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PHYSICO-CHEMICAL AND HEAVY METAL ASSESSMENT OF PAINT INDUSTRY EFFLUENTS IN NAIROBI COUNTY, KENYA

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Abstract

In the recent past, the environment, in both developing and developed countries has witnessed degradation due to persistent pollutants. The pollutants affect the ecosystem and human health. A study was conducted to assess the levels of contaminants in wastewater from paint manufacturing industries in Nairobi's industrial area in Nairobi County. The effluents were analysed for conductivity, pH, oil and grease, total suspended solids (TSS), Chemical Oxygen Demand (COD), total phosphorus, total nitrogen, total sulphur and heavy metals (Cadmium, Lead and Chromium). The results revealed that the pH ranged between 6.48 - 6.89, oil and grease 3525.00-6374.33 mg/L, TSS 6382.3-7395.33 mg/L, COD 916.77-1881.20 mg/L, total phosphorus 145.00-149.32 mg/L, total nitrogen 1586.67-4442.67 mg/L, total sulphur 72.62-73.41 mg/L. Heavy metal concentrations were 3.03-4.18 mg/L, 2.07-3.04 mg/L and 5.38-17.21 mg/L for cadmium, chromium and lead respectively. The heavy metal levels were above the regulatory set levels by the National Environmental Management Authority (NEMA) in Kenya for effluents. These high levels of contaminants in the effluents, without proper treatment, end up to the environment causing its degradation and impacting human health. This necessitates proper legislation and enforcement to protect the environment.

Key word: *Pollutant, Effluent, Environmental degradation, Legislation*

1. Introduction

Industrial and population growth in developing countries have led to environmental degradation due to discharge of polluted waste water loaded with organic and inorganic contaminants directly to the environment without any or adequate treatment (Kabbaj *et al*., 2014). In Kenya, various factories within Nairobi's industrial area discharge effluents directly into the surrounding ecosystem without mandatory pre-treatment thus posing environmental and health hazards to the inhabitants of Nairobi and its surrounding (Odhiambo *et al*, 2016). Kenya has for long been perceived to be economically strong in East Africa, with residential and industrial construction boosting consumption of paints and coatings. Upsurge in urbanization, infrastructure expansion, public and private development; construction of low cost and middle-class housing units, office buildings in major city centers and county headquarters have heightened demand for paints, pigments, varnishes and other architectural coatings (Kigotho, 2017). Most industries are located in major towns due to availability of labour, well established infrastructure and high demand for the finished products (Mathenge *et al.*, 2018). These companies produce paint allied products like varnishes, industrial and architectural coatings (Wurm, 2016).

The nature of a particular paint and attributes of the waste produced in its manufacture is dictated by constituents in the blend (Körbahti and Tanyolac¸ 2009), which normally emanate from washing of implements, floors and packaging materials (Jolly *et al*, 2012). Most paint companies use batch process in the manufacture of paints and more often employ a three step process (mixing, milling and tinting and thinning) to come up with a finished product. Paint components include binder, pigment, solvent and additives (Jesionowski and Ciesielczyk, 2013). Pigment which is further categorised as organic (*azo, anthraquionone*) or inorganic (*white lead, lead chromates, cadmium yellow),* gives colour, opacity and gloss (Jolly *et al*, 2012). Binder, which can either be resin or oil, forms a continuous coat on the surface of the substrate hence responsible for good adhesion of the film to the surface (Talbert, 2008). Solvent is essential in mixing of the paint components in molecular or colloidal form and enhance application. It can be categorised into hydrocarbon, oxygenated and water (Mannari and Patel, 2015). Additives modify certain characteristics of the end paint product in its production, storage, transport processes or application (Lambourne and Strivens, 2014). Examples include silica (SiO_2), talc (hydrated magnesium silicate), whiting ($CaCO_3$) and barytes ($BaSO_4$). Although the legislation dictates that the industries must treat their effluent before discharging to the environment, some of these industries do improper treatments which ultimately cause some of the contaminants to be drained into surrounding land and water bodies (EMCA, 2006). This in turn has led to escalated discharges of huge volumes of sources of physical, chemical and heavy metal ion contaminants by these paint industries into surrounding ecosystem (Ogilo *et al*, 2017). Moreover, the continued release of these products has led to bioaccumulation in the human system via ingestion or nutritional hierarchy especially of heavy metals (Fu and Wang, 2011).

Research efforts have been concentrated on the assessment of industrial effluents from some industries in Nairobi (Ogilo *et al*, 2017; Odhiambo *et al*, 2016) but there are gaps on specific literature on assessment of the paint industry effluents in Kenya. Therefore, this study sought to document levels of heavy metal contaminants and other physico-chemical properties of effluents being discharged from paint manufacturing industries into the environment situated in Nairobi's industrial area and compare the levels with the Kenya's regulatory standard. This information will be useful to authorities charged with environmental protection and management for policy formulation and law enforcement.

2. Materials and methods

2.1 Study area

The study was conducted within the Nairobi industrial area in Nairobi County. The county lies in the geographic coordinates of 01°17′10″S 36°49′02″E and altitude of 1600 to 1860 m above sea level. Sampling was done from three paint companies coded A, B and C.

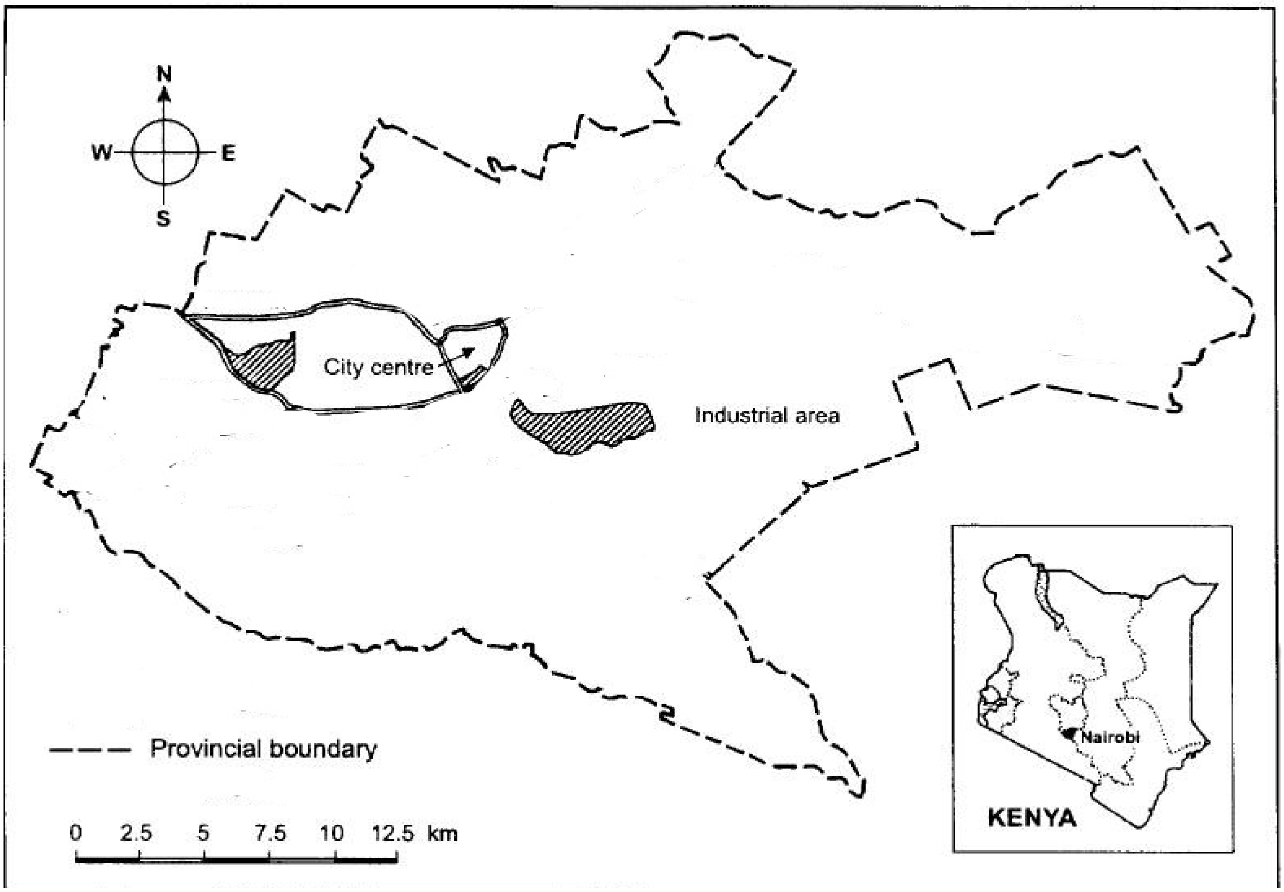

Figure 1: Map of Kenya showing Nairobi County (Adapted from Walingo et al., (1997)

2.2 Sampling

The effluent grab samples were drawn using an auto sampler to a depth of about 50 cm from the waste water receiving tanks. The tanks act as meeting points for each of the companies' releases from washings prior to discharge into municipal sewage drainage. The samples were transferred into 2.5 litre clean amber glass bottles coded A, B and C which represented the respective paint factories. They were then taken to Kenya Plant Health

Inspectorate Service (KEPHIS) Analytical Chemistry Laboratory (ACL) and stored at 5^{o} C awaiting laboratory analysis.

2.3 Physico-chemical and heavy metal analysis

Physical and chemical effluent parameters were analyzed in accordance with the standard methods. The pH of the effluents was determined using Hanna HI1225 EC/pH meter. Oil and grease was conducted using liquid-liquid extraction method using hexane as the extracting reagent. TSS was analysed using gravimetric method using UF 160 MEMMERT oven. COD was analysed using Hanna COD Reactor and quantified using Hanna Multiparameter photometer HI 83099 model. Total nitrogen was determined using classical Kjeldahl method while total sulphur was determined by measuring the turbidity of the samples using UV-Vis spectrophotometer, Perkin-Elmer Lambda 25 model.

Phosphorous was analysed as per AOAC 978.01, by complexing using ammonium molybdate-vanadate mixture then measuring using UV-Vis spectrophotometer, Perkin-Elmer Lambda 25 model. The level of cadmium, chromium and lead was determined by use of Thermo Electron Atomic Absorption Spectrophotometer after Aqua regia digestion at respective wavelengths.

2.4 Data analysis

The collected data was analysed using SPSS statistical package version 23. Each parameter was analysed in triplicate and data presented as mean and standard deviation. ANOVA was used to determine if there exist statistical significant difference between the means in the samples and the limit set by the regulatory body, NEMA.

3.0 Results and Discussion

The results of the physicochemical characterization of industrial effluents from the three selected paint factories are summarized in table 1.

The pH of the effluent samples analyzed ranged between 6.48-6.89 indicating slight acidity. The slight acidity was attributed to organic matter from paint components which when broken down by bacteria releases carbon dioxide gas which consequently reduces the pH values (Hong *et al*, 2014). The pH values obtained had statistically significant difference in the samples A, B and C at 5% significance level ($p<0.05$) (Tabe 1). The effluent pH, complied with NEMA standards of pH 6.5 - 8.5 for environmental and pH 6-9 for public sewers discharges respectively (EMCA, 2006).

There was a significant statistical difference in the levels of COD in the three samples at 5% significance level ($p<0.05$), (Table 1). Sample B recorded the highest concentration of 1881.20±24.82 mg/L while A had the lowest COD value; 916.77 ±28.15 mg/L. Sample C recorded 1163.00 ±17.54 mg/L. The difference in the levels of COD can be attributed to different levels of binders, organic solvents, pigments and paint components used in three different companies during paint production (Tesfalem and Abdrie, 2017). The values of COD obtained were all above NEMA set maximum limit of 50 mg/L for effluent discharge into the environment. Sample A only complied with maximum the 1000 mg/L limit for discharge into public sewers.

The level of oil and grease obtained had a significant statistical difference at 5% significance level ($p<0.05$). These values were quite high compared to NEMA third and fifth schedule standards (EMCA, 2006). These high values were attributed to resins and binders used in the paint manufacturing process (Onuigbo and Madu, 2013).

Table 1: Physico-chemical and heavy metal parameters in effluents from the three paint factories

Parameter	A (Mean±SD)	B (Mean±SD)	C (Mean±SD)	P-value	3rd Schedule (EM-CA,2006)	5th Sched-ule (EM-CA,2006)
pH	6.48 ± 0.14	6.89 ± 0.04	6.80 ± 0.03	0.002	6.5-8.5	6-9
COD (mg/L)	916.77 ±28.15	1881.20±24.82	1163.00 ±17.54	<0.0001	50	1000
Oil &grease (mg/L)	6374.33±23.03	3525.00±17.52	3525.00±17.52	<0.0001	nil	10
TSS (mg/L)	7395.33±364.23	6382.33±658.01	7159.00±768.56	<0.0001	30	250
Total Phosphorus (mg/L)	148.69±2.50	149.32±1.22	145.00±3.61	0.1863	2.0	30.0
Total nitrogen (mg/L)	4442.67±70.47	1586.67±29.14	3042.67±21.39	<0.0001	13.5	40.0
Total sulphur (mg/L)	73.41±1.71	73.29±3.77	72.62±3.11	0.9417	0.1	2.0
Cadmium (mg/L)	4.18±0.09	3.03±0.83	3.47±1.04	0.1761	0.1	0.5
Lead (mg/L)	12.05±0.41	5.38±1.41	17.21±1.67	<0.0001	0.1	1.0
Chromium (mg/L)	2.07±0.66	2.29±0.24	3.04±0.83	0.2183	2.0	2.0

NEMA limits for TSS in third and fifth schedules are 30mg/L and 250 mg/L for environmental and public sewer discharges respectively (EMCA, 2006). The p-value obtained indicated a significant statistical difference at 5% significance level ($p<0.05$). All the sample concentrations did not meet the set standards by NEMA. The paint components especially binders, additives and pigments were deemed to contribute to the high levels of TSS in the effluent samples (Chidozie and Nwakanma, 2017).

The phosphorus concentrations were higher than recommended by the Water Quality Regulation, 2006 which is 30.0 mg/L (EMCA, 2006). There was no statistical significance difference in the three samples in the levels of total phosphorus ($p>0.05$). The high values for phosphorus may be attributed to phosphorous containing detergents used during cleaning of equipment and paint components (Olaoye and Oladeji, 2015).

There was a significant statistical difference in the levels of total nitrogen in the three samples at 5% significance level ($p<0.05$) with sample A recording the highest value of 4442.67±70.47 mg/L while B recorded the lowest nitrogen level of 1586.67±29.14 mg/L. The high nitrogen values are attributed to high usage of organic pigments especially the derivatives of azo, Anthraquinone, phthalocyanine and binders during paint formulations, which have a direct effect on the levels of total nitrogen in the effluent produced (Sanyaolu *et al*, 2013). These values were higher than set limits by the Water Quality Regulation, 2006 of 40.0 mg/L (EMCA, 2006).

There was no statistical significance difference ($p>0.05$) in the concentration of sulphur across the samples with sample C having the lowest level of 72.62±3.11 mg/L and A showing highest concentration of 73.41±1.71 mg/L as in Table 1. The recommended limit is 2 mg/L, clearly indicating the sulphur levels were extremely higher than set limit (EMCA, 2006). The levels of cadmium in the samples ranged from 3.03±0.83 mg/L to 4.18±0.09 mg/L. The high concentration was attributed to cadmium-containing compounds used as pigments in paint manufacturing (Pravin *et al*., 2011). The EMCA, 2006 limits for cadmium in the environment and public sewers discharge are 0.1 mg/L and 0.5 mg/L respectively. The values obtained for Cadmium had no statistical significance difference in the three samples analysed ($p>0.05$) and were above the recommended limits by EMCA, 2006.

The levels of lead in the samples ranged between 5.38±1.41 mg/L and 17.21±1.67 mg/L. There was a significant statistical difference in the levels of lead in the three samples at 5% significance level ($p<0.05$). The high concentration of lead was attributed to excessive usage of inorganic lead pigment during manufacturing (Bhuiyan, *et al*, 2014) and the use of lead driers. EMCA, 2006 limits for lead in the environment and public sewers discharge are 0.1 mg/L and 1.0 mg/L respectively. These values were above the recommended levels. Chromium concentration in the samples ranged from 2.07±0.66 mg/L to 3.04±0.83 mg/L. These values agree with 1.5 to 9.32 mg/L obtained by Tesfalem and Abdrie (2017) in their analysis of five paint industries effluents in Addis Ababa. Chromium-containing inorganic pigments are used in paint manufacture, hence the presence of chromium in the effluents (Onuegbu *et al*, 2013). EMCA, 2006 limits discharge of chromium into the environment and public sewers to maximum 2.0 mg/L. The values obtained for Chromium had no statistical significance difference in the three samples analysed ($p>0.05$) and were above the recommended limits by EMCA, 2006.

Conclusion

Most parameters in the study, apart from pH, were found to be higher than the maximum recommended limits set by the Environmental Management and Coordination Act of 2006 for discharge into public sewers and the environment (EMCA, 2006). These parameters namely TSS, COD, Total Nitrogen, Total Phosphorus, oil and grease, total Sulphur and heavy metals were above the permissible limits set by Kenya Environment regulatory body. These high levels of inorganic and organic contaminants in the effluents are likely to raise the respective levels in the public sewers into which the effluents are drained into, consequently degrading the environment and human health. This study will guide in further legislation and enhance enforcement required to ensure discharge of effluents into sewage system meets the set standards and thus ultimately promoting public health and environment protection.

Competing Interests

Authors have no competing interest.

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References

[1] A.C. Onuigbo and I.A. Madu, "Assessment of impact of effluent discharge on the quality of Emene River, Enugu, Nigeria", New York Science Journal, vol.6, no.8, pp.34-42, 2013.

[2] A.H. Hong, P.L. Law and O.S. Suleiman, "Determination of physico-chemical quality of municipal wastewater effluent for domestic and irrigation reuse at Lake Geriyo irrigation sites, Yola, Northeastern Nigeria", International Journal of Environmental Science, Management and Engineering Research, vol. 3, no. 1, pp.8-17, 2014.

[3] A. Walingo, C. Alexandre, J. Kabira and P. Ewell, "Potato processing in Nairobi current status and potential for further development", 1997.

[4] B.K. Körbahti and A. Tanyolac, "Electrochemical treatment of simulated industrial paint wastewater in a continuous tubular reactor", Journal of Chemical Engineering, vol. 148, pp. 444–451, 2009.

[5] B.W. Tesfalem and S.H. Abdrie, "Toxicity Study of Heavy Metals Pollutants and Physico-Chemical Characterization of Effluents Collected from Different Paint Industries in Addis Ababa, Ethiopia". Journal of forensic sciences and criminal investigation, Vol.5, no. 5, pp.1-5, 2017.

[6] D, Wurm, "The greening of paint: An eco-paint buyer's guide", Renew: Technology for a Sustainable Future, vol.136, pp. 74-78, 2016.

[7] EMCA, "Environmental Management and Coordination Act", Kenya Gazette. Government Printers, Nairobi, Kenya, 2006.

[8] F. Fu and Q. Wang, "Removal of heavy metal ions from wastewaters: A review", Journal of Environmental Management, vol.92, pp.407-418, 2011.

[9] H. Kabbaj, H. El Mai, M.D. Galindo-Riãno and M. Stitou, "Physicochemical characterization and Analysis of total metal concentration of grease and wastewater samples: Case study for two wastewater treatment plants in the North of Morocco: Tangier and Tetouan". Journal of Materials and Environmental Science, vol. 5, no.5, pp. 1622-1632, 2014.

[10] J. K. Ogilo, A.O. Onditi, A.M. Salim, and A.O. Yusuf, "Assessment of Levels of Heavy Metals in Paints from Interior Walls and Indoor Dust from Residential Houses in Nairobi City County, Kenya", Chemical Science International Journal, vol.21 no.1, pp. 1-7, 2017.

[11] J. Odhiambo, A. Yusuf and J. Onyatta, "Assessment of Selected Parameters for Industrial Effluents from Some Industrial Sites in Nairobi, Kenya", Universal Journal of Chemistry, Vol.4, no.2, pp.65-68, 2016.

[12] K. Chidozie and C. Nwakanwa, "Assessment of Saclux Paint Industrial Effluents on Nkoho River in

Abia state, Nigeria". Journal of Ecosystem and Ecography, Vol.7, no.2, pp.1-6, 2017.

[13] K. Kigotho, "Kenya paint market and industry growing into key East African hub in East African coatings congress report', 2017.

[14] M.A.H. Bhuiyan, S.B. Dampare., M.A. Islam, S. Suzuki, "Source apportionment and pollution evaluation of heavy metals in water and sediments of Buriganga River, Bangladesh, using multivariate analysis and pollution evaluation indices", Environmental Monitoring Assessment journal, vol. 187, no.1, 2014.

[15] R. A. Olaoye, and O. S. Oladeji, "Preliminary Assessment of Effects of Paint Industry Effluents on Local Groundwater Regime in Ibadan, Nigeria", International Journal of Engineering Research Vol.4, no.10, pp. 518-522, 2015.

[16] R. Lambourne and T.A. Strivens, "Paint and Surface Coatings: Theory and Practice". A volume in Woodhead Publishing Series in Metals and Surface Engineering Book.2, Woodhead, Publishing Limited, Cambridge, United Kingdom, 2014.

[17] R.Talbert, "Paint Technology Handbook", CRC Press, New York, pp. 91-93, 2008.

[18] S.G. Mathenge, W.G. Njoroge and O.M. Mutuku, "Assessment of heavy metals in soil and untreated wastewater used for irrigation in urban and peri-urban farms in eastern Nairobi city, Kenya", Journal of medical Science and clinical research, vol.6, no.8, pp. 743-749, 2018.

[19] T. Jesionowski and F. Ciesielczyk, "Pigment, Inorganic. In: Luo R. Encyclopedia of Color Science and Technology", Springer, New York, NY, 2013.

[20] T.U. Onuegbu, E.T. Umoh and I.T. Onwuekwe, "Physicochemical analysis of effluent from Jacbon Chemical industries limited, makers of Bonalux emulsion and gloss paints", International Journal of Science and Technology, vol.2, no.2, pp.169-173, 2013.

[21] U. Pravin, G. Asmita and S.L. Ram, "Water pollution by discharge effluents from Gove Industrial Area of Maharashtra, India: Dispersion of heavy metals and their Toxic effects", International Journal of Global Environmental Issues, vol. 11, no.1, pp. 28-36, 2011.

[22] V. Mannari and C.J. Patel, "Paint component. Understanding Raw Materials". Vincentz Network, Hanover, Germany, 2015.

[23] V.T. Sanyaolu, A.A. Sanyaolu and A. Babayeju, "Determination of the physicochemical parameters of an industrial effluent: A case study of Pz Cussons Plc., Ikorudu, Lagos State", Journal of Environmental Conservation and Restoration, vol. 1, no.2, pp.12-20, 2013.

[24] Y.N. Jolly, A. Hossain, A. Sattar and A. Islam, "Impact of heavy metals on water and soil environment of a paint industry", Journal of Bangladesh Chemical Society, vol. 25, pp.159-165, 2012