



• Original Article

Swimming pools quality risk assessment for heavy metal deposition and intake via oral and dermal exposure

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The deplorable environmental conditions coupled to poor management practices employed by public swimming pool owners have led to suspicions over the safety of these recreational sites. This study was carried out to determine the physicochemical properties, heavy metal contents and accumulation, and associated risks of six swimming pools in Owerri, Capital of Imo State, Nigeria. Physicochemical analysis was conducted using standard methods while determination of heavy metals was carried out using an atomic absorption spectrophotometer. Results obtained showed that the turbidities and total dissolved solutes exceeded the Nigeria standard for water quality. Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), nickel (Ni), and lead (Pb) exceeded the drinking safety values from United States Environmental Protection Agency, National Standards for Drinking Water Quality, and World Health Organization, while selenium (Se), chromium (Cr), and zinc (Zn) values fell within the permissible limits. From the bioaccumulation models applied, the enrichment factors showed anthropogenic source of deposition of the metals in all swimming pool while the heavy metal index were in a range of 27.30-70.19. For the risk assessment results, the chronic daily intake showed that Hg, and As levels for all the swimming pools, and Cu for some swimming pools exceeded the oral reference doses, while the hazard quotient for Hg (5.65-16.95), As (2.26-3.77), and Cu (1.13-4.11) indicated potentials of causing related toxicities. This study has shown that the aesthetic quality of the swimming pools were compromised, and contained elevated levels of Hg, As, and Cu significant enough to threaten the health safety of users of these swimming pools, which should instigate tough measures from Nigerian water regulatory bodies to ensure compliance from public swimming pool owners.

Keywords: Swimming pools; Bioaccumulation; Heavy metals; Risk assessment; Hazard quotient

INTRODUCTION

Water is one of the most important natural resources crucial in supporting life processes in both plants and animals [1]. Notwithstanding the importance of water to human existence, it poses serious threats by serving as a medium for disease transmission, when contaminated [2]. Groundwater accounts for 13% of the total water in earth, and of this percentage, only 2.3% is fit for consumption [2]. Groundwater pollution arising as a direct or indirect consequence of leakage of contaminants from leachates and massive industrialization, poses a worrisome trend to many countries as it is used for domestic purposes, and for various industrial and recreational activities [2].

Heavy metals are pollutants of primary importance [3] and their accumulation in groundwater above safe levels, affects humans and the entire ecosystem by limiting the usage of water [4]. They are predominantly deposited into water through sources such as fertilizers, agricultural wastes water, atmospheric particles, and combustion engine gases. At very minute concentrations above 3×10^{-4} and 3×10^{-5} mg/L/day, arsenic (As) and mercury (Hg) respectively are capable of eliciting very serious toxic effects. Hence, the assessment and management of water quality is a topic of ecotoxicological relevance [5]. According to Amadi et al. [6], the provision of quality water amongst other benefits, enhances recreational opportunities such as in swimming pools that flourish as a resource generating venture in major cities of Nigeria. Swimming pools are recreational environments that provide both social and health benefits, and as such, should not cause harm to swimmers through either toxic substances or pathogenic microbes [7]. That notwithstanding, Barss et al. [8] noted that the rate of in-

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juries that occur particularly in swimming pools is underestimated, and greatly exceeds those in other environments. Some of these injuries include asthma [9, 10], skin and eye irritation [11, 12] and other skin infections [7] thus, requiring the establishment and enforcement of regulatory guidelines for the safety of the recreational environments [13]. Some measures such as chlorination of the pool water and refilling swimming pools every three days using both rain and borehole water are predominantly adopted by pool owners to ensure the mitigation of health risks associated with poor sanitary conditions for the pools. Prior to this present research, no reports exist in literature regarding the heavy metal status of swimming pools. Therefore, it becomes paramount to fill the gap in knowledge created by the paucity of information on the present contamination status of swimming pools, especially those situated in population dense and uncontrolled activity-laden locations. It was on this foregoing that this study was carried out to determine the heavy metal contents and risks associated with oral ingestion of the heavy metals in six swimming pools situated in Owerri Capital city of Imo State, Nigeria.

MATERIALS AND METHODS

Study area

The six swimming pools used for this study, were hotel swimming pools cut across major roads in the Metropolis including Okigwe road, Amakohia road, World Bank road, and Port Harcourt road. The test samples were obtained directly from the swimming pools just before washing and refilling of the pool by the management, while the control samples were obtained from the source of refilling.

Sample collection and preparation

The samples (20 mL) were collected during the rainy season (June, 2018). Triplicate surface water samples were collected from mid-depth portions of each of the swimming pools, as well as their corresponding control samples using sterilized sample bottles. On collection of the samples, the sample bottles were first rinsed thrice with the swimming pool water samples, and stabilized using hydrochloric acid after sample collection. The samples were immediately conveyed to the laboratory for analysis.

Sample analysis

The temperature of the sample was measured by dipping a centigrade thermometer into the sample while the pH, electrical conductivity, and total dissolved solute (TDS) was mea-

sured using a HI 98129 portable pH/EC/TDS/temperature meter (Hanna Instrument, Inc. RI, USA). The alkalinity and dissolved oxygen contents were determined following instructions on HI3811 alkalinity test kit and HI3810 dissolved oxygen test kit (Hanna Instrument, Inc. RI, USA) while the turbidity was determined using a UV-VIS spectrophotometer at 860 nm. The heavy metals; iron (Fe), cadmium (Cd), Hg, As, nickel (Ni), selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu) were determined using an AA-670 atomic absorption spectrophotometer (Shimadzu Corporation. Kyoto, Japan). Briefly, the samples (20 mL) were digested using 15mL mixture of perchloric acid, sulfuric acid, and nitric acid, in a ratio of 1:1:5. The mixture was heated in a heating mantle at 80 °C until a clear solution was obtained and afterwards, cooled and made up to 30 mL with 2% nitric acid and filtered. The heavy metal contents were thus determined in the digested samples using an AA-670 atomic absorption spectrophotometer (Shimadzu Corporation. Kyoto, Japan) after the preparation of a reference solution [3, 14].

Determination of enrichment factor (EF) and heavy metal index (HMI)

The enrichment factor (EF) is expressed mathematically as;

$$EF = \frac{C_n}{C_{tn}} \quad (1)$$

where, C_n (mg/L) represents the concentration of the element n at the test site, while C_{tn} (mg/L) stands for the concentration of the element n at the control site [14]. The EF is a tool used primarily to indicate the source of the contamination. $EF < 1$ relates to a natural source of heavy metal deposition while $EF > 1$ relates to anthropogenic source of contamination

To calculate the heavy metal index (HMI), the following mathematical relationship was applied;

$$HMI = \sum_{i=1}^n \frac{C_n}{S_v} \quad (2)$$

where S_v represents the standard values. The standard values were obtained as mean and standard deviations of permissible levels of heavy metal set by United States Environmental Protection Agency (USEPA) [15], Nigeria Standard Drinking Water Quality (NSDWQ) [16], and World Health Organization (WHO) [17]. The HMI which is equivalent to the contamination factor indicates the degree of heavy metal contamination in a site. Four categories exist for the HMI; when $HMI < 1$ implies low contamination, when $1 \leq HMI < 3$ implies moderate contamination, $3 \leq HMI < 6$ stands for high contamination, while $6 \leq HMI$ implies very high contamination.

Estimation of Chronic Daily Intake (CDI), and Hazard Quotient (HQ)

The chronic daily intake via oral route (CDI_{ing}; mg/kg/day) was determined following the mathematical relationship below [18];

$$CDI_{ing} = \frac{C_n \times IR \times EF \times ED}{BW \times AT} \tag{3}$$

where IR (L/day) represents the ingestion rate, and EF (days/year) represents exposure frequency, ED (year) represents the exposure duration, BW (Kg) represents the body weight and AT (days) represents averaging time. Standard IR for adult swimmers is 21 mL/h. From the swimming pool management data, the average swim time per day (exposure time) is 5.4 h (i.e. 5.4 h/days). Thus, the calculated IR (mL/day) = 21×5.4= 113.4 mL/day = 0.113 L/day.

EF was obtained from documentations of the six pool management and the average EF is represented below;

$$EF = \frac{59+51+65+54+48+45}{6} = 53.6 \text{ days/year} \tag{4}$$

The BW was 70kg representing the average BW of an adult [19]. To calculate ED, the ages of individuals recorded in the registers kept by the management of the swimming pools were obtained. The range of ages of individuals that use these pools were obtained and the ED calculated by subtracting the least age from the maximum age found in the registers for each swimming pool. The average ED was calculated:

- 4 – 68 = 64 years ED for S.P1
- 5 – 61 = 56 years ED for S.P2
- 4 – 73 = 69 years ED for S.P3
- 4 – 64 = 60 years ED for S.P4
- 5 – 60 = 55 years ED for S.P5
- 4 – 61 = 57 years ED for S.P6

$$\text{Average ED} = \frac{64+56+69+60+55+57}{6} = 60.2 \text{ years}$$

$$AT = EF \times ED = 3226.72 \text{ days}$$

The chronic daily intake via the dermal route (CDI_{derm}; mg/kg/day) was calculated following the mathematical expression below;

$$CDI_{derm} = \frac{C_n \times SA \times K_p \times ET \times EF \times ED}{BW \times AT}$$

C_n is the heavy metal concentration (mg/L), SA is the surface body area of an adult given as 18000 cm² [20, 21], K_p (cm/h) represents the dermal permeability coefficient in water; 0.001 cm/h for As, Cd, Cu Se, and Hg, 0.0001 cm/h for Pb, 0.002 cm/h for Cr, and 0.0006 cm/h for Zn [22], 0.001 cm/h for Fe [23], and 0.0002 cm/h for Ni [24], while ET, EF, ED, BW, and AT are as given above.

Hazard quotient (HQ) was calculated following the relationship below;

$$HQ = \frac{CDI}{RfD}$$

where RfD is reference doses obtained from USEPA [25], Agomuo and Amadi [14], and Okereke and Amadi [26].

Statistical analysis

The data obtained was presented as mean ± SD of triplicates. Analysis of the data was carried out using Statistical Package for Science and Social Sciences (SPSS) version 20, using one way analysis of variance (ANOVA) and the least standard deviations (LSD) at 95% confidence interval (CI; p < 0.05) considered as significant.

RESULTS AND DISCUSSION

Fig. 1-7 shows the physicochemical properties of six popular swimming pools situated at Owerri Capital city of Imo State Nigeria. The range of temperature, pH and turbidity are 24.7-29.6°C, 5.6-6.9 and 38-90 NTU, respectively (Fig. 1, 2, 3). The

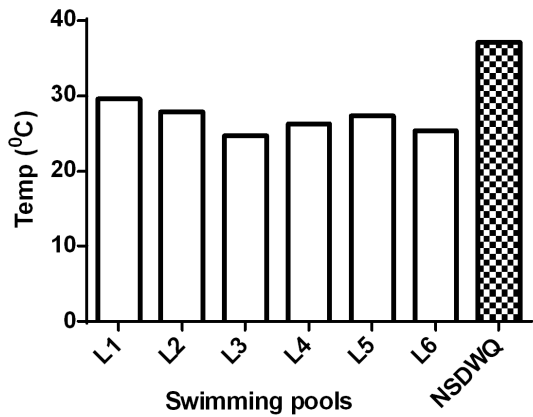


Figure 1. Temperatures of swimming pools
* NSDWQ=Nigeria Standard for Drinking Water Quality

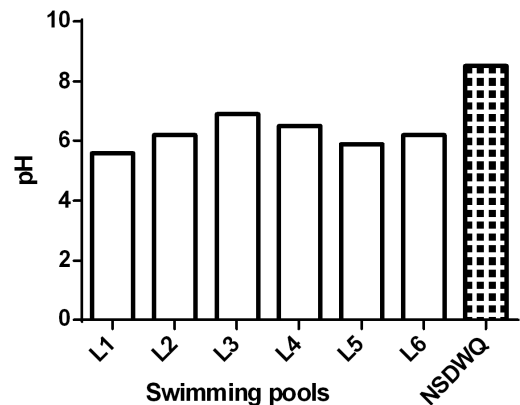


Figure 2. pH of swimming pools
* NSDWQ=Nigeria Standard for Drinking Water Quality

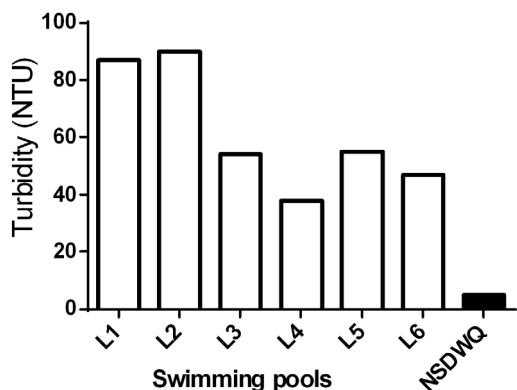


Figure 3. Turbidity of swimming pools
* NSDWQ=Nigeria Standard for Drinking Water Quality

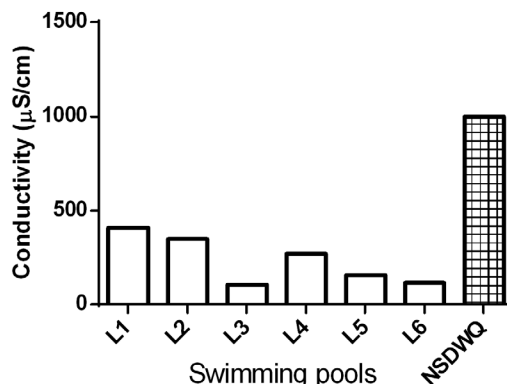


Figure 6. Conductivity of swimming pools
* NSDWQ=Nigeria Standard for Drinking Water Quality

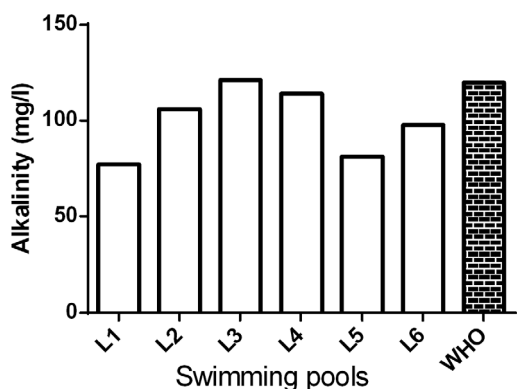


Figure 4. Alkalinity of swimming pools
* WHO=World Health Organization

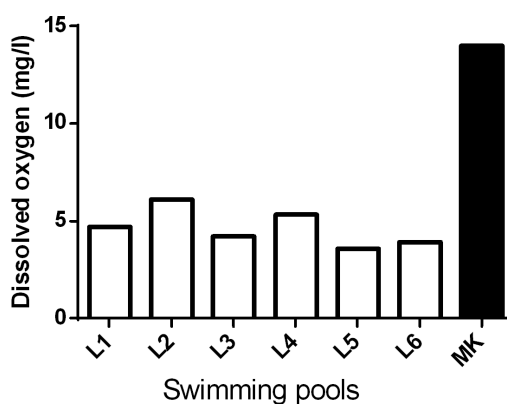


Figure 7. Dissolved oxygen of swimming pools
* MK= Manoj and Avinash [17]

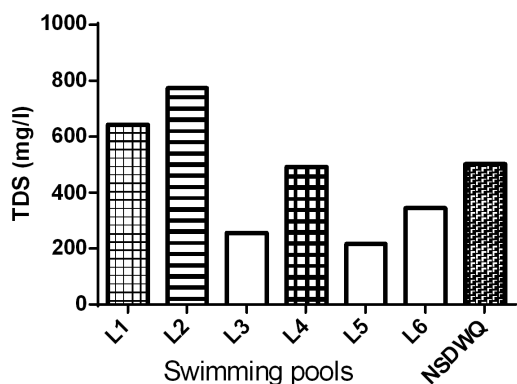


Figure 5. Total dissolved solute (TDS) of swimming pools
* NSDWQ=Nigeria Standard for Drinking Water Quality

range obtained for the alkalinity and TDS values are 77-119 mg/L and 218-9773 mg/L respectively (Fig. 4, 5). The range of the conductivity and dissolved oxygen values are respectively in a range of 109.3-408.5 mg/L and 3.6-6.1 mg/L (Fig. 6, 7). The

temperature, pH, alkalinity, dissolved oxygen, and conductivity recorded for all the swimming pools in this study were still within the regulatory limits adopted from NSDWQ, WHO, and Manoj and Avinash [17].

The turbidity of all the swimming pools shown in Fig. 3 exceeds the permissible limit. This has the potentials to reduce the aesthetic quality of the pools and poses negative impact on the recreational activities by reducing the patronage of the pools, and causes gastrointestinal related diseases [27]. Also, the TDS exceeds the reference value in some swimming pools. The TDS estimates the total organic and inorganic solids in the pools, and from this result, indicates that the aesthetic quality of those swimming pools have been compromised by a broad range of substances. The elevated levels of turbidity and TDS of the swimming pools could have occurred as a result of depositions of contaminants because of situating these swimming pools in the heart of the city without adequate internal safety measures.

Table 1 summarizes the Fe, Cd, Hg, As, and Ni contents of six

Table 1. Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), and nickel (Ni) contents (mg/L) of swimming pools

Swimming pool	Fe	Cd	Hg	As	Ni
L ₁					
Test	3.86±0.9 ^a	0.03±0.0 ^a	0.02±0.0 ^a	0.08±0.01 ^a	0.13±0.01 ^a
Control	1.06±0.3 ^b	BDL	BDL	0.02±0.0 ^b	0.06±0.0 ^b
Standard	0.20±0.1 ^c	0.003±0.0 ^b	0.001±0.0 ^b	0.01±0.0 ^b	0.02±0.0 ^c
L ₂					
Test	4.19±1.31 ^a	BDL	0.03±0.0 ^a	BDL	0.09±0.03 ^a
Control	0.71±0.2 ^b	BDL	0.01±0.0 ^a	BDL	0.03±0.0 ^b
Standard	0.20±0.1 ^c	0.003±0.0	0.001±0.0 ^c	0.01±0.0	0.02±0.0 ^b
L ₃					
Test	1.78±0.40 ^a	0.02±0.0 ^a	BDL	0.03±0.0 ^a	0.07±0.01 ^a
Control	0.35±0.02 ^b	0.01±0.0 ^a	BDL	0.01±0.0 ^b	0.02±0.0 ^b
Standard	0.20±0.1 ^b	0.003±0.0 ^b	0.001±0.0	0.01±0.0 ^b	0.02±0.0 ^b
L ₄					
Test	3.45±0.77 ^a	0.01±0.0 ^a	0.01±0.0 ^a	0.05±0.02 ^a	0.03±0.0 ^a
Control	1.21±0.31 ^b	0.01±0.0 ^a	BDL	0.02±0.0 ^b	BDL
Standard	0.20±0.1 ^c	0.003±0.0 ^b	0.001±0.0 ^b	0.01±0.0 ^b	0.02±0.0 ^a
L ₅					
Test	0.93±0.22 ^a	0.02±0.0 ^a	BDL	BDL	0.06±0.01 ^a
Control	0.31±0.07 ^b	BDL	BDL	BDL	0.02±0.0 ^b
Standard	0.20±0.1 ^b	0.003±0.0 ^b	0.001±0.0	0.01±0.0	0.02±0.0 ^b
L ₆					
Test	0.51±0.13 ^a	0.03±0.0 ^a	0.01±0.0 ^a	0.06±0.02 ^a	0.05±0.02 ^a
Control	0.41±0.11 ^a	0.01±0.0 ^a	BDL	0.01±0.0 ^b	0.03±0.0 ^{ab}
Standard	0.20±0.1 ^b	0.003±0.0 ^b	0.001±0.0 ^c	0.01±0.0 ^b	0.02±0.0 ^b

* L₁-L₆ = Location 1-6.

* Values are means and standard deviations of triplicate determinations.

* For each swimming pool, values bearing dissimilar superscript letter (s). ^{a, b}down the column denote that the mean difference is significant at p < 0.05. BDL = Below Detection Level.

popular swimming pools located in the heart of Owerri Capital, Imo State. From the result, the Fe contents at each of the swimming pools were significantly higher than the controls and standard values, ranging from 0.51-4.19 mg/L and 0.31-1.21 mg/L, respectively. Also, the Cd and Hg contents significantly exceeded the baseline values but occurred below detection levels at L₂, L₃ and L₅, respectively. The concentration of As and Ni also significantly exceeded both the control and baseline values, except at L₂ and L₅ where As was respectively undetected and equivalent to the control. No significant difference was observed between the control and standard values for both As and Ni. These findings pose serious concerns due to the significant numbers of activities and patronage of these commercial swimming pools. The As contents are possibly deposited into the pools from agricultural and mining activities, and leaching from toxic dumpsites [28, 29]. Pacyna and Pacyna [30] suggested that windblown dusts, oil combustion and incinerations of wastes around these pools primarily contributes to the deposition of Ni into these pools. The Fe contents of the swimming pools were higher than those of boreholes in Owerri [31], however, comparable with some control values in this study. The significantly higher control values in some of the swimming pools when compared to standard values observed

in this study may relate to the usage of rain water to refill the pools. Agomuo and Amadi, [14] earlier flagged the excessive contents of Cd and Hg in Owerri metropolis which could have contributed to the elevated amounts of heavy metals in this present study. It is possible that situating swimming pools at the heart of the city increases their susceptibility to Cd and Hg contamination. The report of Amadi [5] for the As and Ni contents of a water body in close proximity to these swimming pools in this study, agrees with the findings of this study. Thus, this implicates the environment possibly contaminated with As and Ni.

Table 2 shows the Se, Cr, Pb, Zn, and Cu levels of swimming pools in Owerri Metropolis. The Se and Cr contents of the swimming pools were within the permissible limits set by regulatory agencies. The concentration of Se was only recorded in one control sample while Cr levels of the control samples were also within the permissible limit. The Pb levels at all swimming pools significantly exceeded the permissible limits. Further, only half of the total swimming pools assessed contained significantly higher Zn levels than their baseline value, while Cu contents of the swimming pools were within the permissible limit. Notwithstanding that some of these heavy metals like Se, Zn and Cu are required for normal body metabolic

Table 2. Selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu) contents (mg/L) of swimming pools

Swimming pools	Se	Cr	Pb	Zn	Cu
L ₁					
Test	BDL	0.05 ± 0.0 ^a	0.05 ± 0.01 ^a	0.63 ± 0.2 ^a	0.33 ± 0.08 ^a
Control	BDL	BDL	0.02 ± 0.0 ^b	0.41 ± 0.1 ^a	0.08 ± 0.02 ^b
Standard	0.03 ± 0.02	0.05 ± 0.0 ^a	0.01 ± 0.0 ^b	4.33 ± 1.2 ^b	1.33 ± 0.60 ^c
L ₂					
Test	BDL	0.07 ± 0.01 ^a	0.09 ± 0.02 ^a	3.87 ± 1.01 ^a	0.50 ± 0.1 ^a
Control	BDL	0.02 ± 0.0 ^b	0.02 ± 0.0 ^b	0.24 ± 0.06 ^b	BDL
Standard	0.03 ± 0.02	0.05 ± 0.0 ^a	0.01 ± 0.0 ^b	4.33 ± 1.2 ^a	1.33 ± 0.60 ^b
L ₃					
Test	0.02 ± 0.0 ^a	0.04 ± 0.0 ^a	0.08 ± 0.02 ^a	3.11 ± 0.92 ^a	0.21 ± 0.05 ^a
Control	BDL	0.01 ± 0.0 ^b	0.04 ± 0.01 ^b	0.93 ± 0.14 ^b	0.20 ± 0.09 ^a
Standard	0.03 ± 0.02 ^a	0.05 ± 0.0 ^a	0.01 ± 0.0 ^c	4.33 ± 1.2 ^a	1.33 ± 0.60 ^b
L ₄					
Test	0.01 ± 0.0 ^a	BDL	0.05 ± 0.01 ^a	1.90 ± 0.50 ^a	1.82 ± 0.31 ^a
Control	BDL	BDL	0.01 ± 0.0 ^b	1.04 ± 0.29 ^b	0.30 ± 0.05 ^b
Standard	0.03 ± 0.02 ^a	0.05 ± 0.0	0.01 ± 0.0 ^b	4.33 ± 1.2 ^c	1.33 ± 0.60 ^a
L ₅					
Test	0.03 ± 0.0 ^a	0.07 ± 0.02 ^a	0.09 ± 0.04 ^a	4.43 ± 0.88 ^a	0.74 ± 0.13 ^a
Control	0.01 ± 0.0 ^b	0.01 ± 0.0 ^b	0.02 ± 0.0 ^b	1.21 ± 0.04 ^b	BDL
Standard	0.03 ± 0.02 ^a	0.05 ± 0.0 ^a	0.01 ± 0.0 ^b	4.33 ± 1.2 ^a	1.33 ± 0.60 ^c
L ₆					
Test	0.01 ± 0.0 ^a	0.04 ± 0.0 ^a	0.06 ± 0.02 ^a	2.75 ± 0.61 ^a	1.32 ± 0.38 ^a
Control	BDL	BDL	0.04 ± 0.01 ^a	2.16 ± 0.93 ^a	0.29 ± 0.05 ^b
Standard	0.03 ± 0.02 ^a	0.05 ± 0.0 ^a	0.01 ± 0.0 ^b	4.33 ± 1.2 ^c	1.33 ± 0.60 ^a

* L₁-L₆ = Location 1-6.

* Values are means and standard deviations of triplicate determinations.

* For each swimming pool, values bearing dissimilar superscript letter(s) (a, b) down the column denote that the mean difference is significant at p < 0.05. BDL = Below Detection Level.

Table 3. Enrichment factor (EF) of heavy metal depositions in swimming pools

Swimming pool	Fe	Cd	Hg	As	Ni	Se	Cr	Pb	Zn	Cu
L ₁	3.58	-	-	4.00	2.17	-	-	1.50	1.54	4.13
L ₂	5.90	-	3.00	-	3.00	-	3.50	4.50	16.13	-
L ₃	5.09	2.00	-	3.00	3.50	-	4.00	2.00	3.34	1.05
L ₄	2.85	1.00	-	2.50	-	-	-	5.00	1.83	6.06
L ₅	3.00	-	-	-	3.00	3.00	7.00	4.50	3.66	-
L ₆	1.24	3.00	-	6.00	1.67	-	-	1.50	1.27	4.55

* L₁-L₆ = Location 1-6.

* Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), nickel (Ni), selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu).

Table 4. Heavy metal index (HMI) of swimming pools

Swimming pools	Fe	Cd	Hg	As	Ni	Se	Cr	Pb	Zn	Cu	MI
L ₁	19.30	10.00	20.00	8.00	6.5	-	1.00	5.00	0.14	0.25	70.19
L ₂	20.95	-	30.00	-	4.5	-	2.33	9.00	0.89	0.38	68.05
L ₃	8.90	6.67	-	3.00	3.5	0.66	0.80	6.00	0.72	0.16	30.41
L ₄	17.25	3.33	10.00	5.00	1.5	0.33	-	5.00	0.44	1.37	44.22
L ₅	4.65	6.67	-	-	3.00	1.00	1.40	9.00	1.02	0.56	27.30
L ₆	2.55	10.00	10.00	6.00	2.5	0.33	0.80	6.00	0.64	0.99	39.81

* L₁-L₆ = Location 1-6.

* Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), nickel (Ni), selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu).

processes, excessive intake could become very poisonous [32]. In this study, though none of those metals including Cr exceeded the baseline values, imminent strategies are required to halt their deposition into these swimming pools. The signif-

icantly high level of Pb in these swimming pools may not be surprising due to proximity of these swimming pools to dump sites and metallic constructions firms during road works, and filling station reservoir tanks for petroleum products. Thus, the

Table 5. Chronic daily intake (CDI; mg/kg/day) of heavy metals in swimming pools via oral and dermal routes

CDI BY ORAL EXPOSURE										
Swimming pool	Fe ($\times 10^{-3}$)	Cd ($\times 10^{-5}$)	Hg ($\times 10^{-5}$)	As ($\times 10^{-4}$)	Ni ($\times 10^{-4}$)	Se ($\times 10^{-5}$)	Cr ($\times 10^{-5}$)	Pb ($\times 10^{-5}$)	Zn ($\times 10^{-3}$)	Cu ($\times 10^{-4}$)
L ₁	6.21	4.85	3.22	1.28	2.04	-	8.05	8.05	1.01	7.46
L ₂	6.74	-	4.85	-	1.45	-	11.27	14.49	6.23	8.05
L ₃	2.86	3.22	-	0.49	1.12	3.22	6.44	12.88	5.01	3.38
L ₄	5.55	1.61	1.61	0.81	0.48	1.61	-	8.05	3.06	29.30
L ₅	1.49	3.22	-	-	0.97	4.83	11.27	14.49	7.13	11.91
L ₆	0.80	4.85	1.61	0.97	0.81	1.61	6.44	9.66	4.43	21.25
CDI BY DERMAL EXPOSURE										
Swimming pool	Fe ($\times 10^{-5}$)	Cd ($\times 10^{-6}$)	Hg ($\times 10^{-7}$)	As ($\times 10^{-6}$)	Ni ($\times 10^{-7}$)	Se ($\times 10^{-7}$)	Cr ($\times 10^{-6}$)	Pb ($\times 10^{-7}$)	Zn ($\times 10^{-6}$)	Cu ($\times 10^{-6}$)
L ₁	8.91	0.69	4.62	1.84	6.01	-	2.31	1.15	0.86	7.62
L ₂	11.34	-	6.93	-	4.15	-	3.23	2.07	5.34	11.55
L ₃	4.11	0.46	-	0.69	3.23	4.62	1.85	1.84	4.29	4.85
L ₄	7.96	0.23	2.31	1.12	1.39	2.31	-	1.15	2.62	42.04
L ₅	2.15	0.46	-	-	2.77	6.93	3.23	2.07	6.11	17.09
L ₆	1.17	0.69	2.31	1.39	2.31	2.31	1.85	1.38	3.79	30.49
RfD**	0.7	1×10^{-3}	4×10^{-5}	3×10^{-4}	2×10^{-2}	5×10^{-3}	3×10^{-3}	3.5×10^{-3}	3×10^{-1}	1×10^{-2}

* L₁-L₆ = Location 1-6.

* Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), nickel (Ni), selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu).

** RfD: Reference dose.

Table 6. Hazard quotient (HQ) of heavy metals and Total Hazard Index of swimming pools via oral and dermal exposure routes

Swimming pool	L ₁	L ₂	L ₃	L ₄	L ₅	L ₆
Fe _{ing} ($\times 10^{-3}$)	8.87	9.62	4.08	7.92	2.12	1.14
Fe _{derm} ($\times 10^{-5}$)	12.72	16.20	5.87	11.37	3.07	1.67
Cd _{ing} ($\times 10^{-2}$)	4.85	-	3.22	1.61	3.22	4.85
Cd _{derm} ($\times 10^{-3}$)	0.69	-	0.46	0.23	0.46	0.69
Hg _{ing}	0.81	1.21	-	0.40	-	0.40
Hg _{derm}	1.15	1.73	-	0.58	-	0.58
As _{ing}	0.43	-	0.16	0.27	-	0.32
As _{derm} ($\times 10^{-2}$)	0.61	-	0.23	0.37	-	0.46
Ni _{ing} ($\times 10^{-2}$)	1.02	0.72	0.56	0.24	0.48	0.40
Ni _{derm} ($\times 10^{-5}$)	3.00	2.07	1.61	0.69	1.38	1.15
Se _{ing} ($\times 10^{-2}$)	-	-	0.64	0.32	0.96	0.32
Se _{derm} ($\times 10^{-4}$)	-	-	0.92	0.46	1.38	0.46
Cr _{ing} ($\times 10^{-2}$)	2.68	3.75	2.14	-	3.75	2.14
Cr _{derm} ($\times 10^{-3}$)	0.77	1.07	0.62	-	1.07	0.62
Pb _{ing} ($\times 10^{-2}$)	2.30	4.83	4.23	2.30	4.83	0.39
Pb _{derm} ($\times 10^{-4}$)	0.33	0.59	0.53	0.33	0.59	0.39
Pb _{ing} ($\times 10^{-2}$)	0.33	2.07	1.67	1.02	2.37	1.47
Pb _{derm} ($\times 10^{-5}$)	0.28	1.78	1.43	0.87	2.03	1.26
Cu _{ing} ($\times 10^{-2}$)	7.46	8.05	3.38	29.30	11.91	21.25
Cu _{derm} ($\times 10^{-4}$)	7.62	11.55	4.85	42.04	17.09	30.49

* L₁-L₆ = Location 1-6.

* Iron (Fe), cadmium (Cd), mercury (Hg), arsenic (As), nickel (Ni), selenium (Se), chromium (Cr), lead (Pb), zinc (Zn), and copper (Cu).

leaching of Pb, and possibly some other heavy metals is obtainable. In addition to this, most of these swimming pools are refilled through old pipes capable of depositing Pb materials into the water and its significantly excessive Pb levels.

Table 3 and 4 represents EF and HMI of six commercial swimming pools situated at Owerri Metropolis. EF is an essential tool that indicates the source of heavy metal pollution at a given location [26]. EF > 1 indicates anthropogenic sources of contamination while EF < 1 shows natural sources of deposi-

tion of these metals. In Table 3, all the swimming pools record EF values > 1 for all the heavy metals detected, whereas some metals in some pools were found below detection limits, indicating anthropogenic sources of heavy metal deposition. Again, the locations of these swimming pools, coupled to perhaps the activities that occur, have been shown to be contributory to the elevations of heavy metal contents of these swimming pools. While describing the usefulness of HMI in determining water quality, Gohera et al., [33] posited its effective-

ness as a parameter for assessing the pollution status of a water sample. It cumulatively takes account of all the levels of each heavy metal evaluated, and when above unity (1), shows that the water is unsafe for consumption. From Table 4, all the swimming pools are highly threatened with heavy metal pollution with L_1 followed closely by L_2 the most threatened, and L_3 the least threatened.

Table 5 and 6 show the CDI via oral and dermal exposure and the HQ of six commercial swimming pools situated at Owerri Metropolis. The CDI result for Fe and Cd implies that their levels of occurrences were still below the reference doses while their respective HQ values indicate that at those levels in which patrons of those swimming pools are unlikely to encounter any Fe or Cd related toxicities. This was the same case for Ni, Se, Cr, Pb, and Zn. However, the deposition of these heavy metals into these swimming pools has to be curtailed. Results for oral intake of Hg especially at L_1 and L_2 exceeded their respective reference doses as shown in Table 5 while in Table 6, the sum of HQs for L_2 exceeded 1, implying the potentials of the pool at L_2 to causing Hg poisoning. Also, oral intake levels of As attained a close level to the reference dose, thus requiring very imminent measures that can effectively curtail the deposition of As in these pools. By dermal exposure, none of the deposited heavy metals exceeded their respective reference doses hence may not portend any toxic risk. Hg toxicities could manifest as desquamation [34], central nerve system and autoimmune diseases [35] and Young's syndrome [34], while for As poisoning, cardiovascular and skin diseases, abdominal pain and cancer could result [37]. Also, as shown in Table 6, only L_2 among six swimming pools portends the potentials of eliciting metal toxicities having shown HQ value greater than 1. In addition, the toxic risk of the cumulative contents of all the heavy metals in each of the swimming pools indicates two of the swimming pools are unsafe.

Conclusion

This study has shown that the aesthetic quality of the swimming pools was compromised, and contained elevated levels of Hg, As, and Cu, which were significant enough to threaten the health safety of users of these swimming pools users. Thus, imminent strategies are required by the regulatory bodies to checkmate the safety processes applied by the management of these commercial swimming pools to prevent the heavy metal contamination, and enforce compliance to standard approaches. Also, this result raises serious concerns over the heavy metal pollution status of the metropolis at large, as well as the rationale behind situating commercial swimming pools

in the heart of population dense cities without adequate protections put in place.

Conflict of interest

No conflict of interest declared.

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