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Preliminary Assessment of Effects of Paint Industry Effluents on Local Groundwater Regime in Ibadan, Nigeria

Olaoye, R. A. and †Oladeji, O. S.
Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
†Corresponding author: osoladeji@lautech.edu.ng; olayinka_oladeji@yahoo.co.uk

Abstract: Although, groundwater constitutes a major source of water supply especially in developing countries, however wastes generated arising from industrial growth and further complication caused by its indiscriminate disposal have been a major risk to groundwater vulnerability. Hence in this study, preliminary impact assessment of wastewater discharged from paint industry on proximal groundwater regime was carried out. Representative groundwater and effluent samples were collected from locations within the study area, and analyzed in accordance to the American Public Health Association standard methods. The values of the measured concentration of the parameters were compared with regulatory standards for drinking water. The concentrations of Mn^{2+}, total Fe, Ca^{2+}, TDS, TSS, total hardness and SO_4^{2-} were mostly higher than the permissible regulatory standards. Total alkalinity values were very low in all the groundwater samples, while the presence of E-coli across all the sampling points indicated wide spread pathogenic contamination. The results showed average lead concentration of 1.18 mg/l compared to the permissible level of 0.01 mg/l. Corresponding higher values of the physico-chemical and biological parameters were observed in the discharged effluent samples. The observed high lead concentration have potential toxic consequences, and hence enforcement of localized waste minimization is recommended in order to promote waste recycling, and ensure adequate protection of public health and the environment.

Key words: Groundwater contamination, Paint effluent, Effluent discharge, Toxicity, Environment

1.0 Introduction

Over the years, wastes generated due to industrial growth and complicated by its indiscriminate disposal has been a major concern in the developing countries. Some components of these wastes contain hazardous chemical elements which may infiltrate and percolate into the sub-surface environment upon discharge and subsequently accumulated in the soil and bed sediment of water bodies (Idzelis *et al.*, 2006). Hence, quality of groundwater has been steadily declining due to these heavy industrialization and human activities (Kumar, 2013). Approximately 35 % of the global population depends on groundwater resources mostly from shallow aquifers, to meet their water needs (UNEP, 2002), including drinking (Fifi *et al.*, 2010). Lack of proper sanitation and non protection of perimeter boundary demarcations of water sources in the developing countries presents public health risk for urban population, with potential consequences for contamination from epidemic pathogens. According to UNEP (2002), over five million deaths are recorded in developing countries annually, due to diseases from poor quality water consumption.

Although, research efforts have been concentrated on the assessment of impact of industrial effluent on surface water (Onuigbo and Madu, 2013; Ayeni, 2013; Oketola and Osibanjo, 2011), however, specific literature assessing impact of effluents from paint industry on groundwater resources are rare. Few related work include Jolly *et al.*, (2008), where the authors determined the effects of paint effluent on soil productivity and concluded that presence of certain trace elements at concentrations higher than 25 % had negative effects on seed germination, dry matter production and the yield of corn and rice.

Jolly *et al.*, (2012) assessed the impact of heavy metals from industrial effluent samples treated with lime and alum for coagulation of suspended matter, prior to discharge into the environment. The authors reported relatively high concentrations of indicator chemical parameters, though generally lower than respective maximum permissible limits. Saha and Ali (2001) analysed groundwater contamination from tannery waste and established that tannery effluents have high pollution potential on groundwater and hence recommended adequate treatment prior to their disposal. In addition, several authors namely Oguzie and Okhagbuzo (2010); Sekabira *et al.*, (2010); Ajibola and Ladipo, (2011); Oketola and Osibanjo (2011); Singh and Singh (2012); Onuigbo and Madu (2013) as well as Hong *et al.*, (2014) assessed impacts of different types of effluent discharges on the quality of both surface water and groundwater. The required specifications (DoE, 2009; FEPA, 1999; ER, 1986) for pre-treatment of industrial effluents prior to its disposal into the environment are summarized in Table 1.

Generally, industrial effluents can potentially affect hydrological and environmental parameters of a catchment, as well as poses significant threats to man and natural ecology. In Nigeria, paint production utilizes large volume of water without adequate wastewater treatment plant. Hence, large quantities of both hazardous and non hazardous wastes are inherently released to the environment, thus causing health related problems, ecological imbalance and bioaccumulations in aquatic organisms. Therefore in this research work, preliminary assessment of specific impacts of direct discharge of effluents produced from paint industry on local groundwater quality was carried out, and possible mitigating measures were proffered.

Table 1: Effluent standard for industrial wastes discharge

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Parameters	Permissible levels		
	ER, 1986	DoE, 2009	FEPA, 1991
pH	6 - 8.5	6-8.5	6.9
Copper (mg/l)		0.2-2.0	< 1.0
Zinc (mg/l)	5	2	1
Lead (mg/l)		0.1	< 1.0
Manganese (mg/l)		0.2	0.05
Iron (mg/l)		0.3	1
TSS (mg/l)	100	100	30
Total hardness (mg/l)	2	2	
BOD	50	50	20
Phenolics (mg/l)	1		
Bio-assay test	90% survival in 96 hrs		
Lead (mg/l)	0.1		
Chromium (mg/l)	0.1		

2.0 Methodology

Ten (10) representative groundwater samples were collected from proximal locations of a paint industry within the study area (Figure 1), using sterile bottles with appropriate labels. Two samples were collected per sampling location and the average value from the analyses was determined. In addition, effluent samples were collected from the paint producing industry after production discharge into open drain, directly into the environment. All the samples were characterized based on American Public Health Association (APHA, 1995) standard method for examination of water and wastewater at the water analysis laboratory of Ladoke Akintola University of Technology, Ogbomoso, Oyo State.
The physical parameters analyzed were colour, pH, temperature, and turbidity. Temperature and pH were determined at the point of sample collection using portable meters, while colour and turbidity were determined using spectrophotometer.

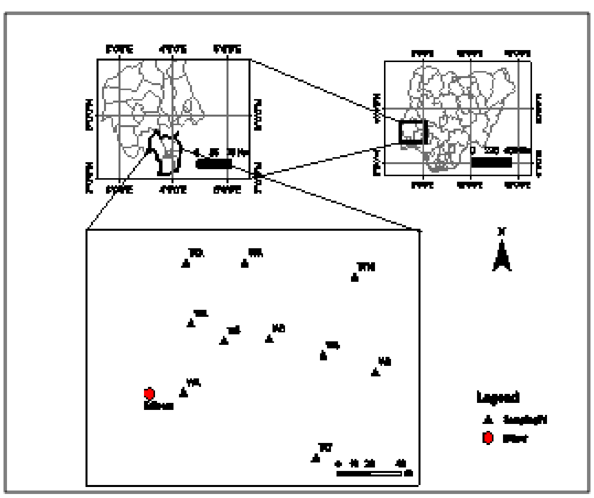

Figure 1: Location of the study area

The chemical parameters determined were Copper (Cu), Zinc (Zn), Lead (Pb), Manganese (Mn), Iron (Fe), Potassium (K), Calcium (Ca), Nitrate (NO_3), Sulphate (SO_4), Phosphates (PO_4), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Alkalinity, Total Hardness and Biochemical Oxygen Demand (BOD). The only bacteriological parameter analyzed was E-*coli.* The values of the measured concentration of the parameters were compared with World Health Organization drinking water standard (WHO, 2011).

3.0 Results and discussion

The results of the physical and chemical tests conducted on the water samples, as well as that of the raw wastewater obtained from the sampling locations are presented in Figures 2 and 3 respectively. The trends in the physical characterization of the water samples (Figure 2) indicated that, with the exception of the sampling locations at W1, W5 and W9, which have colour index value of 0, all other sampling points have values higher than the permissible value of 5 TCU (Figure 1). It is thought that the observed adverse effect in the water clarity indicated by the relatively high colour index values was caused by the impact of the discharges from the proximal paint production processes. This effect appears to be spatially skewed by the local groundwater flow conditions. Excessive colour is an indication of the presence of large amount of organic chemicals, inadequate treatment of the discharged effluents and high disinfection demand. Also, the range of the measured pH values was 9.56 – 10.38, which is higher than the WHO permissible range of 6.5 - 8.5. The average measured temperature and turbidity were 28 ºC and 1.96 NTU, respectively. Maximum turbidity value of 7.93 NTU was obtained in sampling point W4, which probably suggests occurrence of localized contamination.

The measured concentration values for the chemical parameters are presented in Figure 3. The average measured concentration of copper in the water samples was lower than the maximum allowable value of 0.5 mg/l, though with the exemption of the sample W4, where the measured concentration was 0.99 mg/l. This collaborate the suggested hypothesis of a localized contamination occurrence in the neighborhood of the location of sample W4. One of the major sources of copper is the industrial paint waste. Injection of copper can cause stomach and intestinal distress, as well as damage to liver and kidney. It can also impart an adverse taste in water and cause significant staining to clothes and fixtures (Reiser *et. al.,* 1985).

The range of values for zinc concentration in all the sampling points was 0.02 – 0.06 mg/l, lower than the maximum permissible value of 2.0 mg/l. Conversely, the range of the measured concentration of lead was 0.17 – 1.94 mg/l compared to the permissible value of 0.01 mg/l. Lead has been reported to be toxic to both man and aquatic life, and has been recognized as pollutant to natural ecosystem even at low concentrations (Van Dyk *et al.*, 2007; Dahunsi *et al.*, 2012). Concentrations of lead in all the water samples are thought to be indicative of infiltration of paint additives from the discharged wastewater into the subsurface environment.

Several authors (Needleman *et al.*, 1990; Winneke *et al.*,1982; Smith *et al.*, 1983; Carré, 1997; Dahunsi *et al.*, 2012) have indicated that lead affects the chemistry of human red blood cells, delays normal physical and mental development in babies and young children, causes gastrointestinal disturbances and inflammation of the brain and spinal cord as well as deficits in the hearing and learning of children, and possibly carcinogenic.

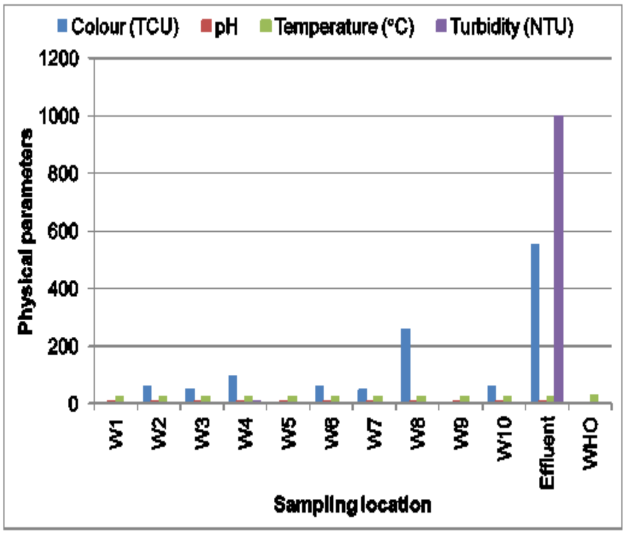

Figure 2: Physical properties of the samples

Furthermore, the range of the measured values of manganese concentration was 42.40 – 56.10 mg/l, compared to the WHO permissible level of 0.05 mg/l. The observed manganese concentration at all the sampling points is believed to be sourced from the raw wastewater from the paint industry The presence of manganese at concentrations greater than 0.15 mg/L tend to stain plumbing fixtures and laundry and produces undesirable tastes in beverages. In addition, the presence of manganese in water supports accumulation of microbial growths in the pipe network systems, forming coatings which may slough off as black precipitates.

In the case of iron, the range of measured concentration values was 0.02 - 0.8 mg/l, suggesting that the water samples were higher than the WHO desirable limit of 0.1 mg/l, with the exception of the sample number W5 and W8, which were lower than the desirable limit. The observed high concentration of manganese and iron in the water samples correlates with values obtained for the raw wastewater sample and hence were thought to be sourced from wastewater discharged from paint industry. These measured high concentrations can potentially affect the taste of water and causes discoloration. The ranges of values obtained for potassium and calcium concentrations in the water samples were 0.87 - 13.17 and 359 - 509 mg/l respectively, compared to the recommended values of 0.01 and 200 mg/l, respectively. These observed concentrations were similar to high concentration values of the total dissolve solids of 140 – 975 mg/l.

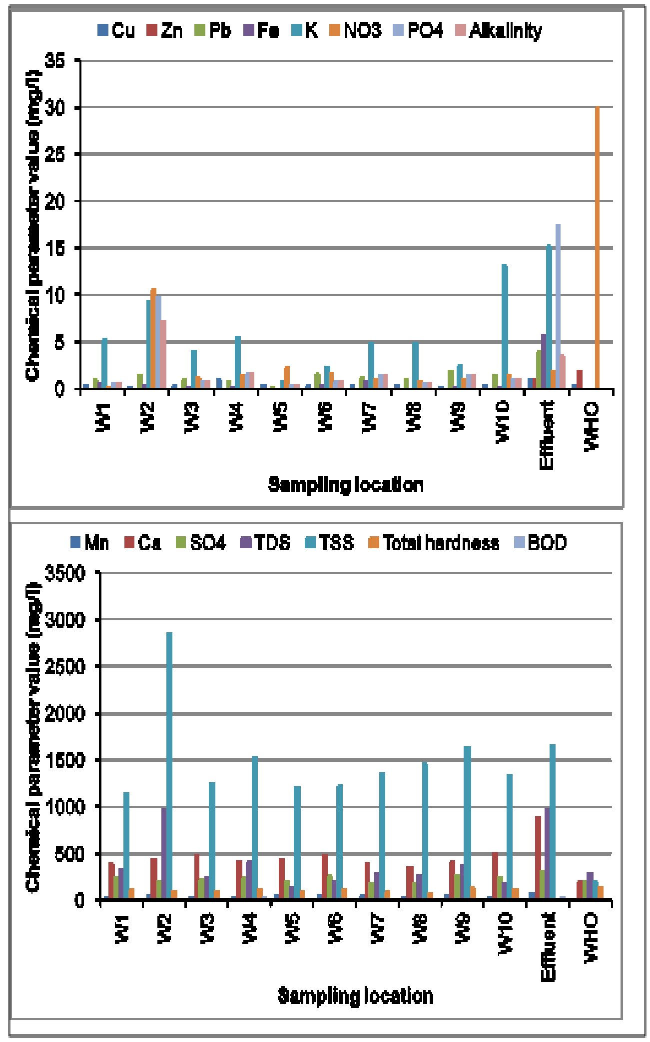

Figure 3: Chemical properties of the samples

The obtained average value of nitrate concentration was 2.22 mg/l, and hence lowers than the WHO desirable limit of 30 mg/l. However, measured range of concentration values of sulphate was 184 – 276 mg/l, and was higher than the WHO desirable level of 200 mg/l. This was with the exception of the water samples obtained at W5, W7 and W8, which have values lower the WHO maximum permissible levels. Sulphate may be found in groundwater as an industrial pollutant commonly from industrial wastes and sewage, and its high concentrations can cause diarrhea.

There were no remarkably high values for total alkalinity (0.5 – 7.2 mg/l) and total hardness (90 – 135 mg/l), as they were all below the WHO desirable limits of 100 mg/l and 150 mg/l, respectively. The hardness in the water samples span from low hardness (61-120 mg/l) for water samples obtained at W1, W2, W3, W5, W7 and W8, to moderate hardness (121-180 mg/l) for samples obtained at W4, W6, W9 and W10. The values obtained for the Biochemical oxygen demand (BOD) were largely above the maximum desirable levels. BOD is a measure of the amount of oxygen used up by biological and chemical processes in a sample of water over a 5-day period, and hence this work indicated biological activities within the regime of the water samples. In addition, the values of bacteriological (E-coli) concentration of 2 – 10 per 100 ml of water sample present are indicative of pathogenic contamination probably due to pollution from paint effluent discharged directly on the soil.

The results of the physico-chemical characterization of the raw effluent generated from the paint production (Figures 2 and 3) showed that average values obtained for all tested parameters were above the values obtained from the groundwater samples. Furthermore, the average values obtained were compared with discharge standards (DoE, 2009; FEPA, 1991; ER, 1986) to ascertain the level of pollution. The analyses of the results showed that the pH value of 9.55 for the effluent sample was above the range of values recommended for paint wastewater discharge by the standards. Average values of copper (0.95 mg/l) and Zinc (1.10 mg/l) concentrations were below the permissible limits of 2 mg/l (DoE, 2009), but the measured zinc concentration is slightly higher than the FEPA (1991) permissible level of 1.0 mg/l. The lead concentration of 3.99 mg/l exceeded all the specifications of 0.01 mg/l. The elemental concentration of manganese, iron, potassium, calcium, nitrate, sulphate and potassium were also higher than the corresponding standard permissible levels (Figure 3). Also, the TDS and TSS values of 987 mg/l and 1665 mg/l were above the respective permissible values (DoE, 2009 and FEPA, 1991). The BOD_5 value of 35 mg/l indicated the presence of degradable substances. The values of the physico-chemical parameters obtained in this work for wastewater discharges are similar to that reported Onuegbu *et. al.,* (2013), and portend danger for natural ecosystems. In addition, the concentration of K, Ca, Mn, Fe, TDS and TSS were found to be much higher than that in the groundwater, though comparable to that obtained by Jolly (2012).

Conclusion

Characterization studies of the raw effluent and groundwater samples suggested loading of physico-chemical and biological parameters at elevated concentrations into the subsurface environment. Particularly, the effluent samples were found to contain relatively higher concentrations of Pb, Mn, Fe, K, Ca, NO_3, SO_4, PO_4, TDS and TSS. Also, average values obtained in the water samples for colour, pH as well as elemental concentrations including manganese, iron and calcium were higher than the standard permissible levels. In addition, concentration values for sulphate, TDS, TSS were also high at several sampling locations. High BOD and bacteriological parameter (E-coli) concentrations suggested pathogenic activities, presence of biological degradable substances and pollution especially at sampling point W4, where localized contamination was indicated. Average concentration values for turbidity, zinc, nitrate, Total hardness, Total alkalinity and copper were generally below the permissible limits permitted of WHO standard for drinking water quality. The groundwater samples indicated the presence of lead infiltration into groundwater, and this poses potential toxic consequences for man, animal and the environment. Conclusively, it is recommended that localized waste minimization for paint industries be enforced. It is hoped that this waste reduction at source approach will promote waste recycling, protect public health and the environment.

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