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Heavy Metal Contents of Effluents and Receiving Waters from Various Industrial Groups and their Environs in Ibadan, Nigeria

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Abstract: The effluent and receiving water and soil quality from thirty three industries from seven different industrial groups, namely: Food (10), Chemical (6), Plastic (7), Pharmaceutical (2), Steel (4), Cardboard (2) and Glass (2) in Ibadan metropolis was investigated. Heavy metals (cobalt, chromium, copper, iron, magnesium, manganese, lead and zinc), anion (nitrate and chlorides) and cation (phosphate and ammonium) contents of the samples were determined using standard methods. Results show that soils around food and chemical industries had significantly higher ($p<0.05$) heavy metal contents. Soil lead content around food and chemical industries are significantly higher ($p<0.05$) than values obtained for effluents, receiving waters and plants in their environs. Lead content is highest in soils (2.48 mg L^{-1}) but lowest in the effluents discharged (0.13 mg L^{-1}), the receiving water (0.22 and 0.25 mg L^{-1}) and plants (0.28 mg L^{-1}) around steel industries. A similar pattern was observed for Pharmaceutical and Glass Industries. Pb discharge is highest in effluents from Cardboard and Paper industries while significantly lower values were obtained for the other industries. Lead contents are 0.14, 0.21, 0.17, 0.21 mg L^{-1} and 0.12, 0.19, 0.12 and 0.19 mg L^{-1} in the effluent, plants, upper receiving and lower receiving waters in soils around chemical and plastic industries, respectively. Magnesium and cobalt, manganese and magnesium, manganese and cobalt, cobalt and zinc were highest in effluents released by steel, cardboard, pharmaceutical and glass industries, respectively.

Key words: Effluents, receiving water, soil quality, Ibadan

INTRODUCTION

Various devastating ecological and human disasters of the last four decades implicate industries as major contributors to environmental degradation and pollution (Ademoroti and Sridhar, 1979; Asia and Ademoroti, 2001; Abdel-Shafy and Abdel-Basir, 1991). Industrial wastes and emissions contain toxic and hazardous substances most of which can be detrimental to human health. These wastes are generated from various industrial activities resulting from the production of chemical, pharmaceuticals, steel, cardboard and paper, glass industries among others. Wastes generated include lead, cadmium, mercury, toxic organic chemicals and phenolic compounds (Osibanjo, 1989; Foess and Ericson, 1980). This results in surface and ground water contamination, including loss of land and aquatic resources. Improper disposal of untreated industrial wastes results in odorous and unwholesome surface waters, fish kills and loss of recreational amenities (Ciaccio, 1972; FAO, 1978; Mahida, 1983; Purdom and Stanley, 1983). This is a cause for concern in view of the fact that a large proportion of the populace still rely on surface waters for drinking, cooking and washing; while industries also need water of acceptable quality for their manufacturing processes.

The objective of this research was to investigate the effect of effluents from various industrial groups on receiving water and their environs in Ibadan metropolis.

MATERIALS AND METHODS

This study was conducted in Ibadan metropolis. The study involved collection of effluents from thirty three industries from seven different industrial groups, namely: Food (10), Chemical (6), Plastic (7), Pharmaceutical (2), Steel (4), Cardboard (2) and Glass (2) industries as follows: Water samples were collected at receiving waters at locations down and upper the water course adjacent to the carriage system around the effluents outfall of the industries. Samples were collected at different times of the day in acid-leached 1 litre polyethylene sample bottles and stored in the refrigeration at 4°C. Water samples collected upstream before the discharge of the effluent into the stream served as control. Fresh soil samples were collected cross-sectionally (using an auger) from three points at a depth of 15 cm from topsoil located about 50 m

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from the effluent outfall points of 6 different chemical industries in Ibadan metropolis. The soil and plant samples from the study areas were air-dried, sieved and acid digested before analysis. Control samples were collected at least about 500 m from the nearest industry.

The samples were analyzed for physical and chemical characteristics. Temperature was measured using a standard size field thermometer; pH was measured as described by Anderson and Ingram (1989) using a Model 3020 pH meter (JENWAY, UK). A Conductivity meter (Model 4010, JENWAY, UK) calibrated with a conductivity standard (0.01 m KCl with conductivity 1413 μscm^{-1}) was used for conductivity measurements at 25°0C. In both studies, 20 g of soil samples were weighed and suspended in 50 mL of distilled water and stirred before introducing probe. Heavy metals (Ca, Cr, Cu, Fe, Mg, Mn, Pb and Zn) were determined using AAS (Buck Scientific model 500A) as described by Juo (1982). Sodium and potassium were determined using a flame photometer. Phosphate, nitrate, ammonium and chlorides were determined using standard methods (APHA, 1992; Taras, 1950). The results are expressed in mg kg^{-1}. Means and standard errors of the mean of triplicate readings obtained in the study were subjected to analysis of variance (ANOVA) and Duncan's multiple range test using the Statistical Package for Social Scientist (SPSS 10.0) computer software (Oloyo, 2001).

RESULTS AND DISCUSSION

Table 1-7 shows the heavy metal distribution in the effluent waters, soil, plant and receiving waters in Food, chemical, plastic, steel, cardboard/paper, pharmaceutical and glass industries in Ibadan, Nigeria, respectively.

In areas around Food, Chemical and Plastic industries (Table 1-3), magnesium and cobalt were the highest metals in effluent released to the environment. The values obtained in the effluents were significantly ($p<0.05$) higher than values obtained for receiving water in Food processing and Chemical Industries but comparable in Plastic Industries. The values obtained for receiving water for these metals are comparable with those obtained for soil and plant in the environment. Samples obtained at the upper and lower section of the receiving waters in the Food and Chemical industries were comparable, suggesting uniformity in the composition of the receiving water in the respective industries. There are significant differences ($p<0.05$) in the soil and plant levels of Cr, Cu, Fe, Mn, Pb and Zn (Table 1). It is noteworthy that the lead content in soils around Food processing (Table 1) and Chemical (Table 2) industries are significantly higher ($p<0.05$) than values obtained for effluents, receiving water and plants in the area. The lead contents are 0.13 mg L^{-1} in the effluent, 0.22 mg L^{-1} in the plant, 0.08 mg L^{-1} in the upper receiving and 0.33 in the lower receiving water. A similar pattern is observed in soils around chemical industries where Pb contents are 0.14, 0.21, 0.17 and 0.21 mg L^{-1} in the effluent, plants, upper receiving and lower receiving waters, respectively. In areas around Plastic industries, Pb contents are 0.12, 0.19, 0.12 0.19 mg L^{-1} in the effluent, plants, upper receiving and lower receiving waters, respectively. These values are significantly lower than 3.58, 5.32 and 10.48 mg L^{-1} obtained for soil samples around Food, Chemical and Plastic industries, respectively. The high lead content of the soil cannot therefore be directly attributed to effluents discharged by these industries into the environment. Iron is highest in the plant and soils around these industries: 294.90 and 119.57 mg L^{-1}, 377.69 and 179.59 mg L^{-1}, 288.38 and 114.32 mg L^{-1}, respectively. However, the level of iron in the receiving and effluent water is low (0.92 and 0.15 mg L^{-1}, 0.50 and 0.06 mg L^{-1}, 0.69 and 0.28 mg L^{-1}, respectively) suggesting that the high iron level in the plant and soil may not be due to effluent discharge into the environment.

Table 1: Heavy metal contents of effluents, receiving waters (mg L^{-1}) from food processing industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.99±0.16c	0.07±0.01a	0.10±0.05a	0.15±0.07a	1.11±0.14b	0.53±0.08a	0.13±0.01a	0.15±0.02a
Soil	0.25±0.04ab	0.18±0.02bc	1.01±0.16b	294.90±21.81c	0.41±0.04a	172.92±31.67a	3.58±0.69b	40.26±3.92c
Plant	0.06±0.01a	0.08±0.01a	2.12±0.22c	119.57±14.02b	0.23±0.01a	12.57±1.55c	0.22±0.02a	7.29±0.61b
Receiving (Upper)	0.27±0.02ab	0.15±0.03ab	0.15±0.02a	0.92±0.14a	1.43±0.26b	5.26±0.67b	0.08±0.01a	1.17±0.11a
Receiving (Lower)	0.29±0.02b	0.24±0.05c	0.10±0.01a	0.61±0.05a	1.98±0.31c	5.35±0.80b	0.33±0.10a	1.53±0.18a

Values are means of 3 readings each from 10 industries (3×10)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 2: Heavy metal contents of effluents, receiving waters (mg L^{-1}) from chemical processing industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.39±0.05bc	0.08±0.01a	0.03±0.01a	0.06±0.01a	0.73±0.11a	0.32±0.07a	0.14±0.01a	0.22±0.02a
Soil	0.37±0.04bc	0.17±0.02b	1.85±0.23b	377.69±49.92c	0.38±0.03a	108.01±9.71b	5.32±1.14b	47.60±5.06c
Plant	0.07±0.01a	0.10±0.01a	2.70±0.19c	179.59±48.58b	0.26±0.02a	13.17±2.23a	0.21±0.03a	9.93±1.69b
Receiving (Upper)	0.43±0.05c	0.20±0.04a	0.17±0.02a	0.50±0.02a	2.02±0.39b	5.06±0.82a	0.17±0.03a	1.43±0.25a
Receiving (Lower)	0.28±0.03b	0.10±0.01a	0.16±0.03a	0.57±0.07a	2.99±0.34b	6.15±0.56a	0.21±0.02a	2.43±0.25a

Values are means of 3 readings each from 6 industries (3×6)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 3: Heavy metal contents of effluents, receiving waters (mg L^{-1}) from plastic industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.50±0.12b	0.09±0.01a	0.02±0.01a	0.28±0.14a	1.41±0.11c	0.29±0.08a	0.12±0.01a	0.42±0.08a
Soil	0.43±0.06b	0.17±0.01b	1.24±0.16b	288.38±19.85c	0.65±0.05b	151.77±21.39b	10.48±2.14b	42.62±5.59b
Plant	0.05±0.01a	0.09±0.01a	1.74±0.34c	114.32±24.80b	0.24±0.01a	11.01±1.13a	0.19±0.02a	6.54±0.66a
Receiving (Upper)	0.22±0.02a	0.08±0.02a	0.12±0.01a	0.69±0.11a	0.78±0.15b	4.81±0.53a	0.12±0.01a	1.96±0.28a
Receiving (Lower)	0.20±0.02a	0.15±0.05ab	0.12±0.03a	0.46±0.06a	1.44±0.24c	5.70±0.53a	0.19±0.02a	2.96±0.28a

Values are means of 3 readings each from 7 industries (3×7)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 4: Heavy metal measurements of effluents, receiving waters (mg L^{-1}) from steel industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.57±0.12c	0.08±0.01a	0.01±0.01a	0.04±0.01a	1.88±0.12b	0.17±0.04a	0.13±0.01a	0.11±0.01a
Soil	0.32±0.06b	0.16±0.01a	0.90±0.10b	142.18±10.48b	0.69±0.08a	153.14±36.16c	2.48±0.60b	33.93±6.88d
Plant	0.05±0.01a	0.22±0.07ab	2.43±0.26c	169.36±45.28b	0.38±0.04a	18.58±3.08b	0.28±0.06a	11.09±2.27c
Receiving (Upper)	0.75±0.11c	0.36±0.08b	0.32±0.05a	1.13±0.22a	2.50±0.54b	10.84±1.75b	0.22±0.06a	2.04±0.55b
Receiving (Lower)	0.31±0.08b	0.37±0.08b	0.37±0.09a	0.55±0.09a	5.43±0.71c	11.46±1.93b	0.25±0.02a	3.04±0.55b

Values are means of 3 readings each from 4 industries (3×4)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 5: Heavy metal measurements of effluents, receiving waters (mg L^{-1}) from cardboard and paper industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.29±0.10b	0.04±0.01a	0.03±0.01a	0.01±0.005a	1.10±0.09b	22.96±9.32b	1.20±0.47b	2.79±1.07a
Soil	0.16±0.04ab	0.19±0.01ab	0.31±0.07a	186.74±5.40b	0.30±0.01a	69.97±2.46c	0.45±0.01a	37.03±10.54c
Plant	0.08±0.01a	0.11±0.01a	3.83±1.63b	217.54±67.70b	0.26±0.01a	16.51±3.24b	0.25±0.02a	10.08±2.31b
Receiving (Upper)	0.18±0.01ab	0.28±0.02bc	0.32±0.05a	0.43±0.01a	2.89±1.25b	8.09±1.06a	0.09±0.01a	2.07±0.24a
Receiving (Lower)	0.21±0.03ab	0.38±0.12c	0.25±0.04a	0.53±0.01a	2.43±1.01b	8.10±0.26a	0.19±0.02a	3.07±0.25a

Values are means of triplicate readings each from 2 paper and cardboard industries (3×2)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 6: Heavy metal measurements of effluents, receiving waters (mg L^{-1}) from pharmaceutical industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.45±0.19b	0.09±0.01a	0.01±0.005a	0.04±0.01a	0.25±0.01a	2.68±1.16a	0.14±0.01a	0.21±0.09a
Soil	0.16±0.02a	0.15±0.01a	0.53±0.14b	332.17±24.34c	0.36±0.05a	79.48±14.89b	1.39±0.22b	16.11±1.20d
Plant	0.06±0.01a	0.51±0.18b	3.36±0.17c	115.24±35.42b	0.27±0.02a	7.03±1.84a	0.24±0.09a	5.31±0.25c
Receiving (Upper)	0.17±0.02a	0.05±0.01a	0.18±0.02a	0.49±0.09a	1.37±0.37b	5.40±0.59a	0.09±0.01a	1.41±0.35ab
Receiving (Lower)	0.27±0.08ab	0.30±0.07ab	0.12±0.02a	0.18±0.04a	0.76±0.06a	5.02±0.15a	0.16±0.01a	2.41±0.36b

Values are means of triplicate readings each from 2 paper and cardboard industries (3×2)±SEM, Means followed by different letters are significantly different ($p<0.05$)

Table 7: Mean heavy metal measurements of effluents, receiving waters (mg L^{-1}) from glass industries and their environs (mg kg^{-1}) in Ibadan

Source	Cobalt	Chromium	Copper	Iron	Magnesium	Manganese	Lead	Zinc
Effluent	0.43±0.14b	0.11±0.01a	0.01±0.005a	0.06±0.01a	0.11±0.01a	0.03±0.01a	0.11±0.01a	0.36±0.04a
Soil	0.30±0.01b	0.18±0.01a	1.10±0.04b	157.25±16.53c	0.58±0.02ab	603.24±52.99d	2.04±0.09b	90.97±35.77c
Plant	0.05±0.01a	0.07±0.01a	117.57±50.82c	48.29±5.81b	0.33±0.02a	11.22±1.24c	0.11±0.01a	21.97±0.73b
Receiving (Upper)	0.34±0.08b	1.02±0.44b	0.07±0.02a	0.72±0.07a	1.07±0.14b	2.28±0.52b	0.12±0.01a	0.78±0.05a
Receiving (Lower)	0.34±0.08b	0.30±0.13a	0.11±0.01a	0.58±0.05a	1.07±0.40b	3.50±1.57b	0.19±0.01a	1.78±0.06a

Values are means of triplicate readings each from 2 paper and cardboard industries (3×2)±SEM, Means followed by different letters are significantly different ($p<0.05$)

The highest metals in effluent released by Steel (Table 4), Cardboard and paper (Table 5), Pharmaceutical (Table 6) and Glass (Table 7) are magnesium and cobalt, manganese and magnesium, manganese and cobalt, cobalt and zinc, respectively. In Cardboard and paper industries the highest metals in the effluent, soil, plant, receiving (upper and lower) were Mg (1.88 mg L^{-1}), Mn (153.14, 10.84 and 11.46 mg L^{-1}), respectively. In areas around Steel Industries, lead content is highest in soils (2.48 mg L^{-1}) but lowest in the effluents discharged (0.13 mg L^{-1}), the receiving water (0.22 and 0.25 mg L^{-1}) and plants (0.28 mg L^{-1}). A similar pattern was observed for Pharmaceutical and Glass Industries. In areas around Cardboard and paper industries, Pb is significantly higher in the effluents (1.20 mgL $^{-1}$) than receiving (0.09 mgL^{-1}), soil (0.45 mgL^{-1}) and plants (0.25 mgL^{-}).[1] On a comparative note, Pb discharge is highest in effluents from Cardboard and Paper industries while significantly lower values was obtained for the other industries.

Values obtained for effluents from Food and Chemical industries with respect to Cr, Cu and Pb were within the range recommended by FEPA (1991) and the Chinese Environmental Protection Agency (Tang and Ferris, 2000). Values obtained for Zn is higher in effluents from Food and Chemical industries than the recommended standard. Receiving waters around Food Industries had Cr and Zn contents higher than the recommended standard. However, Cu and Pb were within the recommended values (FEPA, 1991). For chemical industries, Cr, Cu, Fe, Mn and Pb contents are within the FEPA (1991) recommended values while Zn is higher than the recommended values. The presence of metals and other mineral elements at various concentrations revealed that the effluents from these industries contaminated the soils, a condition similar to that reported by Tripathi (1990). Lead occurs widely in the environment and is a well known contaminant of drinking water (Conning and Lansdown, 1983).

CONCLUSION

The harmful effects of wastewaters on receiving streams and adjoining soils, caused by low quality of effluents, call for improvement of the current treatment technologies and development of advanced treatment processes as well as waste minimization in industrial processes to meet the increasing water quality standards.

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