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Ecological risk assessment for small omnivorous mammals exposed to polycyclic aromatic hydrocarbons: A case study in northeastern Mexico

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HIGHLIGHTS

- An ecological risk assessment was performed using the hazard quotient (HQ) method.
- HQs were obtained for omnivorous mammals exposed to polycyclic aromatic hydrocarbons.
- Risks for the oral exposure route were less than benchmarks in all cases (HQ < 1).
- More research must be done in Mexico aimed primarily at obtaining TRVs for mammals

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ABSTRACT

An ecological risk assessment (ERA) was performed using the hazard quotient (HQ) method to evaluate the risks of oral exposure to polycyclic aromatic hydrocarbons (PAHs) for medium sized omnivorous mammals. This is the first in a series of three papers. In Mexico there is little experience in performing this kind of assessment for the terrestrial compartment, in particular for birds and mammals exposed to hydrocarbons. The purpose of this paper is to perform an ERA and to establish if the omnivorous mammalian species living in the area are at risk of adverse effects. The studied site is a land that in past years had been used for the disposition of petroleum tank bottom sludges, and scrap metals. Soil and water samples were collected and analyzed, and we obtained a list of the site's wildlife species as well as samples of the specimens, which were analyzed also. HQs were calculated for the hydrocarbons identified as chemicals of potential ecological concern (COPECs) and the omnivorous mammals of the site were evaluated. Toxicity reference values (TRVs) were taken from the appropriate literature, and the doses of exposure were estimated considering the ingestion of water, soil, and diet. Results indicated that potential risks associated to the oral exposure route were less than benchmarks for effects (in all cases HQ < 1). The methodology is adequate in terms of the parameters considered in the calculations, but it was concluded that in order to reduce uncertainty, more research is required in Mexico. This should be primarily aimed at obtaining TRVs for mammals, and consider test species with body weights more similar to those found in the local fauna.

1. Introduction

The application of quantitative ecological risk assessment methodologies, e.g., the hazard quotient (HQ) method, for terrestrial wildlife in Mexico has a short history. Ecotoxicological studies have primarily focused on the effect of metals, pesticides and, to a lesser extent, hydrocarbons in the aquatic environment; cladocerans, algae, and oysters are the most popular organisms studied (Bernal-Hernandez et al., 2010; Carvalho et al., 2009). Ecotoxicological studies focused on soil microorganisms and macrofauna, mainly earthworms, have been performed with certain regularity (Espinosa-Reyes et al., 2010; Hernández-Hernández et al., 2007).

Most investigations address the issue of the health of organisms by measuring both effects and exposure biomarkers, or concentrations of contaminants in the tissues, but they do not indicate if the concentrations in the natural media pose a risk to organisms of upper trophic levels and the magnitude of the risk. Organisms in the upper trophic levels, e.g., herbivorous, carnivorous, or omnivorous vertebrates, are rarely chosen as ecological receptors for assessment and, as a consequence, terrestrial risk assessments are almost non-existent in Mexico. Some studies have focused on the study of biomarkers in rodents, reptiles, and birds (Ilizaliturri-Hernández et al., 2008; Tovar-Sánchez et al., 2012) or on measuring residual concentrations of contaminants in tissues, mainly organochlorine substances (Pardío et al., 2012;

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Ruelas-Inzunza et al., 2007), but in these investigations no risk values or clean-up concentrations have been proposed. Sometimes vertebrates are not considered as assessment targets since their populations frequently have much larger home ranges than the area of contaminated sites, so it is expected that the effects may be diluted over the range of the population (Suter, 1997). Nevertheless, this is not a valid reason to exclude this group of organisms from assessments, since biomagnification may be important in food chains, leading to potentially high levels of exposure in wildlife that feed on organisms from lower trophic levels.

The purpose of this paper is to perform an ERA and to establish if the omnivorous mammalian species living in the area are at risk of adverse effects. This is the first in a series of three papers. The HQ method is applied to estimate the risk of exposure to polycyclic aromatic hydrocarbons (PAHs) for mammals found in a vegetated area close to a petroleum facility. Since no previous studies of this kind exist in Mexico, a secondary objective is to identify future lines of research that would need to be strengthened to attain better results.

The HQ method is a technique developed for performing risk estimations. It is defined as the ratio of estimated level of exposure of various environmental receptors to appropriate toxicity reference values (TRVs):

$$HQ = (\text{Concentration or dose of exposure})/\text{TRV} \tag{1}$$

In this work, only the oral pathway was considered, so the HQ is expressed as follows:

$$HQ = (\text{Dose}_{\text{oral}})/\text{TRV} \tag{2}$$

TRVs are usually derived from review of published toxicity studies, and identify concentration values or dose values that correspond to a no-observed adverse effect level (NOAEL) and/or a lowest observed adverse effect level (LOAEL). Each TRV is both chemical-specific and species-specific (USEPA, 2008).

In this study, HQs for the oral route were computed for five medium sized omnivorous mammals to evaluate the risks from exposure to PAHs. They are present in petroleum products and they were chosen as contaminants of concern for this site because they are known to cause adverse health effects, including cancer and reproductive effects in animals (Chung et al., 2011). They are moderately toxic and persistent and can accumulate to hazardous levels at locations where heavy fractions of petroleum have been deposited (Suter, 1997).

2. Material and methods

2.1. Study area

The field work for the ERA was conducted in a vegetated area located within a petroleum facility located in northeastern Mexico. Distillation processes took place at this facility, producing gasoline, intermediate distillates (turbosine and diesel), combustoleum, carbon black, avgas, LP gas, coke, sulfur, and asphalt that were stored in facility tanks. The vegetated area, where the research was conducted, is located in the northwestern side of the facility covering a surface of 21 ha. For the purposes of this research, this area was named Study Area. Before the year 2000, residual sludge from oil storage tanks was disposed directly onto the soil, as well as in a dumping area located in the western border of this location. For comparison purposes, a Background Area was chosen. The Background Area was considered to be representative of sites not affected by the disposal of residual sludges; this site had an extension of 17 ha and was located at the East of the facility, it was verified that no oil sludges were present and that the vegetation was similar to that of the Study Area.

Both sites are located on alluvial sandy soil. The geology of the area consists of two sedimentary basins with Tertiary rocks mainly formed by shales and sandstones. The climate is warm and semi-humid with rains in the summer. Annual mean precipitation and temperature are 927.8 mm and 24.2 °C, respectively. No groundwater wells are present in the Study Area but, according to the literature, the region has aquifers with static levels that vary between 3 and 80 m. The groundwater generally moves in the direction of the superficial streams, which run from West to East. The stratigraphy of the area is composed of clayey silt with low content of organic matter (0–0.30 m), silty sand or sandy silt (0.30–2.80 m), and sand with small-sized gravel and shell fragments (2.8–22.8 m). During soil sampling activities, in some of the areas there were sand or silty sand deposits in the first 0.40 m; this material was used to cover bottom tank sludges that were disposed on the site. Soil pH was measured in the field considering a 1:1 soil:water (distilled) ratio. The measurement was made using pH paper and had a value of 6.

2.2. Problem formulation

In this stage of the assessment, site visits were made to gather information about sources of contamination, contaminants of potential concern and their concentrations, and additional information used to develop a conceptual model (e.g., biota present at the site).

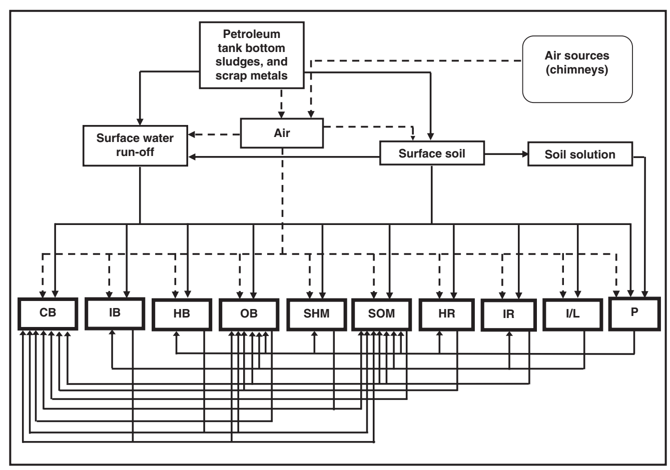

Fig. 1. Conceptual model. Rectangles with heavy borders represent receptors that are assessment endpoints and dashed lines represent exposure routes present at the site but that were not assessed. CB = Carnivorous birds, IB = Insectivorous birds, HB = Herbivorous birds, OB = Omnivorous birds, SHM = Small herbivorous mammals, SOM = Small omnivorous mammals, HR = Herbivorous reptiles, IR = Insectivorous reptiles, IL = Invertebrates/Larvae, P = Plants.

2.2.1. Soil and water sampling and analysis

For soil characterization 64 samples were obtained; 32 samples were taken from 0.00 to 0.05 m depth and 32 samples were taken from 0.20 to 0.40 m depth. A grid of 100 × 100 m was followed and positions were recorded with a Garmin Etrex GPS. Due to financial resource restrictions, only five random soil samples were gathered in the Background Area.

Samples were collected in stainless steel tubes that were sealed after collection and preserved at 4 °C until analysis. Samples were analyzed for TPHs, PAHs, and BTEX (benzene, toluene, ethylbenzene, and xylenes), as defined by the Mexican standard NOM-EM-138-ECOL-2002 (DOF, 2002) that was in force at the time of the study. For PAHs, NOM-EM-138 only considers six of these compounds, but, for this study, we included the 16 priority PAHs established by USEPA. For the analysis, the following methods were used: EPA-8310 for PAHs, EPA-8260 for BTEX, and EPA-418.1 for TPHs, as indicated by the standard mentioned before. Table 1 summarizes the PAHs and TPHs content found at the upper soil layer.

Since the assessment endpoints were terrestrial organisms present at the site, surface water sources were sought. Five water samples