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Modeling Jambo wastewater treatment system to predict water re-use options

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The harmful nature of chemicals used in the tannery industries and the disposal of wastes from facilities is well documented. In this study, Jambo tannery which is located in Busia District, (Uganda) with a daily processing capacity of 6.6 tonnes of hides and skin utilises 20 m^3 of water to produce 17 m^3 of wastewater/day. The generated wastewater is treated on site in the wastewater treatment plant whose performance was assessed. The main objective of this study was twofold: (i) to investigate how processes can be efficiently improved and optimized for environmental safety, and (ii) to develop Dev C++ programme to implement Brown's model for determining water quality usage of the effluent of the factory. Specifically, wastewater parameters measured were temperature (T), electro conductivity (EC), pH, total suspended solids (TSS), total dissolved solids (TDS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), total phosphorus (TP), total chromium (TCr), chromium hexavalent (Cr^{6+}) and chromium trivalent (Cr^{3+}). The results of the tannery wastewater were far from the National Environment Management Authority (NEMA) standards in Uganda for COD (100), BOD_5 (50), TP (10), TC (2.0), CH (0.05), TSS (100), TDS (1200), EC (1500) and pH (6.0-8.0). It can therefore be concluded that the performance of the wastewater plant is not satisfactory in the current state. The effluent quality is therefore not currently suitable for release in the environment and re-use for Agricultural and Domestic purposes as per National Environmental Management Authority (NEMA) Standards 1995. However, with improvements in the WWTP unit operations, it could be improved, re-used for irrigation. As such, a model was developed to model wastewater system to predict re-use options especially for agriculture. The study clearly showed that the use of the model and the developed C++ computer programme in predicting the re-use options of the wastewater treatment system was a success and can be applied to other wastewater treatment system as well as improving and managing the existing one.

Key words: Wastewater treatment, tannery effluent, water standards, water quality, environment safety.

INTRODUCTION

In the African continent, because of the erratic rainfall patterns that are dominating the agricultural sector, the possibility of using wastewater such as urban storm water and industrial water is being considered for irrigation, though more studies should be done on the benefits and limitations (Kirkham, 2006; Khambete and Christian, 2014a; Yao et al., 2014). For example, Dikinya and Areola (2010) studied the water quality of treated urban wastewater

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in terms of heavy metal concentrations that is being used for irrigation of different crops olive, maize, spinach and tomatoes in the Glen Valley near Gaborone City (Botswana). Wang et al. (2007) studied the possibility of recycling treated wastewater for irrigation and the resulting impacts on the soil, crop and the overall environment.

Livestock contributes about 5.2% of Uganda's total gross domestic products (GDP) and agricultural GDP. Small holder farmers in Uganda own about 98% of the cattle herd and 100% of the small ruminant and non-ruminant stock (Muramuzi, 2009). Uganda lacks modern slaughter houses and facilities as such animals are largely slaughtered on open grounds with minimal hygiene and safety standards. It follows that most of the hides and skins from rural slaughter slabs/butchers, slaughter houses and abattoirs pass through wholesale agents. The rest are collected by small traders and then sold to wholesalers/tanners for processing/export. Apart from internal trade in unprocessed hides and skins, there is a substantial informal cross-border trade between the East African (EA) countries. Official statistics show that on average more than 50% of the hides and skins are exported in unprocessed form, though this proportion varies across the EA countries.

Despite the ever growing trade in hides and skins, the effluent quality from tannery industries is still a little studied topic. This study sought to assess the quality of the effluent at the Wastewater Treatment Plant (WWTP) at Jambo Tannery (U) limited. Jambo tannery with a daily capacity of 6.6 tonnes of hides and skins in two loadings, utilize 20 m^3 of water, estimated to be 3.03 m^3 per tonne. The effluent is treated through unit operations that include sedimentation, oxidation, clarification, sludge drying bed, second oxidation pond and maturation for the beamhouse and chromium lines. The tannery uses raw materials in the form of cow hides, goat and sheep skins and a number of imported chemicals. Different types of chemicals are used in leather manufacturing which ranges from common salt to very expensive chrome sulphates. The four major categories of production processes in Jambo tannery include: (i) hide and skin storage and beam house operations, (ii) tarn yard operations, (iii) post tanning operations and (iv) finishing operations.

After the hides and skins are flayed from the carcass at the abattoirs slaughter house, they are delivered to the hide and skin market, directly to the tannery. Where necessary, hides and skins are cured before transport to the tannery in order to prevent them from putrefying. The hides and skins are then sorted, trimmed, cured and stored pending operations in the beam house. The processes involved in the beam house include soaking, unhairing, liming, fleshing and splitting. The tan yard processes include de-liming, bating, pickling, and tanning take place. The tanned hides and skins are tradable intermediate products (wet-blue) as they have been converted to a non-putrescible material (leather). The operations at Jambo tannery end at tanning, with no polishing/finishing operations being done. The Processes typically carried out in post-tanning operations are: summing, setting, splitting, shaving, retaining, dyeing, fat liquoring and drying. The selection of finishing processes depends on the specifications of the final product.

In essence, the current effluent treatment process is quite expensive and time consuming such that the possibility of recycling water is attractive option to consider. After a careful assessment of operations that require water usage, this study proposed to carry out an audit of the prevailing production circumstances. The layout of the wastewater treatment plant (WWTP), the constructed wetland, the factory and the surroundings of the Jambo Tanning Factory in Busia (Uganda) is indicated in Figure 1. The main objective of the study was twofold: (i) to investigate how processes can be efficiently improved and optimized for environmental safety, and (ii) to develop Dev C++ programme to implement Brown' model for determining water quality usage of the effluent of the factory.

Water quality index for categorizing water and wastewater quality

Pollutant yield from the various processing unit operations of the tanning industry are well documented (Bosnic et al., 2000; Ludvik, 2000a,b; Chattha and Shaukat, 1999). Chromium is highly toxic and carcinogenic to human beings, animals, plants and general environment (soil and water), (Jabari et al., 2009; Muramuzi, 2009; Belay, 2010; Afify et al., 2013). There are limits established by Environmental Authorities for these pollutants that are allowable for release into the environment and water reuse as well as water quality monitoring for fish and ecological purposes. Poorly treated effluents from the tannery industry can lead to wide spread contamination of food chains, sharp decline in productivity of food crops, soil, vegetables, livestock including milk production, if used for irrigation.

Wastewater quality physico-chemical parameters estimated in the samples have been used to determine the wastewater quality index (WWQI) which is regarded as a most effective way to communicate wastewater quality parameters (Khambete and Christian, 2014b). There are several ways to assess the quality of water as deemed fit for drinking, irrigation and industrial use. Yogendra and Puttaiah (2008) presented the water quality index (WQI) which is a characteristic number for representing the overall quality of water for public or for any intended use as well as in the pollution abatement programmes and water quality management. The WQI was determined basing on various physico-chemical parameters. WQI provides a single number that expresses overall water quality at a certain location and time, based on these several water quality parameters.

Quality for raw and treated wastewater has also been

Figure 1. Aerial view of Jambo Factory in Busia District, Uganda.

determined by multi-parameter aggregated index (MPAI) using a fuzzy multi-criteria decision making approach (Khambete and Christian, 2014a). Banerjee and Srivastava (2009) successfully applied the WQI for assessment of surface water quality surrounding integrated industrial estate-Pantnagar. WQI approach and statistical tools in fingerprinting of heavy metal pollution and comparison of spatial variability of multiple contaminants have been found effective and a useful tool for assessment of water quality (Boyacioglu, 2012).

WQI has been successfully used to study the water quality of a stream receiving industrial effluents in the Brazilian Northeast where a potential risk to the population was identified (Abrahao and Carvalho, 2009). The application of the WQI classification indicated that the water quality was poor could pose risk. In regards to stream/river water quality flows, Alam and Pathak (2010) successfully carried out the assessment of River Ramganga in using WQI and a computer programme. Additionally, Moscuzza et al. (2007) were able to assess river water quality within the agricultural Pampean plains (Argentina).

There has also been application of WQI in classifying the quality of groundwater (Vasanthavigar et al., 2009; Balakrishnan, 2011). Vasanthavigar et al. (2009) applied the WQI for ground water basin basing on dominant cations (Na^+, $Mg2^+$, Ca^{2+}, K^+) and anions (Cl^-, HCO_3^-, SO_4^{2-}) and was able to show suitability of groundwater for irrigation purposes. Balakrishnan (2011) was able to use WQI values to develop *Isopleth* map that was used for regional decision making geared towards better planning and management of groundwater quality in the Gulburga City (Karnataka State, India).

Model setup equations and tables

In the study, the WQI was used with the NEMA standards using the weighted arithmetic index method (Brown et al., 1970). It incorporates the use of the generated Dev C++ computer language programme with a setup to determine the usage. The overall WQI is calculated by aggregating the quality rating with the unit weight linearly using a model developed by Brown et al. (1970) as in Equation (1) below:

$$WQI = \frac{\sum q_n W_n}{\sum W_n} \quad (1)$$

Where: q_n = Quality rating for the n^{th} water quality parameter; W_n = unit weight for the n^{th} parameters.

Table 1. Comparison of WQI and status of water quality.

Water quality index level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Medium water quality
76-100	bad water quality
>100	Very bad water quality

Source: (Chatterjee and Raziuddin, 2002; Yogendra and Puttaiah, 2008).

The quality rating was calculated using Equation (2).

$$q_n = 100 \times \frac{[V_n - V_{io}]}{[S_n - V_{io}]} \quad (2)$$

Where: q_n = Number reflecting the relative value of the parameter in the polluted water with respect to its standard permissible value; V_n = observed value of the nth parameter at a given sampling station; V_{io} = ideal value of the nth parameter in pure water. (That is, 0 for all other parameters except the parameter pH of 7.0 mg/l and dissolved oxygen of 14.6 mg/l; S_n = standard permissible value of the n^{th} parameter.

The unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter in Equation (3).

$$W_n = \frac{K}{S_n} \quad (3)$$

Where: *K* is a constant for proportionality.

A comparison of water quality index and identification of the status of water quality were made based on the criteria variously used by Yogendra and Puttaiah (2008) and Chatterjee and Raziuddin (2002), which is reproduced in Table 1.

Excessive sodium and salinity concentrations in irrigation water result in sodium hazard, as well as salinity hazard. Sodium ion in water replacing calcium and magnesium ions in soil causes reduced permeability and soil hardening (Zhang et al., 2012). To assess irrigation water quality, the parameters such as percent sodium (Na %) and sodium adsorption ratio (SAR) are calculated based on the chemical variables of water samples (Zhang et al., 2012). Sodium in soil is considered vital for determining groundwater suitability for irrigation purpose because Na reacts with soil to reduce its permeability and support little or no plant growth. The irrigation water assessment indices including:

$$Na\% = \left\{\frac{[Na^+]}{[Na^+] + [Ca^{2+}] + [Mg^{2+}] + [K^+]}\right\} \times 100 \quad (4)$$

$$SAR = \frac{[Na^+]}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}} \quad (5)$$

Where, all the ionic concentrations are expressed in millequivalents per liter (meq/L) of the respective ions. The SAR is probably the only one in current use and is generally considered an effective evaluation index for most water used in irrigated agriculture (Zhang et al., 2012).

Water quality assessment programme and prediction of re-use options

The programme was developed using Dev C++ computer language. This programme incorporates the water quality index (WQI) model developed by Brown et al. (1970) and the sodium adsorption ratio equation. The logic flow chart for the programme is shown in Figure 2. The WQI is given by Equation 1. The Quality rating was calculated using Equation 2. The unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter in Equation 3. To assess irrigation water quality, the parameters such as percent sodium (Na %) and sodium adsorption ratio (SAR) are calculated based on the chemical variables of water samples (Zhang et al., 2012). The irrigation water quality assessment indices were calculated from Equations 4 and 5 (Table 2).

The developed programme determines the usage of effluent water. This commercially available programme has a setup file called KYESP WQIC which runs on the following windows: Windows 95, Windows 98, Windows ME, Windows NT, Windows 2000, Windows XP, Windows vista and Windows 2003 server. After successful installation, it displays an interface where you are required to press numbers one or two depending on what you want to determine. The developed programme prompts the user to decide which usage to test. It does so by asking you either to press 1 or 2 for domestic or irrigation use, respectively.

MATERIALS AND METHODS

Location of the site

Jambo Tannery (U) Limited is a tannery with a capacity to process 250 hides and 3,000 kg skins per day. The tannery is located in

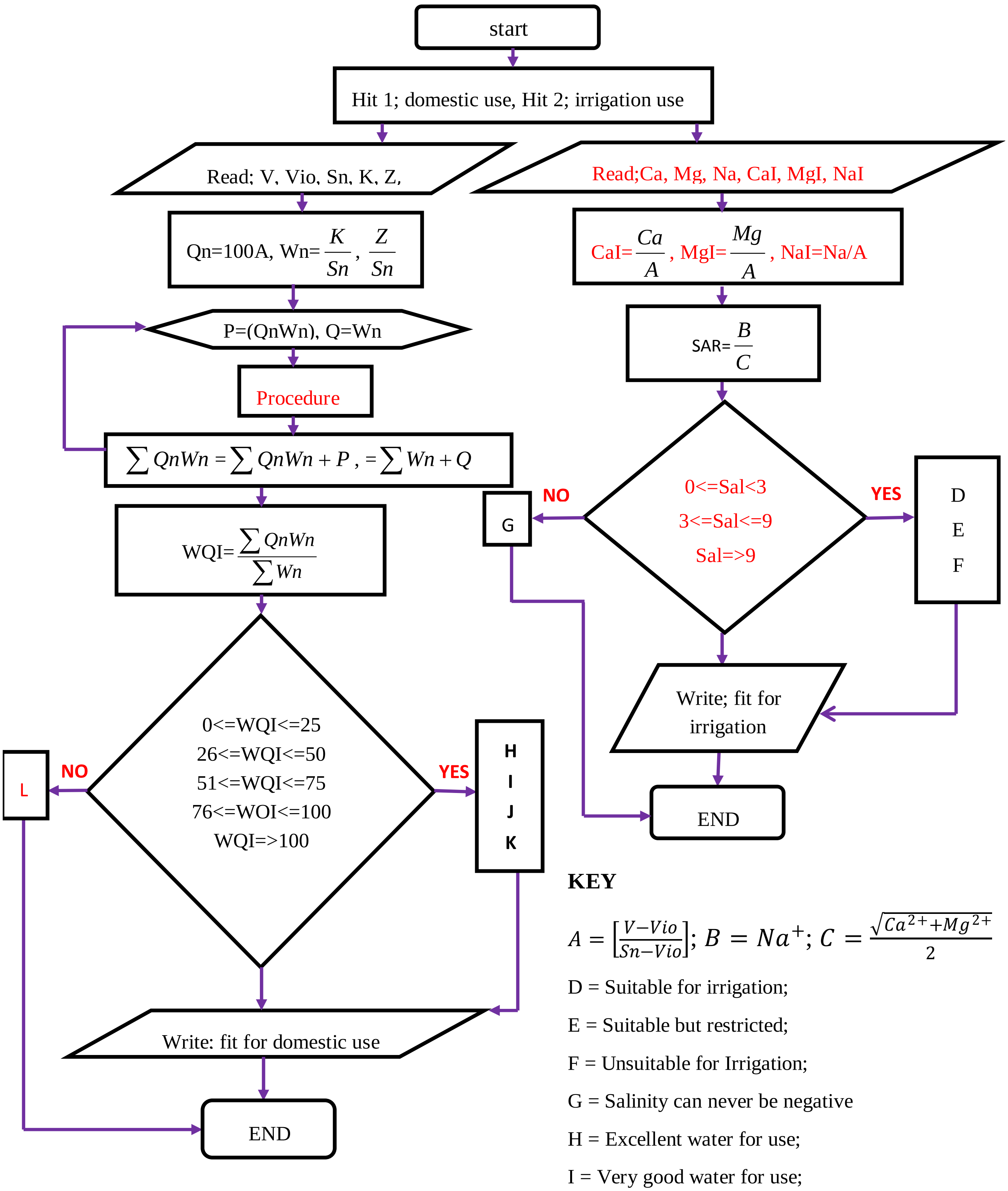

Figure 2. Flow chart of the water quality program.

Solo A village, Busia Municipal Council Industrial Area, in Busia District (Uganda). The tannery is located at GPS coordinates N 00.2840° and E 034.4965°. Busia District developed a master plan which mainly focuses on improving water quality in the area. Currently, the effluent from the wastewater treatment plant at Jambo Tannery (U) Limited flows to Solo stream which is a source

Table 2. Irrigation water quality status.

International SAR standards	Water quality status for irrigation
SAR < 3	Suitable for irrigation
3 ≤ SAR ≤ 9	Used but may be restricted
SAR ≥ 9	Unsuitable for irrigation

of livelihood to communities downstream. The master plan, with a time horizon of 30 to 50 years, requires industrial production units to process their effluents to NEMA standards before disposal.

Sample collection and analysis

Samples were collected in polyethylene plastic bottles which were rinsed out with distilled water and then onsite with sample water. The sampling method followed the spot type but duplicate samples were taken per each site and only one sample was taken to the laboratory for analysis. During sample collection, sample bottles were filled to the top allowing for minimum storage between the time of sampling and delivery to the laboratory, samples were chilled and kept in an insulated container with ice bricks. The water samples were collected at five sample sites. Water samples were analyzed in the Medical School Molecular Laboratory at Makerere University for the following phsico-chemical water quality parameters: Total suspended solids (TSS), pH, electro-conductivity (EC), total dissolved solids (TDS), total phosphorus (TP), ammonium-N, total chromium (TCr), chromium trivalent (CrT), chromium hexavalent (CrH), biological oxygen demand (BOD_5), chemical oxygen demand (COD), sulphide, chlorides and sulphates.

Total dissolved solids (TDS)

TDS were determined by the evaporation method which involved evaporating the waste samples to dryness. In this method, 50 ml of sample were transferred to a weighed evaporating dish, and evaporated to dryness by heating for 1-2 hours at 180°C to a constant weight. Total dissolved solids were calculated using Equation 6.

$$TDS = \frac{1000\, mg\ of\ residue}{ml\ of\ sample} \quad (6)$$

Total suspended solids (TSS)

TSS was determined using the gravimetric method as described by Punmia (1998). Cleaned dish was taken and ignited to constant weight (W_1). 25 ml of well mixed sample was transferred to the above dish. The sample was evaporated to dryness at 103°C for 24 h, in constant temperature oven. It was then cooled in a desiccator and weight was determined (W_2). The dish was ignited at 600°C in furnace for 30 min. The dish was cooled in a desiccator a gain and its weight was determined as W_3. The total solids content was calculated from Equation 7.

$$TSS = \frac{(W_2 - W_1) mg/l \times 100}{V} \quad (7)$$

Where: W_1 = Weight of empty dish; W_2 = weight of the dish after evaporation and V = volume of the sample.

pH and electro-conductivity (EC)

The pH and EC of the wastewater were measured in the field using the HI-98129 type combination meter.

Total phosphorus (TP)

TP was determined following the method of Digestion. 25 ml of the sample was acidified with 1 ml of H_2SO_4, 0.04M, and then 5 ml digestion reagent was added and mixed well. A blank (25 ml distilled water) and phosphate standard was prepared by taking 25 ml of known standard concentration. Both the blank and phosphate standard were treated in the same way as the samples. They were heated for 30 min in an autoclave at 120°C and cooled to room temperature. The color reaction was made in the destruction bottles by adding 3 ml of combined reagent which comprised of 50 ml of 5 N H_2SO_4, 5 ml potassium antimonyl tartrate, 15 ml ammonium molybdate and mixed well. 1 ml of ascorbic acid was added to each sample and the samples were allowed to stand for 20 min for blue color development. The concentration in mg/l at 880 nm wavelength using the spectrophotometer CECIL 1000 series was determined and the reading was multiplied with the dilution factor. To derive the concentration in mg/l of TP in the sample, the formula in Equation 8 was used.

$$TP\left(\frac{mg}{l}\right) - \frac{(mg)\ TP \times 1000}{Sample\ volume\ (ml)} \quad (8)$$

Ammonium nitrogen (ammonium-N)

Ammonium-N was determined by the Nesslerisation method. 25 ml of sample was measured and poured into the nessler tube. 25 ml of the blank was prepared from distilled water. 1 ml of nessler reagent was pipetted into each sample in the nessler tubes, the stopper was placed in each case and tubes inverted several times to mix. They were allowed a minute for the reaction. Each sample was poured into respective blank and the prepared cells. The concentration was measured in mg/l at 425 mm using DREL spectrophotometer. The reading was multiplied by the dilution factor. To derive the concentration in mg/l of ammonium-N in the sample, the formula in Equation 9 was used.

$$Ammonia - N\left(\frac{mg}{l}\right) = \frac{(mg) NH_3 \times 1000}{Sample\ volume\ (ml)} \quad (9)$$

Total chromium (TCr)

TCr was determined using colorimetric method. 0.25 ml (5 drops) H_3PO_4 was added. 0.2 N H_2SO_4 and pH meter to adjust solution to pH of ± 0.5 was used. A solution was transferred to a 100 ml volumetric flask, diluted to 100 ml and mix. 2 ml diphenyl carbazide solution was added, mixed and let to stand 5 to 10 min for full color development. An appropriate portion was transferred to 1 cm absorption cell and its absorbance measured at 540 nm, using reagent water as reference. From the corrected absorbance, chromium micrograms were determined by reference to the calibration curve. A calibration curve was constructed by plotting corrected absorbance values against micrograms of chromium in102 ml final volume. TCr was determined using Equation 10.

$$mg\frac{Cr}{l} = \frac{mg\ Cr\ (in\ 102\ ml\ Final\ Volume) \times 100}{A} \quad (10)$$

Where: A = ml of original sample

Chemical oxygen demand (COD)

The COD was determined according to the method reported by Rand et al. (1975). 10 ml of the sample were taken in a 100 ml bottle then 5 ml of concentrated H_2SO_4 was added and about 1 g of copper sulphates ($CuSO_4$) also added. Then 3 ml of prepared N/40 $KMnO_4$ solution was added and the bottle immersed in boiling water for 30 min while keeping the surface of the boiling water at the higher level than the surface of the sample. Then 3 ml prepared N/40 sodium oxalate (Na_2C2O_4) was added and immediately titrated with N/40 potassium permanganate ($KMnO_4$) until violet color appeared then repeated for the blank separately under same condition using 10 ml of distilled water instead of 10 ml of sample.

$$COD\ as\ mg\ of\frac{O_2}{l} = \frac{\left(\frac{1}{40}\right) \times 8000 \times (A - B)}{ml\ of\ sample} \quad (11)$$

Where: A = ml of $KMnO_4$ used for sample; B = ml of $KMnO_4$ used for blank; (1/40 = molarity of $KMnO_4$; and 8000 is the Mill-equivalent weight of oxygen × 1000 ml/l.

Biological oxygen demand (BOD_5)

The BOD_5 was determined using Winkler method as described by Rand et al. (1975). Two 100 ml bottles were obtained with lid and cleaned well. 25 ml sample was taken in each bottle and 75 ml of distilled water was added to the two bottles. The two bottles were closed well. One bottle was kept in the incubator at 20-22°C for 5 days. 10 ml of manganese sulphates solution and 2 ml of alkali-iodide solution were added to the other bottle well below the surface of the liquid by using a syringe. The bottle was closed and its content mixed by inverting the bottle several times. When the precipitate settles leaving a clear supernatant above the precipitate, it was shaken again slowly by inverting the bottle. When the solution setting has produced at least 50 ml supernatant, 8 ml of concentrated H_2SO_4 were added. The bottle was closed and mixed by gentle inversion until dissolution was completed. 100 ml of the sample was titrated with 0.05 M Na_2SO_3 solution until a pale yellow solution is reached. 2 ml of freshly prepared starch solution was added and titration was continued until a blue color appeared. The procedure was then repeated using 100 ml distilled water (blank). This procedure was repeated for incubated sample after 5 days. The BOD_5 was calculated using Equation 12.

$$BOD\ as\ mg\frac{O_2}{l} = 16(V_1 - V_2) \quad (12)$$

Where: V_1 = ml of Na_2SO_3 used for the sample before incubation; and V_2 = ml of Na_2SO_3 used for the sample after incubation.

RESULTS AND DISCUSSION

Physio-chemical experimental data results and discussions

The physico-chemical wastewater quality parameters analyzed included pH, EC, TDS, TSS, TP, NH_3-N, total chromium, trivalent chromium, hexavalent chromium, BOD_5, COD, sulphide, chlorides, sulphates, and oil and grease. The results from the laboratory analyses for the physico-chemical wastewater quality parameters for the five sampling sites at Jambo Factory (Busia District, Uganda) are summarized in Table 3.

The process involves use of sodium chlorides which acts as a preservative; however, this could have led to high values of EC of 7920 and 27170 µsm and chlorides of 22.5 and 20 mg/l content in the wastewater on average for both S1 and S2, respectively as indicated in Table 3. Higher levels of chlorides are also attributed to the use of constant common salt in prickling process. The high levels of BOD_5 and COD values observed at all the sampling points in tannery treatment system could have been due to high amount of organic matter from various chemicals used during the soaking, tanning and post tanning processing of hides and skins. It has been reported that only about 20% of the large number of chemicals used in the tanning process is absorbed by leather, the rest is released as waste (UNIDO, 2005), thereby increasing the levels of BOD_5 in the effluent. More still, these processes yielded higher values of TDS in the wastewater as observed in Table 3.

In unhairing and liming processes, calcium hydroxide and sodium sulphide as reducing agents are introduced to dissolve and remove the hair. This could have caused the presence of high levels of TDS for the beam and chrome lines respectively in the wastewater as observed from Table 3, higher values of TDS are also attributed to the fleshings from the fleshing process, hence contributing to pollution load. The concentration of different parameters were higher for the chrome linemost likely due to addition of solids from runoff water, mixing of sewage and industrial waste, and the oxidation processes occurring within the chrome treatment line (Table 3). According to Table 3, varying higher values of sulphates are recorded in the wastewater. This could be due to excessive ammonium sulphate which is added to de-lime the hides/skin. A trend of lower pH was due to the dilution of alkaline substances and high turbidity, whereas high pH could be attributed to high temperatures, which enhance microbial activity, causing excessive production of carbon dioxide.

Implementation of the developed programme and the results

Successful implementation of the developed programme depends on the knowledge of the input water physio-chemical quality parameters indicated in Table 3. The typical sample collection and analyses were carried out at five sites. With these typical values in mind from the facilities and the developed programme using Dev C++ computer language, inputs were made into the programme.

Table 3. Wastewater analysis at the sampling sites S1, S2, S3, S4 and solo stream.

Parameters	Units	Sample S1		Sample S2	Solo stream	Sample S3		Sample S4	
		Untreated	Treated	Treated		Untreated	Treated	Untreated	Treated
pH		10.2	8.4	8.3	8.5	11.2	7.31	3.77	8.47
EC	μs/cm	16600	9640	35400	32900	15000	4200	69000	18940
TDS	mg/l	10624	6170	22656	21056	9600	2814	44160	12122
TSS	mg/l	330	46	17	24	708	145	333	16
TP	mg/l	29.08	11	7	1.12	27.6	10.3	33.8	5.9
NH_3-N	mg/l	182.6	23	13	2.6	122	87	300	33
TCr	mg/l	9.5	2	0.9	0.006	10.1	1.6	22.7	0.7
Cr^{3+}	mg/l	3.1	0.7	0.4	0.001	2.93	0.4	7	0.1
Cr^{6+}	mg/l	5.6	0.9	0.4	0.004	6.3	0.8	13.8	0.4
BOD_5	mg/l	869	426	300	266				
COD	mg/l	8864	2986	9008	1860				
S^{2-}	mg/l	0.61	0.48	0.01	0.01	0.7	0.4	1.11	0.13
Cl^-	mg/l	50	42	24	16	35	3	127	16
SO_4^{2-}	mg/l	72	58	173	39	675	125	2525	1475
Oil and grease	mg/l	9.8	3.3	0.64	0.1				

EC = Electro-conductivity; TDS = total dissolved solids; TSS = total suspended solids; TP = total phosphorus; NH_3-N = ammonium nitrogen; TCr = total chromium; Cr^{3+} = trivalent chromium;Cr^{6+} = hexavalent chromium; BOD_5 = biological oxygen demand after 5 days; COD = chemical oxgyen demand; S^{2-} = sulphides, Cl^- = chlorides; SO_4^{2-} = sulphates; mg/l = milligrams per litre; S1, S2, S3, S4 are sample sites.

The resulting output from the programme implementation yielded the results shown in Figure 3 for the four samples S1, S2, S3 and S4

For the first sample analysis, the following parameters were chosen to test the quality of water using the developed programme for both samples S1 and S2; EC, TDS, TSS, TP, ammonium-N, TC, BOD_5, COD, chlorides, sulphates, and oil and grease. These parameters yielded a water quality index of 239.568 and 246.962 for sample S1 and S2, respectively, as shown in Figures 3a and b. According to the comparison table incorporated within the programme, the water is characterized as unsuitable for use because the calculated index is greater than 100. The second sample analysis, the following parameters were tested in the programme for both sample S3 and S4; EC, TDS, TSS, TP, ammonium-N, TC, sulphide, chlorides, and sulphates. The parameters yielded a quality index of 274.742 and 152.297 for both S3 and S4 as shown in Figures 3c and d. The water is characterized as unsuitable for use because the calculated index is greater than 100.

However, the option for re-use of effluent for the factory should be considered after improving on the efficiency of the treatment system through (i) separating both the Beamhouse line and Chrome line; (ii) incorporating screens to remove biodegradables like hair and fleshings or where possible, hair should be recovered by using hair-shaving methods to reduce on the pollution loads; and (iii) possible re-use of wastes such as hair in the watershould be explored for making clothes and carpets. The factory should explore alternative use of chemicals to reduce on the bulky use of different chemicals in the process of tanning. The alternative use to be considered should include: free soak (soaking enzyme), Microdep C in unhairing and liming and unhairing assist.

Conclusion

The analyses of the physicochemical parameters indicated that the wastewater has the potential of causing eutrophication due to the high BOD_5 and nitrate concentrations. The levels of COD and BOD_5 in the tannery were found to be higher than the optimum range for the discharge of tannery. A relatively higher concentration of chlorides, phosphates and sulphates indicate the unsuitability of water for domestic use since they were higher than the NEMA limits for the discharge of industrial effluent into the environment. The application of water quality index in Dev C++ computer language programme for the overall assessment of the water quality of Jambo Tannery wastewater treatment system was consistent with the measured values of the physico-chemical water quality parameters and was found to be useful tool for assessing the effluent from the WWTP. The water quality index obtained for the tannery on two different days of the study period showed poor quality of water. This water quality rating study clearly showed that, the status of the tannery wastewater is eutrophic and unsuitable for the human, industrial and agricultural use. This clearly showed that the use of the model and the developed C++ computer programme in predicting the re-use options of the

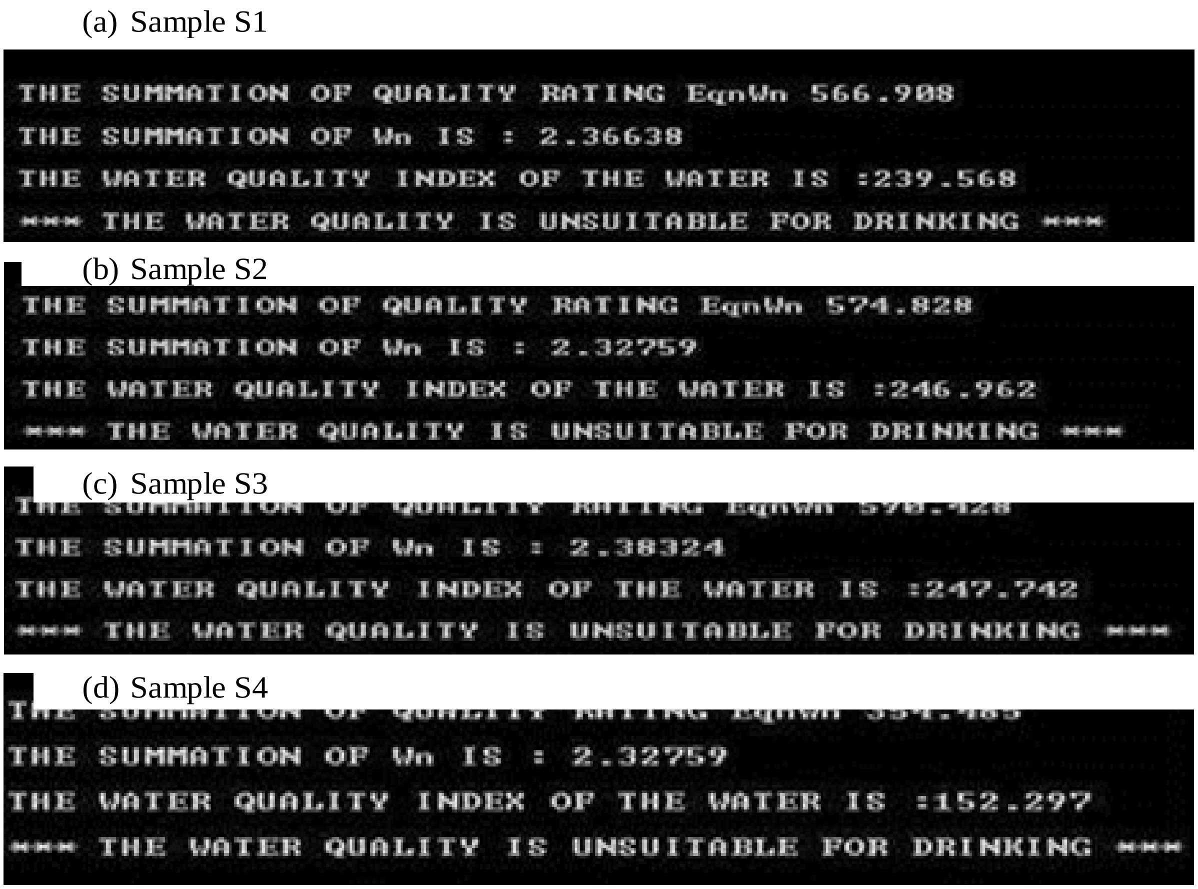

Figure 3. Water quality index programme results for different samples.

wastewater treatment system was a success and can be applied to other wastewater treatment system.

REFERENCES

Afify M, Arafa A, Maksoud NAE (2013). Evaluation of some health hazards among egyptian leather tannery workers. J. Appl. Sci. Res. 9(4):2959-2964.

Alam M, Pathak JK (2010) Rapid Assessment of Water Quality Index of Ramganga River, Western Uttar Pradesh (India) Using a Computer Programme. Nature Sci. 8(11):1-8

Banerjee T, Srivastava RK (2009). Application of water quality index for assessment of surface water quality surrounding Integrated Industrial Estate-Pantnagar. Water Sci, Technol. 60 (8): 2041-2053

Belay A (2010). Impacts of Chromium from Tannery Effluent and Evaluation of Alternative Treatment Options: J. Environ. Protect. (1): 53-58.

Bosnic M, Buljan J, Daniels RP (2000). Pollutants in tannery effluents: Definitions and environmental impact, and Limits for discharge into water bodies and sewers. Regional programme for Pollution Control in the Tanning Industry in South-East Asia. United Nations Industrial Development Organization (UNIDO). US/RAS/92/12.

Boyacioglus H (2012). Utilization of environment and index methods as water quality comparative assessment tools focusing on heavy metal content: Achieves of environment protection. 38 (3):17-28.

Brown RM, McClelland NI, Deininger RA, Tozer RG (1970) A water quality index: do we dare?" Water and Sewage Works. *117: 339-343*.

Chatterjee C, Raziuddin M (2002) Determination of water quality index (WQI) of a degraded river in Asansol Industrial area, Raniganj, Burdwan, West Bengal. Nature, Environment and Pollution Technology. 1 (2): 49-59:181-189.

Chattha J, Shaukat M (1999). An assessment of environmental concerns in the leather industry and proposed remedies: a case study of Pakistan. GIK Institute of Engineering Sciences and Technology Topi, Dist. Swabi NWFP, Pakistan.

Dikinya O, Areola O (2010)Comparative analysis of heavy metal concentration in secondary treated wastewater irrigated soils cultivated by different crops. Int. J. Environ. Sci. Tech., 7 (2), 337-346.

Jabari M, Aqua F, Shahin S, Khatib A (2009). Monitoring Chromium Content in Tannery Wastewater: The Journal of the Argentine Chemical Society. 97 (2):77-87.

Kirkham MB (2006). Cadmium in plants on polluted soils: Effects of soil factors, hyper-accumulation and amendments. Geoderma 137 (1-2):19-32.

Khambete AK, Christion RA (2014a). Predicting efficiency of treatment plant by Multi-Parameter Aggregated Index. J. Environ Res. Develop. 8(3):530-539

Khambete AK, Christian RA (2014b). Statistical analysis to identify the main parameters to effecting WWQI of sewage treatment plant and predicting BOD. Int. J. Research in Engineering and Technology (IJRET). 3(01): 186-195

Ludvik J (2000a). Chrome balance in leather processing: Regional Programme for Pollution Control in the Tanning Industry in South-East Asia. UNIDO. US/RAS/92/120/11-51.

Ludvik J (2000b). The Scope for decreasing pollution load in leather processing: Regional Programme for Pollution Control in the Tanning Industry in South-East Asia. UNIDO. US/RAS/92/120/11-51.

Moscuzza C, Volpedo AV, Ojeda C, Cirelli AF (2007) Water quality index as a tool for river assessment in agricultural areas in the

Pampean plains of Argentina. J. Urban Environ. Engr 1(1):18-25.

Muramuzi F (2009). The Leather tannery industry in Uganda: Risks to the environment and human health.

Punmia BC, Jan AK (1998). Environmental Engineering-2: Waste Water Engineering. *2 nd Ed. EWW-0618-150: 1-555. Laximid Publications (P) Ltd*.

Rand MC, Taras MJ (1975). Standard methods for the examination of water and wastewater. *13th Ed. American Public Health Association, American Water Works Association and Water Pollution Control Federation.*

Vasanthavigar M, Srinivasamoorthy K, Vijayaragavan K, Rajiv Ganthi R, Chidambaram S, Sarama VS, Anandhan P, Manivannan R, Vasudevan S (2009). Hydrogeochemistry of thirumanimuttar basin: an indication of weathering and anthropogenic impact. Int. J. Environ. Res. 3 (4):617-628.

Wang J, Wang G, Wanyan H (2007). Treated wastewater irrigation effect on soil, crop and environment: Wastewater recycling in the loess area of China. J. Environ. Sci. 19 (9):1093-1099.

Yogendra K, Puttaiah ET (2008). Determination of Water Quality Index and Suitability of an Urban Water Body in Shimoga Town, Karnataka. Proceedings of the 12th World Lake Conference, Taal, Published by the International Lake Environment Committee. 342-346.

Yao Jin, XiaoyanQu, Yuan Li, Ruoren Yu, and Keisuke Ikehata (2014). Health Effects Associated with Wastewater Treatment, Reuse, and Disposal. Water Environ. Res. 86(10): 1970-1993.

Zhang B, Song X, Zhang Y, Han D, Tang C, Yu Y, Ma Y (2012). Hydrochemical characteristics and water quality assessment of surface water and groundwater inSongnen plain, Northeast China. Water Research. 46(8):2737-2748.