

Assessment of Exposure to Lead in Humans and Turtles Living in an Industrial Site in Coatzacoalcos Veracruz, Mexico

N. A. Pelallo-Martínez · C. A. Ilizaliturri-Hernández ·
G. Espinosa-Reyes · L. Carrizales-Yáñez ·
D. J. González-Mille

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Abstract The intake of lead from the environment may occur thru various receptors. In order to measure lead levels absorbed, samples were taken from Children who live in three localities surrounding an industrial complex in Coatzacoalcos, Veracruz. Samples were also taken from turtles. Samples were analyzed and results were compared against the general population. In children tested, over 75% of all values were determined to be above CDC's safety levels of (10 µg/dL). The geometric mean lead concentration was 11.4 µg/dL, which is clearly higher around the industrial complex than in the general population. In turtles, lead blood levels in the exposed population were 2-fold above (24.2 µg/dL) those of turtles in the reference population (10.1 µg/dL). Lead levels observed represent a risk for both human and fauna health.

Keywords Lead · Exposure assessment · Children · Turtles

History shows a 20-fold increase in lead deposition during the last 150 years around the globe. A sudden increase in atmospheric lead occurred during the industrial revolution, with a later burst during the 1920s when lead alkyls were first added to gasoline. Through emission, lead moves through the atmosphere to various components within the environment. Lead is deposited in soil and plants as well as

in animals. (EPA 1986) Lead is highly toxic and affects virtually every system of the body. It can damage a child's kidneys, central nervous system and cause anemia. Hematological and neurological responses are the most commonly reported afflictions from extended lead exposure in animals. (EPA 1986; ATSDR 2007; Levin et al. 2008).

In Coatzacoalcos, Veracruz, located in the Mexican Isthmus, there is a large chemical and petrochemical industrial complex. This site served until recently to run and operate Tetraetilo de México (TEMSA) the most important producer of tetraethyl lead, which has been used as a gasoline additive for approximately 37 years. In 1997, production of tetraethyl lead stopped. Consequently, Tetraetilo de Mexico was closed. (Flores and Albert 2004) Coatzacoalcos City (population: 234,174) is located at ≈7 km from this industrial complex. Moreover, the Coatzacoalcos river basin has been one of the most diverse biological areas in Mexico (Bozada and Páez 1986). Unfortunately, these ongoing emissions of lead to the environment by TEMSA's production activities, suggest a continued exposure of the population who live around the industrial complex and a significant negative impact to the biota in the area.

Wildlife species can be used for detection and evaluation of chemical contamination in the environment. Turtles are suitable indicator species because they have several key characteristics associated with their metabolism, life history and ecology (Overman and Krajicek 1995; Gibbons 1990). This makes them ideal for studies of chronic exposure to local contaminants. *Trachemys scripta* is geographically widespread across Mexico and Central America (Burger and Gibbons 1998). This species has been utilized for exposure assessment to metals, radiation, organochloride pesticides and polybrominated biphenyls

N. A. Pelallo-Martínez (✉) · C. A. Ilizaliturri-Hernández ·
G. Espinosa-Reyes · L. Carrizales-Yáñez · D. J. González-Mille
Departamento de Toxicología Ambiental, Facultad de Medicina,
Universidad Autónoma de San Luis Potosí, Avenida Venustiano
Carranza 2405, Col. Lomas Los Filtros, 78210 San Luis Potosí,
SLP, México
e-mail: na_pelallom@yahoo.com.mx

(Bickham et al. 1988; Bergeron et al. 1994; Meyers-Schöne and Walton 1994; Lovelette and Wright 1996; Burger and Gibbons 1998; Willingham and Crews 1999, 2000).

As a first step to quantify the problem, we measured lead absorbed in blood (PbB) in samples taken from turtles and children living near the industrial complex.

Materials and Methods

Blood samples were collected from 54 schoolchildren from three localities near the Petrochemical Complex: Allende, Coatzacoalcos (López Mateo's neighbor) and Mundo Nuevo. Samples were taken during October 2006. The three localities and populations that are potentially most exposed considering the dominant winds blowing to the south and southeast are as follows: Mundo Nuevo; Coatzacoalcos; and Allende, respectively. Sample locations are shown in Fig. 1.

Studies involving humans were conducted in accordance with national and institutional health guidelines for the protection of human subjects. Children were selected at random from among those who met the following inclusion criteria: healthy children (as reported by their parents) aged 6–12 children who were born and had always lived in their community since they were born. A questionnaire was used to collect information about health status and risk factors. Twenty-one children were selected for the study. All of them decided to participate in the study. Blood was drawn from veins using lead-free tubes

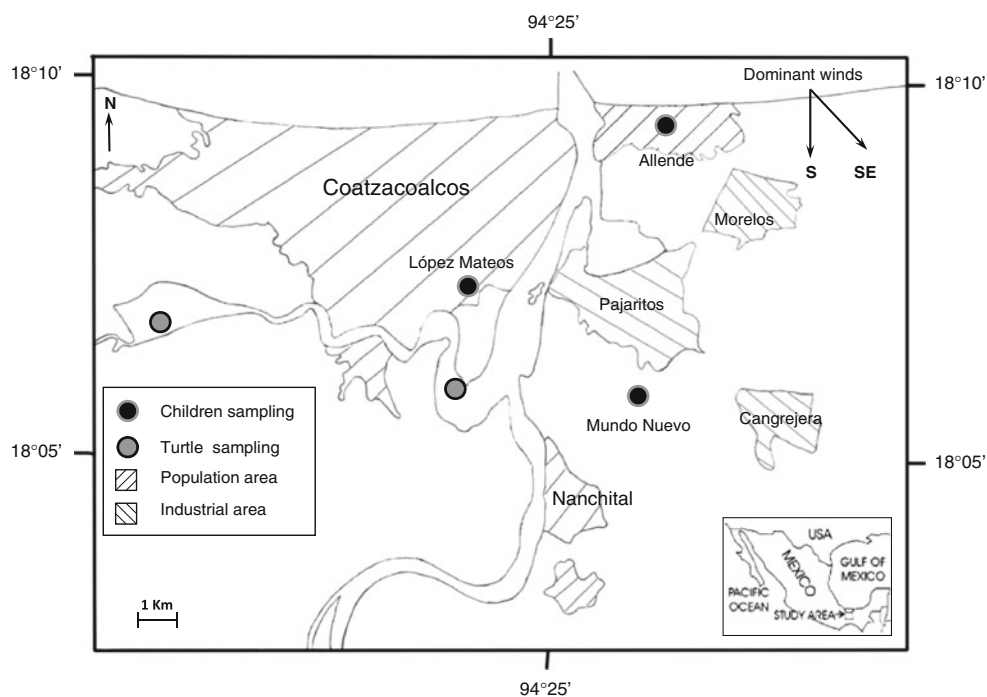
containing ethylene diamine tetra- acetic acid (EDTA) as an anticoagulant.

Three turtles per site were captured from each of two areas of the lower basin of the Coatzacoalcos River (Fig. 1). Area one (López Mateos), regarded as a high exposure area, is located 5 km away from TEMSA. Area two (Laguna del Tepache) was considered a reference area, located 15 km away from TEMSA. Baited piper traps were placed near fallen trees and along the edge of the river during the afternoon and checked early the following morning. After capture, 3 ml whole blood samples were drawn using a heparinized needle and syringe from the brachial vein. In Mexico, slider turtles are considered an endangered species and are protected by Mexican laws. All turtles were caught on October 2006 and collected with a Scientific Collector's Permit (Colector Científico de Flora y Fauna Silvestre) issued by SEMARNAT (No. FAUT-0133).

The presence of lead in blood (PbB) in children and turtle samples were determined using a matrix modifier (diammonium hydrogenphosphate-Triton X-100 in the presence of 0.2% nitric acid) according to Subramanian (1989), and the samples were analyzed with a Perkin-Elmer 3110 atomic absorption spectrophotometer using a graphite furnace with a Limit of detection of 1 µg/L. At the time of the study, our laboratory was participating in the blood lead proficiency testing program of the Center for Disease Control with recoveries of 97%.

The difference between PbB in turtle blood was assessed using Mann–Whitney U test data. PbBs differences in

Fig. 1 Localization of sampling point



children were evaluated using Kruskal–Wallis' test. Analyses were conducted using STATISTICA version 8.0 (STATISTICA 2001).

Results and Discussion

The reference level (10 µg/dL) for PbB is a guideline set by the US Center for Disease Control (CDC 1991). We observe that the children's exposure exceeds safe levels. The percentage of children with lead levels above CDC guidelines increased in relation to the location of the community with dominant winds blowing to the south and southeast (Table 1). There is a significant difference between communities ($p < 0.1$). Many studies have demonstrated neuro-developmental disorders at PbB levels of 5 µg/dL (ATSDR 2007). In this study, all of the tested children consistently showed levels above this value. Furthermore, PbB levels (Mean $\pm$ Standard Error, Fig. 2) in turtles collected at López Mateos (exposed animals) were significantly higher (24.2 ± 2.3 µg/dL, $p < 0.05$) than those collected in the reference area (10.1 ± 0.25 µg/dL).

Observing the results that were obtained we can infer that human population and fauna living near the industrial complex in Coatzacoalcas are exposed to lead. The significant difference between PbB within the reference population and that of the exposed population shows that there is a distinct lead contribution to the environment.

In humans, the average elimination time of lead from blood is approximately 30 days. The presence of PbB usually means relatively recent exposure and cannot be used to distinguish between low-level, intermediate or chronic exposure and high-level acute exposure. Laidlaw et al. (2005) has demonstrated the PbB variability associated to seasonal variation of children's Pb exposure. On the other hand, the metabolic rate and physiological characteristics of poikilotherms, is correlated with a long red cell life span. The mean life span of the turtle's red cells is between 600 and 800 days (Altland and Brace 1962). This means that the turtle's PbB intake occurred about 20 months ago. PbB in turtles is a biomarker that shows chronic exposure to lead driven by a distinct and constant lead emission to the environment. In areas with dynamic

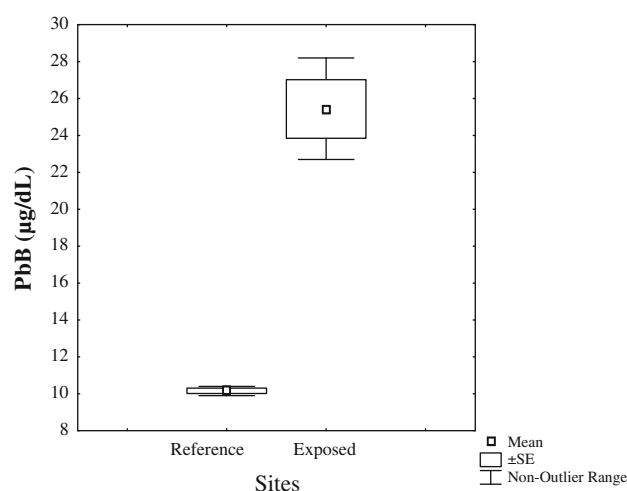


Fig. 2 Blood lead levels in turtles from reference and exposed area

meteorological conditions these play a relevant role because wind changes, hurricanes, storms and other climate parameters or variations of industrial emissions modify the patterns of exposure. In this case, evaluating exposure to lead in turtles can be used to minimize these uncertainties. In addition, this testing establishes physiological benchmarks which further support the usefulness of poikilotherms as good biomonitors of lead exposure in industrial sites (Arrieta et al. 2001).

In addition, it is clear that there is bioavailability and resulting exposure to lead taking place here both in humans and in the biota. Levels detected in children (>5 µg/dL) may be associated with neurobehavioral disorders. There are no guidelines for lead levels in turtles. However, some authors (Lovelette and Wright 1996) have demonstrated a long-term effect of Pb exposure on reducing ALAD activity in slider turtles as compared with controls (up to 73% decline) and a small decline (10%) in hemoglobin levels; Overman and Krajicek (1995) found that ALAD was dramatically lower (60–90% decline) in snapping turtles (*Chelydra serpentina*) collected in areas of lead contamination in comparison with those taken from reference sites.

Long term lead exposure in humans has also shown a decrease in ALAD activity (Ahamed et al. 2005). For this reason, ALAD activity has been considered to be the most sensitive biological indicator of lead exposure. So, in this particular case, ALAD activity evaluations in humans and biota can further support the cumulative effect assessment. This will result in a new integral approach to risk assessment.

An integrated approach can be an interesting tool for developing countries. In this context the remediation programs should be established in terms of public health issues and/or preservation of natural resources, including biota

Table 1 Lead in blood concentration (µg/dL) in children

Locality	n	G Mean	Min–Max	% >5 µg/dL	% >10 µg/dL
Allende	12	10.5	8.9–13.5	100	58
López Mateos	22	11.2	9.2–19.1	100	81
Mundo Nuevo	24	12.4	9.1–25.4	100	96

G Mean geometric mean, Min minimum, Max maximum

protection. And, uncertainties have to be reduced as much as possible in order to justify an intervention and remediation program in polluted sites.

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