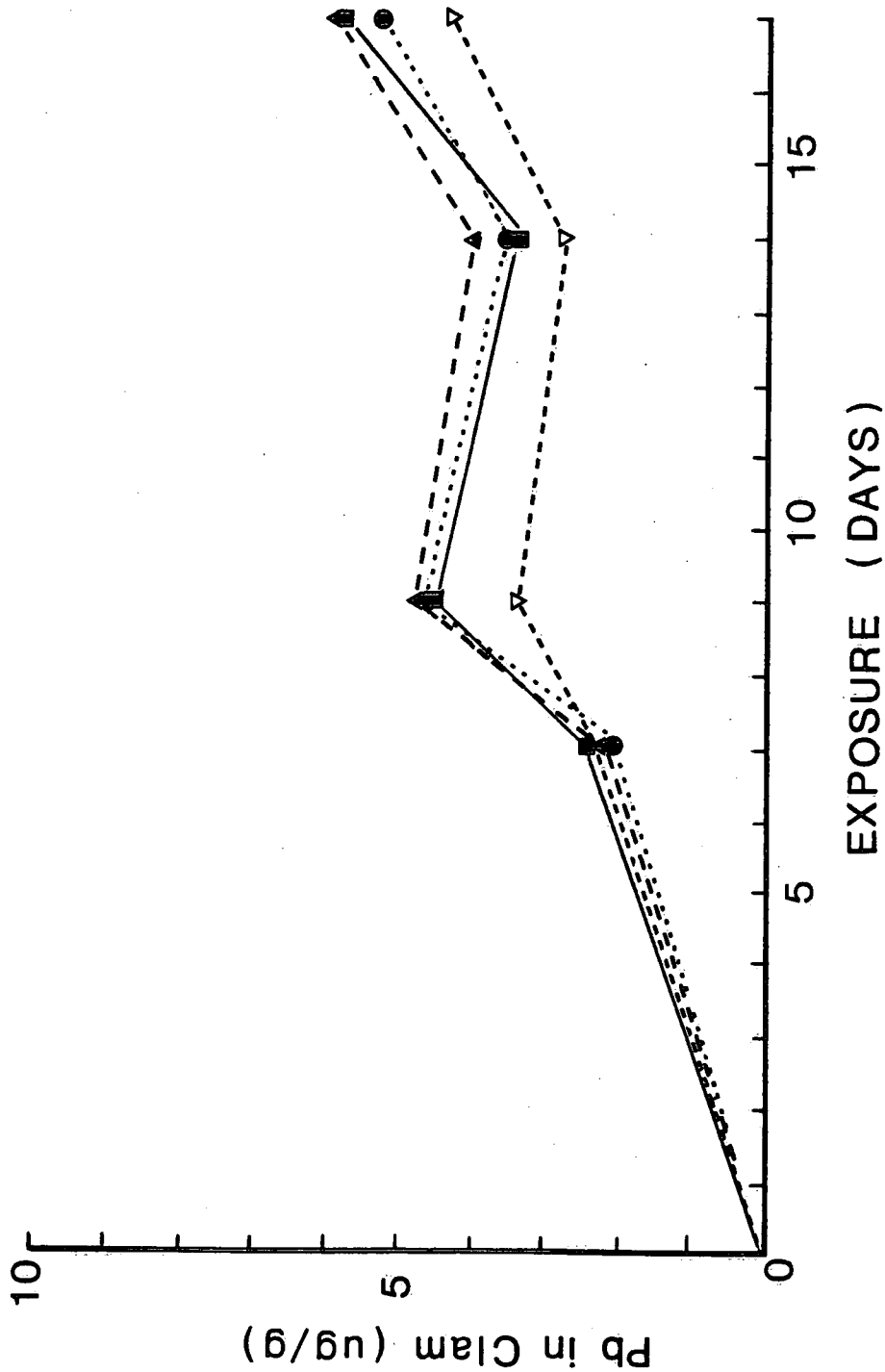
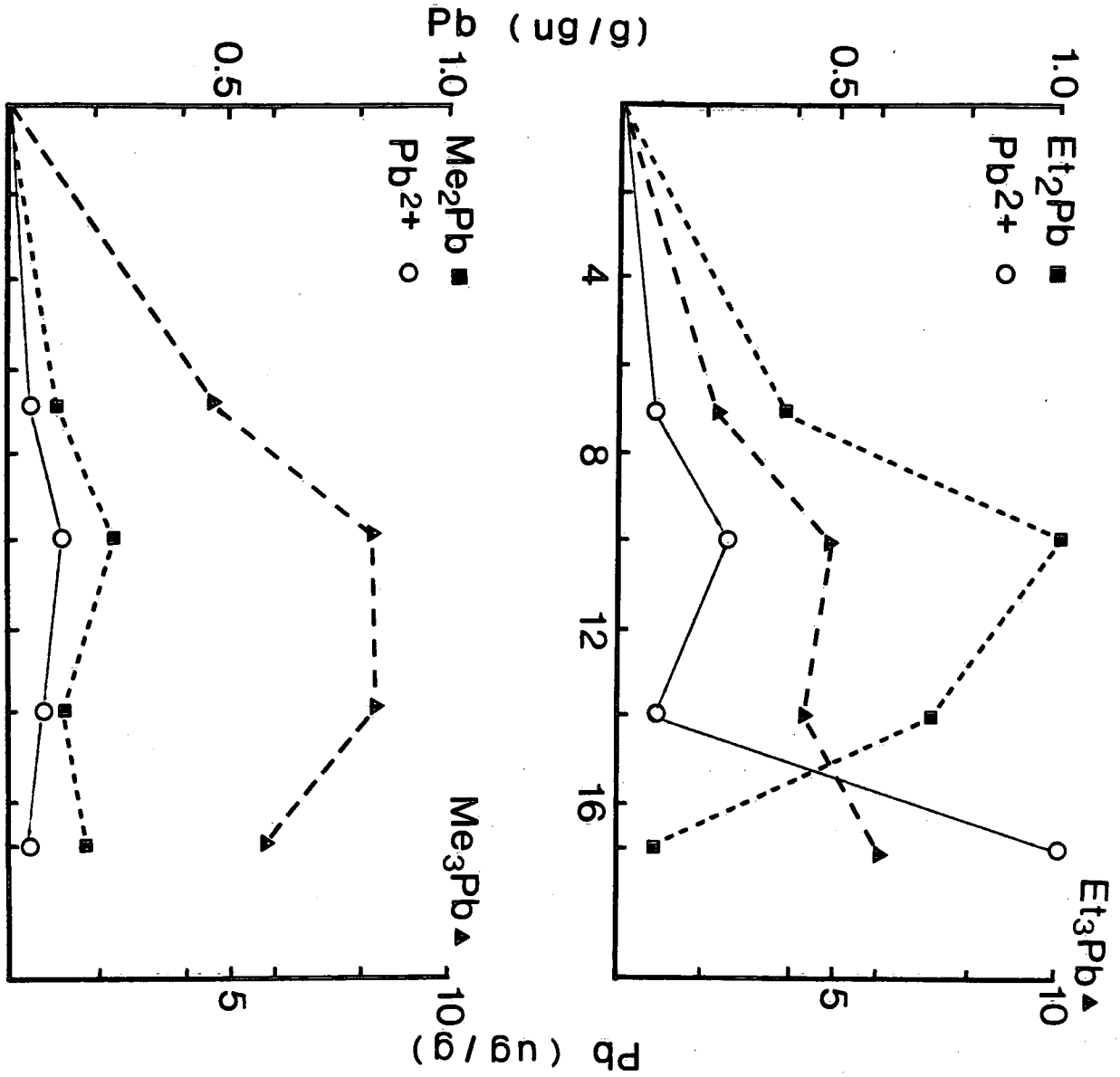


Figure 3



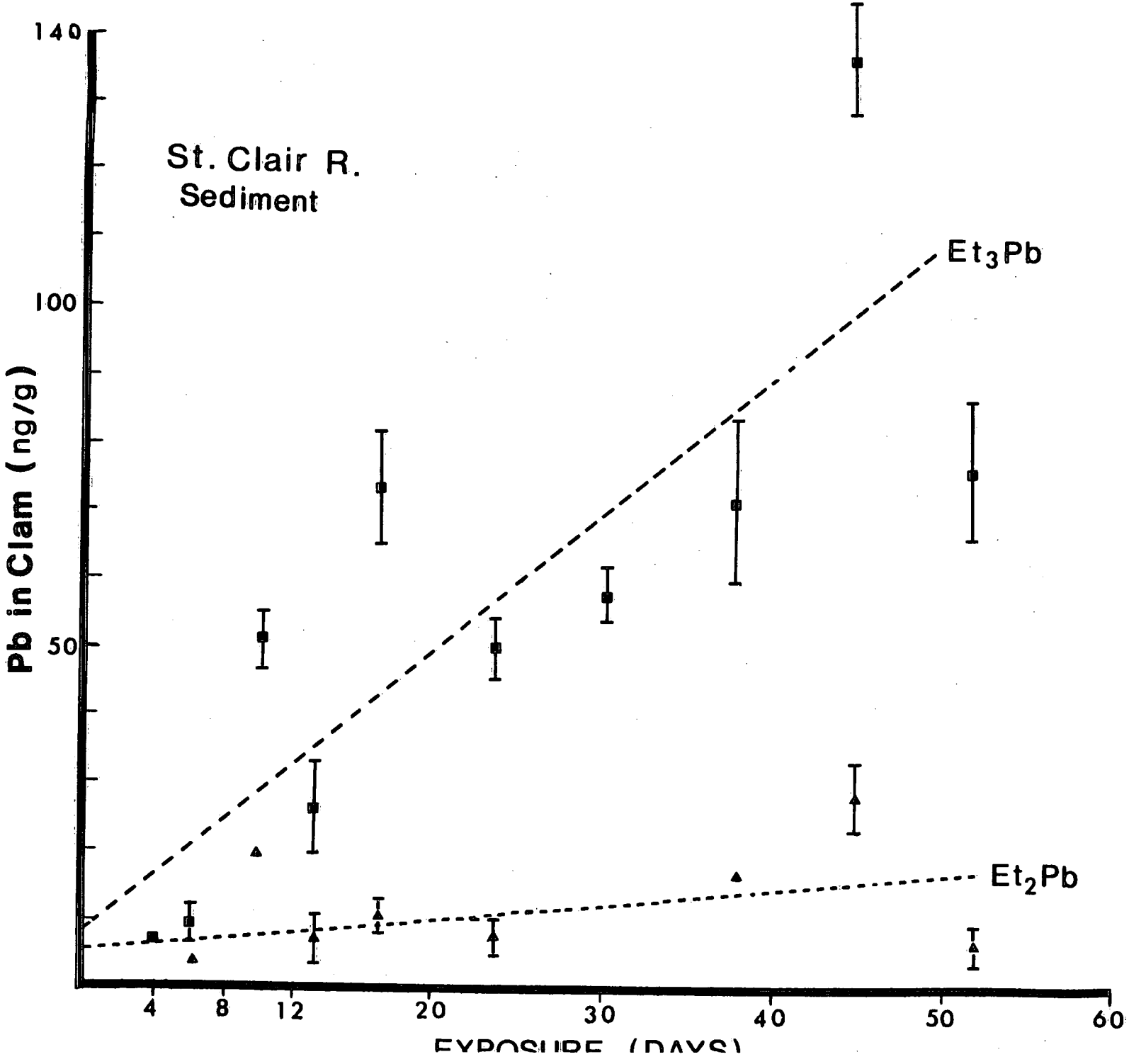

St. Clair R.
Sediment
Et_3Pb
Et_2Pb
Pb in Clam (ng/g)
140
100
50
4
8
12
20
30
40
50
60
EXPOSURE (DAYS)

Figure 4A

Figure 4B

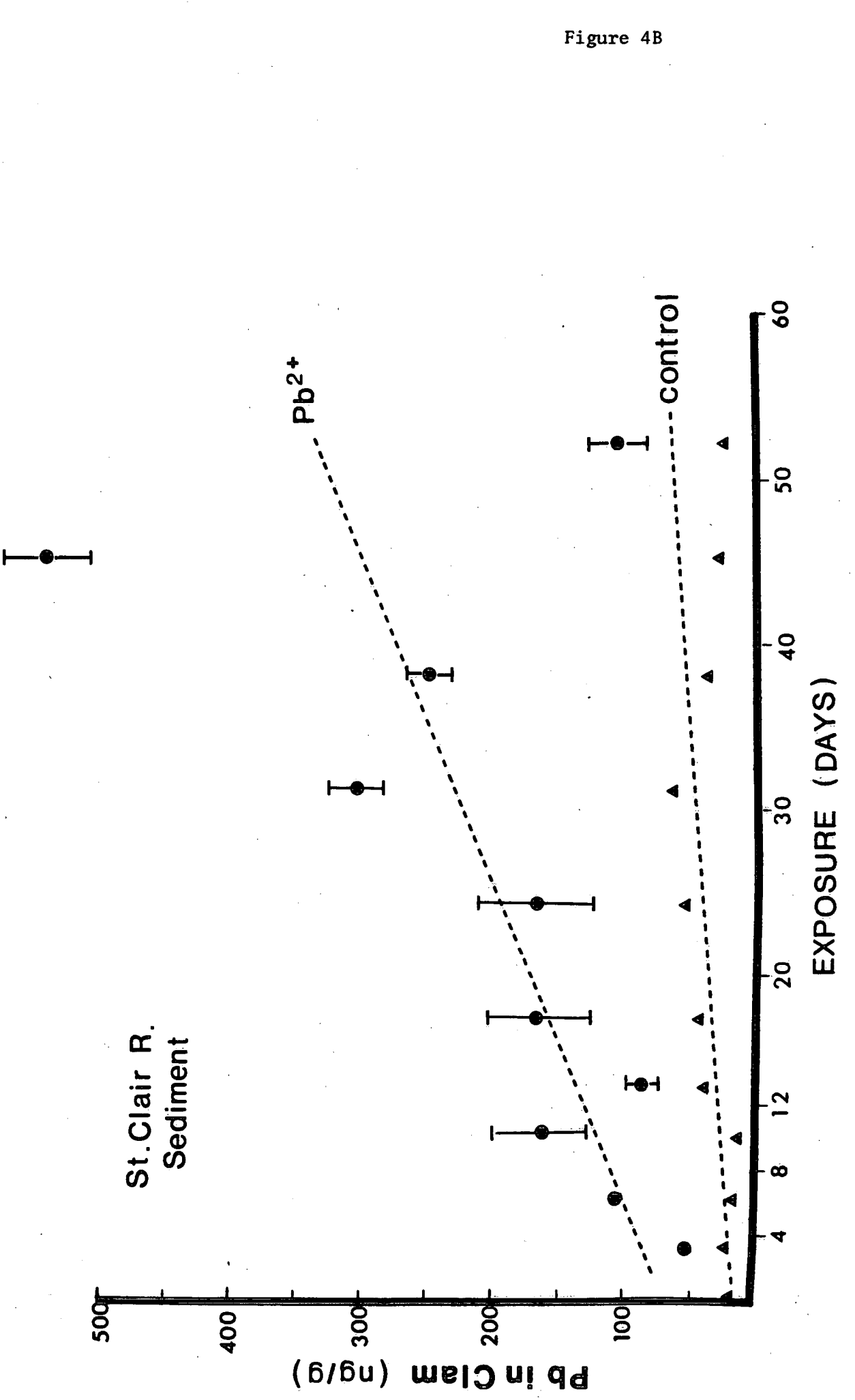

Pb in Clam (ng/g)
500
400
300
200
100
4
8
12
20
30
40
50
60
EXPOSURE (DAYS)
St.Clair R.
Sediment
Pb^{2+}
control

Figure 5A

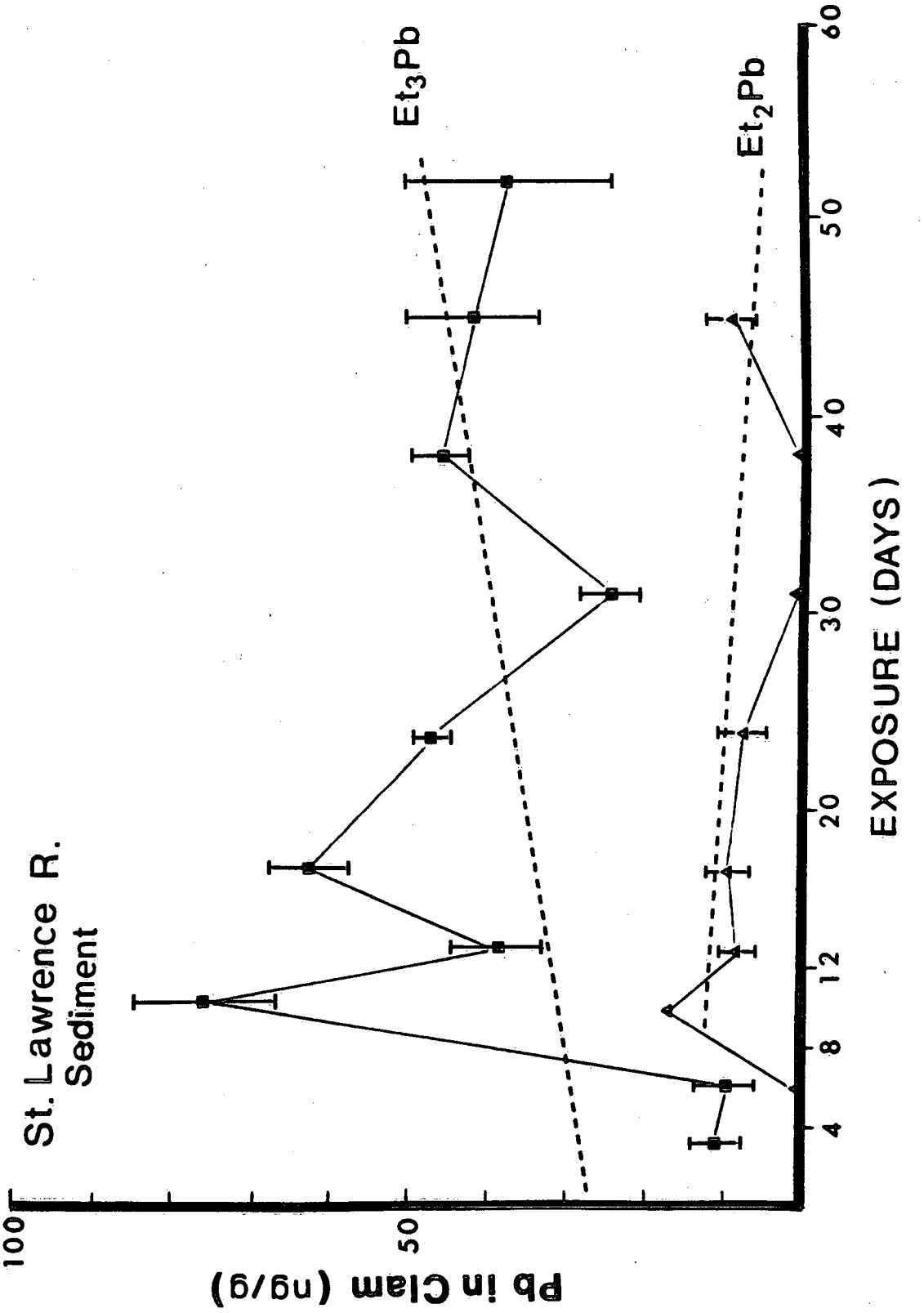
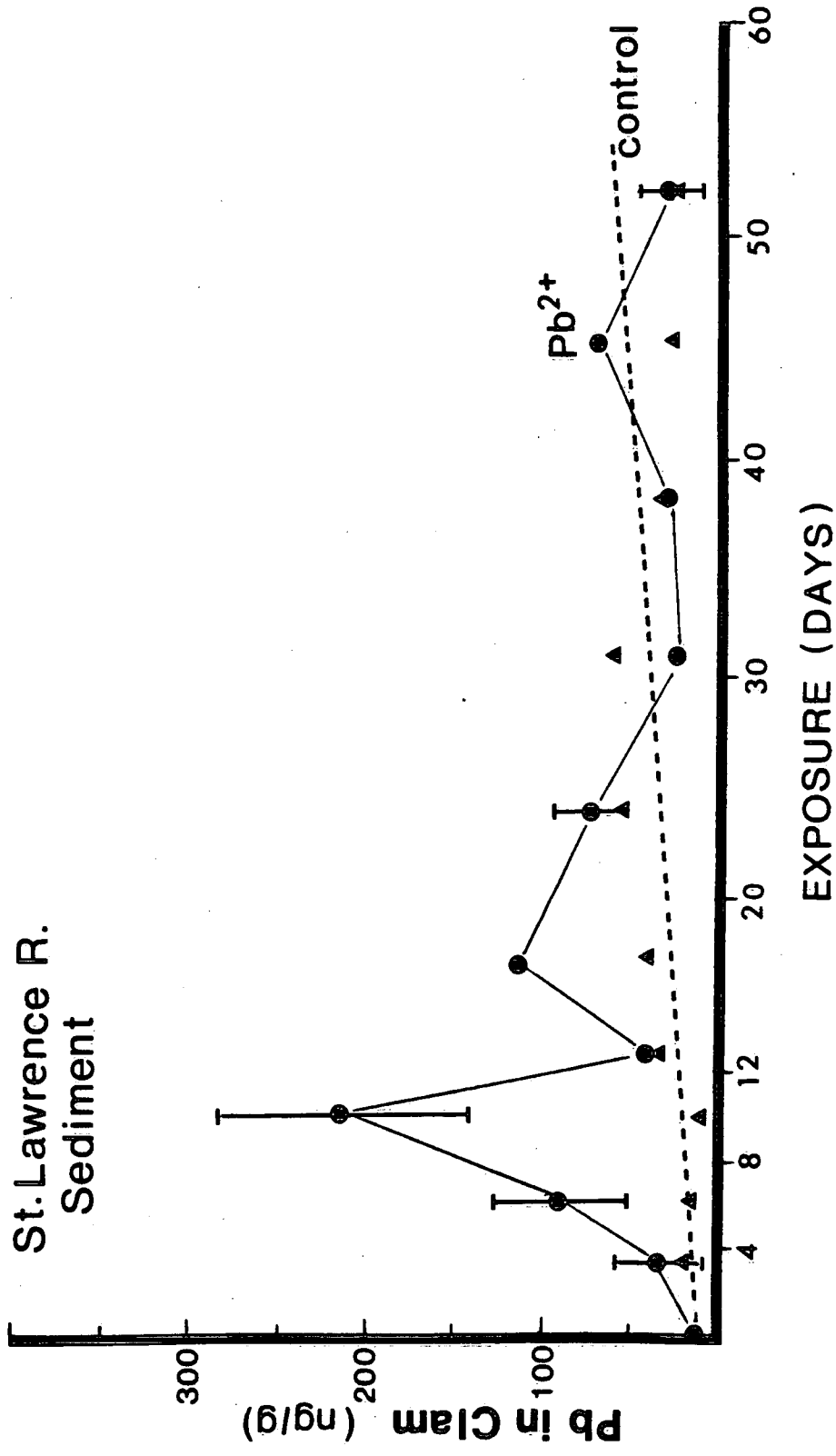

St. Lawrence R.
Sediment
Et_3Pb
Et_2Pb
Pb in Clam (ng/g)
100
50
4
8
12
20
30
40
50
60
EXPOSURE (DAYS)

Figure 5B


St. Lawrence R.
Sediment
Pb in Clam (ng/g)
300
200
100
4
8
12
20
30
40
50
60
EXPOSURE (DAYS)
Pb^{2+}
control