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Wastewater Effluents at Sierra Leone Bottling Company Limited: Composition, Assessment and Removal Efficiency of Physico-chemical Parameters

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Abstract: The analyses of industrial effluents at Sierra Leone Bottling Company Limited (SLBC) in Freetown, the capital city of Sierra Leone were conducted to assess its composition, and removal efficiency of physico-chemical parameters. Fifteen (15) samples were collected from the drain water (influent), pre treatment effluent and treated effluent (effluent) for five days. There were significantly higher concentrations of influents parameters relative to those of the corresponding effluents. The influent levels for pH, electrical conductivity and chloride were higher than permissible threshold. 80% of the samples at the influent point were within permissible guideline for TDS but all were in total agreement with the effluent samples for the same parameter. Comparative analyses showed significant reduction in values for pH, temperature, iron and chromium in the effluent samples relative to the influent samples and all of the other parameters did not show any statistically significant differences. The treatment plant was noted to be highly efficient in removing iron and chromium but least efficient for total dissolved solids and water temperature. Huge variances with respect to removing contaminants for chloride, electrical conductivity and total dissolved solids were observed. The average overall removal efficiency of contaminants in industrial effluents was low but the practice of treating industrial wastewater by SLBC was plausible. Considering the pollution load of certain parameters being investigated, it is imperative for the SLBC to initiate the process of setting up waste stabilization ponds (WSP) so as to contain industrial effluents for further examination before they are discharged into the environment.

Keywords: Industrial Effluent, Wastewater, Physico-Chemical Parameter, Removal Efficiency, Sierra Leone

1. Introduction

There is a direct proportionality between increasing urbanization or industrialization and the rate of water pollution. In beverage industries, water is the key processing medium and it is used throughout the stages of mineral production which includes drink production, sweetening and coloring processes, cleaning and washing of bottles, plant wash down. This consequently increases the demand of water usage and ultimate discharge of wastewater whether treated or untreated into the environment. Effluents from industries are discharged into water bodies such as, rivers, lakes, streams *etc*, and such a practice has significant implications for aquatic ecosystem. Wastewater composition varies from the type of industry or manufacturing process (es) that is involved. For instance, high electrical conductivity was observed in a beverage industry in Pakistan [1] but high content of biological oxygen demand (BOD) and chemical oxygen demand (COD) are characteristic of diary wastewater [2]. The problem of effective treatment of wastewater is more acute in underdeveloped or developing countries due to the high cost of conventional treatment systems [3] and such untreated or poorly treated wastewater eventually find its way to agricultural farm lands which have deleterious long-term effects on soil, groundwater and human health [4].

Several studies have looked wastewater characteristics in other countries [5-7] and others have investigated removal efficiency of wastewater indicators [8, 9] while another study assessed the possibility of reuse of wastewater [2] and two other studies have looked at removing heavy metals from industrial effluents [10, 11]. However, one that has evaluated the composition and removal efficiency of wastewater indicators in Sierra Leone is unavailable. The Environment Protection Agency Sierra Leone (EPA-SL) has put in place policies for effective conservation and management of natural resources. This is against the backdrop that there is unsustainable and wasteful utilization of resources (water). Despite the gains made by EPASL over the years in managing our ever dwindling resources, challenges are still apparent due to the insufficient mobilization of resources. Given the lack of empirical data on the quality of effluent discharged into water bodies in Sierra Leone, there was the need to assess the composition and removal efficiency of selected physico chemical indicators contained in effluents released by Sierra Leone Bottling Company Limited (SLBC) which is one of the very few companies in Sierra Leone with waste water treatment plant. Information obtained from this study would guide decision makers in their discharge of policies geared towards protecting the health, resources and livelihood options for the local population.

2. Materials and Method

The Sierra Leone Bottling Company Limited (SLBC) formally known as Freetown Cold Storage Company Limited is located at George Brook Dworzark Farm in Freetown, the capital city of Sierra Leone. It lies along latitude 8° 29' 2.39" N and longitude 13° 14'2.40" W. Dworzark is located along the mountainous terrain west of the city which is approximately 1.5km from city center via Pademba Road. The SLBC is situated on a piece of land with a total area of 23,945m^2 and the facility is positioned about 15m from the George Brook on the west bank of the stream that runs across the company perimeter. The company in recent years has embarked on standard best practices by installing state of the art equipments in rebranding the company's image. Coca-Cola products such as Coco-cola, Vimto and Parrot beverages are produced and package in 300 ml bottles and PET plastic bottles. Because of its significance, the company is one of the biggest companies in Sierra Leone with significant prospect of growth.

Samples were collected from three locations or points; point one (the drain of the washer and production referred to as influent), point two (the pre-treatment effluent) and point three (treated effluent). Polyethylene bottles already washed with dilute mineral acid solution and rinsed with demineralized water were used to collect the samples. Sampling containers were rinsed two to three times with the samples to be collected. Grab type sampling technique was used. Collected samples were analyzed for the parameters pH, temperature, Electrical Conductivity (EC), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Phosphate (PO_4^{3-}) Chloride (Cl^-), Iron (Fe) and Chromium (Cr). Samples were taken to the laboratory on the same day of sampling to determine various parameters according to standard methods for examining waste water.

Biotec in Brazil installed the wastewater treatment plant. Wastewater treatment will start with pretreatment in a special channel where solids and coarse substance (coarse solids, sand and soil, fats and oil are removed. Bars screen (grit separator) are installed at the reception channel to remove materials. This then is followed up in the calamity tank where waste waters with moderate or high toxicity or high concentration such as caustic soda or hazardous characteristics are removed. Next in the treatment process is the entry of wastewater into the buffer tank where anaerobic process starts. Eventually the aeration basin mixed liquor flows by gravity into the final clarifier where the treated wastewater and sludge are separated. The bottom of the clarifier is tronc-conic to facilitate the sludge removal from it. Part of the settled activated sludge is returned to the aeration tank to maintain a minimum amount of active biomass.

Three samples a day were collected from the three locations or points for five consecutive days resulting in fifteen (15) samples collected during the study period. In situ measurements were made for pH, temperature, electrical conductivity, total dissolved solids and dissolved oxygen using the appropriate probes in the field. Samples not analyzed in the field were immediately taken to the Sierra Leone Water Company (SALWACO) for chemical analyses. The chemical analysis was conducted by Spectrophotometric Method using the HACH DR/2800 Spectrophotometer. Laboratory analytical procedures were in accordance with procedures outlined in the HACH Water Analysis Handbook, 4th Edition. All devices and equipment used were kept in the laboratory and reference materials necessary were of analytical grade. Calibration procedures for all tests were in accordance with the reference manual for each indicator. Efficiency was calculated in accordance with the literature [8, 9].

$$\text{Removal Efficiency} = \frac{\text{Influent Concentration} - \text{Effluent Concentration}}{\text{Influent Concentration}} \times 100$$

3. Results and Discussion

The week long survey revealed that all of the samples collected at the influent point showed that higher pH values were outside guideline standards (5.5-9.0) for influents, but those collected at the effluent point were all within the guideline standards. All the influent and effluents samples for EC were higher than the permissible levels (150 µS/cm) as reported by [8]. 80% of the samples at the influent point were within guideline standards of (2100 ppm) for TDS but all were in total agreement with the effluent samples for the same parameter. 20% of the influent samples collected for Cl^- were higher than the guideline standard (600 mg/L) but all of the samples collected at the effluent point conform fully to the agreed standard for the same parameter. Effluent temperatures and phosphate levels at both the influent and effluent sampling points were in good agreement with the guideline standards (45°C and 5 mg/L), respectively. Similarly, samples for both iron and chromium collected at the influent and effluent points were in conformity with the guideline standards (3 mg/L and 2 mg/L), respectively.

The results for nine parameters associated with effluents discharge is presented in Figure 1. It could be observed that influent and pretreatment effluents for pH, temperature and iron, do not show meaningful differences. However, samples collected at the influent and pretreatment containments showed considerable differences in the values for conductivity, total dissolved solids, dissolved oxygen, phosphate, chloride and chromium as revealed in Figure 1.

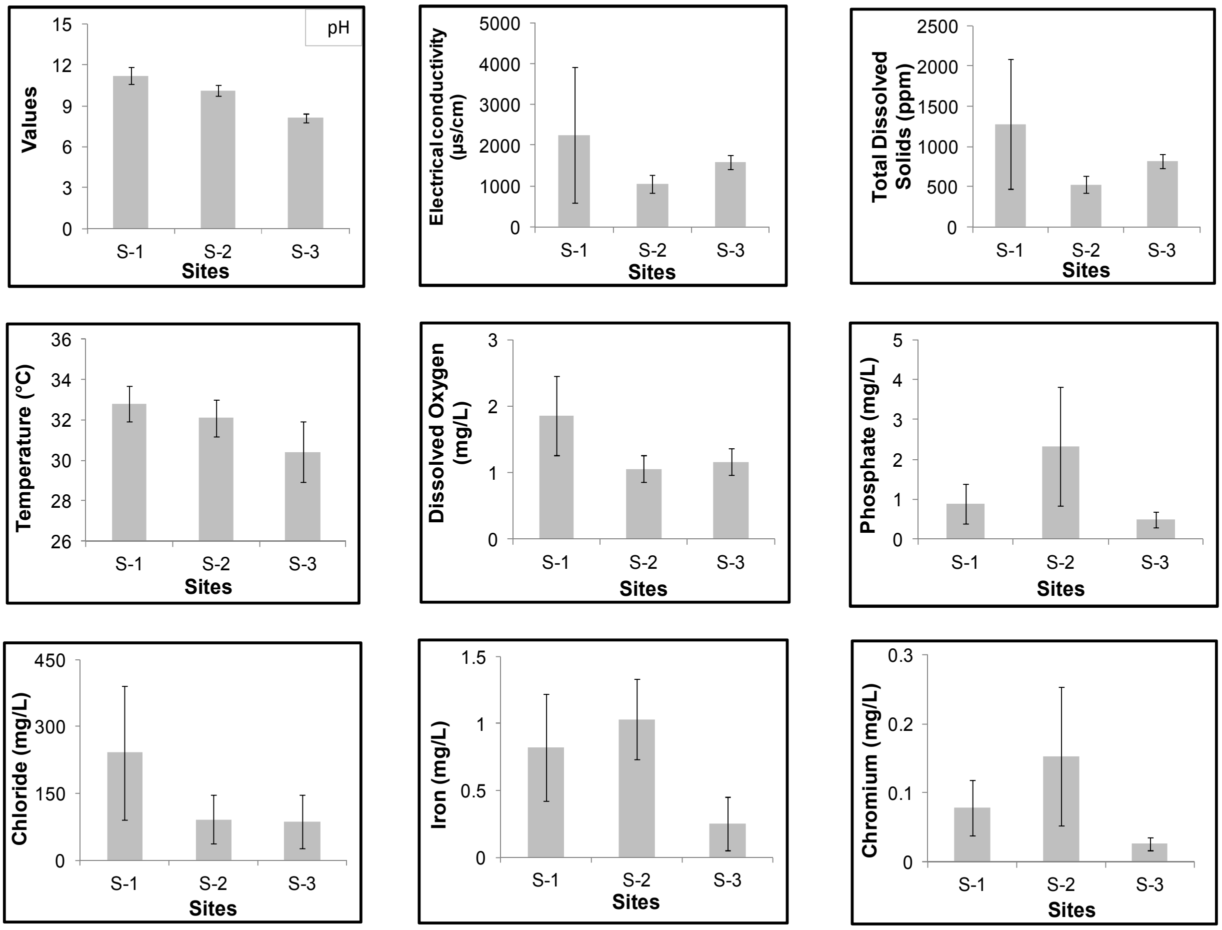

Figure 1. Showing results for influents, pre-treatment effluents and effluents concentrations. S-1 denotes influent concentration site; S-2 denote pretreatment concentration site and S-3 denotes effluent concentration site.

Table 1 presented comparison between influent and effluent concentrations. From Table 1, there was significant reduction in values of pH, temperature, iron and chromium in the effluent samples relative to the influent samples. All other parameters did not show any statistically significant differences between the two points.

Table 1. Comparison between influent concentrations and effluents concentrations for all the indicators studied.

No	Indicators (Units)	Site 1	Site 3	p-value
1	pH	11.2±0.6	8.1±0.3	< 0.001
2	Conductivity (µS/cm)	2252.1±1665.9	1582±165.7	0.160
3	Total Dissolved Solids (mg/L)	1278.8±805.5	816.4±83.2	0.089
4	Temperature (°C)	32.8±0.9	30.4±1.5	0.003
5	Dissolved Oxygen (mg/L)	1.9±0.6	1.2±0.2	0.016
6	Phosphate (mg/L)	0.9±1.1	0.4±0.5	0.215
7	Chloride (mg/L)	242.3±415.0	85.8±113.3	0.178
8	Iron (mg/L)	0.8±0.4	0.3±0.2	0.016
9	Chromium (mg/L)	0.08±0.04	0.03±0.01	0.015

Figure 2 showed the removal efficiency of contaminants before being released into the environment. The treatment plant is noted to be highly efficient in removing iron and least efficient for water temperature as reflected in Figure 2. Huge variances for chloride, electrical conductivity and total dissolved solids were noted according to Figure 2.

The pH value in this study at the influent point pointed to alkalinity which could be strongly attributed to carbonated (CO_3^{2-}) content that must have been used in fizzing mineral drinks. The pH level at the effluent point appeared in the range of neutrality. Results for pH in this study is in contrast with previous studies that have investigated effluent compositions even though there are variation in the study design and processes investigated [5, 8, 12] but in line with a waste treatment plant in a municipality in Thailand [9]. Lower pH values have been reported to precipitate heavy metals [8, 13] and our observed values at the effluent point are in line with breakdown organic materials by bacteria into inorganic substances.

The amount of cation or anions in water could describe the conductiveness of that solution and is mostly measured by the conductivity. The significance of EC of water is its measure of salinity which greatly affects its taste with implication to water potability and irrigation purposes. Both the influent and effluent concentrations were significantly higher than the effluent discharge limit of 150mS/cm although the influent concentrations are relative higher than the effluent concentrations. Even though our results for both the influent and effluent points are relatively lower than few sites that reported EC in Uganda [14], but there was one site which revealed high levels of EC in the same Ugandan study. Nevertheless, our results are far higher than what was reported in South Africa [8]. It should be noted that food and beverage industries release effluents with high levels of EC largely due a combination of sweeteners, dissolved minerals serving as additives or preservatives *etc*, added to the production process and the ultimate cleaning process after production. All of these processes may eventually find their ways into the water stream which are considered effluents in this study. TDS is a measure of the amount of dissolved minerals that influences the usability of water. TDS was found to be significantly reduced in the effluent concentrations at 90% significance level. We presumed that cationic minerals were probably present in the wastewater even though these ions were not measured.

Though a significant reduction in the mean temperature was noted for the effluent point, our results are lower than the values recorded for effluents released in a pharmaceutical industry in Nigeria [6] but are well within the permissible for wastewater discharge. High temperatures in industrial effluents reduce solubility of oxygen and amplify odor due to anaerobic reaction and could further affect the amount of dissolved oxygen in water. Results for DO in the current study showed a significant reduction in values relative to the permissible level of 5 mg/L. Effluent concentrations was considerably reduced relative to the influent concentrations which could partly be attributed to the temperature driven process(es) of the wastewater treatment plant. Our results for DO are much lower than a previous study in Malawi [15], and we share similar sentiment that pollution load released from some of the industrial processes were high oxygen demanding waste containing organic matter and we share similar viewpoints with those reported earlier for wastewater treatment in Nepal [12] and that in Gaborone for indicators in industrial effluents [7]. For instance, the syrup room represents a potential of 50% of all BODs discharged and is due to the concentration of sugar in the syrup which may be relatively high in the liquid volume but this is transformed into by products in the buffer tank. There was a significant reduction in concentrations of effluent wastewater of iron and chromium relative to the influent concentrations were observed, and our results are in line with a previous study on beverage industry in wastewater composition in Pakistan which could have been due to treatment process [1].

The overall removal efficiency for each indicator was calculated and proportions and deviations are presented in Figure 2. The following pattern of Fe>Cr>Cl>PO4>DO>EC>pH>TDS>Temp was observed indicating that the wastewater treatment plant of SLBC was highly efficient to remove trace metals before released into the environment. Removal efficiency of TDS was in agreement with a previous study [12]. Even though Fe and Cr were the two highly removed contaminants in the effluents of this study, previous studies have shown significant reduction in removal efficiency of less than 40% in South Africa [8, 11]. In the same study, the removal efficiency for PO_4^{3-} is comparable with what we have reported. Difference in removal efficiency of contaminants in industrial effluents could be partly due to the treatment processes involved, varied composition of industrial effluents due to manufacturing procedures, age of the treatment plant *etc*.

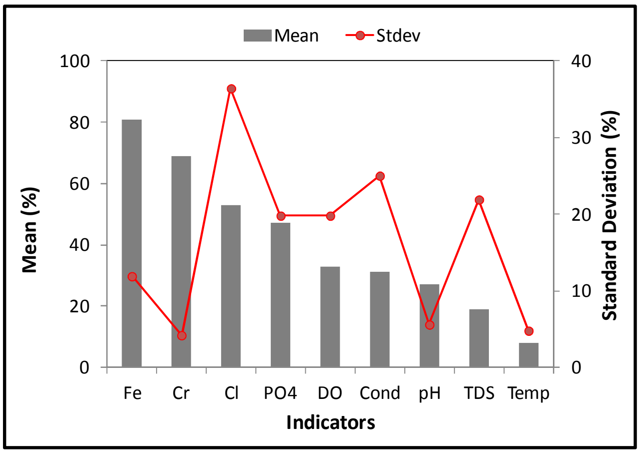

Figure 2. *Removal efficiency reported in proportion for indicators investigated.*

The SLBC requires huge volume of fresh water to drive its production and washing processes and ultimately discharges considerable amount of polluted wastewater considering the fact SLBC does not recycle its wastewater to reduce discharge into nearby streams. It was earlier reported that a beverage industry would require 3-4 liters to produce 250ml-300ml of mineral drink [1]. In general, the performance of wastewater treatment plant depends on the type of macrophyte used, system configuration, pollutant loading and temperature. Considering the pollution load of certain parameters being investigated in this study, it is imperative for the SLBC to initiate the process of setting up Waste Stabilization Ponds (WSP) so as to contain industrial effluents for further examination before discharged into the environment. Although such proposed system is relatively cheap, land acquisition could be a main disadvantage considering this scarce resource around the vicinity of the company. Nonetheless, it was reported in Kenya that the removal efficiencies of certain parameters in wastewater were high [16] and this could serve as an incentive to improve the company's environmental performances.

4. Conclusion

This study has shown that release of effluents from SLBC into nearby streams and waterways are a source of contamination. High concentrations of electrical conductivity were observed although levels for almost all other indicators were within permissible limits of effluents standards. Absolute concentrations of the effluents were relatively lower than the influent concentrations and the removal efficiency of most contaminants are low with the exception of trace metals. Despite attempts have been made by SLBC to treat their wastewater, more treatment procedures are encouraged so as to increase the removal efficiencies of contaminants, and until then, such water is deemed unfit for irrigation and agricultural purposes.

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