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Risk Assessment of Raw Effluents Discharged From an Industrial Estate in Lagos, Southwestern Nigeria

By

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Research Article

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ABSTRACT

An industrial area was selected for geo-environmental studies in Lagos due to the discharge of raw effluents into the open drains. Effluent samples were collected from nine sites and taken to the analyzing laboratory for chemical analysis. The concentrations of constituent elements were determined using Inductively Coupled Plasma (ICP) and Optical Electro Spectrometer (OES) standard methods. The results obtained for toxic heavy metals show mean concentrations in the order of abundance given as Fe>Mn>Zn>Cu>Pb>Cd.
Physico-chemical parameters, such as electrical conductivity (EC), total dissolved solids (TDS), temperature, pH and elemental composition were obtained and the trend of abundance of elements is given as Na>Ca>Mg>K>P. The coefficient of determination r^2= 0.9967 obtained for EC and TDS shows a good positive correlation coefficient between the two parameters while temperature and pH varied anomalously. This study reveals that the concentrations of toxic heavy metals and physico-chemical parameters were significantly higher than the permissible limits of WHO which could pose a huge adverse effect to man and the environment. Therefore, the polluting industries have the duty-of-care to manage their effluent disposal in order to safeguard the aesthetic integrity of the environment and to ensure public safety.

Keywords: risk assessment, raw effluents, industrial estate, heavy metals, pollution, health, environment.

INTRODUCTION

The increasing rate of industrialization, technical development and socio-economic growth has led to rapid expansion of the industrial sector in developing countries. Sequel to this, the quantity of toxic wastes being discharged into the environment on a daily basis is rapidly creating undue environmental degradation and health hazards. An industrial area in Lagos, southwestern Nigeria was mapped out for environmental risk assessment studies due to point source discharge of raw effluents into the environment which may pose potential health risks to the inhabitants and also constitute an environmental nuisance.

Prolonged exposure of man to toxic heavy metals in the cities has been reported by many researchers. Heavy metals such as As, Hg, Fe, Ni, Pb, Zn, Cu and Cd are prominent components of industrial effluents (Nriagu and Pacyna, 1988; Schalscha and Ahumada, 1998). Hollum (1977) reported the cadmium poisoning from a Zn refinery which caused bone damage to the consumers of rice irrigated with the polluted water. Heavy metals have become increasingly significant within the framework of environmental pollution investigation (Le Riche and Weir, 1963; Helz et al., 1975; Malle, 1990).

Heavy metals are of serious concern as a result of their persistence in the environment and their carcinogenicity to human beings. They transform from one oxidation state or organic complex to another because they are not biodegradable (Garbisu and Alkorta, 2001; Gisbert et al., 2003). Indiscriminate disposal of untreated industrial effluents into the drains at the study sites have been creating environmental nuisance which tends to degrade the aesthetic integrity of the environment. The discharge of raw effluents from the industries flows freely through the open channels in the cities. This research is focused on the appraisal of the nature of chemical composition, toxicity levels of the effluents, potential health risks posed to the inhabitants and likely pollution management approach that could be adopted for sustainable co-existence and development.

MATERIALS AND METHODS

Raw effluent samples were collected from point source discharge at the sites of various manufacturing industries which includes but is not limited to agrochemical, pharmaceutical, confectionery, paints and dye. The sites were denoted with Lag-01 to Lag-10 as shown in Table 1. Effluent samples were collected in plastic containers;

pre-washed in non-ionic detergent, rinsed with tap water and later soaked in 10% HNO_3 for 24 hours before it was rinsed with distilled water prior to usage.

The samples were labeled appropriately and conveyed to the laboratory for chemical analysis using the standard procedures. The chemical components were analyzed using Inductively Coupled Plasma (ICP) and Optical Electro Spectrometer (OES) proposed by Thompson and Welsh (1989). The effluent temperature, EC, TDS and pH were measured in the field using a Symphony SP80PC portable instrument. Accuracy was ±0.1℃ for temperature, ±0.05 for pH and 1% for EC. The concentrations of heavy metals, physico-chemical parameters and constituent elements in the effluent samples vary considerably from one site to another.

RESULTS

The results obtained from the chemical and statistical analyses of effluent samples are reported in Tables 1 to 4 and depicted graphically in Figs. 1 to 5 respectively.

Table 1: Heavy metal concentrations in effluent samples at various sampling points (mg/L)

Sampling points	Fe	Mn	Pb	Zn	Cu	Cd
Lag-01	8.5	3.3	0.8	2.9	3.6	0.7
Lag-02	6.1	3.6	0.7	2.2	2.4	0.8
Lag-03	10.7	3.4	0.8	3.9	3.9	0.7
Lag-04	3.8	2.7	0.5	3.1	1.8	0.3
Lag-05	7.4	3.2	0.8	3.8	3.5	0.5
Lag-06	3.9	3.4	0.8	3.0	2.0	0.2
Lag-07	6.1	3.8	0.9	2.8	3.0	0.4
Lag-08	4.7	2.9	0.4	3.4	2.2	0.3
Lag-09	11.9	5.0	0.9	4.9	4.0	0.9

The concentrations of heavy metals in effluent samples varied from one location to another which is presented in Fig. 1 below.

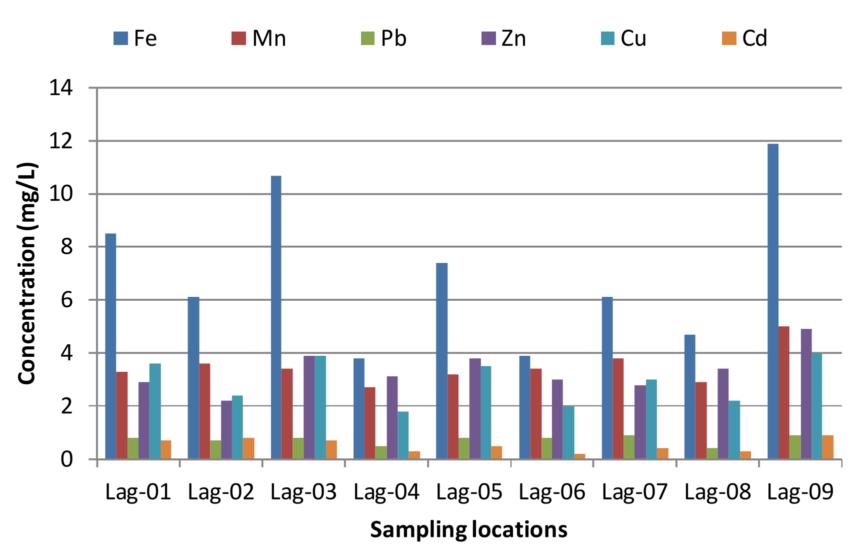

Figure 1: DISTRIBUTION OF HEAVY METALS IN EFFLUENT SAMPLES

Table 2 presents the results of statistical analysis computed for the heavy metals. Mean concentrations of heavy metals in the order of abundance is given as Fe>Mn>Zn>Cu>Pb>Cd. Fe has the highest value of 11.9 mg/L while Cd has the least value of 0.2 mg/L. Fig. 2 is a graphical illustration of the mean concentration of heavy metals in effluent samples.

Table 2: Some statistical parameters obtained for heavy metals in effluent samples (mg/L)

Parameters	Fe	Mn	Pb	Zn	Cu	Cd
Minimum	3.8	2.7	0.4	2.2	1.8	0.2
Maximum	11.9	5.0	0.9	4.9	4	0.9
Average	7.01	3.48	0.73	3.33	2.93	0.53

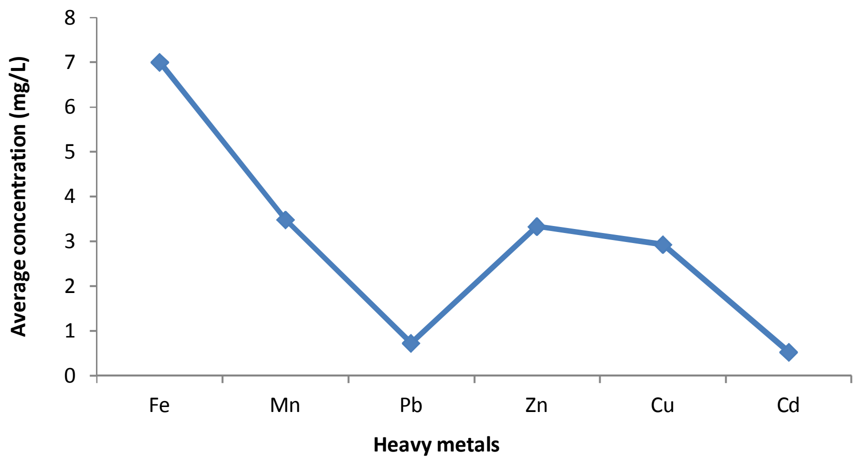

Figure 2: AVERAGE CONCENTRATION OF HEAVY METALS IN EFFLUENT SAMPLES

Physico-chemical parameters and elemental composition

The measured physico-chemical and statistical parameters are shown in Tables 3 and 4 respectively. The elements under consideration are Ca, Mg, Na, K and P whilst the physico-chemical parameters are EC, TDS, temperature and pH respectively.

Table 3: Physico-chemical parameters and elemental composition of effluent samples at various sampling points

Sampling Points	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	P (mg/L)	EC (*µmhos/cm*)	TDS (mg/L)	Temp. (°C)	pH
Lag-01	395.6	200.1	400.8	180.6	80.4	4102.8	3780.2	33	6.3
Lag-02	361.8	180	350	150.3	30.3	3200.6	2799.4	28	5.8
Lag-03	400.1	210.7	410.5	193.8	100.8	4446.2	4001.8	35	5.2
Lag-04	280.6	162.9	300.7	140	8.9	1989.7	1567.8	30	7.7
Lag-05	386	198.9	390.4	177.7	40.4	4000.8	3655.7	31	5.5
Lag-06	300.5	170	255.6	100.3	20.5	2300.4	1898.9	27	7.8
Lag-07	380	190.5	396	150.5	85.3	3789.5	3345.9	30	5.7
Lag-08	320.3	177.3	322.8	90.9	50.7	2898.1	2400.5	32	6.0
Lag-09	450.4	250.8	480.7	200.6	92.8	4659.7	4200.6	39	5.0

The distribution of elements in effluent samples varied from one site to another as shown in Fig. 3 below.

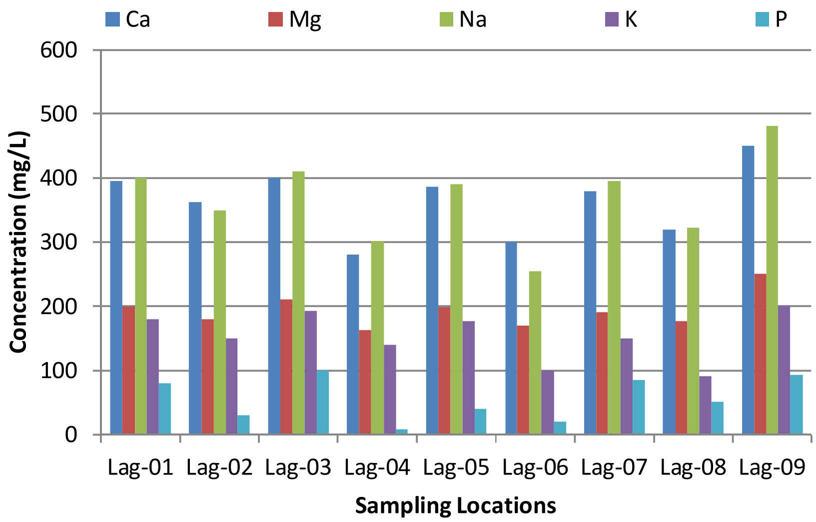

Figure 3: DISTRIBUTION OF ELEMENTS IN EFFLUENT SAMPLES

Table 4 presents the results of some statistical analysis computed for the various elements. Mean concentration of elements in the order of abundance is reported as Na>Ca>Mg>K>P. Na has the highest value of 480.7 mg/L while P has the least, which is 8.9 mg/L. Fig. 4 is a graphical illustration of the mean concentration of constituent elements in effluent samples.

Table 4: Some statistical parameters of chemical elements in effluent samples (mg/L)

Parameters	Ca	Mg	Na	K	P
Minimum	280.6	162.9	255.6	90.9	8.9
Maximum	450.4	250.8	480.7	200.6	100.8
Average	363.3	193.5	367.5	153.9	56.7

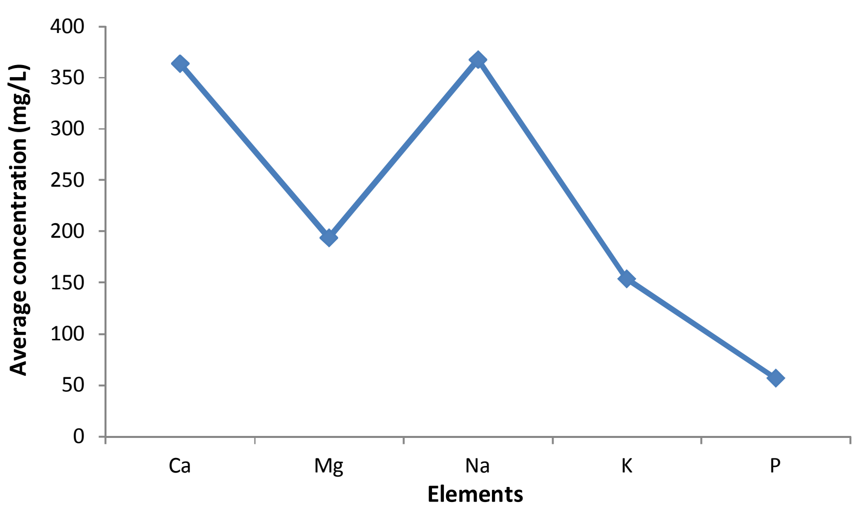

Figure 4: AVERAGE CONCENTRATION OF ELEMENTS IN EFFLUENT SAMPLES

The relationship between EC and TDS is shown on a regression plot in Fig. 5. The coefficient of determination r^2= 0.9967 obtained corroborates a very good positive correlation coefficient between the EC and TDS while temperature and pH varied anomalously.

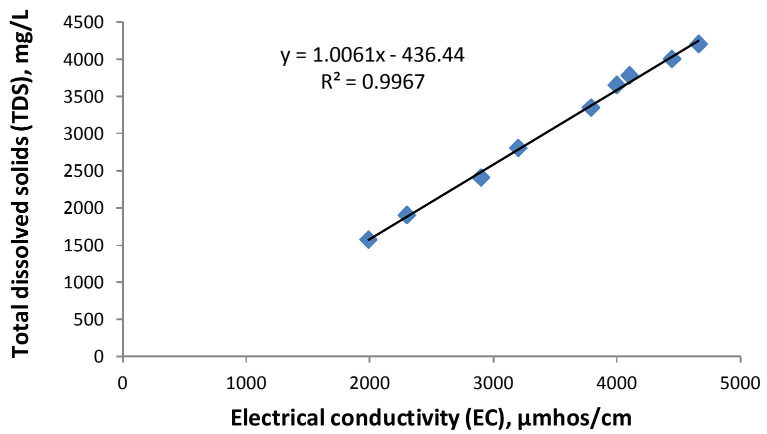

Figure 5: LINEAR REGRESSION OF ELECTRICAL CONDUCTIVITY (EC) AND TOTAL DISSOLVED SOLIDS (TDS)

DISCUSSION

The concentrations of heavy metals showed a significant variability across the geographic spread of the sample points. The order of relative abundance of heavy metals in effluent samples is given as Fe>Mn>Zn>Cu>Pb>Cd indicating a higher concentration of Fe. Higher values obtained for Fe could have been due to high Fe content of chemical additives used in the production chain on one hand, and enrichment by leaching from Fe-rich Laterite soils underlying the base of the drains where the effluent samples were taken from. Sankpal and Naikwade (2012) reported Fe enrichment of effluent composition due to Fe-rich soils. Hence, the heavy metals reveal the chemical composition of additives used for the processing and manufacturing of various products in the study area.

The concentrations of individual heavy metals are generally higher than the permissible WHO (2003) limits. These heavy metals are toxic and could cause adverse health conditions due to persistent exposures. Momodu and Anyakora (2010) reported Pb poisoning causing abdominal pain, constipation and severe kidney and brain damage as a result of prolonged exposure. Cu compounds have been widely used in industrial processes and agriculture. Sharma et al. (1988) affirms that Cu plays a salient role in chemical and biological processes in the environment. Hollum (1977) reports that cadmium poisoning caused bone damage to the consumers of rice irrigated with polluted water. Zn toxicity may occur due to excessive intake and the symptoms that could be exhibited are vomiting, nausea and loss of appetite (Institute of Medicine Food and Nutrition, 2001).

The average concentration of elements such as Na, Ca, Mg, K and P and physico-chemical parameters in effluent samples, such as electrical conductivity (EC), total dissolved solids (TDS), temperature and pH are higher than the permissible limits recommended by the WHO (2002;2003). The elemental composition of wastewater has been reported (Ademoroti, 1996). The coefficient of determination obtained for EC and TDS is a function of very strong positive correlation that exists between the two parameters. Uwidia and Ukulu (2013) confirm the strong positive relationship between EC and TDS.

CONCLUSION

The higher concentrations of toxic heavy metals in industrial effluents indicate indiscriminate discharge and negligence of the manufacturing industries towards duty-of-care since the effluents were not pre-treated prior to disposal. Therefore, the polluting industries should endeavour to treat raw effluents using state-of-the-art technologies before disposal in order to keep the environment safe and reduce the potential health risks in the area.

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