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Status of Potentially Harmful Elements (PHEs) in Soils around the Vicinity of a Newly Constructed Sporting Facility in Omagwa, Nigeria

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KEYWORDS: Pre-urbanization data, soil, heavy metals, Greater Port Harcourt City

ABSTRACT: A study, intended to generate pre- urbanization baseline data of the soils at the Greater Port Harcourt site of the new stadium, the Adokiye Amiesimaka Stadium, has been conducted. Concentrations of heavy metals (Cd, Cr, Cu, Ni and Pb) and physicochemical properties of surface and sub-surface soils at the study sites have been determined using spectrophotometric and other standard methods. The results indicate that the pH of the soil ranged between 5.3 and 6.2 while the percent organic carbon ranged between 1.73 – 2.50 %. The ranges of the percentages of total organic matter and total nitrogen in the soil were 2.98 – 4.31% and 0.24 – 0.34% respectively. The particle size distribution results obtained for sand, silt and clay were 59.0 – 74.0 %, 3.8 – 6.0 %, and 21.2 – 37.2 %, respectively. The mean concentrations of the metals for surface and sub-surface soils were respectively as follows: Cd (0.21±0.05 mg/kg and 0.24±0.15mg/kg); Cr (1.98 ± 1.07 mg/kg and 2.23 ± 1.67 mg/kg); Cu (11.8 ± 4.48 mg/kg and 12.4 ± 5.40 mg/kg); Ni (2.39 ± 0.66 mg/kg and 2.46 ± 0.53 mg/kg) and Pb (1.32 ± 0.87 mg/kg and 1.23 ± 0.88 mg/kg). The results indicate that the levels of the physicochemical characteristics in the soils of the study area are, in general, lower than soils in the city that have long been disturbed as a result of anthropogenic inputs. On the other hand, the heavy metal levels were similar in both surface and sub- surface soil samples. This may be as a result of the geogenic nature of the sites. However, the pristine nature of the study sites may be responsible for the relatively lower metal levels compared with disturbed soils in the city. These values thus provide baseline data for the study area. @JASEM

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In Nigeria, because of biased developmental strategies, most rural areas lack basic amenities required by the local population. For example, economic advantages, educational placements, sporting opportunities and cultural richness are only available at the capital cities of most the states of the country. Consequently most capital cities have become overpopulated. One of such cities is Port Harcourt – the capital city of Rivers State of Nigeria. To address the overpopulation of the Port Harcourt city, the Rivers State Government in 2009 commenced the development of a parallel city called the Greater Port Harcourt city project. Most of the land areas selected for the new city was previously forested.

The entire project was planned in phases and one of the earliest amenities completed for public use was the Adokiye Amiesimaka Stadium. The stadium houses a swimming pool, a handball court, volley ball court, athletics tracts and hockey field. In 2011, between 27th June and 9th July, the Rivers State Government, at the newly constructed sporting facility, hosted the 17th edition of the Nigerian National Sport Festival tagged "Garden City Games 2011". A total of 15,430 athletes and officials (but not including security operatives) participated in the festival (Garden City Games, 2011). The 13-day festival also attracted about thirty thousand spectators each day (Garden City Games, 2011).

Although, there are concerns that urban use of productive and forest soils may lead to food scarcity, threaten environmental sustainability and reduce soil quality (Chen, 2007), in developing countries, studies focused on land-use changes, induced by urbanization, are rarely conducted. A number of studies have suggested associations between urbanization/industrialization, on one hand and heavy metal pollution of surface soils on the other (Imperato *et al*., 2003; Ideriah *et al*., 2004; Chen, 2007; Douay *et al*., 2007; Wei and Yang, 2010; Olorundare *et al*., 2011). In order to establish such association, reliable pre-urbanization soil heavy metal concentrations data are required. At present, most published studies investigating the challenge urbanization poses to soil quality are limited because of lack of local or regional background (baseline) soil data for heavy metals concentrations.

The objective of this study was thus to generate pre-urbanization baseline data of concentrations of heavy metals (Cd, Cr, Cu, Ni and Pb) and physicochemical properties of the soils at the Greater Port Harcourt site of the new stadium.

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Study Area: The Greater Port Harcourt city project annexes land from eight local Government areas (Port Harcourt city, Obio/Akpor, Ikwerre, Etche, Oyigbo, Eleme, Okirika and Ogu-Bolo) (Greater Port Harcourt Development Authority, 2013). The project is divided into phases and is currently at the phase 1 stage. The phase1 stage stretches from the Port Harcourt International Airport roundabout to the Professor Tam David-West road. On completion, the phase 1 shall include 3,000 housing units ,a golf course, power sub-station, roads, waste water plant, storm water drains, sewage plant, a university, a hospital, business areas, service areas, innovation park and the sport complex (Greater Port Harcourt Development Authority, 2010). Only the sport complex area (Figure 1) was investigated for this study. The sport complex is sited behind the International Airport Hotel on a 50.8 hectare of land.

Fig. 1 Aerial photograph of construction projects at the study site
http://dilemmaxdotnet.files.wordpress.com/2012/06/port-harcourt-stadium.jpg

*Methodology***:** A total of 18 surface and sub-surface samples were collected from 0-15 cm and 15-30 cm, respectively with stainless steel trowel from sites across the sports complex (Figure 2). The study area was a pristine land mass before the sport complex was built on it. Each sample of 5 closely spaced subsamples, which were bulked to a composite of about 50 g (wet-weight). Samples were air-dried, disaggregated and sieved through a 75 µm mesh with the < 75 µm fraction retained for digestion on a pre-heated hot plate for 1 hour in aqua regia (HCl : HNO_3 in ratio 3:1 v/v) and analysed for Cd, Cr, Ni, Cu and Pb content by Flame (air-acetylene) Atomic Absorption Spectrophotometer (AAS, GBS Avanta PM A600; made in Australia) using external standards prepared with 2% HNO_3 from 1000 mg/Litre stock solutions of the metals.

Air dried 10.0 g of < 2mm fraction of each sample was added to 25 ml water in a bottle with screw cap and the resulting suspension was mixed for 15 min by shaking. The suspension was swirled, the probe was inserted and measurements taken using Corning pH meter-model 7. Total nitrogen was determined with macro-Kjeldald method (Bremner, 1996). Soil organic matter was determined by mass loss on a muffle furnace at 550 ^{o}C (Rowell, 1994). Soil organic carbon was determined by the Walkey and Black method (Rowell, 1994). Particle size distribution analysis was determined by both dry sieving and hydrometer methods (Bremner, 1996).

Analytical accuracy of the aqua-regia digestion was assessed using BCR 143R (aqua-regia certified sewage sludge amended soil LCG, London) and good results were obtained for the heavy metals of interest when compared to certified values (Table 1). For the pH measurements, the instrument was calibrated using pH 4.0 and pH 6.9 buffer solutions before use. The conductivity meter was calibrated with 5 mM NaCl solution.

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RESULTS AND DISCUSSION

The descriptive statistics of the mean, standard deviation, minimum and maximum values of pH, electrical conductivity, organic carbon, total Nitrogen, carbon-nitrogen ratio, percent sand, silt and clay are presented in Table 2. The pH range 5.3 – 6.2 observed in this study is consistent with values 6.1 - 6.3 (Port Harcourt Municipality, Nigeria) and 5.8 – 6.4 (Akure, Nigeria) previously reported by Ogbonna *et al*., (2009) and Manuwa and Olajide, (2012) respectively. However, from a dumpsite study at Port Harcourt, expectedly, a wider pH range 4.0 – 8.2 was reported by Ideriah *et al*., (2006). The percent organic carbon range observed in this study 1.73 – 2.50 % is consistent with the range 0.48 – 2.62 % reported for arable soils from Akure, Nigeria. The top soil percent organic matter range 2.98 – 4.31 observed in this study is above the range 1.86 – 2.62 (Manuwa and Olajide, 2012) reported for rural samples from Akure, western Nigeria, but is within the ranges 0.39 – 6.75 and 1.18 – 5.93 reported for previous studies at Port Harcourt by (Ideriah *et al*., 2006) and Ogbonna *et al*., (2009) respectively.

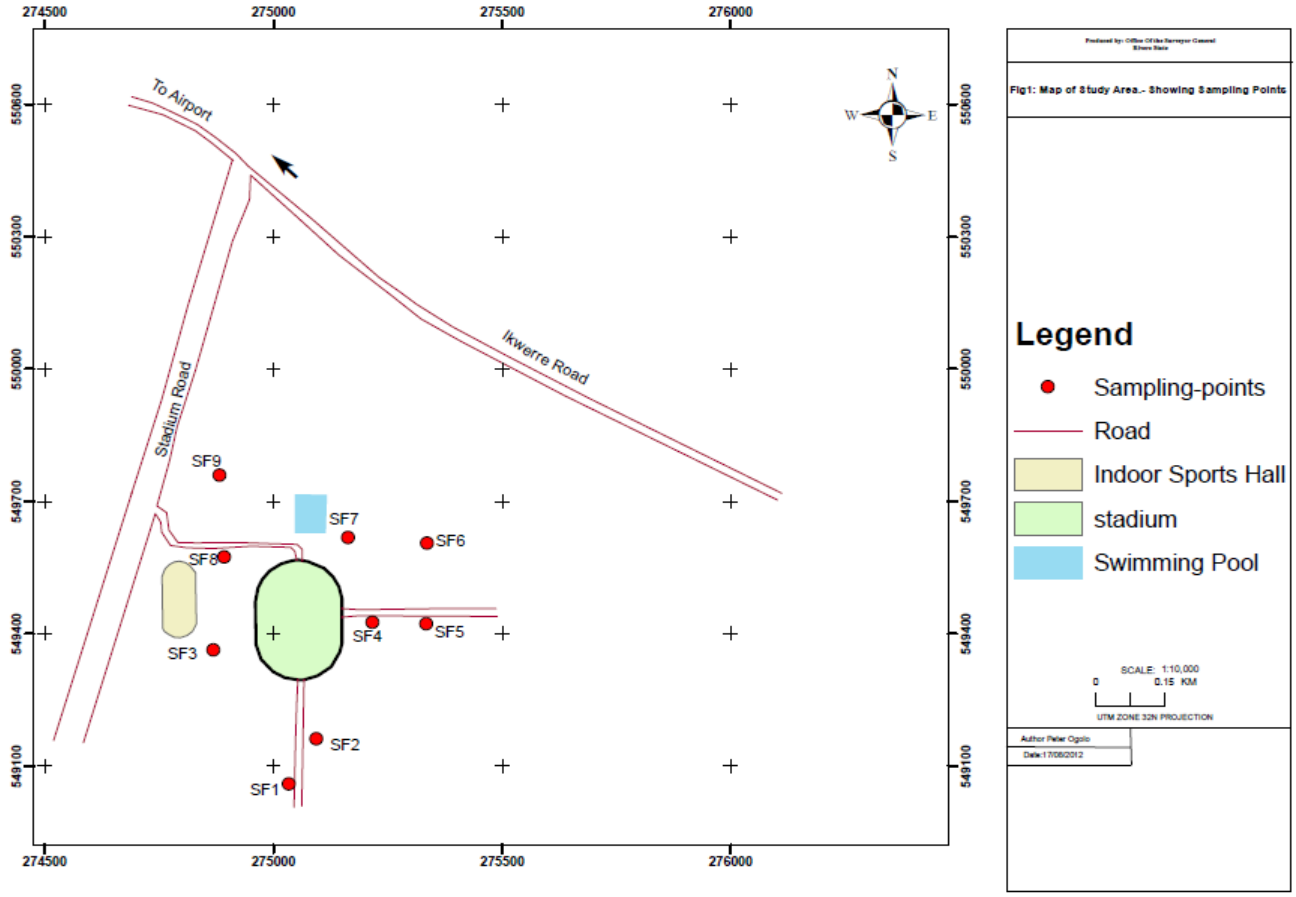

Fig 2: Map of the study area showing sampling points.

Table 1: Analytical quality control data (mg/kg) for the aqua-regia digestion of BCR 143R

Metal	Aqua-regia Certified	Aqua-regia measured
Cd	72.0 ± 1.8	65.4 ± 2.4
Cr	426 ± 12	399 ± 14
Cu	NA	120 ± 10.6
Ni	296 ± 4	271 ± 10
Pb	174 ± 5.0	169 ± 5

NA – data not available

The wider organic matter range recorded previously for urban parts of Port Harcourt by Ideriah *et al*., (2006) and Ogbonna *et al*., (2009) is expected because the sites have long been under anthropogenic inputs. The % total nitrogen range 0.24 – 0.34 observed in this study is above 0.03 – 0.20 reported for disturbed areas of Port Harcourt and the higher range recorded in this may be due to the fact that the location was previously forested. The particle size distribution results obtained for sand, silt and clay in

this study are 59.0 – 74.0 %, 3.8 – 6.0 %, and 21.2 – 37.2 %, respectively and the ranges are consistent with those published by Onweremadu *et al*., (2011)

The descriptive statistics of the mean, standard deviation, minimum and maximum concentrations of the heavy metals are presented in Table 3. The mean concentration 0.21 mg/kg of Cd obtained in this study for surface soils is above 0.10 mg/kg reported by Chinese Environmental Protection Administration (CEPA, 1990) as background value for Chinese soils. The difference may be a reflection of variance in geogenic nature in the different locations. The concentration range of Cd 0.18 – 0.33 mg/kg obtained from our study site is as expected significantly below the range 0.55 – 4.70 mg/kg reported for solid waste dumpsites around Port Harcourt (Ideriah *et al*., 2006).

Table 2: Descriptive Statistics of surface soil and subsurface soil physicochemical properties

Variable	Mean	StDev	Min	Max
Surface				
pH	5.80	0.19	5.44	6.00
Org.C (%)	2.14	0.31	1.73	2.50
Org.M (%)	3.68	0.54	2.98	4.31
TN_2 (%)	0.29	0.03	0.24	0.34
Sand (%)	63.7	3.12	60.0	67.5
Silt (%)	4.89	1.19	3.00	6.50
Clay (%)	31.4	3.47	28.0	37.0
Subsurface				
pH	5.98	0.28	5.30	6.25
Org.C (%)	1.72	0.35	1.18	2.35
Org.M (%)	2.92	0.61	2.03	4.05
TN_2 (%)	0.24	0.04	0.16	0.29
Sand (%)	65.7	4.41	59.0	74.0
Silt (%)	4.48	0.49	3.80	6.00
Clay (%)	29.9	4.65	21.2	37.2

Org. C: Organic carbon, Org.M: Organic matter, TN_2: Total Nitrogen

The mean Cr concentrations obtained in this study for surface and subsurface soils are 1.98 ± 1.07 mg/kg and 2.23 ± 1.67 mg/kg, respectively. Both surface and subsurface concentrations are similar and the similarity may be an indication that Cr is mainly geogenic at our study site. The mean value 1.98 ± 1.07 mg/kg obtained in this study is significantly below mean values 44.2 ± 17.3 mg/kg and 12.5 ± 3.90 mg/kg reported for soil samples from heavy traffic density and low traffic density areas of old Port Harcourt (Ideriah *et al*., 2004). The mean Cr concentration value 1.98 ± 1.07 mg/kg obtained from this study is however, consistent with 3.58 ± 2.22 mg/kg reported for uncontaminated Port Harcourt samples (Ideriah *et al.*, 2004).

The mean Cu concentrations obtained in this study for surface and subsurface soils are 11.8 ± 4.48 mg/kg and 12.4 ± 5.40 mg/kg, respectively. Both surface and subsurface concentrations are similar and the similarity may be an indication that Cu is mainly geogenic at our study site. The mean value 11.8 ± 4.48 mg/kg obtained for surface soils in this study is significantly below mean values 37.2 ± 15.9 mg/kg reported for soil samples from heavy traffic density but similar to 12.0 ± 2.48 mg/kg and 3.34 ± 1.25 mg/kg reported for low traffic density and uncontaminated areas of old Port Harcourt, respectively (Ideriah *et al*., 2004).

The mean Ni concentrations obtained in this study for surface and subsurface soils are 2.39 ± 0.66 mg/kg and 2.46 ± 0.53 mg/kg, respectively. Both surface and subsurface concentrations are similar and the similarity may be an indication that Cu is mainly geogenic at our study site. The mean value 2.39 ± 0.66 mg/kg obtained in this study is significantly below mean values 23.6 ± 8.06 mg/kg and 7.10 ± 1.93 mg/kg reported for soil samples from heavy traffic density and low traffic density areas of old Port Harcourt (Ideriah *et al*., 2004). The mean Cr concentration value 2.39 ± 0.66 mg/kg obtained from this study is however, consistent with 2.29 ± 1.90 mg/kg reported for uncontaminated Port Harcourt samples (Ideriah *et al*., 2004).

The mean Pb concentrations obtained in this study for surface and subsurface soils are 1.32 ± 0.87 mg/kg and 1.23 ± 0.88 mg/kg, respectively. Both surface and subsurface concentrations are similar and the similarity may be an indication that Cr is mainly geogenic at our study site. The mean value 1.32 ± 0.87 mg/kg obtained in this study is significantly below mean values 60.6 ± 29.6 mg/kg and 19.0 ± 4.11 mg/kg reported for soil samples from heavy traffic density and low traffic density areas of old Port Harcourt (Ideriah *et al*., 2004). The mean Cr concentration value 1.32 ± 0.87 mg/kg obtained from this study is however, consistent with 4.00 ± 3.22 mg/kg reported for uncontaminated Port Harcourt samples (Ideriah *et al*., 2004).

Table 3: Concentration of heavy metals in surface and subsurface samples (n=9)

Metal	Mean	StDev	Min	Max
Surface				
Cd (mg/kg)	0.21	0.05	0.18	0.33
Cr (mg/kg)	1.96	1.07	0.71	3.89
Cu (mg/kg)	11.8	4.48	6.09	20.2
Ni (mg/kg)	2.39	0.66	1.20	3.25
Pb (mg/kg)	1.32	0.87	0.37	3.16
Subsurface				
Cd (mg/kg)	0.24	0.15	0.05	0.47
Cr (mg/kg)	2.23	1.67	0.52	5.48
Cu (mg/kg)	12.4	5.40	6.62	22.6
Ni (mg/kg)	2.46	0.53	1.88	3.56
Pb (mg/kg)	1.23	0.88	0.46	2.87

*Conclusion***:** The results obtained in this study have established pre- urbanization baseline data of the soils at the Greater Port Harcourt site of the new stadium,

the Adokiye Amiesimaka Stadium. Further studies, in the area, may establish a relationship between urbanization and metal pollution as the stadium continues to play host to a number of sporting activities.

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