ANALYSIS OF INDUSTRIAL EFFLUENT FROM SOME FACTORIES IN TEMA

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ABSTRACT

This research work analysed the quality of some important physico-chemical parameters of industrial effluents collected from two soap factories (A and B) in the Tema industrial area. In the study, PO_4^-, NH_3, BOD, COD, TSS and turbidity for both factories were high compared to the EPA standards. Measures of NO_3^-, total hardness, calcium, and chloride, for both factories were below the EPA standard. Alkalinity value for factory A was below the EPA standard while that for factory B was higher. pH value for factory A was within the pH range for EPA while that of factory B was higher. TDS and conductivity for factory A were below the recommended EPA standard while that of factory B was higher. Due to the high amount of PO_4^-, NH_3, and turbidity, eutrophication could occur in the receiving water, thereby affecting aquatic life. The high BOD, COD and TSS contribute to the decrease in oxygen supply in the receiving water which indicates high pollution by organic pollutants. The high alkalinity, TDS, conductivity and pH could contribute to the deformity and death of fishes in the receiving water from especially Factory A. Effluents from both factories were highly polluted in many respects and so EPA audits must be intensified to prevent pollution of water bodies in Ghana.

Keywords: BOD, COD, Industrial Effluent**,** Physico-Chemical, TDS, TSS, Water Pollution.

INTRODUCTION

Industrial development is essential for the economic growth of every country. Unfortunately, many industries are not able to manage their wastes and so dispose them into nearby water bodies such as rivers and lagoons. Wastes from industries usually contain toxic substances which pollute the sink (water, air or land) in which they are released into. According to Kannj and Achi (2011), effluent discharges from industries have polluted many water bodies in most part of the world. The chemicals in these industrial effluents are detrimental and threaten the lives of fauna and flora in the environment. For instance, heavy metals in industrial effluents can enter the food chain and bio-accumulate in organisms in higher trophic level which can be lethal to them at a certain concentration.

The increasing pollution of rivers, streams and lagoons have attracted the attention of many scientific and administrative authorities globally (Hassan & Amadi, 2013). In Ghana, rapid industrialisation is increasing the volume of industrial effluent released into water bodies. Aboyeji (2013) reported that fresh water resources are important but are being contaminated uncontrollably through industrial effluent and anthropogenic activities. The rate at which industrial wastewaters are released into streams and rivers in Ghana is high so there is the need to check their quality before releasing them into the environment. For instance, Abubakari *et al* (2016) reported that the Onukpawahe stream at the Tema Motorway Industrial Area in Ghana can no longer undergo the natural self-purification process as good quality water source. They attributed the cause to high release of industrial effluent. In their study, a general increase in concentrations of physicochemical and microbial parameters was reported.

In order to improve the quality of water resources and protect aquatic life, it is essential to evaluate the quality of effluent released into the environment to ensure sustainable development. Hanson *et al* (2007) found that pesticides such as propoxur, lindane and pentachlorophenol at very low levels could hamper the reproduction in fresh water fishes such as *C. gariepinus, C. nigrodigitatus* and *O. niloticus* and soften their bones also. This could be transferred and bio-accumulate in humans through the food chain, as has already been intimated. Such contaminated fresh water from farm and road run-offs could end up in water for use in homes. The level or concentration of physico-chemical parameters which determines the use of water in a community must be periodically monitored. This work assess the quality of effluent discharged from two soap industries in Tema and compares the results with Environmental Protection Agency (EPA) permissible standards for industrial waste discharge to find out if they have a desirable or otherwise impact on the environment, and appropriate measures suggested.

MATERIALS AND METHODS

Study area

The study was conducted at two soap factories (A and B) in the Tema industrial area to analyse effluent discharges.

Sampling procedure

Five different samples were taken from each of the soap factories in Tema for five days. Samples were also collected from the drains of these factories with a rubber container into plastic bottles. Each day, two samples were collected (i.e. in the morning and mid-afternoon) and then composited. Samples were stored in the refrigerator at a temperature of four degree Celsius. The sampling points were designed in relation to the industries under study. All samples for laboratory analysis were placed into thoroughly cleaned (with 0.1 M dilute HNO_3 and rinsed with distilled water before use) 1 litre plastic bottles and glass bottles. Each of these bottles was rinsed with appropriate amount of water or effluent sample before collecting the sample. The samples were placed in cooler boxes which were protected from sunlight and taken to the laboratory for analysis.

Physiochemical analysis

In order to carry out physiochemical analysis of obtained samples of water, temperature, pH, electrical conductivity, turbidity, total dissolved solids, chloride, total hardness, calcium hardness, magnesium, alkalinity, dissolved oxygen, nitrate, sodium, phosphate, biological oxygen demand, chemical oxygen demand were assessed. Standard Methods for the Examination of Water and Wastewater (Standard Methods), 19th edition, APHA, AWWA, WEF, 2012 were used for analysis of water samples. Obtained results were compared with standards given by EPA in Ghana.

RESULTS AND DISCUSSION

The results of physicochemical analysis of industrial effluent samples from Factory A are presented as Table 1.

Table1: Physicochemical parameters results for Factory A

Parameters	Day					Mean	SD	Min	max	EPA
	1	2	3	4	5					
pH	6.60	6.60	6.62	6.60	6.62	6.61	0.011	6.60	6.62	6.0-9.0
PO_4^-(mg/L)	0.979	0.989	0.989	0.979	0.999	0.987	0.0	0.99	0.99	0.4
NO_3(mg/L)	0.666	0.666	0.676	0.676	0.676	0.672	0.01	0.666	0.676	50
NH_3(mg/L)	2.040	2.060	2.040	2.070	2.070	2.056	0.015	2.04	2.07	1.0
ALK(mg/L)	42.00	42.00	42.01	42.02	42.02	42.01	0.01	42.0	42.02	200
TH (mg/L)	40.00	40.00	40.03	40.01	40.02	40.012	0.013	40.0	40.03	300
Ca^{2+} (mg/L)	4.00	4.02	4.02	4.01	4.01	4.012	0.01	4.00	4.02	75
Cl^-(mg/L)	6.00	6.00	6.00	6.02	6.02	6.008	0.01	6.00	6.02	250
BOD(mg/L)	315.00	315.01	315.01	315.02	315.00	315.008	0.008	315	315.02	50
COD(mg/L)	1575.0	1575.01	1575.02	1575.00	1575.02	1575.01	0.01	1575.0	1575.02	250
TSS(mg/L)	158.00	158.00	158.01	158.01	158.01	158.006	0.01	158.0	158.01	50
TDS(mg/L)	108.0	108.01	108.012	108.012	108.00	108.007	0.01	108.0	108.01	1000
TUR (NTU)	158.0	158.00	158.02	158.02	158.02	158.012	0.011	158.0	158.02	75
CON (µS)	180.0	180.02	180.02	180.02	180.00	180.012	0.01	180.0	180.02	1500

From Table 1, pH value obtained from the analysis of industrial effluent samples of Factory A ranged from 6.60 to 6.62 and had a mean value of 6.61 ± 0.01 which was within the permissible EPA range of 6.0-9.0, PO_4^- mean value was 0.98 ± 0.0 mg/L which was higher than the EPA value of 0.4 mg/L, NO_3^- value was 0.672 ± 0.01 mg/L and was less than the EPA value of 50 mg/L. The NH_3 value recorded was 2.056 ± 0.02 mg/L which was greater than the EPA value of 1.0 mg/L. Alkalinity was 42 ± 0.01 mg/L which was less than 200 mg/L. Total hardness, Ca^{2+}, Cl^-, TDS and conductivity had concentrations of 40.012 ± 0.01 mg/L,4.01 ± 0.01 mg/L,6.01 ± 0.01 mg/L,108.01± 0.01 mg/L and 180.01± 0.01 µS respectively and all these parameters were below their corresponding EPA values. Also, BOD, COD, TSS and TUR values were 315 ± 0.01 mg/L, 1575 ± 0.01 mg/L, 158 ± 0.01 mg/L and 158 ± 0.01 NTU respectively and all these values were higher than their corresponding EPA permissible levels.
The results of physicochemical analysis of industrial effluent samples from Factory B are presented in Table 2.

Table 2: Physicochemical parameters results for factory B

Parameters	Day					Mean	SD	Min	Max	EPA
	1	2	3	4	5					
pH	12.16	12.18	12.18	12.19	12.19	12.18	0.013	12.16	12.19	6.0-9.0
PO_4^-(mg/L)	2.560	2.580	2.580	2.560	2.560	2.568	0.01	2.56	2.58	0.4
NO_3^-(mg/L)	0.328	0.328	0.338	0.338	0.338	0.334	0.01	0.328	0.338	50
NH_3(mg/L)	10.20	10.20	10.21	10.22	10.22	10.21	0.01	10.2	10.22	1.0
ALK(mg/L)	1224.0	1224.00	1224.02	1224.02	1224.01	1224.01	0.00	1224.0	1224.02	200
T/H(mg/L)	51.00	50.02	50.50	50.01	50.01	50.31	0.44	50.01	51.00	300
Ca^{2+}(mg/L)	12.10	12.00	12.20	12.00	12.20	12.200	0.01	12.0	12.2	75
Cl^-(mg/L)	154.10	154.00	154.20	154.21	154.10	154.12	0.09	154.0	154.21	250
BOD(mg/L)	192.00	192.02	192.02	192.02	192.00	192.012	0.01	192.0	192.02	50
COD(mg/L)	960.00	960.02	960.01	960.01	960.01	960.01	0.007	960.0	960.02	250
TSS(mg/L)	207.00	207.00	207.00	207.01	207.02	207.006	0.008	270.00	207.02	50
TDS(mg/L)	15960.2	15960.3	15960.2	15960.4	15960.2	15960.26	0.09	15960.2	15960.4	1000
TUR(NTU)	208.00	208.02	208.02	208.10	208.00	208.03	0.04	208.0	208.10	75
CON (µS/cm)	26600.1	26600.4	26600.1	26600.1	26600.2	26600.18	0.13	26600.1	26600.4	1500

From Table 2, the pH value obtained from the analysis of industrial effluent samples of Factory B ranged from 12.16 to 12.19 and had a mean value of 12.18 ± 0.01 which was higher than the permissible EPA range of 6.0-9.0, PO_4^- mean value was 2.57 ± 0.1 mg/L which was higher than the EPA value of 0.4 mg/L. The NO_3^- value was 0.334 ± 0.01 mg/L and was less than the EPA value of 50 mg/L. The NH_3 value recorded was 10.21 ± 0.01 mg/L which was greater than the EPA value of 1.0 mg/L and Alkalinity was 1224.01 ± 0.00 mg/L which is higher than 200 mg/L. Also, Total hardness, Ca^{2+} and Cl^- had concentrations of 50.31 ± 0.44 mg/L,12.2 ± 0.01 mg/L and 154.12± 0.09 mg/L respectively and all these parameters were below their corresponding EPA values. Again, BOD, COD, TSS, TDS, TUR and conductivity values were 192.01 ± 0.01 mg/L, 960.01 ± 0.01 mg/L,207 ± 0.01 mg/L,15960 ± 0.09, 208.03 ± NTU and 26600.18 ± 0.13 µS respectively and all these values were higher than their corresponding EPA permissible values. Comparisons of effluent quality of factories A and B against the EPA values have been presented graphically in Figures 1 to 4. Figure 1 shows the effluent quality parameters obtained from Factories A and B as compared to EPA standards.

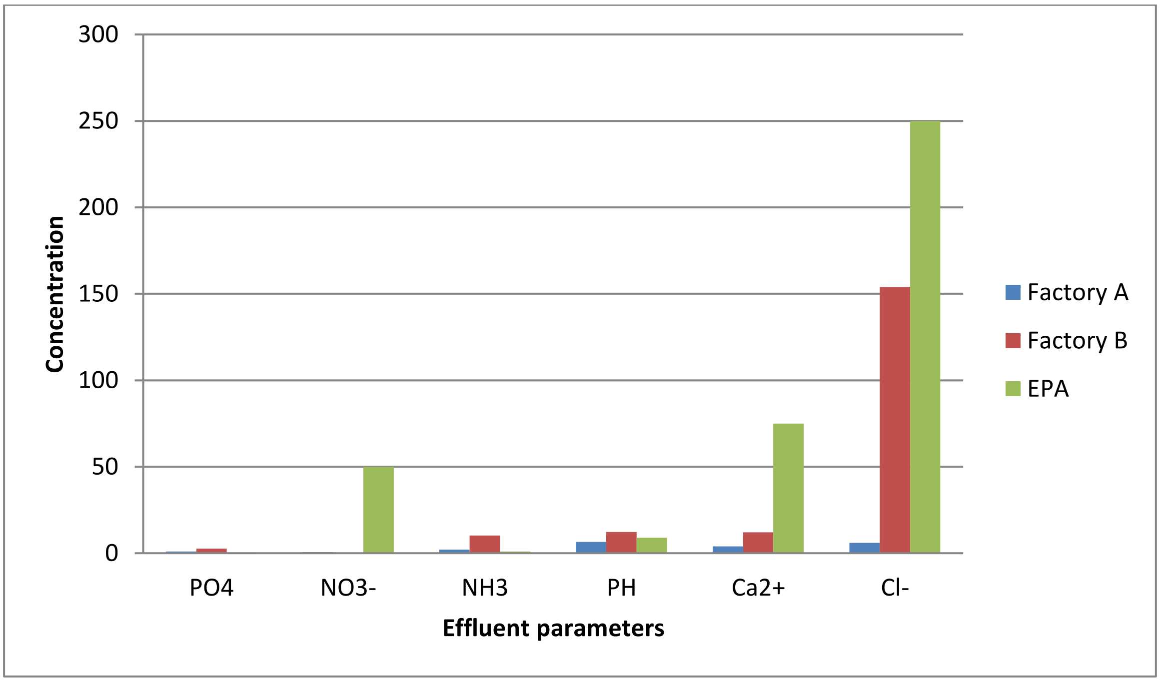

Fig 1: A bar graph showing effluent quality parameters compared to EPA standards

From Figure 1, it is observed that most of the assessed concentrations of effluent parameters are superficially relatively low as compared to standard parameters.

A graphical representation of levels of alkalinity, biological oxygen demand, chemical oxygen demands, total dissolved solids and turbidity, that describe the nature of solution are shown in Figure 2.

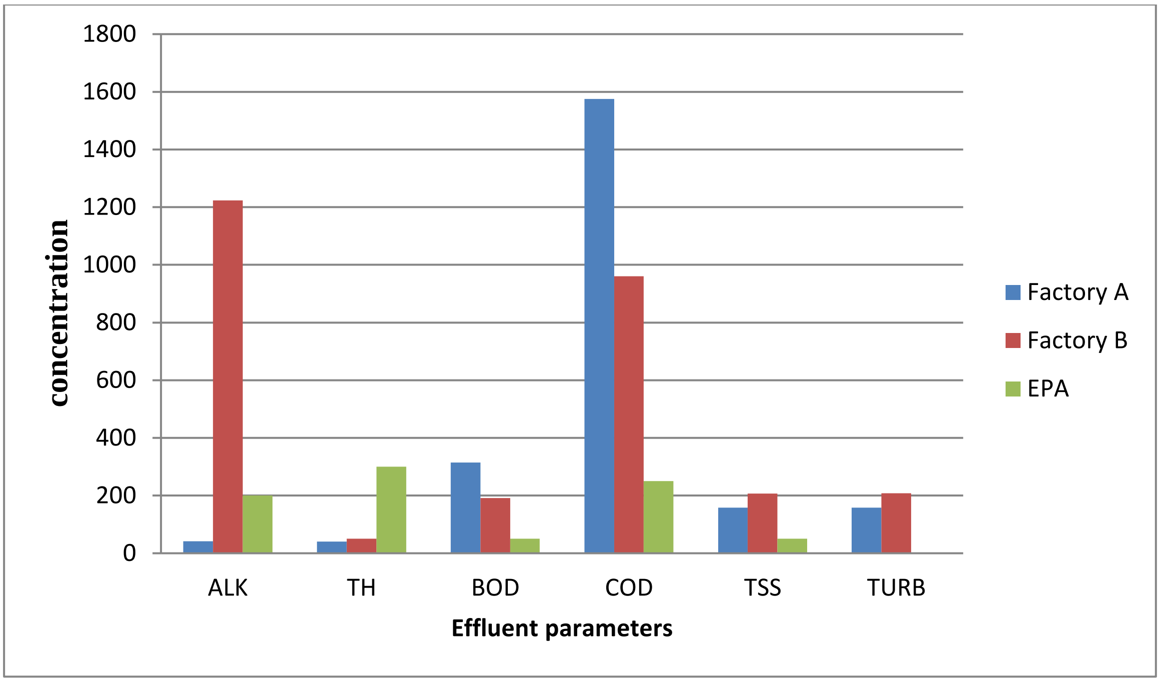

Fig 2: A bar graph showing effluent quality parameter compared to EPA standards.

From Figure 2, it is observed that alkalinity, chemical oxygen demand, suspended solids and turbidity are all higher in discharges from the two factories.

A comparative analysis of dissolved solids and conductivity of Factory A presented, as against standard parameters in Figure 3.

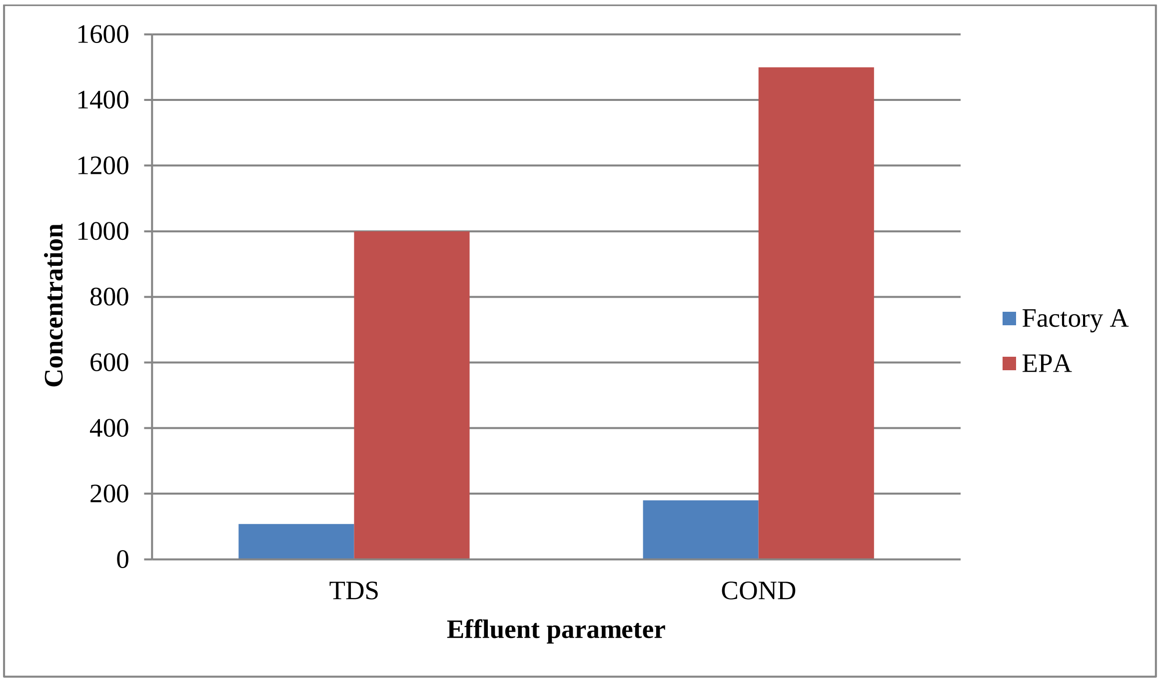

Fig 3: A graph comparing TDS and Conductivity values of Factory A to EPA values
It is observed that the TDS and conductivity values for Factory A are within acceptable limits. The same parameters are measured for Factory B against the EPA standards.

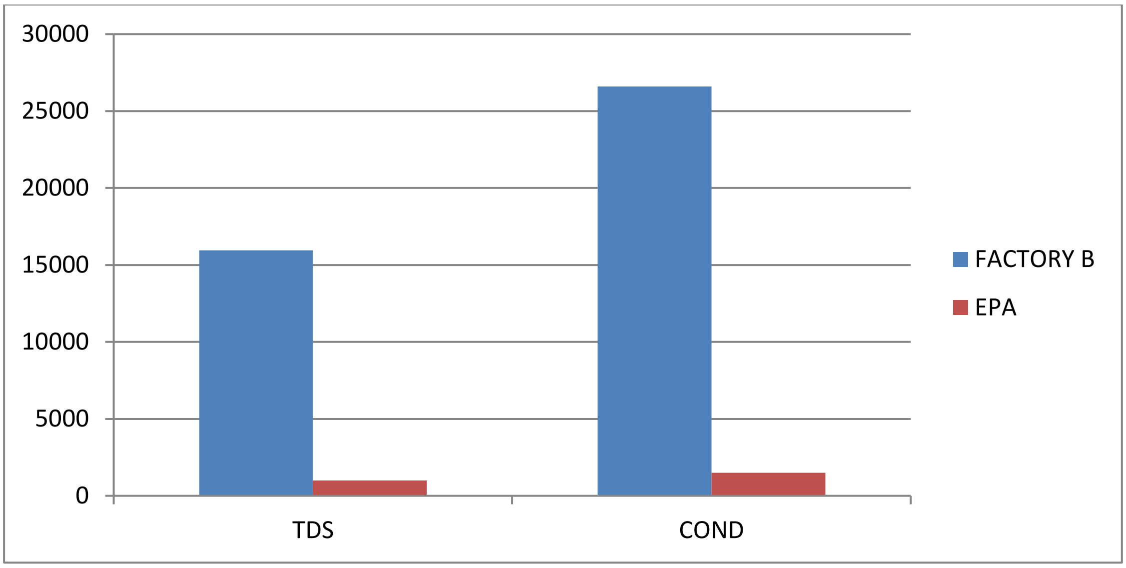

Fig 4: A graph comparing TDS and Conductivity values of factory B to EPA values.
From Figure 4, it is observed that the levels of TDS and COND outstrip that for acceptable levels.

Phosphate

The PO_4^- mean values for Factories A and B were 0.987± 0.01 mg/L and 2.568 ± 0.01 mg/L respectively. These values when compared to EPA value of 0.4 mg/L (see fig 1) showed that phosphate level from these factories were high and could lead to eutrophication where algae and weeds would grow rapidly, and choke the water way, and use up large amounts of precious oxygen. This would culminate into the death of many fishes and aquatic organisms. Soap factories with concentrations of ortho-phosphates higher than 2 mg/L in effluents use raw materials rich in phosphorus elements as adjuvants or bleaching agents (sodium tripolyphosphates: $Na_5P_3O_{10}$, sodium pyrophosphate: $Na_4P_2O_7$, trisodium phosphate: Na_3PO_4) for the formulation of their detergents and cosmetics. These compounds contain the soluble inorganic phosphorus in solution, that are transformed into orthophosphates which come from the hydrolysis of phosphoric acid. Even in very small quantity, orthophosphates are harmful for the environment due to the fact that they are easily absorbed by the soil, polluting nearby well water and the ground-water sheet Ehouman *et al* (2017).

Nitrate

Nitrate level for Factories A and B were 0.672 ± 0.01 mg/L and 0.334 ± mg/L respectively while the standard allowable EPA value is 50 mg/L showing that small amounts of nitrate are released into the environment by these factories. High levels of nitrate could lead to the development of a condition that doctors call methemoglobinema (Irick, 2014). The condition is also called blue baby syndrome because the skin appears blue gray or lavender in colour and also causes the death of fishes in water. Its presence is often noticed late in black (African) children who are dark in colour, and so could be lethal for dark-skinned children. Ehouman *et al* (2017) in a similar study on discharges from a soap factory reported high levels of nitrates in soap effluent and attributed it to the use of nitrogenous compound such as nitrilotriacetic acid (NTA: $C_6H_9NO_6$) and ethylene diamine tetraacetic acid (EDTA) in the formulation of detergents and cosmetics. As indicated earlier, nitrate levels were low in the effluents studied in Ghana and will particularly not be harmful to aquatic organisms such as fish. According to Aboyeji (2013), nitrate is relatively nontoxic for fish health, except when the concentration of nitrate exceeds 90 mg/L in water.

Ammonia

Values of ammonia obtained from the Factories A and B were 2.06 ± 0.01 mg/L and 10.21 ± 0.02 mg/L respectively whiles the EPA standard is 1.0 mg/L. Both factories showed an increase (see fig 1) in ammonia level but factory B showed a higher level. Toxic concentrations of ammonia in humans may cause loss of equilibrium, convulsion, coma and death. It is also toxic to fresh water organisms at concentrations ranging from 0.53 to 22.8 mg/L. Similarly, Abubakari *et al* (2016) recorded high ammonia values and stated that continuous discharge of effluent with high ammonia could cause algal outbreaks (eutrophication) which could eventually kill aquatic organisms and eventually a water body.

Alkalinity

Alkalinity is a measure of capacity of water to neutralize a strong acid (Patel, Mehta, & Solanki, 2017). Alkalinity of water is directly related to pH. Alkalinity for Factory A was 42.01± 0.01 mg/L, while that for B was 1224.01± 0.0 mg/L; the EPA standard is 200 mg/L. Comparison of these values (see fig. 1) showed that factory A had low alkalinity that fell within an acceptable range while factory B had a much higher value than the standard recommended value. Minor variation in alkalinity leads to changes in pH and causes diverse effect on aquatic flora and fauna. This high level of alkalinity in the discharges from Factory B, could therefore lead to death of flora and fauna in receiving water.

Total Hardness

Total hardness for both Factories was lower than the EPA standard (300 mg/L) and so were found to be non-threatening to life. Factory A had a total hardness measure of 40.012 ± 0.01 mg/L, and B measured 50.01 ± 0.44 mg/L. It is known that calcium and magnesium, along with their carbonates, sulphates and chlorides naturally confer temporary and permanent hardness. Water having 0-75mg $CaCO_3$ was described as soft, 75-150 mg $CaCO_3$ as medium hardness of water, while samples having total hardness of over 300 mg $CaCO_3$ per litre were described as hard, according to Adeyeye and Abulude (2004). The effluent in this study could therefore be described as soft water.

Calcium Levels

High calcium level in water often leads to hypercalcemia in aquatic organisms (Patel, Mehta, & Solanki, 2017). The calcium content in Factories A and B were 4.012± 0.01mg/L and 12.2 ± 0.01 mg/L, respectively. The calcium levels, when compared to the EPA recommended value of 75 mg/L, were low.

Chloride Levels

The chloride content for Factories A and B were 6.01 ± 0.01 mg/L and 154.01 ± 0.09 mg/L respectively. Comparing these values to the EPA permissible value for chloride (i.e. 250 mg/L), the obtained chloride values in this study is within acceptable levels. The implication is that the chloride levels in the effluents from the two factories might not pose risk to the water quality as far as plants, animals, and humans who depend upon the receiving water are concerned.

pH

pH is a measure of alkalinity or basicity of a system. The pH values for Factories A and B were found to be 6.61± 0.01 and 12.18 ± 0.01 respectively. Comparing the obtained pH values to the EPA standard, it could be observed (Figure 1) that the mean pH value for Factory A is acceptable since, as it falls within the recommended range of 6.0-9.0. However, the mean pH value for Factory B was higher than the EPA standard. Ehouman *et al* (2017) asserted that soap factories that have alkaline pH discharges that are as high as observed from Factory B, engage in saponification processes that contain triethanolamine, which is a weak organic alkaline agent.

BOD

The biological oxygen demand (BOD) values for Factories A and B were 315.008 ± 0.01 mg/L and 192.012 ± 0.01 mg/L respectively while the EPA standard at the time of this study was 50 mg/L. There was a big difference between obtained BOD values and the standard. The high BOD values are attributed to the discharge of industrial effluent with high levels of organic compounds. Monney *et al* (2013) reported that BOD concentration has direct influence on dissolved oxygen content of water body. The impact of releasing effluents with high BOD concentrations into water bodies is anaerobic conditions which could influence an aquatic environment, leading to fatality of fishes, stench and unpleasant environmental imbalances and disturbances. It is important here to note that low BOD content is an indicator of good quality water, while a high BOD indicates polluted (poor quality) water. In this study the effluents from the factories caused highly pollution in the water. Though the receiving water could have been clear (for factory B), and looked superficially good for domestic and agricultural use, it in truth lacked the necessary amount of oxygen to support aquatic life.

COD

Chemical Oxygen Demand (COD) determination measures the oxygen equivalent of that portion of an organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. The COD values for Factories A and B were 1575.01 ± 0.01 mg/L and 960.028 ± 0.01 mg/L respectively. Comparing these values to the standard EPA value of 250 mg/L, COD measure of effluent in the receiving waters from the two factories is very high. This shows that effluents from the two factories contain high oxidable organic materials. Ehouman *et al* (2017) reported from a similar study that oxidable organic materials could be the source of such an observation. He found that the use of organic raw materials like fatty acids, surfactants, glycerine, phenolic compounds, polyalcohols, nitrogenous and phosphorus compounds and colorants in soap formulation, lead to the production of excess organic and mineral matter waste. When such effluents are discharged into streams, the consequences are that they impair light penetration, oxygen depletion and leads to reduction in photosynthesis in plant. The fauna and flora are thus affected adversely.

TSS

The standard EPA value for TSS in Ghana is 50mg/L. The TSS values for Factories A and B were 158.006 ± 0.01 mg/L and 207.006 ± 0.01 mg/L; higher than the EPA standard. This shows that the TSS values from these factories are unacceptable. Lokhande, Singare and Pimple (2011) reported high TSS values in a similar study and elaborated on how they could encourage bacterial growth, to the detriment of organisms that live in the water. Their findings further showed that effluents obtained from textile industries showed high TSS and TS values of 1475.6 mg/L and 13499.2 mg/L respectively and were harmful to aquatic life. Also, Abubakari *et al* (2016) reported that high TSS affects fish feeding and growth, light penetration in water for production of food (photosynthesis) and supports microbial pollution which are harmful to humans, because suspended particle serves as attachment side for bacteria.

TDS

The amount of salt content in water is a measure for salinity. A large number of salts are found dissolved in natural waters, the common ones are carbonates, bicarbonates, chlorides, sulphates, phosphates, and nitrates of calcium, magnesium, sodium, potassium, iron, and manganese, etc. A high content of dissolved solid elements affects the density of water, influences osmoregulation of freshwater in organisms, reduces solubility of gases (like oxygen) and utility, of water for drinking, irrigational, and industrial purposes. Waters can be classified based on the concentration of TDS (Lokhande, Singare, & Pimple, 2011.) as, desirable for drinking (up to 500 mg/L), permissible for drinking (up to 1,000 mg/L), useful for irrigation (up to 2,000 mg/L), not useful for drinking and irrigation (above 3,000 mg/L). The total dissolved salts (TDS) for Factories A and B were 108.007 ± 0.01 mg/L and B was 15960 ± 0.01 mg/L respectively, as against an EPA standard of 1000 mg/L. A comparison of the obtained values for dissolved salts showed that the TDS value for Factory A was less than that of Factory B, which was higher than the Ghanaian recommended value. The TDS for Factory B was above 3000 mg/L and is likely to contaminate the receiving stream, thereby making it unsuitable for irrigation.

Turbidity

Turbidity values of Factories A and B were 158.012 ± 0.01 NTU and 208.008 ± 0.01 NTU respectively, while EPA standard is 75 NTU. The results indicated that effluents from these factories were turbid. This could be due to high colloidal and suspended particles in waste effluent discharges of the two factories. Increased turbidity in water reduces light penetration needed for photosynthesis by some aquatic life (Diya'uddeen, et al., 2014). Poor photosynthesis would lead to inadequate nutrition and thereby result in stunting and dearth of plant life in receiving waters.

Conductivity

Conductivity values for Factories A and B were180.012 ± 0.01 µS/cm and 26600 ± 0.01 µS/cm, as against an EPA standard of 1500 µS/cm. Factory A gave a value less than the EPA standard while B gave a value higher than the recommended. The high conductivity level in these industrial effluents is ascribed to the presence of ions which include chlorides, phosphates and nitrates (Lokhande, Singare, & Pimple, 2011.). Besides, soap discharges contain mainly aldehydes and other organic compounds such as glycerols, polyphenols and polyalcohols which can oxidize to increase the amount of ions in effluent discharge. Claude (2001) opined that organic compounds in soap effluent discharge undergo oxidation. In this study, the high TDS value obtained for Factory B indicates high amount of dissolved salts. This suggests that high conductivity in the recent study is due to high mineralization due to the oxidation of organic nutrients as well as inorganic salts. Dongo et al.(2013) found in a similar study that when water with high minerals are deposited into water bodies, oxidation reactions of the various ions reduce oxygen concentrations in the receiving environment and so affects aquatic life.

CONCLUSION

Based on gathered findings, it could be concluded that measured parameters such as PO_4^-, NH_3, BOD, COD, TSS and turbidity for both factories were high, as compared to the EPA standards. However, NO_3^-, total hardness, calcium, chloride, for both factories were below the EPA standard. Alkalinity value for Factory A was below the EPA standard while that of Factory B was higher than the EPA standard. pH values for Factory A was within the acceptable range while that of Factory B was higher. Again, the TDS and conductivities for Factory A were below the recommended EPA standard while those for Factory B, were higher. It was deduced from the above parametric measures that Factory B was flaunting the environmental laws for production of pollutants into the environment for safe living.

Furthermore, as far as plant life was concerned, the high levels of PO_4^- and turbidity, which amount to pollution of water bodies, could result particularly in eutrophication. Also, the high amount of NH_3 could affect the hatching and growth rates of fishes hence reducing their population. As observed by Hanson *et al* (2007) polluted waters could affect the reproduction rate adversely in fishes. The high BOD, COD and TSS contribute to the decrease in oxygen supply in the receiving water and increases organic pollutants. The High alkalinity, TDS, conductivity and pH contributes to the deformity and death of fishes in the receiving water.

In order to protect aquatic life industries should ensure that their waste effluents released into water bodies do not cause detrimental effects. Also, EPA and other environmental agencies should intensify their monitoring on industries to ensure that their wastes are well treated before discharge into the environment.

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