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Lead-poisoning in two distant states of Nigeria: an indication of the real size of the problem

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Summary

Lead is a toxic trace metal but useful in a number of industries and occupations. In view of its wide usage appropriate attention to precautionary measures against excessive exposure is desirable. The study was carried out in two phases; one based in Southwest Nigeria involving 137 subjects comprising 86 occupationally exposed subjects and 51 controls. Phase 2 of the study involved 880 occupationally unexposed subjects as follows: 115 subjects ffom Iseyin, 280 subjects from Shaki, 284 subject from Ogbomoso and 201 subjects from Sokoto, NorthWest Nigeria. Alcohol, salt and tobacco consumption were carefully monitored in this second phase of the study as well as sources of potable water. Lead (pb) was determined by atomic absorption spectrophotometry (AAS). In phase one in occupationally exposed individuals PbB was significantly higher than in controls *(P<0.00.1)*; 95.3% of the test subjects had PbB greater than 40*µg*/dl, the universal upper limit of acceptable PbB in Pb workers. About 70% had PbB greater than 55*µg/dl*, a level now considered indicative of excessive exposure. Additionally, about 40% of the Pb workers had PbB of 60 *µg/dl* and above, a level indicative of the need to remove affected individuals from further exposure. Only about 5% of the Pb workers had PbB below 40 *µg/dl*. Interestingly, in the control subjects only about 18% had blood Pb levels falling within commonly acceptable PbB levels, about 7% of controls (Occupationally unexposed) had PbB level within the range considered indicative of moderate toxicity, over 8% had PbB above levels acceptable in occupational exposure, while about 4% fell within the range indicative of severe toxicity. PbB for unexposed population therefore, also give cause for toxicity. Phase 2 study revealed that excessive use of alcohol and tobacco, undue exposure to exhaust from vehicles using leaded gasoline, exclusive use of wells as sources of drinking water and increased consumption of the Nigerian table salt may all be pathways for increased Pb burden in this environment. These data suggest Pb poisoning of a high magnitude arising from occupational and environmental factors probably largely due to high gasoline Pb. Precautionary measures appear desirable by all who are occupationally or environmentally exposed to Pb.

Keywords: *Blood lead level, Saturnism, Environmental lead, Pollution, Gasoline, Lead workers.*

Résumé

Le plomb est un element metalique toxique, mons utile dans un certain nombre d,industries et d'occupations. A cause de s large utilisation, une attention particulars sur les mesures a preudre contre les effets indesirables due a son exces d'utilisation. Cette etude a ete faite en 2 phases; l'une base au Sud-ouest du Nigeria incluant 137 sujets, fait de 86 travailleurs exposes au plomb et 51 sujets controles. La deuxieme phase de l'etude a inclue 880 travailleurs non-exposes divises de la maniere sui vant: 115 sujets provenant de Iseyin, 280 sujets de Shaki, 284 sujets de Shaki, 284 sujets d'Ogbomosho et 201 sujets de Sokoto au Nord-ouest du Nigeria. La consomation d'alcool, sel et tabac autant que les sources d'eoux potable ont ete aftantivement etudies pendant la deuxie.e phase de cette etude. La presence de plomb a ete determine par la spectrophotometre d'absorption atomique (AAS). Dans la premiere phase de l'etude le taux de plomb chez les travailleurs exposes au plomb etait signficatif compares aux controles (P 0.001). 93.3% des sujets testes ont en un taux de plomb sanguin superieur a 40 ug/dl, valeur superieur a la limite superieure du taux de plomb universelle acceptable chez les travailleurs exposes Pb sanguin de 60/ug/dl et au dessus, valeur indicative d'un besoin urgent deviter a les indivudus a une exposition prolonge. Seul environ 5% de ces travailleurs exposes au plomb on eu un taux de plomb on eu un taux de plomb sanguin en dessous de 40 ug/dl. II est interessant de mentioner que environ 18% des sujets seulement ont eu le taux de plomb sanguin en dessous du taux acceptable chez les controles. Environ 7% des controles (non exposes par leurs occupations) ont eu leur taux de Pb sanguin compris dans la marge consideree comune moderement toxique. Plus de 8% des sujets ont eu un taux au dessus du taux acceptable d'apres leur occupation, tandisque 4% des sujets environ sont tombes dans la marge indicative de toxixite severe. Le taux de Pb sanguin cause aussi la toxicite chez les population non-exposes. La deuxieme phase de l'etude a revele une utilisation excessive de l'acool et du tabac, et l'exposition abusive des fumes provenant des vehicules utilisant le gasoil plombe. Les oaux de source et la consomation du sel de table pourrait aussi etre implique dans l'augmentation des traces de Pb sanguin dans cet environement. Ces resultats suggerent une forte magnitude d'empoisonement due a l'occupation d'exposition au Pb. Par ailleurs, les facteurs environementaux telsque la forte consomation de gasoil plombe sentribuent aussi a cette toxicite. Les mesures de precautions sont necessaire pour toux cause qui sont occupationellement ou environementalement expose au plomb.

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Introduction

Lead (Pb) is a soft greyish-blue heavy metal with poisonous chemical salts. It has three oxidation states of o, + 2, + 4. The element is universally present in rocks, soil and plants and its concentration is higher in urban areas than in the hinterland [1]. The largest single use of Pb is for the manufacture of storage batteries [2]. Lead salts also form the basis of many paints and pigments [3]. In its arsenate compound, it enjoys wide applicability in the insecticide industry. The sulphate and acetate compounds, it enjoys wide applicability in the insecticide industry. The sulphate and acetate compounds have important uses in rubber compounding while lead naphtenate is used extensively as a dryer. Tetra-ethyl lead, one of the most important compounds of lead, is used as an "anti-knock" additive for gasoline. In view of this wide applicability of lead in the industries, painstaking attention should always be paid to those precautionary measures that are capable of guarding against an undue exposure of workmen, artisans and the general populace to Pb. This is because Pb is a poison in all its forms [3]. Excessive exposure of humans to lead in the air, water and food products has been known to have significant adverse effects on the renal [15], nervous, hemopoietic [7], immune [8] and endocrine [9] systems. In the light of these wide-range adverse implications of severe lead exposure, it was decided to explore the magnitude of the problem of lead posoning (plumbism, saturnism) in Nigeria.

Materials and methods

Subjects

In the first phase of these investigations, 137 subjects were selected comprising of 86 test subjects and 51 controls. The test subject were recruited from two battery plants, one paint industry, a petroleum depot, an insecticide – producing company and 10 gasoline distribution centres, all located at Ibadan, SouthWest, Nigeria. The distribution of lead workers in the study was as follows: battery plant A 17 subjects, battery plant B 20 (for both plants 37 subjects): paint industry 20 subjects, petroleum dept 14 subjects; insecticide factory 5 subjects and one each from 10 gasoline distribution centres. The control, unexposed subjects were indoor administrative office workers who were not occupationally exposed to lead. They were selected to match the exposed group in age, sex socio-economic status and level of education. Those who consume alcohol and those who use tobacco were carefully noted. The mean age of the control subjects was 25.3 (S.D. ± 4.7, range 23-52) years. The criteria for selection of control subjects was history of absence of occupational or hobby exposure. In the second phase, a total of 880 subject who were not occupationally exposure to lead were selected from three additional locations in South-West Nigeria (Iseyin 115, Shaki 280 and Ogbomoso 284) and one location in North-West Nigeria (Sokoto, 201). The mean age of this large group of unexposed subjects was 25.8 (SD 6.3, 20 – 55) years. They were largely artisans and farmers who were occupationally exposed to Pb. Those who use tobacco and alcohol were carefully noted. In addition, those who by habit, compulsively add salt to any food they are about to consume were also carefully noted. The source of drinking water for each of the subjects was established.

Analysis of blood lead

Disposable pyrogen and leadfree needles and syringes (Becton – Dickinson, Dublin, Ireland) was used to collect all blood specimens. Blank test on these syringes did not reveal any lead. After a stable baseline was established with water-saturated methyl isobutyl ketone (MIBK), the absorbance was also recorded to validative linearity. Additionally, in order to avoid contamination, all containers and other equipment employed for sampling, analysis and storage were checked for lead content before sampling in a manner similar to that of united Nations Environment Programm/World Health Organisation (Human Exposure Assessment location, programme UNEP/WHO, Nairobi, Kenya).

In all 1,017 subjects' whole blood was measured by Atomic Absorption Spectrophotometry (AAS) using the modified method of Hessel [10].

The method is based on chelation and extraction, thus enhancing sensitivity. The method compares favourably with Graphite Furnace absorption spectrophoto-metry (GFAAS). The assay was carried with an extractor to suck away contaminated air. (Trace metal clean procedures). The significance of difference was assessed using the student's test for unpaired observations and the X^2 test for association. Informed consent was received from all subjects that participated in this study.

Result

Table 1 shows the mean blood lead levels PbB in lead-workers, control subjects and in a larger group of unexposed subjects. The only difference between the latter group and the designated control group was that subjects were selected from a very wide area of the country.

Table 1: Blood lead levels (PbB) in lead-workers, control unexposed subjects and in other occupationally subjects.

	Number of Subjects	Age (Years)	Blood Lead Level $\mu g/dl$
Lead-workers	86	24.8 ± 5.8	56.3 ± 0.95 (26 – 97)
Control subjects	51	25.3 ± 4.7	30.1 ± 1.47* (10 – 58)
Other unexposed Subjects	880	25.8 ± 6.3	28.8 ± 1.22* (15 – 63)

All values are means ± S.D. with range in parenthesis
**Compared with lead-workers, values are significantly lower (P < 0.001).*

The PbB in lead-workers was, as expected, significantly higher than those of unexposed subjects (*P , 0.001 in both cases*). Furthermore, it is necessary to look at the distribution of the PbB more closely. A high percentage (95.3%) of the test subjects had PbB greater than 40 $\mu g/dl$. (Table 2). This is the universal current upper limit of acceptable PbB in lead-workers [11,12]. About 70% had PbB of 55 $\mu g/dl$ and above, a level now considered to be indicative of severe exposure [13]. Worse still, about 40% of the lead-workers had PbB of 60 $\mu g/dl$ and above, a level indicative of the need to remove an affected individual from further exposure [14]. Only about 5% of the lead workers had PbB of less than 40 $\mu g/dl$ (Table 2).

Table 2: Distribution of blood lead levels in exposed and unexposed subjects.

Category of subject	Number of subjects Pb values	Blood lead levels (µg/dl)	% of subjects exhibiting critical Pb values
Exposed	86	>40	95.3
Exposed	60	55-59	69.8
Exposed	31	60 and above	37.2
Exposed	4	<40	4.7
Unexposed	9	10 – 20	17.6
Unexposed	36	21 – 39	70.6
Unexposed	4	40 – 54	7.8
Unexposed	2	>55	3.9

The data for control (unexposed) subjects are equally interesting and noteworthy. The most widely currently acceptable range of PbB in unexposed population is between 10 and 20 µg/dl [15]. In the present study, only about 18% of the designated control subjects fail within this acceptable range (Table 2). In actual fact, about 70% of the occupationally unexposed subjects had PbB that falls within the range regarded as moderate toxicity level (21-39 µg/dl [16] for unexposed populations. It is also of significant importance that about 8% of the unexposed subjects exhibited PbB well above the acceptable level in occupationally exposed subjects exhibited PbB well above the acceptable level in occupationally exposed subjects (40-54 *µg/dl*) while about 4% within the group actually appeared classifiable with the severe toxicity group (>55 *µg/dl*, Table 2).

From the large number of occupationally unexposed subjects that were available, investigations were carried out on test of association between PbB and various indices/parameters such as age, alcohol and tobacco use, undue exposure to leaded gasoline, local table salt and source of drinking water. The results are shown in Tables 3-8.

Discussion

The high mean PbB obtained in occupationally exposed subjects in this study is consistent with the findings in other previous reports of similar populations throughout the world [17-20]. However, unlike what obtains in such previous studies, our own mean PbB is higher than those found in the United States [2], (37.1 *µgdl/*) in Jamaica [21] (33 µg/dl), in Korea [22] (45.7 µg/dl) and in the Untied Kingdom [15] (39.4 µg/dl). Indeed, the mean PbB in occupationally exposed subjects in a wide section of this country as reported in our present study falls within the range normally currently classified as severe lead poisoning. The implication of this finding for the subjects selected for our study can therefore be viewed in one of two ways. Firstly most of the subjects should have long left their duty posts in the various industries in order to stop further undue exposure to the environmental poison. Secondly and in the alternative, most of them should be undergoing treatment for lead poisoning as well as being kept under very strict surveillance for adverse manifestations of lead poisoning.

To the best of our knowledge, neither of these suggestions was being considered for the lead workers at the time of sampling and actually neither the employers nor the employees themselves were entertaining any anxieties about the dangers associated with undue exposure. This re-emphasizes the low level of awareness of the risks involved with prolonged exposure to lead in this environment.

The mean PbB obtained for control unexposed subjects is considered to be of even more serious concern. The value obtained in this study is about 2-3 times the current levels in similar populations elsewhere [22,23]. Indeed, the level falls within the range currently being considered to be moderate lead poisoning [16]. The question therefore arises about what specific unexposed subjects. Following the distribution profile of PbB in unexposed subjects (Table 2) correlation patterns with various factors and/or indices were considered useful. We were not able to confirm that age plays any significant role even in a cumulative manner in PbB of subjects who were not in any way occupationally exposed to lead either in their living environments or in their work environments (*P> 0.20*, Table 3). The subjects selected for the investigation were teetotalers and their source of drinking water was filtered tap water.

Table 3: Association between age and PbB in occupational unexposed subjects.

Age range (years)	Occupation	No. with raised PbB	No. with normal PbB	X^2 test	*P* value
24 - 28	Clerical Assistants	16	24	1.48 2	>0.2 0
44 – 47	Clerical assistants	11	18		

In Nigeria, available sources of alcohol for its users are in four categories. These are lager beer, local wines and spirits obtainable from natural sources such as kernel and raffia palm, wine and spirits from standard, registered and properly duty-controlled distilleries and wines and spirits from crude local distilleries. The local wines and spirits are usually produced by all kinds of people using all sorts of materials and utensils with complete disregard for any form of quality control. We established very high levels of PbB in individuals that are chronic users of such locally produced wines and spirits (Table 4).

Table 4: Association between alcohol use and PbB

	Occupation	PbB of >40 µg/dl	PbB of <20 µg/dl	X^2 test	*P* value
Alcohol user	Office messengers	23	17	5.210	<0.05
Tee Totaler	Office messengers	10	30		

A strong association between use of tobacco and high PbB was also established (Table 5).

Table 5: Association between tobacco use and PbB

	Occupation	PbB of >40 μg/dl	PbB of 20 μg/dl	X^2 test	*P* value
Smokers	Medical Students	31	11	6.815	<0.01
Non-smokers	Medical Students	14	46		

The results are therefore instructive enough for the need to discourage the general populace at large from excessive usr of alcohol and tobacco and thereby safeguarding them against the subtle and long-term effects of chronic lead-poisoning such as loss of memory [24], mental retardation [25] and rapid ageing [26]. Alcoholic beverages, particularly the crude locally-produced ones, contain excessive amounts of lead and alcohol which in addition has an added disadvantage of enhancing gastrointestinal tract absorption of lead [27-29]. It has also previously been established that cigarette smoke contains large amount of lead [27] and that smokers inhale excess of about 1μg of lead per stick of cigarette compared with non-smokers. We established during the course of this study that smokers who use the lowest grade of tobacco have the highest values for blood lead levels. This implies an indirect relationship between the grade of tobacco and blood lead level. The effect of leaded gasoline in significantly contributing to PbB is highlighted in Table 6.

Table 6: Association between heavy exposure to motor vehicle exhaust and PbB

Location Residence	Occupation	PbB of >40 μg/dl	PbB of 20 μg/dl	X^2 test	*P* value
Along heavily used highways	Hotel Receptionist	16	7	6.633	<0.01
Remote Farm Lands	Farmers	4	21		

We carefully selected individuals who reside along heavily-used highways but who otherwise do not engage in any vocation normally associated with excessive exposure to lead. Lead in gasoline (petrol) is commonly considered to be one of the most important contributors to environmental lead which determines lead levels in unexposed subjects. Petroleum products that contain high lead levels are major factors in atmospheric lead pollution in countries using such energy sources [15]. The lead content of Nigeria's petroleum is very high [3] and no significant effort in reducing it has yet been made [31].It will amount to wise planning and a clearer vision in harnessing human resources if real attempts are immediately initiated in reducing lead content of Nigeria's gasoline. Many countries that had initiated such a measure now have reasons to be satisfied with the outcome of such a policy [32,33].

Another probable avenue that we considered, by which elevated levels of blood lead may occur in non-occupationally exposed subjects is the common table salt. There are reports that the common table salt produced in Nigeria contains higher levels of lead compared to those obtainable from other parts of the world [34]. This probably implies that high dietary lead is being presented to the general populace which in turn can raise PbB in the general population. Indeed, our findings in this aspect of the study suggest such a conclusion (Table 7).

Table 7: Association between excessive salt intake and PbB.

	Occupation	PbB of >40 μg/dl	PbB of 20 μg/dl	X^2 test	*P* value
Salt-shakers	Teachers	21	13	5.142	<0.05
Non-salt-shakers	Teachers	8	17		

The subjects selected to test this association were those classified as "salt-shakers" These are individuals who habitually and almost compulsively add salt to any food or snacks they are about to eat.

Finally, we also established high PbB in individuals who exclusively obtained their drinking water from wells. Most of these wells are quite shallow and for our study population, we selected subjects whose wells were close to mechanic workshops and battery plants. In those locations, dumps that are rich in lead waste are expected to be abundant.

Table 8: Association between source of drinking water and PbB.

Sources of Drinking water	Occupation	PbB of >40 μg/dl	PbB of 20 μg/dl	X^2 test	*P* value
Filtered, tap	Sub-dean Teachers	24	60	5.183	<0.05
Shallow wells <25ft deep	Sub-urban Teachers	32	22		

Overall, our corroborated investigations present the picture of a study, which suggests that, the magnitude of the problem of lead-poisoning (plumbism, saturnism) in the states studies and by corollary in Nigeria, going by current standards, is very substantial.

In conclusion, we have been able to suggest that a variety of factors such as excessive alcohol and tobacco use, increased salt intake, prolonged use of shallows well water as an exclusive source of drinking water and undue exposure to leaded gasoline may all be wholly or partly responsible for the development of chronic lead-poisoning in Nigeria. It is our wish tat efforts be geared towards public enlightenment about the adverse effects of these factors. In addition, both employers of labour and employers in lead-based industries should cooperate in designing and formulating safe and rigid precautionary measures against under exposure to lead in work and living environments. All these suggestions taken together will definitely help in eliminating the silent harm of plumbism with numerous complications and aetiological contribution to other disorders.

References

1. Shapiro H, Johnston JD. Lead: In Encyclopedia of Chemistry. Parkers (ed) McGrawhill Book Company New York 1982; pp. 55-61.
2. Gartise PS Buncher CR Lerner S. Relationship of air lead and blood lead of worker at an automobile battery factory. Int. Arch. Environ Health 1982; 50: 1-10.
3. Zielhuis RL. Lead alloys and inorganic compounds. In Encyclopedia of occupational Health and Safety permeggiani. L. (ed). Revised 3rd edition vol. 2 International labour orgnisation Geneva 1983; pp 1200-04.
4. Shy CM Lead in petrol: the mistake of the Xxth century. World Health Stat. Q. 1990; 43: 168-176.
5. Goyer RA Ryne B. Pathological effects of lead. Int. Rev. Exper Pathol 1973; 12: 1-77..
6. Goyer RA Lead toxicity: current concern .Environ health perspect 1993; 100: 177-187.
7. CDC: Preventing lead poisoning in young children. J. Pediat 1978; 93: 709-720.
8. Jaremin B. Immunological humoral responsiveness in men occupationally exposed to lead. Bull Inst Trop Med Gdymia 1990; 4: 27-36.
9. Cullen MR., Robins JM Eskenazi B. Adult inorganic lead intoxication: presentation of 31 cases and review of recent advances in the literature. Medicine 1983; 62: 221-247.
10. Hesset DN. A simple and rapid quantitative determination of lead in blood. Atom Absopt News Lett. 1968; 1.7:50-55.
11. WHO (World Health Organisation). Recommended Health based limits in occupational exposure to heavy metals. Technicals report series 647, World Health Organisation, 1980; Geneva pp. 116.
12. Landrigan PJ. Strategies for the epidemiologic studies of lead in bone in occupationally exposed populations. Environ Health Perspect. 1991; 91: 81-86.
13. Harvey B. Should blood screening recommendations be revised? Pediatics 1994; 93: 201-240.
14. OSHA (Occupational Safety and Health Administration). Occupational exposure to lead. Final Standard Fed. Register. 1978; 43: S 2952 – 3014.
15. Ferguson JE Lead: Petrol lead in the environment and its contribution to human blood levels. Sci. Total Environ. 1986; 50: 1-54.
16. US Environmental Protection Agency. Control techniques for lead air emissions EPA 1977; 450/2-77-012.
17. Grobler SR Mavesky LS and Karze TJV. Reduction of petrol and blood lead. Concentration in athletes. Arch. Environ Health 1992: 47: 139-142.
18. Marinho PE. Frazblau A, Lilis R, Landrigan PJ Acute lead poisoning in construction workers: The failure of protective standard. Arch Environ Health 1989; 44: 140-145.
19. Goldman RH, Baker EL., Hanna M, Kameron DB. Lead poisoning in automobile radiator mechanics. N Engl J. Med. 1987; 317: 214-218.
20. Clausen J Rastogi S, Heavy metal pollution among automobile workers. Brit. J. Ind Med 1977; 34: 208-215.
21. Matten JD Figuerra JP Ostrowski S. and Burr G. Lead poisoning among household members exposed to lead-acid battery repair shop in Kingston, Jamaica, Int. J. Epidemol 1989: 18: 874-81.
22. Kim Y, Haruda K, Ohmori S, Lee Bk Miura H and Ueda A., Evaluation of lead exposure in workers at a lead-acid battery factory in Korea. Occup. Environ. Med 1995; 52: 484-488.
23. Leung FY, Bradley C, Peller T. Reference intervals for blood lead and evaluation of Zinc protoporphyrin as a screening test for lead toxicity. Clin Biochem 1993: 26: 491-496.
24. Anthony DC, and Graham DG., Toxic responses of the nervous system. In: Casarett and Doull's Toxicology: The Basic Science of poisons. Amdur M.O., Doull J, Klassen C.D. (eds). 4th edn. Pergamon Press, New York, 1991; pp. 407-429.
25. Louria DD. Trace metal poisoning In: Cecil Text book of Medicine. Wyngaarden JB, Smith LH., (eds) WB Saunders Company, Philadelphia 1985; pp 2307 – 2309.
26. Waldron HA. Industrial Toxicology. In: Lecture note on occupational medicine, 4th edn. Blackwell Scientific Publications. London 1990; pp. 12 – 18.
27. Savory G. Lead Clin Chem News 1989; 15 : 7 and 17.
28. Muldoon SB., Cowley JA., Kuller LH., Scott J, Rohay J. Lifestyle and sociodemographic factors as determinants of blood lead levels in elderly women. Amer. J. Epidemiol 194; 139; 599-608.
29. Goyer RA., Toxicology effects of metals. In: Casarett and Doull's J, Klassen C.D. (eds) 4TH edn. Pergamon press, Basics Science of Poisons. Amdur MO., Doull J. Klassen C.D. (eds) 4th edn. Pergamon Press, N.Y. 1991; pp 623-680.
30. Arah RO. Lead-free gasoline in Nigeria by the year 2000. Proc 4th Int. Seminar on the Petroleum Industry and Nigerian environment, Fed. Min. Works and Housing, Nigeria, 1985; pp. 339-346.

31. Osibanjo O. and Ajayi SO. Trace metals analysis of petroleum products by flame AAS Nig. J Nat Sci 1989; 4: 33-40.
32. Kapaki EN, Varelas PN, Syrigen et al. Blood lead levels of traffic – and gasoline-exposed professionals in the city of Athens. Arch Environ Health 1998; 53: 287 – 291.
33. Elinder CG, Friberg L, Lind B, Nilson B, Svartengren M, and Overmark, I: Decrease blood levels in residents of Stockholm for the period 1980 – 84. Scand J. Work Environ Health 1984; 12: 114 – 120.
34. Dim LA., Kinyua AM., Muniyitha J.M. and Adetunji J. Lead and other metal distribution in local cooking salt from the Fofi Salt Spring in Akwana, Middle Benue through, Nigeria J. Environ Sci. Health 1991; 26: 357 – 365.