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Exposure risks to polycyclic aromatic hydrocarbons by humans and livestock (cattle) due to hydrocarbon spill from petroleum products in Niger-delta wetland

Uzochukwu C. Ugochukwu[a,*], Alfred Ochonogor[b], Chika M. Jidere[c], Chizoba Agu[a], Frida Nkoloagu[a], John Ewoh[a], Virginia U. Okwu-Delunzu[d]

[a] Centre for Environmental Management & Control, University of Nigeria, Enugu Campus, Nigeria
[b] Department of Pure & Industrial Chemistry, University of Nigeria, Nsukka, Nigeria
[c] Department of Soil Science, University of Nigeria, Nsukka, Nigeria
[d] Department of Geography and Meteorology, Faculty of Environmental Sciences, Enugu State University of Science and Technology, Agbani, Enugu State, Nigeria

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ABSTRACT

In this study, the human and livestock (cattle) health risks of exposure to polycyclic aromatic hydrocarbons (PAHs) in a wetland of Obuaku, Abia State Nigeria contaminated by hydrocarbon spill due to incidents of hydrocarbon theft and pipeline vandalization were assessed. Gas chromatography-flame ionization detector and gas chromatography–mass spectrometry were employed in analyzing the TPH and PAHs respectively. The contaminated soil was delineated into sub-locations AOC-1, AOC-2, AOC-3, AOC-4, AOC-5 and AOC-6 to reflect the discrete patches (areas) of the contaminated site and for effective planning of remedial actions. The concentration of the PAHs in AOC-4 was insignificant but was quite significant in AOC-1, AOC-2, AOC-3 and AOC-6. The average percentage distribution of the PAHs in all the sites is 9.8% carcinogenic and 91.2% non-carcinogenic. The ecological risk assessment revealed that only sub-location AOC-4 contains PAH to a level of insignificant biological impairment while sub-locations AOC-1, AOC-2 and AOC-6 contain PAHs that pose the highest ecological risks. The assessment of health risk exposure to carcinogenic and non-carcinogenic PAHs indicated insignificant risks for all sub-locations whereas the assessment of health risks using PAH toxicity method indicates that only sub-locations AOC-1, AOC-2 and AOC-6 were toxic. These sub-locations were also found to be of significant health risks to livestock (cattle). Robust empirical models describing the relationships between TPH and any of the risk parameters were generated such that TPH can be used in predicting the risk parameters for spillage peculiar to petroleum products.

1. Introduction

Over the past few decades, there has been a large worldwide increase in the exploration and exploitation of crude oil with an associated increased risk of accidental discharge to the environment (Das and Mukherjee, 2006; Delille and Coulon, 2008; Nikopolou and Kalogerakis, 2009). The spillage of crude oil and its fractions in the environment has resulted in large numbers of contaminated sites (Vidali, 2001). Environmental pollution by crude oil and its fractions has become a major concern in the world today as it is one of the main causes of ecological and social damage (Shaw, 1992; Burger, 1993; Burns et al., 1993; Adebiyi et al., 2015). It has been reported that crude oil hydrocarbons especially polycyclic aromatic hydrocarbons (PAHs) have adverse health effects on livestock such as cattle that graze around hydrocarbon polluted sites (Khan et al., 1996; Coppock et al., 1996). The effects of PAHs in soils have direct impact on human health as a result of exposure from inadvertent soil ingestion and dermal contact (Obidike et al., 2007; Abha and Singh, 2012).

PAHs contain two or more benzene rings fused together with a pair of carbon shared by two fused rings. Based on the biological, chemical and physical characteristics of the PAHs, they are traditionally divided into two groups namely, low molecular weight PAHs and high molecular weight PAHs. The low molecular weight PAHs with higher water solubility are more toxic than the higher molecular weight PAHs whereas the higher molecular weight PAHs are more carcinogenic than the lower molecular weight ones as per the chronic effects of exposure to these PAHs (Boonchan et al., 2000). The higher molecular weight PAHs are also more recalcitrant to biodegradation as a result of low

* Corresponding author.
E-mail address: uzochukwu.ugochukwu@unn.edu.ng (U.C. Ugochukwu).

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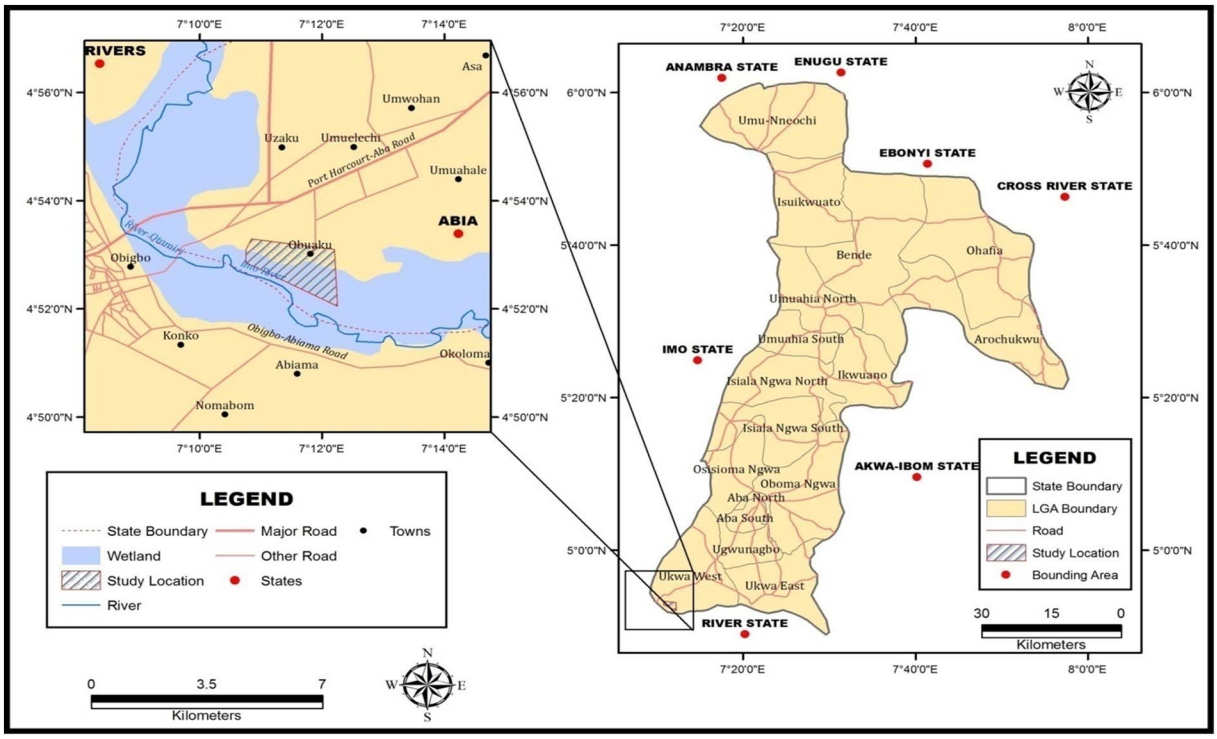

Fig. 1. Map of the study area in Obuaku wetland.

bioavailability caused by inherent poor solubility of the PAHs thereby limiting the success of application of treatment processes such as bioremediation (Cerniglia, 1992; Duan et al., 2013).

The most common source of petroleum hydrocarbon pollution in Nigeria is petrogenic source arising from accidental spillage of crude oil or/and illegal oil bunkering activities which are prevalent in the Niger-delta region of the country. Between 1976 and 2005, Nigeria's Niger delta recorded over 3.0 million barrels of oil spilled in the environment in 9107 spill incidents (Egberongbe et al., 2006).

Human health risk assessment of PAH-contaminated sites includes evaluation of general soil toxicity and excess lifetime cancer risk (ELCR) for a given exposure. Risk management activities by regulatory agencies which include prioritization for remediation, access restriction, and determination of site suitability for subsequent agricultural, residential, industrial, or commercial use are based on the outcome of human health risk assessments. The routes of exposure to PAHs at any contaminated soil are non-dietary (inadvertent) ingestion and dermal contact with the soil (Health Canada, 2010).

Several studies have reported the ecological and human health risks of exposure to PAHs due to hydrocarbon pollution in soils and sediments (Qiao et al., 2006; Khairy et al., 2009; Jiao et al., 2015; Laffon et al., 2016; Xu et al., 2017). However, it is not yet well known the level of ecological and human health risks associated with hydrocarbon soil pollution from spill incidents due to pipeline vandalization and theft of refined products such as petrol, diesel and kerosene at a site in Obuaku Wetland, Abia State in Niger-delta region of Nigeria where about 2.4 ha of agricultural land area has remained polluted for about seven years now.

The pollution of the environment by PAHs poses very serious environmental and health risks as a result of the mutagenicity and carcinogenicity of the PAHs (ATSDR, 1995). The study of Sverdrup et al. (2002) revealed that PAHs can induce immunotoxicity, reproductive toxicity, carcinogenicity and genoticity. It is very important to understand how spill incidents of this nature affect ecosystems, human health and agricultural activities such as livestock for proper policy formulation and implementation.

The management of long term contaminated sites involves a risk-based approach that seeks to only mitigate those risks that are unacceptable. This way, the removal of all the contaminants may neither be necessary nor cost effective (Duan et al., 2013). There has been development of health risk exposure models and software employed in assessing risks from PAHs due to crude oil spills based entirely on PAH variable inputs (Cocarta et al., 2017). It is very important to have a robust model that can assist in estimating and predicting ecological and health risk parameters based on TPH variable inputs as this promises to be cost effective. These sort of empirical models are not well known both for sites contaminated by crude oil and petroleum products such as diesel, petrol and kerosene.

This study would therefore seek to achieve the following objectives:

- Determine the concentration of TPH and PAHs in the polluted soil environment and establish extent of hydrocarbon contamination
- Determine PAH toxicity arising from the hydrocarbon contamination
- Estimate human health non-carcinogenic and carcinogenic risks due to the PAHs
- Estimate risks to livestock (cattle) that graze at the contaminated site
- Generate regression models that could predict ecological and health risk parameters for contaminated sites by petroleum products.

Till the time of this study and preparation of this manuscript, the authors are not aware of any study on Obuaku wetland hydrocarbon contamination due to illegal bunkering and pipeline vandalization activities. This is probably the first study that assesses exposure of both livestock and humans to health risks of PAHs in a wetland typical of Niger delta of Nigeria in which hydrocarbon contamination is due to spillage of petroleum products rather than crude oil. The rationale for carrying out this study is based on the fact that the conceptual site model of the contaminated area indicates a complete source-pathway-receptor linkage thereby revealing ecological and health risks to exposed humans and livestock. The exposed humans are herdsmen and locals who still use the soil for agricultural purposes whereas the exposed livestock are cattle that graze on the area.