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Assessment of the Suitability of Wastewater from a Soap Factory in Cape Coast-Ghana for Crop Production

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Abstract:
The purpose of this study was to assess the suitability of wastewater from a Soap Manufacturing Industry for crop production. The study showed that seven (7) out of twenty (22) effluent properties were within acceptable limits. These are nitrate-nitrogen, electrical conductivity, total dissolved solids, chlorine, iron, copper and zinc. Nine (9) effluent properties exceeded quality guidelines. These include pH, temperature, turbidity, chemical oxygen demand, biological oxygen demand, oil and grease, total suspended solids, phosphorus and ammonium nitrogen. Effluent potential was relatively high for improving soil CEC. On the basis of nitrogen, potassium and phosphorus concentrations which were adequate and the low micro nutrients (Fe, Cu, Zn) concentrations, the effluent has the potential for use as irrigation water. Effluent ESP and EC however may pose the challenge of soil sodicity and salinity which could erode the economic benefits of any gain a farmer may make from applying this effluent to farmland. There is therefore the need to fashion out an effluent treatment system which could adequately reduce effluent ESP and EC.

Keywords: *Industrial Effluent/wastewater, BOD, COD, macro and micro nutrients, cation exchange capacity (CEC), exchangeable sodium percentage (ESP)*

1. Introduction

Wastewater is an inevitable by-product of most industrial production processes. Though various countries enact laws that make it mandatory for industries to treat wastewater prior to discharge into the external environment (rivers, ponds, lakes, sea, land, etc), the relatively large volumes of wastewater generated on daily basis make it difficult for them to comply. Consequently volumes of untreated effluent are discharged into the external environment without any proper treatment (Hillebrand, Musallam, Scherer, Nodler, and Licha, 2013; Ternes, Joss, and Oehlmann, 2015). As an alternative measure to this problem, some countries adopted the use of industrial effluent to irrigate farmlands especially during the dry season, enabling farmers to produce food crops all year round (Loos *et al*., 2013 & Mills *et al*., 2014). This was against the background that some industrial effluents are nutrients rich and could provide substantial amount of plant nutrients. Major set-backs identified from the practice however include the build-up of toxic elements such as Boron (Bo) Lead (Pb) and Molybdenum (Mo), which hinder crop production. (Ahmad, Manderia, and Mandria, 2012; Ahmad, Anawar, Chowdhury and Ahmad, 2011; Ali, 2011 and Arun, and Kanjan, 2012.) Sodium build-up also impose soil sodicity and alkalinity, which destroy soil structure which leads to poor soil aeration and water infiltration, high bulk density, low microbial activity among other. (Gatta *et al*., 2014; Petrie, Barden, and Kasprzyk-Hordern, 2014; Gardner *et al*., 2013 and Gardner *et al*., 2012). The need to carefully evaluate the quality of industrial effluent before applying to crop land is therefore very necessary to desirable yields. Ameen Sangari Industries Limited in Cape Coast is one of such industries. The industry extracts palm oil from palm fruits and combines this with alkali (NaOH) to produce soap. The wastewater generated from this production process has been discharged onto a nearby land for about 43years. The land gradually lost its ability to support plant growth. As the result, farmers who used to crop the land eventually stopped as yield dwindled to un-economic levels. It was assumed that the wastewater discharged by the industry onto the land could have deleterious substances which destroyed soil fertility. This experiment was therefore designed to evaluate the quality of the wastewater discharged onto the land as compared to the standards prescribed by the Environmental Protection Agency. Findings from this experiment would inform the Management of the industry about the need to adopt a more efficient way to manage their wastewater and also, enable the land owners to fashion out suitable approaches to reclaim the affected land.

2. Materials and Methods

In this study, wastewater samples were collected from the discharge point into plastic bottles with necessary precautions for laboratory analysis. Physicochemical properties such as pH, Turbidity, Temperature and Electrical Conductivity (EC) were immediately determined on site after sampling (APHA, AWWA and WEF, 2005). Determination of parameters such as Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Oil and Grease (OG), Total Suspended Solids (TSS), Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Phosphorus (P), Ammonium Nitrogen (NH_4^+-N), Nitrate Nitrogen (NO_3^-N), Chlorine (Cl), Zinc (Zn), Iron (Fe) and Copper (Cu) were carried out in the laboratory of Water Research Institute of Council for Scientific and Industrial Research. Other effluent temperature and pH were measured using the pH meter which also has a thermometer. Sample turbidity was determined using turbidimeter. Electrical conductivity (CE) and Total Dissolved Solids (TDS) were determined by aid of a conductometer (USEPA, 1979). Total Suspended Solids (TSS) was measured by ratio of weights of known volume of effluent and residues left behind after evaporation (APHA, 1975), whilst Chemical Oxygen Demand (COD) was determined by the dichromate digestion method. Biological Oxygen Demand (BOD) was determined be the dilution method (APHA, 1975), determination of Oil and Grease (OG) by the method described by Stenstrom, Fam and Silverman (1986), whist Sodium (Na^+) and Potassium (K^+) were determined using flame photometer. Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) determination were by EDTA titration whilst Ammonium Nitrogen (NH_4^+-N) and Nitrate Nitrogen (NO_3^-N) of effluent were determined by spectrophotometry at 410nm. Available phosphorus (P) was measured using the spectrophotometer at 400nm wavelength (Kennedy, 1984) and Chlorine (Cl) determined by $AgNO_3$ titration (Balaara, Paintsil and Vitenu, 2008). Copper (Cu) was determined by spectrophotometry at 457nm (Gahler, A.R. 1954) and Zinc by spectrophotometer method defined by Platte & Marcy (1959). Determination of iron (Fe) in effluent used the spectrophotometer method at 510 nmwavelength. (Mehlig and Hulett, 1942). Data obtained was compared to the standards of the Environmental Protection Agency of Ghana.

3. Results and Discussion

Table 1 shows the results of the physicochemical properties of the effluent from the soap manufacturing industry located in Cape Coast industrial area as compared to the effluent quality standards of the Environmental Protection Agency of Ghana.

Parameter	Mean Value	Standards
pH	11.20 ± 0.02	6.0 – 9.0
Temperature (°C)	36.80 ± 0.22	< 30°C
Electrical Conductivity (dS m^{-1})	4.37 ± 0.015	1,500.0
Total Dissolved Solids (ppm)	5.87 ± 0.010	1,000.0
Turbidity (NTU)	959 ± 0.186	75.0
Chemical Oxygen Demand (COD, mg/l)	6,090 ± 4.92	250.0
Biological Oxygen Demand (BOD, mg/l)	805 ± 0.166	50.0
Oil and grease (ml/l)	159 ± 0.225	5.0
Total Suspended Solids (ppm)	2,090 ± 0.567	50.0
Sodium [Na^+ (cmol/l)]	26.44 ± 0.045	-
Potassium [K^+ (cmol/l)]	16.36 ± 0.010	-
Calcium [Ca^{2+} (cmol/l)]	0.70 ± 0.05	-
Magnesium [Mg^{2+} (cmol/l)]	0.3 ± 0.005	-
Phosphorus [P(mg/l)]	111.57 ± 3.953	2.0
CEC	43.8 ± 1.901	-
ESP	60.4 ± 3.936	-
Ammonium Nitrogen [NH_4^+-N(mg/l)]	19.1 ± 0.11	1.0
Nitrate Nitrogen [NO_3^--N(mg/l)]	17.4 ± 0.010	50.0
Zinc [Zn(mg/l)]	0.59 ± 0.04	10.0
Copper [Cu(mg/l)]	1.73 ± 0.07	5.0
Chlorine [Cl(mg/l)]	0.39 ± 0.049	250.0
Iron [Fe(mg/l)]	0.79 ± 0.09	10.0

Table 1: Effluent quality parameters of the Soap Manufacturing Industry

3.1. Effluent temperature, pH, Electrical Conductivity and Micro Nutrients

Effluent temperature is a very important parameter because it can influence the physical, chemical and biological properties of a receiving medium. In the soil, temperature is known to influence seed germination, nutrient availability, plant root and fruit development, microbial activities and organic matter decomposition, etc. (Martias and Musil, 2012 and Nwankwo and Ogugurue, 2012). The temperature of the effluent was 36.80 °C as against the recommended temperature of < 30 °C. This may imply that some effluent is discharged right from source without any temporary holding for treatment.

Effluent pH was 11.19 as against the standard range of 6.0 - 9.0. The discharge of such an effluent onto agricultural land could upset the soil regime. Soil pH directly affects the life and growth of plants because it affects the availability of all plant nutrients in the soil. Between pH 6.0 and 6.5, most plant nutrients are in their most available state (Muamar *et al*., 2014). An effluent with such a high pH could increase soil pH to alkaline conditions. Under such alkaline condition, the availability of phosphorus and most micro nutrients are adversely affected.

Electrical conductivity of the wastewater is a measure of its capability to pass electrical flow (Perlman, 2014). This ability relates to the concentration of ions in the wastewater, derived from dissolved and inorganic materials such as alkalis, chlorides, sulfides, and carbonate compounds (Lourenzi *et al*., 2011; EPA. 2012). A high conductivity depicts the presence of more dissolved ions and vice versa. The effluent sample registered a relatively low electrical conductivity of 4.37 dS m^{-1} compared to an approved standard of 1,500.0 dS m^{-1} for discharge into the external environment. This gives a 34,324 % lower value when compared to the standard hence could be described as negligible. This reflected in the relatively low values obtained for all the micronutrients namely Copper (1.73 mg/l), Zinc (0.59 mg/l), Chlorine (0.39 mg/l) and Iron (0.79 mg/l) as against standards of 10.0, 5.0, 250.0 and 10.0 respectively. Despite the low levels of these ions, continuous discharge of this effluent onto land for a long term could lead to their build-up in soil to levels which could be detrimental to plant growth. The use of such wastewater for irrigation may be beneficial at the onset but yields may dwindle over time as these micronutrients build-up in soil and negatively impact on crop growth and yield.

3.2. Total Suspended Solids, Chemical and Biological Oxygen Demands

Total suspended solids (TSS) is a measure of organic and inorganic solid materials in effluent. It positively correlates with effluent Turbidity (T). The organic components of suspended solid of soap industrial effluent includes palm fiber, oil and grease (O&G) whist the inorganic fraction comprises mainly of sand, silt and clay (Ale, Jha and Belbase, 2008). The values obtained for TSS, T and O&G for the soap factory effluent were 2,090 ppm, 959 NTU and 159 mg/l respectively as against standards of 50 ppm, 75 NTU and 5.0 mg/l in that order. These represent 4,18 %, 1,28 % and 19,18 % increase over the standards. Even though the discharge of such an effluent into water bodies could negatively impact water quality; its discharge onto farm land over time could lead to accumulation of organic matter in soil (Czuba *et al*., 2011). Soil organic matter improves soil aggregate stability, aeration, water infiltration, water holding capacity, nutrient retention and release to soil solution for plant roots absorption, etc. The sand, silt and clay fractions of effluent may come from erosion of the banks and base of drains that conduct the effluent.

The biological oxygen demand (BOD) of effluent sample measured 805 mg/l compared to a standard value of 50 mg/l. This represents a 1,161 % increase over the standard. Chemical oxygen demand (COD) of effluent was 6,090 mg/l as against a standard value of 250 mg/l, giving a 2,436 % deviation from the standard. BOD and COD make a common demand on the soil regime by depleting soil oxygen. BOD indirectly depletes soil oxygen following the increase in microbial activity towards the decomposition of organic matter (Botalova and Schwarbauer, 2011; Ahmad, Bajahlan and Hammad, 2008), whilst COD demands soil oxygen in order to oxidize long fatty acids, typical of palm oil and soap manufacturing industries (Arun and Kanjan, 2012). The combined effect of BOD and COD in soil therefore is the creation of anaerobic condition which slows down microbial activity, organic matter decomposition and also increase gaseous loss of some soil-plant nutrients, notably ammonium and nitrate nitrogen.

3.3. Sodium, Calcium and Magnesium,

Sodium (Na^+) in effluent sample was 26.44 cmol/l. Calcium (Ca^{+2}) recorded 0.70 cmol/l and magnesium (Mg^{+2}), 0.30 cmol/l. The relatively high value for Na^+ in effluent is as the result of the use of NaOH as alkali for soap production by the industry. The exchangeable forms of sodium (Na^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}) are very important parameters which must be monitored in any form of wastewater intended for application to farm land. This is because sodium accumulation in soil is known to be the lead cause of sodicity, an undesirable soil condition which destroys soil structure, aggregate stability, water infiltration and hydraulic conductivity, microbial activity and nutrient supply. Ca^{+2} and Mg^{+2} on the other hand enable the formation of salts [$CaCO_3$ $MgCO_3$, $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$], which cause soil salinity.

3.4. Potassium, Phosphorus, Ammonium and Nitrate Nitrogen

Potassium (K^+), phosphorus (P), ammonium nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3^--N) are effluent properties desirable for soil fertility and plant nutrition. The effluent sample recorded 16.36 cmol/l, 111.57 ml/l, 19.1 ml/l, and 17.4 ml/l for K^+, P, NH_4^+-N and NO_3-N respectively. The value obtained for P has exceeded the standard by 5,578.5 %, that for NH_4^+-N exceeded by 1,901 % whist the value for NO_3-N (17.4 ml/l) was far below the standard of 50 ml/l. the discharge of such an effluent into water bodies could cause eutrophication and a significant degradation of aquatic life. Discharging it onto a farm land, however could be a source of major plant nutrients. The impact of other physicochemical properties of the effluent however would have to be considered alongside.

4. Conclusion

This study was conducted to assess the suitability of soap industrial effluent for use as irrigation water for crop production. The effluent exhibited good potentials for macro plant nutrients such as nitrogen, potassium and phosphorus. A high potential was also exhibited for improving the cation exchange capacity (CEC) of soil. Low levels of micro plant nutrients such as Copper, iron and zincwere also recorded. The Exchangeable sodium percentage (ESP) of effluent however was high. This together with electrical conductivity (EC) of effluent may pose the challenge soil sodicity and salinity. A treatment system would therefore be required to reduce ESP and EC levelsto limits desirable for crop production.

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