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ABSTRACT: Due to the increase in students' population over the years, the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, and its surrounding communities have seen an increase in the number of beauty salons. The assessment of the quality of salon wastewater has received little attention, as a potential source of environmental and public health hazard, due to the lack of literature on this issue. The main aim of this study is to assess wastewater effluent characteristics in KNUST and its surrounding areas, in relation to its physicochemical and microbial parameters. A total of 48 wastewater samples were collected monthly in 250 L polystyrene bottles, over a two-month period from the KNUST and Ayigya, Ayeduase, and Bomso communities. Standard methods of American Public Health Association (APHA, 19th edition) were employed in the determination of the physicochemical parameters and microbial content of the wastewater samples. The results showed that all the sampling towns had mean chemical oxygen demand (COD; 60.04 ± 1.82 mg/L), biological oxygen demand (BOD; 30.03 ± 9.11 mg/L), dissolved oxygen (DO; 3.00 ± 0.53 mg/L), pH (9.55 ± 0.42), nitrate (5.42 ± 0.36 mg/L), phosphate (23.61 ± 0.16 mg/L), acidity (1.70 ± 0.01 mg/L), alkalinity (70.88 ± 2.59 mg/L), turbidity (20.29 ± 3.86 NTU), electrical conductivity (EC; 1404.89 ± 114.11 μm/S), and total dissolved solids (TDS; 1150.25 ± 262.10 mg/L) in the salon waste. In the case of bacterial levels, pathogenic bacteria such as fecal coliforms, *Escherichia coli*, *Shigella dysenteriae*, and *Salmonella enterica* were absent, while the levels of *Staphylococcus aureus* and *Pseudomonas aeruginosa* did not pose any health risk. The correlation matrix showed a significant positive correlation between and among pH, alkalinity, TDS, and turbidity ($P < 0.05$). The results revealed that the wastewater collected from the salon effluents contain pollution indicator parameters such as EC, pH, PO_4^{3-}, BOD, and turbidity, considerably higher than the tolerance limits recommended by the World Health Organization. The principal component analysis indicated that pH, alkalinity, acidity, COD, PO_4^{3-}, *S. aureus*, *P. aeruginosa*, turbidity, TDS, EC, DO, and BOD were the most influential parameters to wastewater variations. Based on these characteristics, a call for a regular and persistent monitoring strategy by the relevant authorities is significant to ensure best practices with respect to the discharge of salon wastewater into the environment.

KEYWORDS: principal component analysis, physicochemical, microbial, beauty salon, wastewater

Introduction

The use of alternative water resources has been identified in recent years as a conclusive solution to issues such as water scarcity and quality deterioration.[1] Reclamation and reuse of municipal wastewater as well as desalination of sea water are among the most popular alternative water resources.[2] Water quality has been an important worry for human welfare.[3] Water is important for domestic uses, living systems, agricultural production, and industrial processes.[4] The dependability on water for various purposes relies on its physical and chemical quality. Groundwater chiefly contains pollutants from natural and anthropogenic sources, such as industrial pollution, waste disposal facilities, on-site sanitation, and wastewater treatment works.[5] Physicochemical parameters such as nutrient loads, temperature, dissolved oxygen (DO),

salinity, and pH have been reported to influence biochemical reactions within water systems.[6]

Pollution from wastewater is presently the greatest risk to the sustainable use of ground and surface water. Discharged wastewater may contain toxic substances, health-compromising pathogens, and/or chemical substances, which may cause adverse environmental impacts such as decrease in biodiversity, changes in species composition and aquatic habitats, and impaired use of contaminated drinking water and recreational waters.[7] Wastewater can be classified as domestic, sanitary, and industrial. Domestic wastewater is generated from residential sources, such as sinks, toilets, laundry, and bathing, while industrial wastewater is released by commercial enterprises and manufacturing processes.[8] In general, wastewater is characterized based on its organic contents, specific

contaminants, and physical characteristics.[9] Surface waters are the main repository of domestic and industrial wastewater disposal.[10] The stagnating pools of wastewater on the roads and in the open gutters often provide habitat for several viruses and bacteria, as well as breeding grounds for mosquitoes.[11]

Cosmetic wastewater is characterized by the concentration and composition of pollutants, which is caused by the changeable production profile. The continuous trend toward the manufacture of novel hair products and formulation of new beauty tips to satisfy the demands of the growing populace causes environmental pollution.[12] Cosmetologists, beauticians, and to some extent customers are exposed to high concentrations of several compounds that are included in the various chemical products used in their work or treatments. Many products used in the beauty industry are unregulated, and many may release carcinogens and volatile organic compounds (VOCs), such as lithium hydroxide, calcium hydroxide, guanidine carbonate, and ammonium thioglycolate.[13] These chemical constituents could change the odor, appearance, and taste of water sources.[14] Occupational skin and respiratory disorders and disputable reproductive and genotoxic effects have been linked to chemical exposures of beauty workers.[15–18] Today's salons offer a wide range of services from skin treatments and hair styling to manicure, makeup, and tanning application. In providing these services, waste is generated. Hair dressing salons generate waste in the range of various alkalis, acids, relaxer, dyes, and other chemicals, which can greatly influence the physicochemical properties of receiving water resources.[19] Discharging into water bodies is a major problem due to the uncontrollable nature of some of the contaminants in the beauty salon wastewater.[20]

Although most of the industries in Ghana operate under strict guidelines of the Environmental Protection Agency, the situation of environmental pollution is far from satisfactory. Different guidelines and norms are given for all the industries depending upon their pollution potentials. Most of these major industries have their own treatment facilities. However, the small-scale industries cannot purchase pollution control equipment due to their slender profit margin.[21] In some countries, such as United States, Singapore, and Malaysia, wastewater of this kind is generally treated by anaerobic treatment, slow aggregate filtration systems, adsorption, and reverse osmosis.[22–25] In Ghana, there is limited knowledge on wastewater treatment technology for small-scale wastewater such as salon effluent. Moreover, a greater population of Ghanaians lack knowledge concerning the reusability potentials of treated wastewater. The waste generated from hair dressing salons therefore does not go through any segregation and treatment. The wastewater generated may end up in septic tanks or on the bare floor and find their way into surface water bodies. Therefore, to maintain the health of inhabitants and preserve the integrity of the environment, it is significant to regularly and persistently monitor the quality of salon wastewater effluent discharging into the environment. The aim of the present study is to assess the level of physicochemical parameters of beauty salon effluents and their impact on the receiving environment.

Materials and Methods

Study area. Wastewater samples for physicochemical analysis were collected from salons in Ayeduase, Ayigya, and Bomso communities and Kwame Nkrumah University of Science and Technology (KNUST), all within the Kumasi Metropolis. Kumasi is the capital of the Ashanti region of Ghana and situated between latitudes 06°41′N and longitudes 01°28′W.[26] The climate of Kumasi is classified as tropical dry and wet, with relatively constant temperatures throughout the year. The mean minimum temperature ranges from 21 °C (August–September) to 23 °C (February–March). The mean maximum temperature ranges from 27 °C (August) to 34 °C (February). Kumasi receives an average of 1488 mm of precipitation annually, with the main share appearing in the rainy season from March through July. A second, shorter rainy season appears from September to November. The dry season is experienced from December to February, as a result of the dry and dusty West African trade wind blowing from Sahara into the Gulf of Guinea. The mean relative humidity yearly is recorded as 83.2%, with a monthly variation from 75% in February to 87% in June–October.

Sample collection and preparation. Samples were collected directly from the salon shops in the Kumasi metropolis, Ghana. A total of 48 wastewater samples were collected from KNUST and Ayigya, Ayeduase, and Bomso communities. The sampling points are indicated in Figure 1. Sampling and analysis of each parameter was conducted monthly for a period of two months, between the period of October and September, 2015. Wastewater samples meant for physicochemical analysis were collected in polystyrene bottles of 500 mL storage capacity. Prior to treatment, the wastewater from each salon was homogenized. The bottles were previously washed with 10% nitric acid and subsequently with demineralized water. For microbial analysis, wastewater was collected in a 250 mL sterile plastic bottle pretreated with sodium thiosulfate. During sampling, sample bottles were rinsed three times with some of the salon wastewater and then filled to the brim. The bottles were then sealed, stored away from sunlight, transported on ice chest to the laboratory, and stored at 4 °C. Samples were analyzed within 48 hours of collection.

Physicochemical analysis. The wastewater samples were analyzed for the physicochemical parameters using Standard Methods for the Examination of Water and Wastewater by American Public Health Association (APHA).[27] All field equipment and meters were checked and appropriately calibrated according to the manufacturers' instructions. Electrical conductivity (EC), pH, and total dissolved solids (TDS) were measured in situ. pH was read using Alpha Electronics PH-204 pH meter. pH of 4.01, 7.00, and 9.20 were prepared by pouring about 30 mL each of pH 4.01, 7.00, and 9.20 buffer
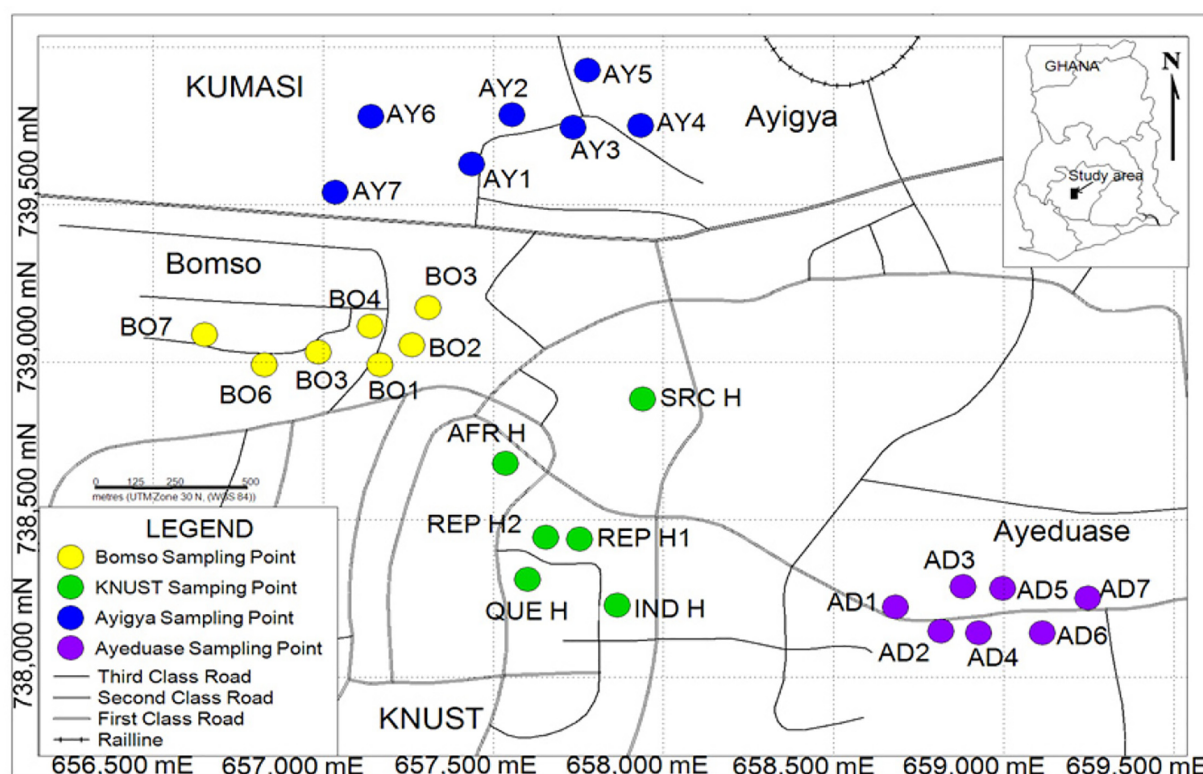
Figure 1. Map of study area indicating sampling points.

into a 50 mL beaker and covered with a watch glass prior to calibration. The pH was calibrated following the manufacturer's calibration instructions. EC and TDS were measured using a WTW LF538 multifunctional meter. Chemical oxygen demand (COD), DO, and biological oxygen demand (BOD) were determined by the Winkler method of APHA.[27] Nitrate and phosphate levels were determined using Wagtech Photometer 5000. The turbidity of the wastewater samples was measured using a Hanna Turbidity Benchtop Meter (HI 88713). The concentrations of nitrate and phosphate were determined using the standard photometric method with Wagtech Model 5000 photometer. Acidity and alkalinity were determined using titrimetric method.

Microbiological analysis. Wastewater samples (10 mL) were aseptically pipetted into a sterile Erlenmeyer flask and diluted tenfold by adding 90 mL of sterile buffered peptone water (BPW) followed by subsequent decimal dilution using the BPW. Total plate count for wastewater samples were conducted in triplicate according to the APHA,[27] using standard plate count agar and incubated at 30 °C for 48 hours. For fecal coliforms, 1.0 mL of the diluted sample was poured in sterile Petri dish, and then, 10 mL of Violet Red Bile Dextrose Agar (Biolife 402188) was added. After solidifying the media, a 10 mL overlay of the same molten medium was added. The incubation was carried out at 37 °C for 24 hours. For *Escherichia coli* and fecal coliform, the detection was done by using the selective Chromo-Cult Coliform agar (Merck KgaA). *Pseudomonas aeruginosa* counts were determined using Selective Agar (Biolife, 401963)

by spreading 0.1 mL of the sample onto the media and incubation at 37 °C for 24 hours. *Staphylococcus aureus* strains were identified using Baird–Parker Agar (Biolife) and incubated at 37 °C for 48 hours after streaking of Staphylococcus strains. *Salmonella enterica and Shigella dysenteriae* were counted with the aid of Agar (SS Agar, LAB052, UK) after incubation for 24 hours at 37 °C. All plates were examined for typical colony types and morphological characteristics associated with each culture medium. Pure stock cultures were identified and characterized using the criteria of Holt and Krieg, 1994.[28]

Statistical analysis. The IBM Statistical Package for Social Sciences 20.0 was used for the data analysis. Analysis of variance (ANOVA) was used to determine the significant differences in the concentration of pollutants in salon wastewater collected from different communities at $P < 0.05$ level of significance using the least significant difference (LSD) as the post hoc test. LSD method is used in ANOVA to create confidence intervals for all pairwise differences between factor level means while controlling the individual error rate to a significance level. The principal component (PC) analysis and Pearson correlation matrix were performed using XLSTAT 2016 statistical software. Pearson correlation matrix indicates the probable common source of pollutants. PC analysis is designed to transform the original variables into new and uncorrelated variables.

Results and Discussion

Physicochemical characteristics. The compositions of wastewater (Table 1) as suggested by Metcalf and

Eddy[29] were employed to determine the strength of the parameters analyzed.

Descriptive statistics such as mean, range, and standard deviation of the physicochemical parameters in salon wastewater are given in Table 2. The results showed that the pH values of all the analyzed samples were alkaline. The pH levels exhibited a highly significant difference ($P < 0.05$) with an LSD value of 2.14. The lowest pH was recorded at Ayeduase site with a value of 9.18 ± 1.74. According to the classification by Metcalf and Eddy,[29] the pH level was in the high category (Table 1). The highest pH was recorded at KNUST site with

a measured value of 10.14 ± 1.97. The alkaline wastewater was as a result of the bleaching agents and chemicals, such as NaOCl, hair relaxers (which are mainly from sodium hydroxide), surfactants, hair dyes (phenylenediamine (PPD)), and sodium phosphate used in the beauty process.[30,31] Sodium hydroxide can cause damage to the respiratory tract and severe pneumonitis. PPD may cause damage to the liver, kidneys, nervous system, and respiratory tract. The pH values recorded in the present study were similar to reports by Akan et al.[32] in watersheds and wastewater effluents at Jakara and Ile-Ife. The composition of effluent varies from town to town depending on the type of public facilities, households, and industrial waste discharging into the environment,[7] and this could be an essential contributory factor to the observed differences in pH. The mean pH values recorded for all sampling points were above the World Health Organization (WHO) and Ghana EPA acceptable limit of 6.00–9.00 for wastewater to be discharged into the environment.[33,34] However, pH values ranging from 3 to 10.5 could favor the growth of both pathogenic and indicator microorganisms.[35]

EC showed a highly insignificant difference ($P > 0.05$) with an LSD value of 0.85. The highest EC was recorded

Table 1. Typical wastewater characterization adopted from the study by Metcalf and Eddy.[29]

PARAMETER	HIGH	MEDIUM	LOW
COD	1200	750	500
BOD	560	350	230
pH	8.0	7.5	7.0
Alkalinity	7	4	1
COD/BOD	2.5–3.5	2.0–2.5	1.5–3.5

Table 2. Physicochemical parameters of wastewater samples from different communities.

PARAMETERS		SAMPLE POINTS				ALL TOWNS	WHO (2004)	GHANA EPA (EPA-GHANA 2007)
		AYEDUASE	AYIGYA	BOMSO	KNUST			
Turbidity	Range	18.51–35.21	22.54–30.23	9.52–38.40	12.53–36.24	9.52–38.40	5	75
	Mean ± SD	23.08 ± 4.21	24.13 ± 4.04	16.61 ± 2.65	17.34 ± 4.71	20.29 ± 3.86		
TDS	Range	1097–2021	1240.00–1998.00	714.00–1610.00	945.00–1864.00	714.00–1998.00	2000	1500
	Mean ± SD	1360.00 ± 210.00	1384.00 ± 242.00	861.00 ± 216.00	996.00 ± 233.00	1150.25 ± 262.10		
EC	Range	980.00–2580.00	99.00–2980.00	1060.00–2250.00	1150.00–2450	99.00–2980.00	1000	1500
	Mean ± SD	1350.35 ± 430.00	1490.65 ± 400.00	1270.45 ± 380.00	1508.12 ± 210.00	1404.89 ± 114.11		
pH	Range	9.00–12.40	9.60–12.40	10.10–12.42	10.80–12.60	9.00–12.60	6–9	6–9
	Mean ± SD	9.18 ± 1.74	9.37 ± 1.70	9.49 ± 1.91	10.14 ± 1.97	9.55 ± 0.42		
NO_3^-	Range	5.26–9.80	5.21–10.00	3.24–7.42	3.40–8.24	3.24–5.21	45	50
	Mean ± SD	5.85 ± 0.91	5.59 ± 1.00	5.15 ± 1.00	5.09 ± 0.77	5.42 ± 0.36		
PO_4^{3-}	Range	17.00–41.80	14.16–44.96	11.60–56.00	23.40–70.40	11.60–70.40	5	2
	Mean ± SD	23.75 ± 3.34	23.47 ± 3.34	23.47 ± 7.34	23.75 ± 3.34	23.61 ± 0.16		
Alkalinity	Range	69.00–112.00	70.00–125.00	42.00–117.00	50.00–119.00	42.00–70.00	(–)	(–)
	Mean ± SD	69.00 ± 13.00	71.00 ± 13.00	74.50 ± 9.33	69.00 ± 13.00	70.88 ± 2.59		
Acidity	Range	1.23–3.25	1.25–2.45	1.35–3.47	1.44–3.20	1.23–3.47	(–)	(–)
	Mean ± SD	1.69 ± 0.26	1.70 ± 0.26	1.70 ± 0.57	1.69 ± 0.26	1.70 ± 0.01		
COD	Range	48.00–86.00	52.00–89.00	69.00–84.00	50.00–84.00	48.00–89.00	250	250
	Mean ± SD	58.86 ± 13.00	58.29 ± 14.83	60.71 ± 13.67	62.29 ± 7.66	60.04 ± 1.82		
BOD	Range	26.00–47.56	29.00–45.25	12.20–45.00	15.00–45.20	12.20–47.56	30	50
	Mean ± SD	42.87 ± 31.19	29.46 ± 7.55	21.86 ± 6.93	25.91 ± 6.32	30.03 ± 9.11		
DO	Range	2.23–4.94	2.47–5.10	1.22–4.50	1.80–4.60	1.22–5.10	4	5
	Mean ± SD	3.19 ± 0.37	3.46 ± 0.31	2.24 ± 0.70	3.11 ± 0.31	3.00 ± 0.53		

Notes: All units of parameters are in mg/L except pH, turbidity (NTU), and EC (µS/cm); (–) indicates not available.

at KNUST, with a value of 1508.12 ± 210.00 µS/m. The lowest was recorded at Bomso with a measured value of 1270.45 ± 380.00 µS/m. The high level of EC in the effluent could be ascribed to the high levels of dissolved ions in the wastewater.[36] All the mean recorded EC values fell above the WHO permissible limits of 1000 and 1500 µS/m for wastewater.[33] However, the mean EC values at Ayeduase, Ayigya, and Bomso were below the Ghana EPA acceptable limits of 1500 µS/m.[34]

A highly insignificant difference ($P > 0.05$) was recorded for the alkalinity and acidity of the wastewater samples with LSD values of 11.20 and 0.95, respectively. Alkalinity is a measure of the buffering capacity of wastewater to neutralize acids. The presence of alkalinity in wastewater is as a result of carbonates and bicarbonates.[37] The levels of alkalinity in this study ranged between 69.00 ± 13.00 and 74.50 ± 9.33 mg/L. The alkalinity concentrations were categorized as high strength (Table 1). Acidity is the quantitative expression of water's capacity to neutralize a strong base. Acidity is used to determine the corrosive nature of wastewater. Acidity is usually caused by weak organic acids, such as tannic and acetic acids, and strong mineral acids, such as hydrochloric and sulfuric acids. Acidity levels in the wastewater varied from 1.69 ± 0.26 to 1.70 ± 0.26 mg/L.

TDS showed a highly significant difference ($P < 0.05$) with an LSD value of 32.86. The highest and lowest TDS were measured at Ayigya and Bomso with values of 1384.00 ± 242.00 and 861.00 ± 216.00 mg L^{-1}, respectively. All the mean recorded TDS values fell below the WHO and Ghana EPA acceptable limits of 2000 and 1500 mg/L, respectively, for effluents to be discharged into the environment.[33,34] The TDS values in the present study were higher than those found by Igbinosa and Okoh.[38] However, higher TDS values of 2.210–2.655 mg/L reported by Akan et al.[32] for the receiving watershed were higher than those observed in the present study.

Turbidity is a measure of suspended particles in water systems and normally correlates significantly with microbial load.[39] Turbidity also showed a significant difference ($P < 0.05$) with an LSD value of 4.04. The turbidity of the wastewater systems under study varied from 16.61 ± 2.65 NTU (Bomso) to 24.13 ± 4.04 NTU (Ayigya). The values were similar to those reported by Igbinosa and Okoh,[38] but relatively higher than those observed by Fatoki et al.[40] The mean turbidity fell above the WHO acceptable limit of 5 NTU for wastewater discharge,[33] implying that the water systems receiving the wastewater understudy may not be suitable for domestic and recreational purposes. The high turbidity of salon wastewater could be ascribed to the large number of components including several VOCs [such as LiOH, Ca(OH)$_2$], methacrylates, phthalates, sulfates, parabens, neurotoxins, and formaldehyde.[41,42] Formaldehyde has been classified as a potential carcinogen and can also cause sensory and respiratory irritation.[43] Parabens can mimic estrogen at an extremely weak level. Estrogen causes both healthy and cancerous cells to divide within the body, which accounts for its adverse role in breast cancer.

A highly insignificant difference ($P > 0.05$) of COD, BOD, and DO was observed with LSD values of 5.30, 44.22, and 2.88, respectively. COD is a measure of the amount of oxygen required to break down both inorganic and organic particles in water system.[32] High concentrations of COD in water systems may lead to drastic oxygen depletion.[40] The concentrations of COD ranged between 58.29 ± 14.83 and 62.29 ± 7.66 mg/L with the highest value recorded at KNUST campus and the lowest value at Ayigya. The levels of COD were in the low range according to Metcalf and Eddy[29] wastewater classification. According to Henze,[44] the composition of wastewater may change with time on a given location as a result of the variations in the amounts of substances being discharged. The mean COD levels fell below the permissible limits of 250 mg/L recommended by the WHO and Ghana EPA for wastewater.[33,34] BOD is a measure of the concentration of biodegradable substances in the wastewater. The concentrations of BOD ranged from 21.86 ± 6.93 to 42.87 ± 31.19 mg/L with the highest value recorded at Ayeduase and the lowest at Bomso. Thus, BOD concentration was in the low category. The mean BOD concentrations fell below the acceptable limit of 50 mg/L recommended by the WHO (2004). The BOD/COD ratios in the wastewater have a significant impact on the functioning and selection of wastewater treatment processes.[44] According to Belaid et al.[45], BOD/COD ratio <0.5 means the presence of a large proportion of nonbiodegradable matter in the effluent. The BOD/COD ratio obtained ranged from 1.37 to 2.78 (Fig. 2). This is also an indication of a large portion of biodegradable matter in the effluent. The BOD/COD ratios were in the low to medium category.[29]

The concentration of DO in this study varied between 2.24 ± 0.70 and 3.46 ± 0.31 mg/L, which was comparable with those found by Akan et al.[32] and Oluyemi et al.[46] The mean DO levels were below the WHO and Ghana EPA acceptable limit of 4 and 5 mg/L, respectively.

The nitrate (NO_3^-) levels showed a highly significant difference with an LSD value of 0.84. Nitrate concentration in
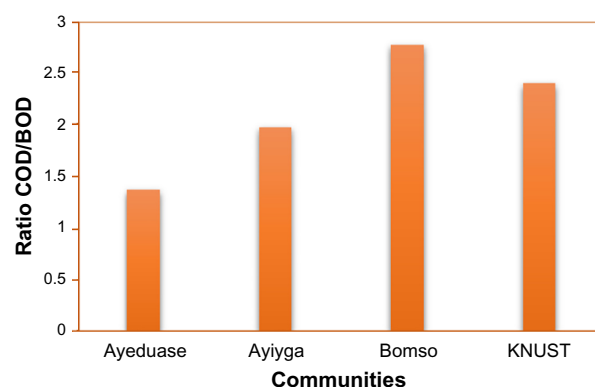

Figure 2. COD/BOD ratio for beauty salon waste.

this study ranged between 5.09 ± 0.77 and 5.85 ± 0.91 mg/L and fell within the WHO and Ghana EPA permissible limit of 45 and 50 mg/L, respectively, for wastewater. The highest value was measured at Ayeduase and the lowest at KNUST campus.

Phosphate (PO_4^{3-}) levels in the wastewater varied from 23.47 ± 3.34 to 23.75 ± 3.34 mg/L. The PO_4^{3-} levels in this study were comparable to those reported by Ogunfowokan et al.[47] and Akan et al.[32] The PO_4^{3-} levels recorded in this study were above the WHO and Ghana EPA acceptable limit of 5 and 2 mg/L, respectively. The high PO_4^{3-} levels could be attributed to phosphate containing shampoos and conditioners used in these salons as well as organic and inorganic compounds present in dissolved and particulate forms.[48] Phosphate levels can also come from many diverse sources, such as agriculture, aquaculture, septic tanks, urban wastewater, urban storm water runoff, industry, and fossil fuel combustion.[49] These elevated levels of PO_4^{3-} (>0.1 mg/L), if not removed before discharge, could cause eutrophication of surface water bodies.[50]

Microbial content. The occurrence of microorganisms in the wastewater is presented in Table 3. The results revealed the presence of *P. aeruginosa* and *S. aureus*, which was isolated from all the tested samples. The occurrence of *P. aeruginosa* and *S. aureus*, which was isolated from all the communities, was not surprising since *P. aeruginosa* is a particularly adaptable organism found in various habitats.[30] *S. dysenteriae* and *E. coli* were absent from all the samples collected, as they are associated with fecal matter and none of the salons had any public toilet or septic tank close to its discharge point.[51] Inference can therefore be made that there was little or no fecal contamination of the wastewater. This result was found to be consistent with that reported by Ajuzie and Osaghae[52] in Benin State. The low occurrence of the microbial content in the wastewater was as a result of the use of chlorine-treated pipe-borne water in the salons. Chlorine is bactericidal to enteric bacteria and therefore could account for a reduction in the microbe population. *S. enterica* was not found in any of the water samples.

Correlation among physicochemical parameters. Correlation matrix using Pearson's correlation coefficient was used to identify interrelationship between the various parameters. Table 4 shows the correlation matrix of the physicochemical parameters investigated in this study. There was significant positive correlation between and among pH, alkalinity, TDS, and turbidity ($P < 0.05$), while acidity negatively correlated

Table 3. Mean microbial count of wastewater samples from different communities.

MICROBIAL	SAMPLE POINTS			
	AYEDUASE	AYIGYA	BOMSO	KNUST
Total plate count	102.00–224.00	218.00–415.00	217.00–378.00	101.00–367.00
P. aeruginosa	1.35–8.12	1.10–7.11	1.06–7.11	1.00–3.79
S. aureus	1.67–7.08	1.13–4.24	1.36–4.24	1.33–8.44
Fecal coliforms	Nil	Nil	Nil	Nil
E. coli	Nil	Nil	Nil	Nil
S. dysenteriae	Nil	Nil	Nil	Nil

Note: All units of microbial counts are in 1 mL (CFu) × 10^3.

Table 4. Correlation matrix of physicochemical parameters in beauty salon wastewater.

	TURBIDITY	TDS	EC	pH	ALKALINITY	ACIDITY	COD	BOD	DO	NO_3^-	PO_4^{3-}
Turbidity	1.0										
TDS	0.988[a]	1.0									
EC	0.301	0.372	1.0								
pH	−0.672	−0.590	0.495	1.0							
Alkalinity	−0.864	−0.825	0.214	0.960[a]	1.0						
Acidity	−0.519	−0.405	0.585	0.934	0.808	1.0					
COD	−0.905	−0.836	0.065	0.895	0.939	0.829	1.0				
BOD	0.719	0.776	−0.014	−0.579	−0.791	−0.329	−0.580	1.0			
DO	0.779	0.843	0.800	−0.065	−0.394	0.129	−0.447	0.550	1.0		
NO_3^-	0.908	0.907	−0.034	−0.811	−0.625	−0.965[a]	−0.870	0.906	0.571	1.0	
PO_4^{3-}	−0.499	−0.379	0.578	0.943	0.998[b]	0.779	0.819	−0.274	0.148	−0.587	1.0

Notes: [a]$P = 0.05$, [b]$P = 0.01$; significant correlation (two-tailed).

with NO_3^- ($P < 0.05$). In addition, positive correlation at $P < 0.01$ was observed between acidity and PO_4^{3-}. The positive correlation between alkalinity and PO_4^{3-} indicated that the levels of alkalinity in the wastewater decreased with decreasing the concentration of PO_4^{3-}, indicating that the more alkaline-receiving wastewater may increase the levels of PO_4^{3-} and this attributed to the high concentrations of PO_4^{3-} recorded in the wastewater. The positive correlation between pH and alkalinity generally signifies a higher pH concentration of the more alkaline-receiving wastewater. The significant negative correlation of acidity with nitrate also points to the less acidic salon effluent as the source of NO_3^- in the wastewater. The significant correlation between turbidity and TDS indicates that these two parameters may represent one another in the determination of wastewater quality, regardless of internal and external influences. However, turbidity is not a direct measurement of the TDS materials in water.

Source identification. PC analysis is a powerful tool that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables.[53–55] PC analysis was used to illustrate the underlying dataset and pinpoint the possible sources of contamination via a reduced new set of orthogonal variables. Varimax rotation of PCs was used to deduce and extract the Varimax factor. Eigenvalues >1 were taken as a benchmark for the extraction of the PCs. Table 5 summarizes the PC analysis results, including the eigenvalues, percentage variance, and the cumulative variance contribution rate. The first component accounts most of the variance in the dataset, and the other successive components account for the remaining variance. Three components were extracted for the salon wastewater, which accounts for 100% of the total variance.

According to Liu et al.[56], component loadings can be categorized as strong (>0.75), moderate (0.75–0.50), and weak (0.50–0.30). The variables with loadings >0.30 for the three identified components are summarized in Table 6. Among the three components, component 1, explaining 42.46% of total variance, has strong positive loadings on pH, alkalinity, acidity, COD, and PO_4^{3-}. This component may be attributed to the non-point source of pollution from physicochemical source of the variability and agricultural activities. Component 2, explaining 32.44% of the total variance, has strong positive loadings on turbidity, TDS, EC, and DO. This component represents physicochemical source of variability and biochemical pollution. Component 3, explaining 25.10% of the total variance, has a moderate positive loading on BOD, *P. aeruginosa*,

Table 5. Principal components and explained variance of wastewater quality parameters in the beauty salon waste.

COMPONENTS	EIGENVALUE	% OF VARIANCE	CUMULATIVE %
1	5.521	42.469	42.469
2	4.217	32.436	74.905
3	3.262	25.095	100.000

Table 6. Component loading for each variable in the salon wastewater.

COMPONENTS (FACTORS)	LOADINGS		
	>0.75	0.50–0.75	0.30–0.50
1	pH, alkalinity, acidity, COD, PO_4^{3-}	EC	–
2	turbidity, TDS, EC, DO	NO_3^-, BOD	–
3	BOD, *pseudomonas, staphylococcus*	NO_3^-	–

and *S. aureus*. This component represents the contribution of non-point source pollution such as transportation of human and animal feces by runoff from adjacent streams to salon effluents as well as organic pollutions from domestic wastewater. Herein, wastewater quality parameter having a strong loading >75% was considered as the major contributor to the wastewater pollution in the studied area. Thus, pH, alkalinity, acidity, COD, PO_4^{3-} turbidity, TDS, EC, DO, BOD, *Pseudomonas*, and *Staphylococcus* were the most influential parameters to wastewater variations.

Conclusion
From the results, the mean levels of the physicochemical parameters were above the WHO regulatory limits for discharged wastewater with isolated cases of low BOD, DO, TDS, and COD levels. The microbial study showed the presence of *P. aeruginosa* and *S. aureus* in salon effluents. The correlation matrix showed a significant positive correlation between and among pH, alkalinity, TDS, and turbidity ($P < 0.05$). Multivariate statistical approach was an effective analytical tool for processing large datasets of wastewater and identifying the major source of wastewater pollution in study catchment. Multivariate statistical analysis results indicated that the three components extracted explained 100% of the total variance. The results from PCA suggested that the wastewater is primarily influenced by the physicochemical source of the variability, agriculture and other anthropogenic activities. According to the PCA results, pH, alkalinity, acidity, COD, PO_4^{3-} turbidity, TDS, EC, DO, BOD, *P. aeruginosa* and *S. aureus* were the most influential parameters to wastewater variations. Thus, the salon wastewater can be characterized as only slightly more of industrial strength than typical domestic and house wastewater. The findings of this study proved that salon effluents can be a potential public and environmental health hazard. Considering the lack of information on monitoring wastewater quality for the salon effluent in Ghana, this study provides a basis for policy considerations to ensure public and environmental health protection.

Author Contributions

Conceived and designed the experiments: MAN. Performed laboratory tests and wrote the first draft of the manuscript: LPMT. Contributed to the writing of the manuscript: FO. Plotted the customized map of the study area and agreed with the manuscript results and conclusions: DDW. Made critical revisions and approved the final version: JHE. All the authors reviewed and approved the final manuscript.

REFERENCES

1. Bouwer H. Integrated water management: emerging issues and challenges. *Agric Water Manage*. 2000;45(3):217–28.
2. Brenner A, Shandalov S, Messalem R, Yakirevich A, Oron G, Rebhun M. Wastewater reclamation for agricultural reuse in Israel: trends and experimental results. *Water Air Soil Pollut*. 2000;123(1–4):167–82.
3. Patil VT, Patil PR. Physicochemical analysis of selected groundwater samples of Amalner Town in Jalgaon District, Maharashtra, India. *J Chem*. 2010;7(1):111–6.
4. Hu B. New strategies for environmental water analysis. Paper presented at: In: Proceedings of the international conference and exhibition on water and the environment2-2 March 2009; Stellenbosch, South Africa.
5. Amoako J, Karikari AY, Ansa-Asare OD. Physico-chemical quality of boreholes in Densu Basin of Ghana. *Appl Water Sci*. 2011;1(1–2):41–8.
6. Hacioglu N, Dulger B. Monthly variation of some physico-chemical and microbiological parameters in Saricay Stream (Canakkale, Turkey). *Fresenius Environ Bull*. 2010;19(5a):986–90.
7. Environment Canada. The state of municipal wastewater effluent in Canada. Minister of Public Works and Government Services Canada; 2001. Available at: http://www.ec.gc.ca/soer-ree. Accessed May 22, 2016.
8. Birhanu GF. Constructed Wetland System for Domestic Wastewater Treatment: A Case Study in Addis Ababa, Ethiopia [PhD]. Ethiopia: Addis Ababa University; 2007.
9. Damelle H. Choose appropriate water treatment technologies. *Chem Eng Prog*. 1995;91(8):54.
10. Mustapha A, Getso BU. Sources and pathway of environmental pollutants into surface water resources: a review. *J Environ*. 2014;1(2):54–9.
11. Saliu J, Eruteya O. Biodiversity of gutters in Lagos metropolis, Nigeria. *J Biol Sci*. 2006;6(5):936–40.
12. Wenninger JA, McEwen GN. *International Cosmetic Ingredient Dictionary*. Vol. 2. Cosmetic, Toiletry, and Fragrance Association, Washington; 1993.
13. International Agency for Research on Cancer. Occupational Exposures of Hairdressers and Barbers and Personal Use of Hair Colourants; Some Hair Dyes, Cosmetic Colourants, Industrial Dyestuffs and Aromatic Amines. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Lyon; 1993:57.
14. United State Geological Survey. Contaminants Found in Groundwater. Department of the Interior; 2016. Available at: http://water.usgs.gov/edu/groundwater-contaminants.html. Accessed July 19, 2016.
15. Leino T, Tammilehto L, Hytönen M, Sala E, Paakkulainen H, Kanerva L. Occupational skin and respiratory diseases among hairdressers. *Scand J Work Environ Health*. 1998;24:398–406.
16. Halliday-Bell JA, Gissler M, Jaakkola JJK. Work as a hairdresser and cosmetologist and adverse pregnancy outcomes. *Occup Med*. 2009;59(3):180–4.
17. Leino T, Tammilehto L, Hytonen M. Occupational skin and respiratory diseases among hairdressers. *Occup Health Ind Med*. 1999;2(40):88.
18. Galiotte MP, Kohler P, Mussi G, Gattás GJF. Assessment of occupational genotoxic risk among Brazilian hairdressers. *Ann Occup Hyg*. 2008;52(7):645–51.
19. Bowers F, Cole K, Hoffman J. *Characterizing Beauty Salon Wastewater for the Purpose of Regulating Onsite Disposal Systems*. New Jersey Department of Environmental Protection Division of Water Quality, Trenton; 2002.
20. Toetora GJ, Funke BR, CL C. *Environmental Microbiology*: *An Introduction*. 6th ed. California, CA: Benjamin Cummings Company; 1997.
21. Rai RK, Upadhyay A, Ojha CSP, Singh VP. The Yamuna River Basin Water Resources and Environment. Springer Netherlands, 2012.
22. Bryant IM, Tetteh-Narh R. Using slow sand filtration system with activated charcoal layer to treat salon wastewater in a selected community in Cape Coast, Ghana. *J Adv Chem Eng*. 2015;5:135.
23. Bartels CR, Wilf M, Andes K, Iong J. Design considerations for wastewater treatment by reverse osmosis. *Water Sci Technol*. 2005;51(6–7):473–82.
24. Rashed MN. Adsorption Technique for the Removal of Organic Pollutants from Water and Wastewater. INTECH Open Access Publisher, Rijeka; 2013.
25. Slater CS, Ahlert RC, Uchrin CG. Applications of reverse osmosis to complex industrial wastewater treatment. *Desalination*. 1983;48(2):171–87.
26. Dickson K, Benneh G. A New Geography of Ghana, Metricated Edition 2nd Impression. London: Longmans; 1980.
27. American Public Health Association. *Standard Methods for the Examination of Water and Wastewater*. 19th ed. Washington, DC: American Public Health Association (APHA); 2005.
28. Holt, J.G. & Krieg, N.R. Bergey's Manual of Determinative Bacteriology, 9th ed., The Williams & Wilkins Co., Baltimore; 1994.
29. Metcalf E, Eddy E. *Wastewater Engineering*: *Treatment and Reuse*. New York, NY: McGrawHill. Inc.; 2003.
30. Paul EA, Clark FE. *Soil Microbiology and Biochemistry*. San Diego: Academic Press; 1989.
31. Gavazzoni Dias MF. Hair cosmetics: an overview. *Int J Trichology*. 2015;7(1):2.
32. Akan JC, Abdulrahman FI, Dimari GA, Ogugbuaja VO. Physicochemical determination of pollutants in wastewater and vegetable samples along the Jakara wastewater channel in Kano Metropolis, Kano State, Nigeria. *Eur J Sci Res*. 2008;23(1):122–33.
33. World Health Oragnization. *Guidelines for Drinking-Water Quality*: *Recommendations*. Vol. 1. Geneva: World Health Organization; 2004.
34. Ghana EPA. *Annual Report*: *Industrial Effluent Monitoring*. Accra, Ghana: Environmental Protection Agency; 2007.
35. Zamxaka M, Pironcheva G, Muyima N. Microbiological and physico-chemical assessment of the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa. *Water SA*. 2004;30(3):333–40.
36. Levlin E. Conductivity measurements for controlling municipal waste-water treatment. Paper presented at: Proceedings of a Polish-Swedish-Ukrainian Seminar, Utron; 2010.
37. Bartram J, Ballance R. Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. Boca Raton, FL: CRC Press; 1996.
38. Igbinosa EO, Okoh AI. Impact of discharge wastewater effluents on the physico-chemical qualities of a receiving watershed in a typical rural community. *Int J Environ Sci Technol*. 2009;6(2):175–82.
39. Obi CL, Momba MNB, Samie A, Igumbor JO, Green E, Musie E. Microbiological, physico-chemical and management parameters impinging on the efficiency of small water treatment plants in the Limpopo and Mpumalanga provinces of South Africa. *Water SA*. 2007;33(2):229–38.
40. Fatoki OS, Gogwana P, Ogunfowokan AO. Pollution assessment in the Keiskamma River and in the impoundment downstream. *Water SA*. 2003;29(2):183–8.
41. Araujo DJ, Rocha SMS, Cammarota MC, Xavier AMF, Cardoso VL. Anaerobic treatment of wastewater from the household and personal products industry in a hybrid bioreactor. *Braz J Chem Eng*. 2008;25(3):443–51.
42. Tsigonia A, Lagoudi A, Chandrinou S, Linos A, Evlogias N, Alexopoulos EC. Indoor air in beauty salons and occupational health exposure of cosmetologists to chemical substances. *Int J Environ Res Public Health*. 2010;7(1):314–24.
43. Liteplo RG, Meek ME. Inhaled formaldehyde: exposure estimation, hazard characterization, and exposure-response analysis. *J Toxicol Environ Health B Crit Rev*. 2003;6(1):85–114.
44. Henze M. Biological Wastewater Treatment: Principles, Modelling and Design. London: IWA Publishing; 2008.
45. Belaid M, Kuipa PK, Ntuli F, Muzenda E, Omoregbe DI. Characterization of effluent from textile wet finishing operations. 2009;1:69–74.
46. Oluyemi EA, Adekunle AS, Makinde WO, Kaisam JP, Adenuga AA, Oladipo AA. Quality evaluation of water sources in Ife North local government area of Osun State, Nigeria. *Edit Advis Board E*. 2005;15(3):319–26.
47. Ogunfowokan AO, Okoh EK, Adenuga AA, Asubiojo OI. An assessment of the impact of point source pollution from a university sewage treatment oxidation pond on a receiving stream-A preliminary study. *J Appl Sci*. 2005;5(1):36–43.
48. Mandiracioglu A, Kose S, Gozaydin A, Turken M, Kuzucu L. Occupational health risks of barbers and coiffeurs in Izmir. *Indian J Occup Environ Med*. 2009;13(2):92.
49. Paerl HW. Assessing and managing nutrient-enhanced eutrophication in estuarine and coastal waters: interactive effects of human and climatic perturbations. *Ecol Eng*. 2006;26(1):40–54.
50. Browman MG, Harris RF, Ryden JC, Syers JK. Phosphorus loading from urban stormwater runoff as a factor in lake eutrophication: I. Theoretical considerations and qualitative aspects. *J Environ Qual*. 1979;8(4):561–6.
51. Cabral JP. Water microbiology. Bacterial pathogens and water. *Int J Environ Res Public Health*. 2010;7(10):3657–703.
52. Ajuzie CU, Osaghae BA. The bacterial and physico-chemical properties of hair salon wastewater and contaminated soil in Benin metropolis. *Afr J Biotechnol*. 2012;10(11):2066–9.
53. Zhao Z-W, Cui F-Y. Multivariate statistical analysis for the surface water quality of the Luan River, China. *J Zhejiang Univ Sci A*. 2009;10(1):142–8.
54. Simeonov V, Stratis JA, Samara C, et al. Assessment of the surface water quality in Northern Greece. *Water Res*. 2003;37(17):4119–24.
55. Boateng TK, Opoku F, Acquaah SO, Akoto O. Groundwater quality assessment using statistical approach and water quality index in Ejisu-Juaben Municipality, Ghana. *Environ Earth Sci*. 2016;75(6):1–14.
56. Liu C-W, Lin K-H, Kuo Y-M. Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Sci Total Environ*. 2003;313(1):77–89.