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Analysis of Lead in Freshwater Clams from the Embarrass River, Coles County, Illinois

Kwaku D. Nantwi

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ANALYSIS OF LEAD IN FRESHWATER CLAMS FROM THE

EMBARRASS RIVER, COLES COUNTY, ILLINOIS

(TITLE)

BY

KWAKU D. NANTWI

B.S., EASTERN ILLINOIS UNIVERSITY

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Zoology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1979

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

22 April, 1980
DATE

22 April, 1980
DATE

The undersigned, appointed by the Chairman of the Department of Zoology,
have examined a thesis entitled

ANALYSIS OF LEAD IN FRESHWATER CLAMS FROM THE
EMBARRASS RIVER, COLES COUNTY, ILLINOIS

Presented by

Kwaku D. Nantwi

a candidate for the degree of Master of Science
and hereby certify that in their opinion it is acceptable.

ABSTRACT

Twenty-two freshwater clams of various genera were collected by hand from two sites on the Embarrass River located at 240 meters and 400 meters downstream from the dam at Lake Charleston and at depths of .4 and 2.5 meters. Ten grams of gill tissue from each clam was prepared by furnace ashing, dissolved in 30 ml. of acid mixture and analyzed for lead content using an atomic absorption spectrometer. The average lead concentration for the clams was 3.60 ppm, while that of the ambient water was 0.33 ppm indicating that these local bivalves show a lead bioconcentration of about ten times. The levels of lead found, and the proximity of the sites to motor routes, suggest that lead from automobile exhaust fumes finds its way into the River.

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
LITERATURE REVIEW	3
MATERIALS AND METHODS	6
Site	6
Collection of Clams	6
Analysis Method	6
Preparation of Clam Tissue for Analysis	7
Preparation of Ambient H ₂ O for Analysis	8
Operation of Instrument	8
Preparation of Standards	9
RESULTS	10
DISCUSSION	17
CONCLUSION	20
BIBLIOGRAPHY	21

LIST OF TABLES

<u>Table</u>		<u>Page</u>
I.	Instrument Settings	9
II.	Name and Number per Specimens of Freshwater Clams Collected from Embarrass River, Coles County, Illinois June-July 1979	10
III.	Data Sheet (For Standards)	12
IV.	Comparison of Absorbance of Ambient H ₂ O and Clam Tissues for Individual Clams	13
V.	Average Concentrations of Pb ²⁺ (ppm) in Clam Tissue According to Species	15

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
I.	Graph of Absorbance against Concentration for Standard Solutions of Pb (in ppm).	11
II.	Absorbance of Level of Pb ⁺² in 10gm of Clam Tissue versus Concentration in ppm Pb ²⁺ with Clams Numbered According to Table V.	16

INTRODUCTION

The impact of heavy metal residues and other industrial wastes on the environment has been a major concern over the last few decades and a number of workers have studied this problem (Brooks, 1977; Brooks and Rumsby, 1966; Brown, 1968; Davies et al., 1976; Chisolm, 1971; Jones, 1938; Jovicie, 1973; Mayfield et al., 1973; Mullins, 1977; Nehring, 1976; Patrick and Loutit, 1975; Patterson et al., 1976; Rehwoldt, 1973; Shepar et al., 1978; Wurtz, 1962). The investigations of Watling and Watling (1976) demonstrate that increasing releases of wastes into the aquatic environment may have a toxic effect not only on the local flora and fauna, but also on humans as well.

Lead (Pb), a heavy metal, is very persistent in the environment. Its source of concern for humans lies in the many reported cases of lead poisoning, especially in children (Chisolm, 1971; Chisolm and Goyner, 1972). In the freshwater environment lead can be concentrated, over an extended period, to high levels in larger long-lived aquatic invertebrate animals (Anderson, 1974; Mathis and Cummings, 1973; Leland and McNurney, 1974).

Freshwater clams are sedentary, long-lived filter-feeding invertebrate animals that commonly occur in relatively large numbers in most inland aquatic habitats. This makes them feasible objects for investigating accumulation of heavy metal residue if a dependable, easily applied, method of analysis can be formulated. The Embarrass River in Illinois

supports a very diverse clam population and receives its share of industrial and agricultural residual waste from farmlands and bordering communities (Durham and Whitley, 1971). With this in mind the purpose of this study is as follows:

- (1) To detect the presence, if any, of appreciable concentrations of lead in clams collected from the Embarrass River in Coles County, Illinois.
- (2) To determine the applicability of the Atomic Absorption Spectroscopy method of Friend et al (1976) for analysis of lead residue in the tissue of freshwater clams and suggest adjustments that may improve the accuracy of the method.
- (3) To determine the concentration of lead dissolved in the ambient water taken in the course of collecting clams.

LITERATURE REVIEW

Lead is a very ubiquitous metal that enters the environment through motor fuel, paints, varnishes and industry (Patterson, 1968, 1973; Davies et al., 1970; Langford, 1973; Ward et al., 1974; Patterson, Settle and Glover, 1976; Mullins, 1977). It is especially dangerous to children who are apt to eat peeling paint, a behavior termed pica.

According to the Committee on Biological Effects of Atmospheric Pollutants (1974), most research on lead poisoning has been restricted to cases involving occupational overexposure, lead-based paints being ingested by children, improperly lead-glazed earthenware vessels, discarded battery casings and illicitly distilled whiskey. In man the daily dietary intake of lead is 0.3mg. In excess, lead accumulates in the soft tissues and leads to a build up of aminolevulinic acid in urine (Chisolm, 1971). Lead has been implicated in ulcers and gastritis in those professions exposed to high concentrations (Jovicie, 1973). Scott et al., (1973) report that in high concentrations lead can inhibit Ca^{2+} uptake thus offsetting mitochondrial membrane transport mechanisms. Industrial waste is a source of concern and Watling and Watling (1976), report that increasing releases of wastes into aquatic environment may have a toxic effect not only on aquatic flora and fauna but also on humans. The most important mechanism of toxic action of metals is thought to be poisoning of enzyme systems (Pringle et al., 1968). Lead is known to be toxic to aquatic organisms with fish being especially

sensitive (Klein, 1962). It is not known to be an essential trace element in animal nutrition (Bowen, 1966). Most studies on the occurrence and accumulation of heavy metals in bivalves and other molluscs have been limited to saltwater forms (Ayling, 1974; Chow, Snyder and Snyder, 1975; Ireland, 1973; Kopfler and Mayer, 1973; Pentreath, 1973; Valiela and Banus, 1974; Windom and Smith, 1972; Brooks and Rumsby, 1965; Brooks, 1977). Reports on studies of heavy metal concentrations in freshwater bivalves are rather few. Mathis and Cummings (1973) report on heavy metal accumulation for three species of Unionidae collected in the Illinois River. Leland and McNurney (1974) have examined the transport and concentrations of lead in various components of a river ecosystem and report that the accumulation of lead by macro-invertebrates is a function of niche and habitat but it is not necessarily concentrated by a food chain mechanism. Anderson (1977) reports on the concentration of cadmium, copper, lead and zinc in six species of freshwater clams in Illinois and Wisconsin. One of the earliest studies on toxicity of metals was done by Jones in 1938. He calculated the various concentrations at which salts of lead and zinc showed adverse effects on the stickleback. He also showed that Ca^{2+} has antisnergistic effects on lead salts. Wurtz (1962) and Davies et al (1976) have since noted similar effects of Ca^{2+} on the toxicity of lead salts on mollusks.

Tatsumoto and Patterson (1963) reported the ability of invertebrate animals to concentrate high levels of lead. Shepar et al (1978) concluded that exposure of invertebrate animals to $32\mu\text{g}/\text{L}$ of lead for 28 days led to accumulations of 1000-9000 (fold). Goldberg (1965) reports bioaccumulations of 10^5 of many heavy metals by many lower members of food chains. However, the method of mechanism of such high ability to

concentrate heavy metals is not well understood although various theories have been proposed (Brooks and Rumsby, 1966). The toxicity of lead and cadmium to aquatic life has been investigated (Benoit et al, 1976; Davies et al, 1976; Holcombe et al, 1976; Shepar, 1976).

Research thus far indicates that many heavy metals entering aquatic environments are not magnified along straightforward trophic levels (Enk and Mathis, 1977). The relationship is more complex. Mathis and Cummings (1973) have demonstrated that bottom sediments act as a "sink" for heavy metals and organisms that dwell at the bottom have high concentrations. This is in agreement with the finding of Leland and McNurney (1974).

With the realization of the hazards of lead and other heavy metals on life, more recent and sophisticated analytical methods have been reported (Sprague, 1961; Mount and Brungs, 1967; Langford, 1969; Yeager et al, 1971; Mushak, 1977; Delves, 1978; Ediger, 1973; Friend et al, 1977).

MATERIALS AND METHODS

Site

The Embarrass River has its origin as a drainage ditch in the south campus of the University of Illinois in Champaign-Urbana. It flows south through the town of Villa Grove where it receives East Branch and Jordan Slough creeks. The enlarged flow continues southeast through Douglas, Coles, Cumberland and Jasper Counties. Two tributaries, Riley and Kickapoo creeks, flow into it carrying treated sewage effluents from Charleston and Mattoon, Illinois. The Embarrass empties into the Wabash River at Crawford County, Illinois.

Collection of Clams

Clams were collected at varying depths (10cm - 60cm) using a clam rake and by hand-dipping from two sites along the Embarrass River in Coles County, Illinois, during June and July, 1979. Collection sites were located at 400 meters and 240 meters downstream from the dam at Lake Charleston (used in this study as a reference point). Each clam was returned to the laboratory and immediately frozen at 0° C until ready for analysis.

Analysis Method

Determination of lead (Pb) was carried out using the procedure outlined by Friend et al (1976). The clam tissues were analyzed using a Beckman 485 Model Atomic Absorption Spectrometer. The underlying

principle of Atomic Absorption is that the sample components are converted into the elemental atomic vapor in a flame and this atomic vapor is imposed into a beam of radiation characteristic of the analyte element. For dilute solutions there is a direct correlation between the amount of radiation absorbed (Absorbance) in the flame and concentration of analyte in the solution. For high concentrations there is a broadening effect owing to the closeness of the analyte particles in the vapor state. This, in turn, is due to the interactions of particles with one another. Temperature has a direct effect in making available more particles in elemental form.

Preparation of Clam Tissue for Analysis

Each specimen was thawed, dissected and the gills removed. Ten grams of gill tissue were placed in a 250ml beaker to which was added 10 ml $Mg(NO_3)_2$ (0.1M) in 95 percent ethanol. The material was well mixed by agitation and the ethanol removed by evaporation on a hot plate. The sample was then placed in a muffle furnace that was controlled at $450^\circ C/500^\circ C$ and allowed to char for 20 hours. During this time, complete oxidation of organic matter was accomplished. The sample was then removed from the furnace and allowed to cool. A few drops of nitric acid were added to insure complete oxidation and the sample was warmed at $140^\circ C - 150^\circ C$ for an additional hour. The resulting ash was white in color.

The ash was dissolved in 30ml of an acid mixture (200ml of conc. HCl, 650ml H_2O and 150ml conc. HNO_3) with a little warming. The solution was filtered using a fritted glass filter (Porosity S). The filtrate was analyzed for lead by Atomic Absorption Spectrophotometry and the results reported in parts per million.

Preparation of Ambient H₂O for Analysis

A few drops of conc. HNO₃ were added to 30ml of ambient water to dissolve any particulate matter and bring the pH to an acid value. The solution was filtered and analyzed as described below.

Operation of Instrument

The aspiration rate of a test solution was controlled at about 5ml per (60 - 90) sec. After every aspiration of a sample or standard solution, distilled water was passed through the burner. This treatment was necessary to help clean away any precipitated debris that may have settled on the burner head and which would give rise to flame instability. Blank solutions of the acid mixture used in dissolving the clam tissue were also checked to detect the presence of any background lead, which would exaggerate the actual concentration of lead in the clam tissue.

The span of the instrument is a device that controls the scale of the instrument readout. A scale expansion for samples was used owing to the expected low levels of lead in the clam tissue. The scale was set so that the instrument read 0.200 absorbance units full scale. The scale expansion was obtained by setting the span control of the instrument to 2.00. With the expanded scale, the level of detection of lead was ± 0.03 ppm.

A sample of the solution was transferred into a 5ml aspiration cup which was fitted in place, under the intake point to the flame. Aspiration was effected by a fine capillary tube between the burner and solution. As aspiration occurred, the absorbance of light in the flame was read on the output meter of the instrument. The zero absorbance of the

instrument was set prior to running any sample while operating distilled water into the flame. This zero point was checked periodically throughout the analysis. The instrument settings are presented in Table I below:

Table I
Instrument Settings

Hollow Cathode Lamp Current	20ma
Burner Height	1.2cm
C ₂ H ₂ Pressure	4.0psig
Air Pressure	25.0psig
Analysis Wave Length	283.3nm
Slit Width	0.65mm

Preparation of Standards

A stock solution containing 100ppm Pb²⁺ was prepared by dissolving 0.1599g of Pb(NO₃)₂ in 0.1m HNO₃ and diluting with 0.1m HNO₃ to 100ml. Standards containing 1, 2, 4 and 10ppm lead were obtained by aliquot dilution of the stock lead solution.

RESULTS

Twenty-two clams of eight genera were collected from two sites in the Embarrass River. The species represented in the collection are presented in Table II.

Table II

Name and Number per Specimens of Freshwater Clams Collected from Embarrass River, Coles County, Illinois June-July 1979

Genus Species	Common Name	Number of Specimens
<u>Quadrula quadrula</u>	Maple Leaf	2
<u>Tritogonia vericosa</u>	Buckhorn	3
<u>Strophitus rugosus</u>	Squaws Foot	1
<u>Lampsilis ventricosa</u>	Pocket Book	6
<u>Quadrula metanevra</u>	Monkey Face	1
<u>Lamsigona complanata</u>	White Heel Splitter	2
<u>Actinonaias carinata</u>	Mucket	3
<u>Anodonta grandis</u>	Floater	4

The absorbance readings obtained for Pb^{2+} standards are presented in Table III and Figure I. The linearity observed in Figure I derives from a direct correlation between absorbance levels and concentration of solutions (if they are dilute). In general terms it is known as Beer's Law and is presented as $A = \epsilon bc$ where A is the absorbance, ϵ is the molar extinction coefficient, b is the thickness of the absorbing sample and c is the concentration of the absorbing species.

Figure I. Graph of Absorbance against Concentration for Standard Solutions of Pb (in ppm).

ABSORBANCE

.160

.140

.120

.100

.080

.060

.040

.020

0

Fig. 1

CONCENTRATION OF Pb in PPM

1

2

3

4

5

6

7

8

9

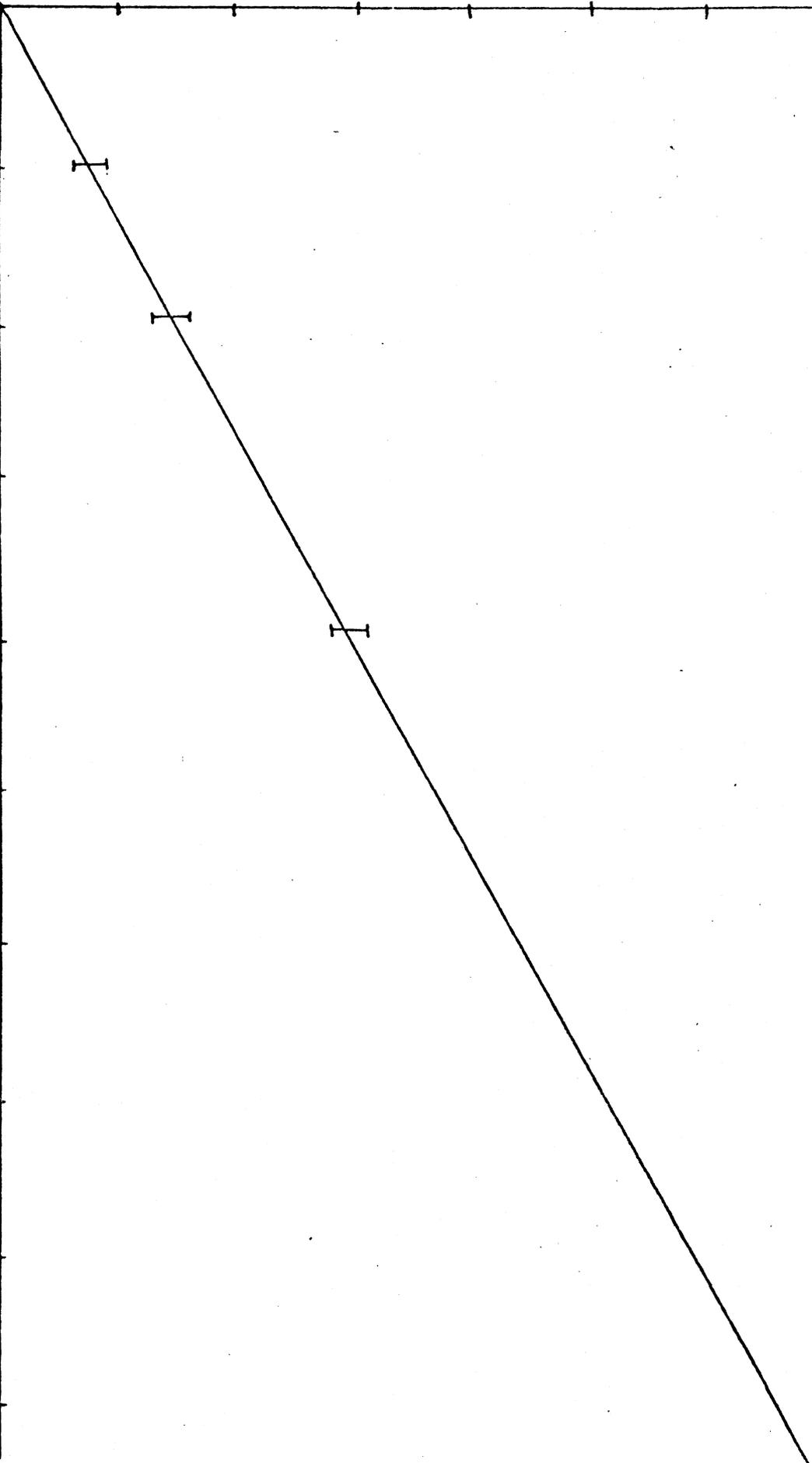


Table III
Data Sheet (For Standards)

Concentration (ppm)	Absorbance
1.0	.018 ± .002
	.016 ± .002
	.018 ± .002
	<u>.018 ± .002</u>
	Average .017 ± .002
2.0	.028 ± .002
	.028 ± .002
	.024 ± .002
	<u>.028 ± .002</u>
	Average .027 ± .002
4.0	.045 ± .002
	.060 ± .002
	.062 ± .002
	<u>.061 ± .002</u>
	Average .057 ± .002
10.0	.142 ± .002
	.142 ± .002
	.140 ± .002
	<u>.144 ± .002</u>
	Average .142 ± .002

For each of the mean absorbance readings reported in Table IV for each solution of clam tissue, the concentration of lead in 30ml of solution can be read from Figure II. The concentration of lead in the clam tissue in ppm can then be computed thus:

$$\frac{\text{Concentration of Pb}^{2+} \text{ in ppm (vol. of sample Sol.)} \times 10^6}{10\text{gm}}$$

These results are reported in Table V.

Table IV
 Comparison of Absorbance of Ambient H₂O
 and Clam Tissues for Individual Clams

Sampled Clams by Name and Number	Measured Absorbance	Mean Absorbance
<u>Quadrula quadrula</u>	.060	.060
	.060	
	.058	
	.060	
<u>Lampsilis ventricosa</u>	.028	.032
	.032	
	.032	
	.032	
<u>Anodonta grandis</u>	.032	.032
	.032	
	.032	
	.032	
<u>Lampsilis ventricosa</u>	.028	.028
	.028	
	.028	
	.028	
<u>Actinonaias corinata</u>	.028	.024
	.020	
	.024	
	.024	
<u>Tritogonia vericosa</u>	.020	.020
	.020	
	.024	
	.020	
	.016	
<u>Quadrula quadrula</u>	.020	.020
	.020	
	.020	
	.018	
<u>Lampsilis ventricosa</u>	.024	.020
	.020	
	.020	
	.020	
<u>Lampsigona complanata</u>	.020	.020
	.020	
	.020	
	.020	
<u>Lampsilis ventricosa</u>	.020	.020
	.020	
	.020	
<u>Lampsilis ventricosa</u>	.016	.016
	.016	
	.016	

Table IV (Con't.)

Sampled Clams by Name and Number	Measured Absorbance*	Mean Absorbance
<u>Tritogonia vericosa</u>	.016	.016
	.016	
	.016	
<u>Anodonta grandis</u>	.016	.016
	.016	
	.016	
<u>Actinonaias corinata</u>	.016	.016
	.016	
	.016	
	.016	
<u>Actinonaias corinata</u>	.012	.012
	.012	
	.012	
<u>Tritogonia vericosa</u>	.012	.012
	.012	
	.012	
<u>Anodonta grandis</u>	.012	.012
	.012	
	.012	
<u>Anodonta grandis</u>	.010	.010
	.008	
	.010	
	.010	
<u>Strophitus rugosus</u>	.008	.008
	.008	
	.008	
<u>Lampsilis ventricosa</u>	.008	.008
	.008	
	.008	
<u>Quadrula metanevra</u>	.006	.006
	.006	
	.006	
Ambient H ₂ O	.004	.004
	.004	
	.004	

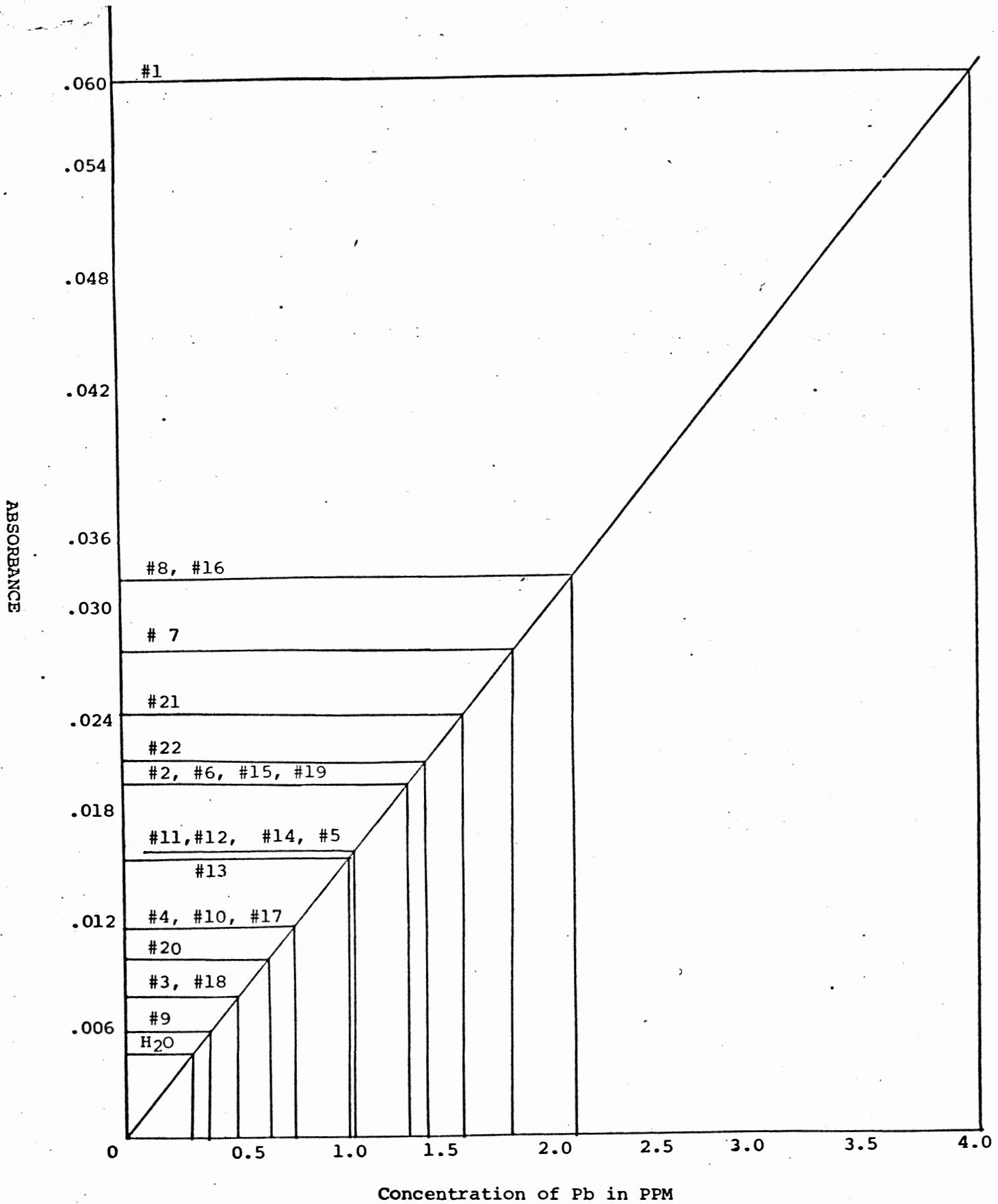
*The measured absorbances are known with the precision of ± 0.002 absorbance units.

From Table IV it is observed that the mean absorbance of 30ml ambient H₂O was lowest of all the analyses. This is also reflected in the Pb²⁺ concentrations computed.

Table V
Average Concentrations of Pb²⁺ (ppm) in Clam Tissue
According to Species

Genus Species	Conc. in ppm	Average Conc. in ppm	Sample # on Fig. II
<u>Quadrula quadrula</u>	12.00	8.02	1
	4.05		6
<u>Quadrula metanevra</u>	1.26	1.26	9
<u>Tritogonia vericosa</u>	2.28	3.21	10
	3.30		14
	4.05		2
<u>Strophitus rugosus</u>	1.53	1.53	3
<u>Lampsilis ventricosa</u>	1.53	4.34	18
	3.30		12
	4.05		15
	4.35		22
	5.34		7
	7.50		8
<u>Lampsigona complanata</u>	3.30	3.67	11
	4.05		19
<u>Actinonaias corinata</u>	2.20	3.07	4
	2.28		13
	4.80		21
<u>Anodonta grandis</u>	1.86	3.73	20
	2.28		17
	3.30		5
	7.50		16

Figure II. Absorbance of Level of Pb^{+2} in 10gm of Clam Tissue versus Concentration in ppm Pb^{2+} with Clams Numbered According to Table V.



DISCUSSION

The finding here that ambient water contains low levels of lead (0.33ppm) is in general agreement with Mathis and Enk (1975) who found 0.5ppm lead in the Jubilee River--a permanent stream in rural Peoria County, Illinois--and in a similar study on the Illinois River Mathis and Cummings (1973) found low levels of lead in the ambient water (0.3ppm). A most comprehensive study on freshwater clams by Anderson (1975) in the Fox River between Big Bend, Wisconsin and Geneva, Illinois, however, shows rather unusually low levels of lead in the ambient water (.021ppm). These low levels of lead in ambient water support the finding by Mathis and Cummings (1973) that the bottom sediments act as a "sink" for most heavy metals. The bottom sediments consequently have the highest concentration of heavy metals, and this in turn reflects on bottom-dwelling macroinvertebrates (Leland, 1974). In general the low lead level in the streams could reflect both a solubility equilibrium between the metal ions and various salts in the sediment and adsorption of metal ions to the sediment clays. Mathis and Enk (1975) report high lead levels of 8.30ppm in the sediment of the Jubilee River. Anderson also reports lead sediment concentrations of 52 - 89.6ppm.

The results of this study also indicate fairly low levels of lead (1.26 - 12.00ppm) in the gills of local bivalves when compared to the Anderson study, which was carried out in the Fox River between Big Bend, Wisconsin and Geneva, Illinois. That study indicates lead levels of

20 - 50ppm in the whole clam and 10.6 - 26.5ppm in the gills. The section of the river studied by Anderson passes through both agricultural and urbanized areas and can be safely assumed to represent an urban-rural environment. Anderson also made a study comparing the shell, muscle, viscera and gills in ability to concentrate lead. This showed that the general relationship for metal concentrations between organs is shell < muscle < viscera < gills for freshwater clams. The gills concentrate between 53 - 56 percent of the total body lead. This is due to the fact that the gills act both as a filtering mechanism for food material and as a respiratory organ. The use of the gills for analysis of lead in the present study was based on the selective accumulation of lead (and other heavy metals) in the gill tissue.

Lampsilis ventricosa, Lamsigona complanata and Strophitus rugosus were used in both studies. The lead levels found by Anderson for these species were 9.0, 13.4 and 13.2ppm. For the present study the lead levels were 4.34, 3.67 and 1.53ppm. This suggests that the higher levels in the Fox River clams is reflective of the exposure of the Fox River bivalves to greater amounts of industrial waste, effluents and exhaust gases from outboard boat motors. The Fox River site also probably has a high sorptive capacity for lead leading to a greater "sink" effect of the metal which in turn is reflected in the bottom-dwelling organisms.

No attempt has been made in the present study to categorize the species of clams with respect to their capability to bioconcentrate lead. This has been necessary owing to the small sample of each genus that was available at the time of the study. (See Table II) A greater sample number of (40 - 50) each genus would be required to adequately make such a distinction. The most variable levels of lead were found

in the genus Quadrula, three of which were analyzed. The lead concentrations in these samples were 1.26, 4.05 and 12.00ppm. These differences appear to be due more to the respective ages of the clams than the depth of the clam at a given location. Age appears to be a factor in this since these lead concentrations showed a direct relationship with increasing shell size. Older and bigger sized clams generally have experienced a longer exposure to an environment since clams are generally sedentary.

The average lead level in clam gills in the study is 3.60ppm whereas the level in ambient water is 0.33ppm. This indicates approximately a ten-fold bioconcentration in local bivalves. The source of this lead is unknown. It is not sewage-industrial waste from the Charleston - Mattoon area as these effluents enter the river below the sites at which the clams were collected. The most logical source of the lead is from automobile and agricultural engines owing to the exposure of the collection sites to motor vehicle routes and operating farm machinery.

CONCLUSION

This study does seem to point to the need for similar studies on the applicability of macroinvertebrates as biological monitors of environmental pollution. Ambient water generally has a lower metal concentration than the level in macroinvertebrates. This finding is in agreement with Mathis and Cummings (1973), Anderson (1974) and Mathis and Enk (1975).

The analytical method employed in this study is very feasible and does not require an extraction and concentration step for detection of lead in the parts per million range.

BIBLIOGRAPHY

- American Public Health Association, American Water Works Association and Pollution Control Federation. 1971. Standard Methods for the Examination of Water and Waste-water. 13th edn. N.Y.
- Anderson, R. V. 1974: Concentration of Cadmium, Copper, Lead, and Zinc in Six Species of Freshwater Clams. *Bull. Env. Cont. Toxicol.* 18(4): 492-496.
- Ayling, G. M. 1974: Uptake of Cadmium, Zinc, Copper, Lead and Chromium in the Pacific Oyster, Crassostrea gigas, Grown in the Tamar River, Tasmania. *Water Res.* 8: 729-738.
- Benoit et al. 1976: Toxic Effects of Cadmium on Three Generations of Brook Trout Salvelinus fontinalis. *Trans. Am. Fish Soc.* 105: 550-60.
- Bowen, H. J. M. 1966: Trace elements in biochemistry. Academic Press. London and N.Y. 241pp.
- Bowen, H. J. M. 1974: *J. Radioanalytic Chem.* 19: 215.
- Brooks, R. R. Pollution Through Trace Elements in Environmental Chemistry. Bocuris, ed. 1977. Plenum Press: New York and London.
- Brooks and Rumsby. 1966: The Biochemistry of Trace Element Uptake by Some N. Zealand bivalves. *Limnol. Ocean.* 10: 521-527.
- Brown, V. M. 1968: The Calculation of the Acute Toxicity of Mixtures of Poisons to Rainbow Trout. *Water Res.* 2: 723-733.
- Carter, John W. and Ivan L. Cameron. 1972: Toxicity of Heavy Metals Using Tetrahymena pyriformis. *Water Res.* 7: 951-961.
- Chisolm, J. J. J. 1971: Lead Poisoning. *Sc. Am.* 224(2): 15-23.
- Committee on Biological Effects of Atmospheric Pollutants. 1974. Medical and Biological Effects of Environmental Pollutants. Nat. Ac. Sc. Washington, D.C.
- Davies et al. 1976: Acute and Chronic Toxicity of Pb to Rainbow Trout (*salmo gairdneri*) in Hard Water and Soft Water. *Water Res.* 10: 199-206.
- Daines et al. 1970: Atmosphere Pb: Its Relationship to Traffic Volumes and Proximity to Highways. *Env. Sc. Technol.* 4: 318-323.

- Delves, H. T. 1978: Analytical Techniques for Blood-Lead Measurements. J. Anal. Toxicol. 1(6): 261-264.
- Durham and Whitley. 1971: Water Poll. Con. Res. Ser. 18050 DZZ. Environmental Protection Agency. Washington, D.C.
- Ediger, R. D. 1973: A Review of Water Analysis by Atomic Absorption. Atomic Absorption Newsletter (12): 151-157.
- Fairhall, Lawrence Turner. Industrial Toxicology. 2nd ed. 1962. Hafner Publishing Co.: New York.
- Friend et al. 1977: Ashing and Wet Oxidation Procedures for the Determination of Some Volatile Trace Metals in Foodstuffs and Biological Materials by AAS. Atomic Absorption Newsletter (16): 2.
- Goldberg, E. D. 1965: Review of Trace Element Concentrations on Marine Organisms. Puerto Rico Nuclear Center. Mayaguez. 535pp.
- Halcombe et al. 1976. Long-term Effects Lead Exposure on Three Generations of Brook Trout (Salvelinus fontinalis). J. Fish Res. Bd. Con. 33: 1731-44.
- Hullinger, David L. 1969: Phosphates in Peoria Lake: A Quantitative and Qualitative Evaluation in Natural Waters. Ill. St. Aca. Sci. Trans. 62(2): 198-217.
- Ireland, M. P. 1973: Result of Fluvial Zinc Pollution on the Zinc Content of Littoral and Sublittoral Organisms in Cardigan Bay, Water. Env. Pollut. (4): 27-35.
- Jones, J. R. E. 1938: The Relative Toxicity of Salts of Pb, Zn, and Cu to the Stickleback and the Effect of Ca on the Toxicity of Pb and Zn Salts. J. Exp. Biol. 15: 394-407.
- Jovicie. Ulcer and Gastritis in the Professions Exposed to Pb and Zn in Pb Poisoning in Man and the Environment. Jerigan et al. ed. 1973. Mss. Inf. Corp.
- Klein, L. 1962: River Pollution II: Causes and Effects. Butterworths London, England.
- Klevay et al. 1971: A controlled Environment for Trace Metal Experiment on Animals. Env. Sci. Tech. 5(12): 1196-1199.
- Kopp, J. F. and R. C. Kroner. 1975. Trace Metals in Waters of the U.S.: A 5-Year Summary of Trace Metals in Rivers and Lakes of the U.S. Cincinnati: U.S. Dept. Int. Fed. Water Poll. Control Adm. Div. of Pollution Surveillance.
- Langford, J. C. 1969: Procedure for the Determination of Pb 210 in Biological Samples. Anal. Chem. 41: 1716.

- Langford, J. C. Particulate Pb, Pb 210, and Po 210 in the Environment in Pb Poisoning in Man and the Environment. Jerigan et al. ed. 1973. Mss. Inf. Corp.
- Leland and McNurney. 1974: Transport of Persistent Chemicals in Aquatic Ecosystems. Sponsored by the National Research Council of Canada.
- Mathis and Cummings. 1973: Selected Metals in Sediments, Water, and Biota in the Illinois River. J. Wat. Poll. Cont. Fed. 45: 1573-1583.
- Mayfield et al. 1973: Heavy Metal Pollution in the Sediments of the Coeur D. Alene River. Env. Pollut. 7(1): 263-266.
- Mount, D. I. and W. A. Brungs. 1967: A Simplified Dosing Apparatus for Fish Toxicology Studies. Water Res. 1: 21-29.
- Mullins. The Chemistry of Water Pollution in Environmental Chemistry. Bockris, ed. 1977.
- Mushak, P. 1977: Advances in the Analysis of Toxic Heavy Elements Having Variable Chemistry Forms. J. Anal. Toxicol. 1(6): 286-291.
- Nehring, R. D. 1976: Aquatic Insects as Biological Monitors of Heavy Metal Pollution. Bull. Env. Cont. Toxicol. 15: 147-154.
- Patrick and Loutit. 1975: Passage of Metals in Effluents Through Bacteria to Higher Organisms. Water Res. 10(4): 333-335.
- Patterson, C. 1965: Contaminated Natural Pb in Environments of Man. Arch. Env. Health 11: 335-344.
- Patterson, C. Pb in the Environment in Pb Poisoning in Man and the Environment. Jerigan et al. ed. 1973. Mss. Inf. Corp.
- Patterson, Settle and Glover. 1976: Analysis of Pb in Polluted Coastal Water. Mar. Chem. 4(4): 305-319.
- Pentreath, R. J. 1973: The Accumulation from Water of ⁶⁵Zn, ⁵⁴Mn, ⁵⁸Co, and ⁵⁹Fe by the Mussel Mytilus edulis. J. Mar. Bio. Assn. UK 53: 127-143.
- Pringle et al. 1968: Trace Metal Accumulation by Estuarine Mollusks. J. Sanit. Eng. Div. Amer. Soc. Civ. Eng. 455-475.
- Rehwalt et al. 1973: The Acute Toxicity of Some Heavy Metal Ions Toward Benthic Organisms. Bull. Env. Contam. Toxicol. 10: 291-294.
- Sartoty, D. P. and B. J. Lloyd. 1976: The Toxic Effects of Selected Heavy Metals on Unadapted Populations of Vorticella. Water Res. 10(12): 1123-1127.

- Scott et al. The Effects of Lead on Mitochondrial Reactions in Pb Poisoning in Man and the Environment. Jerigan et al. ed. 1973. Mss. Inf. Corp.
- Shepar et al. 1978: Toxicity and Bioaccumulation of Cd and Pb in Aquatic Inverts. *Env. Pollut.* 15(3): 195-208.
- Smith et al. 1975: Uptake of Hg by Freshwater Clams (family Unionidae). *J. Fish. Res. Board Can.* 32(8): 1297-1304.
- Sprague. 1961: Measurement of Pollutant Toxicity to Fish. 1. Bioassay Methods for Acute Toxicity. *Water Res.* 3: 793.
- Tatsumoto, M. and C. Patterson. 1963: Concentrations of Common Pb in Some Atlantic and Mediterranean Waters and in Snow. *Nature* 199: 350.
- Trollope, D. F. and Evans. 1976: Concentrations of Cu, Fe, Pb, Ni, and Zn in Freshwater Algae Blooms. *Env. Pollut.* 11(2): 109-115.
- Tuekein et al. 1973: Trace Element Trapping in Pteropod Tests. *Limnol. Ocean.* 18: 240-249.
- Vivian, C. M. G. and K. S. Massie. 1976: Trace Metals in Waters and Sediments of River Tawe, S. Wales in Relation to Local Sources. *Env. Pollut.* 14(1): 47-62.
- Ward et al. 1974: Effect of Pb from Motor Vehicle Exhausts in Trees Along Major Thoroughfares in Palmerston North, N. Zealand. *Env. Pollut.* 6: 149-158.
- Watling, Helen R. and R. J. Watling. 1976: Trace Metals in Oysters from Knysna Estuary. *Mar. Poll. Bull.* 7(3): 45-48.
- Wurtz, C. 1962: Zn Effects on Freshwater Mollusks. *Nautilus* 76(2): 53-61.
- Yeager et al. 1971: Determination of Pb in Biological Samples and Related Material by ASS. *Env. Sc. Technol.* 5(10): 1020-1022.