ASSESSMENT OF ENVIRONMENTAL QUALITY OF TWO INDUSTRIAL CITIES IN NORTH-CENTRAL NIGERIA USING METAL POLLUTION INDICES

Stephen Oyedeji[1], Chinedu N. Eze[2], Clement O. Ogunkunle[3], Paul O. Fatoba[4]

[1,2,3,4] Plant Ecology and Environmental Management Unit, Department of Plant Biology, University of Ilorin, Ilorin, 240003 Nigeria.
Email: [1]oyedeji.s@unilorin.edu.ng

Abstract

The study assessed the environmental quality around industrial areas of Jos and Kaduna, north-central Nigeria using heavy metals concentration in waste water (effluent) and atmospheric dust. Effluent and moss samples collected in replicates from two industrial sites in Jos and Kaduna were analyzed for Cd, Cu, Pb, Zn and Cr using Atomic Absorption Spectrophotometer (Buck Scientific - 210 VGP). The concentrations of heavy metals in the effluents varied with site and location. Heavy metals concentrations were highest at the point of drain (0 m) across the industrial sites. Heavy metals contaminations were observed in mosses across the sites, with NGL (Jos) recording the highest levels. The pollution load indices reflected depletion in environmental quality across the industrial sites.

Key words: contamination, deposition, environmental health, heavy metals, pollution index, waste water.

I. INTRODUCTION

The indiscriminate release of industrial effluents into the environment is on the rise, especially in developing countries where no strict sanctions is in place to check the ugly trend. Industrial wastes generated from multifarious production processes are known to cause undesirable effects in living organisms. Most large cities in developing countries like Nigeria are feeling the pinch of pollution from industrial effluents as tons of untreated or incompletely treated wastes end up yearly in lagoons, rivers and streams [1]. Also, emissions from production and power generating plants, likewise atmospheric deposition from busy traffic of loading and unloading vehicles contribute significantly to heavy metals levels in the immediate environment around industries [2]. Heavy metals pollution is a great environmental problem as these pollutants accumulate to produce toxic effects in living organisms. Unlike biodegradable organic pollutants, heavy metals have great stability in living tissues and are transported throughout the food chain leading to serious ecological and health problems. Humans are exposed to these metals in many ways through air, water, soil and most commonly agricultural crops [3]. The health effects of these metals have been known since ancient history [4]. More worrisomely, some relatively accessible metals like copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb) and zinc (Zn) had been reported to produce toxic effects beyond permissible concentrations [5]. Diminished intellectual capacity, gastrointestinal symptoms, coronary heart disease, variety of cancers, such as renal, skin, and bladder cancers, and even death have also been associated with chronic and/or acute exposures to heavy metals [4]. Growth retardation and associated physiological disorders from Cd, Cr, Cu, Ni, Pb and Zn contaminated soils and irrigation water was also reported for plants [6].

The presence of heavy metal pollutants has been considered as useful indicators of contamination in surface soil, sediment and dust environments [7]. The use of mosses to monitors atmospheric pollutants has been well documented in literature [8][9]. The suitability of moss plants to monitor atmospheric pollution is hinged on their large surface area-volume ratio and the non-selective ability to absorb these chemicals directly from wet or dry deposition [10]. Monitoring environmental standards around industrials sites is necessary to reduce the risk of exposure to heavy metal contaminations associated with waste generation and contamination around the sites. The aim of this study is to assess the environmental quality in the industrial cities of Jos and Kaduna, north-central Nigeria using heavy metals concentration in effluents and atmospheric dusts.

II. MATERIALS AND METHODS

A. Study areas

The study was carried out in the industrial areas of Jos, and Kaduna, north-central Nigeria. Jos, the capital city of Plateau state was established in 1915 to serve as a transportation camp for tin. The city is located between latitudes 08° 30□ to 10° 10□ N and longitudes 08° 20□ to 09° 30□ E and lies on a plateau that stretches approximately 104 km from north to south and 80 km from east to west, covering an area of about 9,400 km^2 [11]. The city enjoys near temperate climate and a beautiful landscape that makes it investor's destination in Nigeria. With an estimated population of about 1,000,000 [12], the city houses many industries with some notable ones being NASCO Group, Grand Cereal and Oil Mills, Jos International Breweries and Northern Nigeria Fibre Products.

Kaduna, the capital city of Kaduna state is located between 10° 27□ N to 10° 38□ N and 7° 20□ E to 7° 35□ E. It is a fast developing city with an estimated population of about 2 million in 2015 [13]. The unprecedented rise in population is adduced to its proximity to the Federal Capital Territory, Abuja [14]. The population growth has led to increased environmental pollution from various human activities including agriculture, mining, deforestation, urbanization, construction and industrialization [13]. Kaduna city today, is home to major industries and factories like Nigerian Breweries, Northern Noodles Ltd. (Indomie), Nigerian National Petroleum Corporation, United Nigeria Textiles Plc, Peugeot Automobile, to mention a few.

B. Sampling and analysis

Sampling locations for the study were selected in late October 2013 (early dry season in north-central Nigeria) based on the availability of moss plant around the factory and the release of wastewater from the factory. Two production factories each were selected in Jos [NASCO Group Limited (NGL) and Grand Cereal and Oil Mill Limited (GCL)] and in Kaduna [Nigerian Breweries Plc. (NBP) and United Nigeria Textiles Plc. (UNP)]. Farin Gada (in Jos) and Angar Makama (in Kaduna), where moss plants were growing with less human interference were chosen as the Control sites. Green/brownish green moss plants reflecting recent seasonal growth were collected in five replicates from wood and sandcrete materials at points around the perimeter of the factory

site. The collected moss samples were washed with de-ionized water to remove debris and air dried to a constant weight. Dried moss samples were homogenized in a stainless steel blender prior to chemical analysis. Effluent samples were collected in five replicates at 0 m (point of release/drain just outside the factory), 10 m and 20 m along each factory wastewater drain and acidified with nitric acid (HNO$_3$) prior to chemical analysis. 1 g of moss sample or 1 ml of effluent sample was digested with 30 ml concentrated nitric acid (HNO$_3$) and 10 ml hydrochloric acid (HCl) was added sequentially. The mixture was heated on a hot plate until a clear solution was visible. The digest was filtered through Whatman filter paper No. 42 and made up to 100 ml with deionized water. Concentrations of cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn) and chromium (Cr) were determined from the filtrate using atomic absorption spectrophotometer (Buck Scientific Model 210 VGP) at wavelengths (λ) of 228.8 nm for Cd, 324.7 nm for Cu, 283.3 nm for Pb, 213.8 nm for Zn and 357.9 nm for Cr. Quality assurance for heavy metals in the moss plants were carried out using certified reference material (IAEA-336) while blanks were prepared for both moss and water samples.

Data obtained for metal concentrations in wastewater and moss plants were analyzed using SAS 9.3 for Windows. Data for heavy metals in the moss plants were used to determine the degree of contamination around the factory using the contamination factor (*CF*), degree of contamination (*C$_d$*), modified degree of contamination (*mC$_d$*) and pollution load index (*PLI*).

The contamination factor was calculated as

$$Contamination\ Factor, CF = \frac{C_m}{C_{background}} \quad ..... (1)$$

Where *C$_m$* is the concentration of the metal in the moss sample around the factory and *C$_{background}$* is the background concentration of the metal in the moss. The degree of contamination (*C$_d$*) is calculated from (1) thus:

$$Degree\ of\ Contamination, C_d = \sum_{1=1}^{N} CFi \quad ....$$
$$(2)$$

Where *CFi* is the contamination factor for the ith metal and N is the number of metals considered. The modified degree of contamination (*mCd*) was obtained from (2) as

$$Degree\ of\ Contamination, mC_d = \frac{1}{N}\sum_{1=1}^{N} CFi$$

..... (3)

The pollution load index (*PLI*) was calculated from thus:

$$Pollution\ load\ index, PLI = (CF_1 \times CF_2 \times CF_3 \times ... \times CF_N)^{1/N}$$

... (4)

The *PLI* gives an estimate of the metal contamination status and the necessary action that should be taken. A *PLI* < 1 denote perfection; *PLI* = 1 indicate that only baseline levels of pollutants are present and *PLI* > 1 indicate deterioration of site quality [15].

The categories for contamination factor (*CF*) and degree of contamination (*Cd*) are presented in Table 1 while the classes of modified contamination factor (*mCd*) according to Likuku et al. [16] are presented in Table 2.

III. RESULTS AND DISCUSSION

A. Metal concentrations in industrial effluents

The results for Cd, Cu, Pb, Zn and Cr concentration in the effluents from NGL (Jos) are shown in Fig. 1. The concentrations of the studied metals were highest at 0 m from the factory. Pb and Cr had the highest and lowest concentrations respectively in the effluent in all three sampling points (0, 10 and 20 m from the drain point). The results of heavy metals in effluents from GCL (Jos) showed Cd had the least concentration at the 3 sampling points (Fig 2). Cr concentration was highest at the 0 m point but lower than Cu at 10 m point. The concentrations of Cr, Cu and Pb were highest in the effluent at 20 m (2.69±0.32 mg/l, 2.51±0.40 mg/l and 2.69±0.70 mg/l respectively). The concentrations of the Cd, Cu, Pb and Zn in the effluents from NGL were higher than 0.38 mg/l, 0.37 mg/l, 1.03 mg/kg and 1.87 mg/l respectively reported in polluted river dam in Jos [17] . The results of Cd and Zn for GCL were within the range of 0.01-0.38 mg/l and 0.95-1.87 mg/l reported respectively for both metals in Jos. Figure 3 showed higher concentrations of all metals at 0 m than at 10 m and 20 m from the factory (NBP,

Kaduna). The order of metals concentration was Cd > Zn > Cu > Cr > Pb at 0 m and 10 m. However, Zn was higher than Cd at 20 m. In waste water from UNP (Kaduna), Cr and Cd concentrations were highest. Metals concentration decreased with increasing distance from the drain point (Fig. 4). The concentrations of the metals in the effluents from GCL were low compared with most of the other sites. The levels of Cd, Cr and Cu in the effluents across the sites were higher than the permissible limits of 0.01, 0.10 and 0.20 mg/l respectively stipulated by FAO for irrigation purposes [18]. The levels of Zn in most of the sampled points also exceeded 2.00 mg/l permitted by FAO, except for the UNP at the 20 m point and GCL at both 10 m and 20 m points. Pb levels across the industrial sites were within FAO permissible limits of 5.00 mg/l except for NGL.

B. Metal concentrations in mosses and environmental quality assessment

The results of metal concentrations in the moss plants revealed significant differences among the metals and variations in various orders of magnitude from site to site (Table 3). Pb concentration was highest in NGL (14.29±1.80 mg/kg) while Cr had the least (5.98±0.71 mg/kg). Metal concentrations in mosses at NGL were higher than at GCL. The concentration of Cu was highest in NBP (10.19±1.35 mg/kg) while Cd was highest in UNP (7.44±1.62 mg/kg). Heavy metal contamination in moss plants gives a reflection of atmospheric quality as these plants are able to obtain elements and nutrients directly from wet and dry deposition [19]. Cd levels in the mosses around NGL and UNP were higher than reported for 1.54 – 2.54 mg/kg reported for Jos [20]. The level of Cd at NBP was within the cited range but it was much lower at GCL. The levels of Cu, Pb and Zn across all sites were lower than the reported ranges of 24.5-67.0 mg/kg, 25.0 - 66.0 mg/kg and 35.0-123 mg/kg respectively for the area [20]. Cr concentrations across the sites were higher than the reported range of 0.019-0.111 mg/kg for Jos [21].

The results of contamination factor (*CF*) shows that NGL was very highly contaminated with Pb, Cu and Cd but considerably contaminated with Zn and Cr (Table 4). GCL was low for Cd contamination, moderate for Zn and Cu, but considerably high for Cr and Pb. NBP was moderately contaminated with Cd but very highly contaminated with Cr, Zn, Cu and Pb. UNP was however

moderately contaminated by Cu and Pb, considerably highly contaminated by Zn and very highly contaminated by Cr and Cd. The assessment of the site quality using metal contamination factors in the mosses around industrial sites, relative to the less polluted control site, showed high contamination with heavy metals ($C_d > 32$), except for GCL. The very high contamination indicated for NGL and NBP by the C_d index was further confirmed by the modified contamination factors (mC_d) of 11.13 and 9.77 respectively. However, mC_d index for NBP revealed high degree of contamination ($mC_d = 6.72$) while GCL ($mC_d = 2.13$) was confirmed to be moderately contaminated. The pollution load index for all the factory sites revealed deterioration of the site quality ($PLI > 1$). Except for the contamination factor for Cd in GCL, *CF and PLI* value were generally higher than the reported for Jos metropolitan [20].
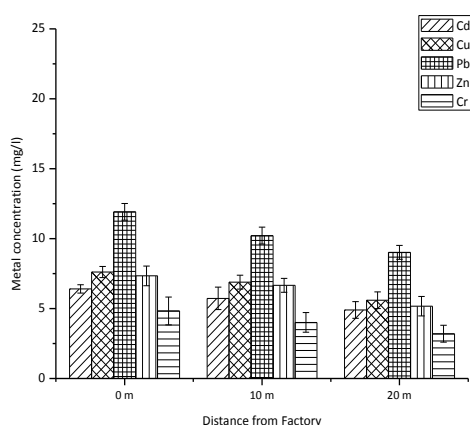

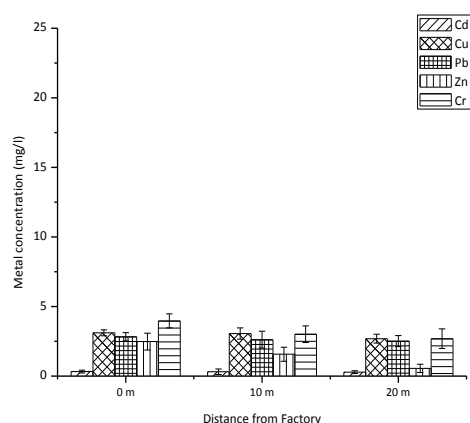Fig. 1: Heavy metal concentrations in effluent from NGL (Jos).

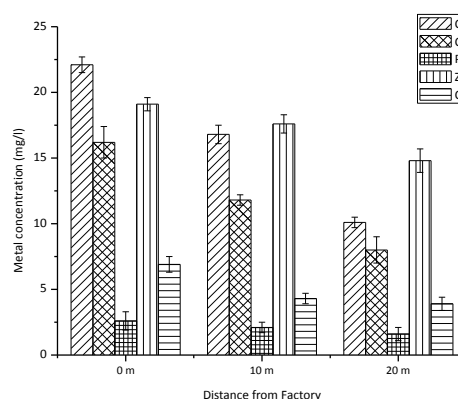Fig. 2: Heavy metal concentrations in effluent from GCL (Jos).

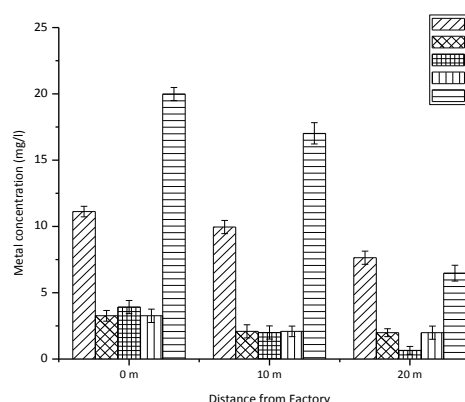Fig. 3: Heavy metal concentrations in effluent from NBP (Kaduna).

Fig. 4: Heavy metal concentrations in effluent from UNP (Kaduna).

Table 1: Contamination factors and degree of contamination categories and terminologies

CF classes	CF and C_d terminologies	C_d classes
CF < 1	Low CF/ low C_d	$C_d < 8$
1 ≤ CF < 3	Moderate CF / C_d	$8 ≤ C_d < 16$
3 ≤ CF < 6	Considerable CF / C_d	$16 ≤ C_d < 32$
CF ≥ 6	Very high CF / C_d	$C_d ≥ 32$

Table 2: Modified degree of contamination classification and description

mC_d classes	Modified degree of contamination level
$mC_d < 1.5$	Nil to very low degree of contamination
$1.5 ≤ mC_d < 2$	Low degree of contamination
$2 ≤ mC_d < 4$	Moderate degree of contamination
$4 ≤ mC_d < 8$	High degree of contamination
$8 ≤ mC_d < 16$	Very high degree of contamination
$16 ≤ mC_d < 32$	Extremely high degree of contamination
$mC_d ≥ 32$	Ultra high degree of contamination

Table 3: Heavy metals concentrations in mosses (in mg/kg) around industrial sites in Jos and Kaduna, Nigeria.

Site	Jos			Kaduna		
	NGL	GCL	Control	NBP	UNP	Control
Cd	$13.34^a \pm 3.19$	$0.49^e \pm 0.04$	1.02 ± 0.30	$2.53^e \pm 0.46$	$7.44^a \pm 1.62$	0.90 ± 0.30
Cu	$13.35^a \pm 2.34$	$2.10^c \pm 0.49$	1.00 ± 0.49	$10.19^a \pm 1.35$	$2.65^c \pm 1.00$	1.10 ± 0.30
Pb	$14.29^a \pm 1.80$	$2.91^b \pm 0.36$	0.80 ± 0.20	$8.52^b \pm 0.70$	$2.25^c \pm 0.61$	1.00 ± 0.19
Zn	$6.17^b \pm 3.15$	$1.14^d \pm 0.12$	1.07 ± 0.30	$5.55^c \pm 1.45$	$2.40^c \pm 0.57$	0.50 ± 0.11
Cr	$5.98^b \pm 0.71$	$3.62^a \pm 0.43$	1.00 ± 0.20	$5.14^d \pm 0.82$	$4.76^b \pm 2.54$	0.30 ± 0.04

Values are mean ± standard deviation. Means with the same superscripted letter are not significantly different at α = 0.05.

Table 4: Contamination factor, degree/modified degree of contamination and pollution index for heavy metals deposits on mosses around industrial sites in Jos and Kaduna.

	Metals	NGL	GCL	NBP	UNP
	Cd	13.08	0.48	2.81	8.27
	Cu	13.35	2.10	9.26	2.41
CF	Pb	17.86	3.64	8.52	2.25
	Zn	5.77	1.07	11.10	4.80
	Cr	5.59	3.38	17.13	15.87
		55.65	10.67	48.83	33.59
C_d		11.13	2.13	9.77	6.72
mC_d		10.01	1.68	8.41	5.09

IV. CONCLUSION

The high concentrations of heavy metals in effluent at close distances to the factory confirm contamination from anthropogenic releases rather than soil weathered materials. The high pollution indices for metal contamination reflect deterioration of site quality from industrial waste releases. It is therefore recommended that industries should be cited remote for residential and agricultural lands as to prevent associated health risk from heavy metals contamination.

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