Current Status in Quality of Treated Wastewater for Potential Reuse Scheme in Ruai, Nairobi County, Kenya

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Abstract
The study examined the current status in quality of the treated wastewater (TWW) discharged at Dandora Estate Sewage Treatment Works (DESTW) in Ruai with a view to assessing its reuse potential and conformity to the national standards recommended for safe use. The DESTW discharges approximately 80,000m^3/day of TWW through its three outlets into the adjacent Nairobi River without any planned use option. However, some people use it directly or indirectly for their livelihoods oblivious of its quality status, putting at risk their own health, public health and the environment. Understandably, with freshwater becoming increasingly scarce, thus limiting livelihood options, water planners and users are forced to reconsider other water resources such as wastewater which can be used both economically and effectively. Samples of TWW were collected from the three outlets (sampling sites) at DESTW, prepared and analysed for heavy metals [lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni) and iron (Fe)]; macronutrients [nitrogen (N) as nitrate, phosphorous (P) as phosphate and potassium (K)] and environmental characteristics [microbes; faecal coliforms (FC) and total coliforms (TC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solid (TS), pH and chlorides]. Raw data were analysed with the help of Statistical Package for Social Sciences [SPSS] software version 20 for both descriptive statistics (means and standard deviations) and inferential statistics (ANOVA's F and post hoc procedures by Tukey and Games-Howell test where applicable & Kruskal-Wallis H test. All inferential statistical tests were conducted at a 0.05 level of significance. Results showed that the content of Cd, Cr, Fe, Mn, phosphate, TS, chlorides, and pH were lower than their safe limits for reuse but that of lead, BOD, COD, nitrates and TC exceeded the recommended threshold limits. Results of one-way ANOVA performed on the data suggested that the levels of all the measured parameters of the study except Fe, Pb, pH, BOD and FC varied significantly among the three sites. Overall, the results show that the TWW is not entirely safe for use in its current quality state. There is need for an improved optimal wastewater treatment configuration at DESTW aimed at rendering suitable effluent for reuse schemes in Ruai.
Key Terms: treated wastewater, quality, water resource, livelihoods, reuse

1. Introduction
1.1 Background
Nairobi City Water and Sewerage Company (NCWSC) operate several wastewater treatment plants with Dandora Estate Sewage Treatment Works (DESTW) in Ruai being the largest and the second biggest in Africa. It processes approximately 80,0000m^3/day equivalent to about 80% of wastewater generated in Nairobi city - using the wastewater stabilization ponds (WSP) system (Mireri et al., (2007).

According to Mara, (2001) and Van der Hoek et al., (2002) the WSP system is one of the alternative lower-cost treatment technologies used extensively in mid-income countries. It can produce an effluent quality that meets the World Health Organization's (WHO) recommendations for wastewater reuse for crop irrigation (Mara, 2001; Carr and Potter, 2013). Thus, the treated wastewater from WSP should be considered as a valuable resource for reuse by water resources managers (Almas and Scholz, 2006). Besides, wastewater reuse stimulates the treatment efficiency of wastewater which results in the decreasing of pollutants emission into natural environments (Lyu, Chen, Zhang, Fan, Jiao, 2016).

According to Bischel et al. (2012) and Water and Sanitation Program and International Water Management Institute [WSP and IWMI], (2016) municipal wastewater that has been treated thoroughly can be returned to the water supply for a variety of beneficial uses including landscape irrigation, agriculture, ecosystem enhancement, industrial cooling and processing, groundwater recharge, and indirect potable reuse. For instance, TWW has been considered as a viable source of water for several decades in several developed countries in Europe, USA, Japan, and others (Shomar and Dare 2015). Shomar and Dare 2015 further noted that suitable uses of TWW are generally defined at a national level and are often based more on the preference and sensibility of decision makers than scientific evidence about its risks and benefits.

However, in the Ruai case, despite operating on a WSP system, DESTW discharges its effluent into Nairobi

River (NCWSC, 2015) without any reuse option, the cost of the entire treatment process, and potential reuse options notwithstanding, thus treating it as a 'waste' rather than a resource. Nevertheless, some people among the communities in Ruai use the effluent directly or indirectly in unsustainable (unplanned and unregulated) ways for their livelihoods oblivious of its quality status, putting at risk their own health, public health and the environment. The quality of the TWW released by Ruai's DESTW needed to be documented with respect to its adaptability for safe use and at the same time verified for compliance to the standards for its safe use as recommended by National Environmental Management Authority (NEMA).

1.2 Objective of the Study

The specific objective of the study was to establish the current status in quality of TWW – in terms of the concentration levels of heavy metals [lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni) and iron (Fe)]; macronutrients [nitrogen (N) as nitrate, phosphorous (P) as phosphate and potassium (K)] and environmental characteristics [microbes; faecal coliforms (FC) and total coliforms (TC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solid (TS), pH and chlorides] - discharged at the three outlets at DESTW.

   To help achieve this objective the study sought to answer the following questions:
   I.   What is the mean concentration of each of the study parameters in the treated wastewater at DESTW?
  II.   Do these levels conform to the national (NEMA) standards recommended for safe use of the TWW in Ruai?
 III.   Do these concentrations vary significantly among the three outlets of TWW at DESTW?

Given the objective of the study, the following hypothesis is spelt out:

H_o: There are no significant variations in the concentration of the heavy metal, nutrients and environmental in the TWW discharged among the three outlets at DESTW.

1.3 Treated Wastewater Quality

Water resource quality defines subsequent uses and inherent risks (Mahjoub et al. 2016). Thus, the quality of treated wastewater is important, not only for compliance with the regulations to protect farmers irrigating with effluent and consumers of the crops, but also to protect local inhabitants and other users of the resource from incidental contact as noted in Rageh (2014). The types of crops, livestock, and fish that farmers can raise are affected by the quality of the wastewater and the characteristic of the environment (Buechler 2004). It is therefore recommended that the quantity and quality be analysed against potential reuse applications and quality requirements in order to guarantee acceptability by end-users, on the one hand, and to mitigate the risks to practitioners and the environment on the other hand (Mahjoub et al., 2016).

   Parameters considered for assessing wastewater quality and selected based on their importance in wastewater treatment and reuse such as in irrigation agriculture included nutrients (Nitrogen [N], Phosphorous [P] and potassium[K], cations and anions (Chlorides and potassium among others), trace elements (iron [Fe], manganese [Mn], copper [Cu], zinc [Zn], cadmium [Cd], lead [Pb],nickel [Ni], cobalt [Co] and chromium [Cr]), and acidity / alkalinity (pH) as described in Alghobar and Suresha (2016). For wastewater, parameters such as BOD and COD are paramount as they indicate the efficiency of the treatment process appropriated. Parameters such as pH can help understand the operating conditions of the system (Kihila et al., 2014). pH is an indicator of the acidity or basicity of water but is seldom a problem by itself. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is abnormal in quality (Pescod 1992). In hot climates with a long dry season, high rates of evaporation causes wastewater to be more saline with high total dissolved solids (TDS) concentration that may restrict the variety of crops that can be cultivated (Buechler 2004).

   Wastewater, particularly from municipal sources, may contain constituents of potential concern including heavy metals (Laurenson et al. 2012), some amount of dissolved mineral salts (Martinez and Clark 2015), nitrogen and phosphorus present as inorganic ammonium, nitrate, and phosphate ions with a smaller proportion of organic forms (Martinez et al., 2015; Ashraf et al., 2017) and soil amendments (Lenntech 2009).

   The term heavy metal refers to metals with a density greater than $5g/cm^3$ (Pfleiderer et al., 2012; Mathenge 2013) but the collective term now includes arsenic, cadmium, copper, chromium, lead, nickel, molybdenum, vanadium and zinc. Some interest also exists in aluminium, cobalt, strontium and other rare metals (Njagi 2013). Wastewater may contain various heavy metals including zinc, copper, lead, magnesium, nickel, chromium, and cadmium, depending on its sources of generation (Bhatia, et al., 2015). These metals may make wastewater unsuitable for irrigation (Hussain et al., 2002; Raja et al., 2015) though some are essential elements for growth and development, for example Zinc, Manganese, Copper and iron (Skudi as cited in Karanja 2015). Metals like copper and zinc are essential for enzymatic activity and many biological processes at low concentrations but may become toxic at higher concentrations (Bhatia, et al., 2015). According to USEPA, 2012 as cited in Amare et al., (2017), nickel, cadmium and lead have no known essential functions or role in the body of living organisms but may be toxic even at low concentrations causing a potential health risk through the food chain. Hence, as Amare et al., (2017) further reported, knowledge about these heavy metals' and their concentration in water for use is important,

more so because they can become a health risk via consumption of contaminated vegetables, milk, fruit, and drinking water. Fortunately or unfortunately, they are typically not removed from wastewater even after treatment, causing risk of heavy metal contamination of wastewater-irrigated soils and, subsequently, can end up in the food chain (Bhatia, et al., 2015).

Wastewater also contains valuable nutrients such as nitrogen, phosphorus and potassium among others which aid in crop growth and could reduce the need for synthetic fertilizers (Kaluli et al., 2011; WSP and IWMI 2016). Nutrients are resources that can beneficially be used by farmers and should not be removed except, during the off-season or whenever nutrients are in excess, where periodic nutrient removal could be a strategy in the treatment system. Nutrients present in the water are beneficial for crop development and depending on the crops grown, the available nutrients are sufficient for crop cultivation, reducing farmer's expenditure on artificial. Balancing nutrients in the field to support crop requirements, while avoiding environmental pollution, gives important incentives to reconsider the wastewater treatment techniques used, as well as the irrigation water management system (Van der Hoek et al., 2002; Van Lier and Hubers 2010; Saldías et al., 2017).

While nitrates are an important source of nitrogen necessary for plants and animals to synthesize amino acids and proteins excessive concentrations of nitrate-nitrogen or nitrite-nitrogen in drinking water can be hazardous to health, especially for infants and pregnant women (Panchagnula 2016) and in wastewater it can lead to over-fertilization and cause excessive vegetative growth, delayed or uneven crop maturity and reduced quality (Van der Hoek et al., 2002; Jiménez 2006 and Qadir et al., 2007 as cited in Oyebode 2015).

The phosphate in the reclaimed water is of particular benefit as it has the potential to meet a substantial proportion of crop requirements depending on the crops grown and the intensity of cropping and also essential for animals (Hack, 1992; Carr et al. 2010). However, too much of it in water can contribute to eutrophication (Hack 1992).

In addition to nutrients, the application of wastewater provides organic matter that acts as a soil conditioner, thereby increasing the capacity of the soil to store water (Hespanhol 1997). The increase in productivity is not the only benefit because more land can be irrigated, with the possibility of multiple planting seasons (Hespanhol 1997).

Wastewater use especially untreated or partially treated can also be a source of microbial risk which arises due to pathogens, i.e. disease-causing organisms. Their presence in water/wastewater may be indicated by the presence of non-pathogenic bacteris such as coliforms. According to Bartram and Pedley, (1996), total coliforms refer is a large group of gram-negative, rod-shaped bacteria that share several characteristics. It includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Their presence in water is evidence of faecal contamination and, therefore, of risk that pathogens are present. The presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermotolerant (faecal) coliforms. Such a result would not necessarily indicate the presence of faecal contamination. It might be caused by the entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. Hence, the most appropriate wastewater treatment to be applied before effluent is used in agriculture is one which will produce an effluent meeting the recommended microbiological and chemical quality guidelines (Sewe et al., 2013).

2. Methodology

This study was carried out in Ruai sub-location Embakasi Sub County in Nairobi East; about 20 km from the city centre (Figure 1). It lies between latitudes $1^0 14'0''S$ and $1^0 18'0''S$ and longitudes $36^0 56'0''E$ and $37^0 6'0''$ E. It borders the following sub-counties: Thika to the north, Kangundo to the East, and Kathiani to south. Ruai is connected to City Centre through Kangundo, Outering and Jogoo roads (Sigoria 2012).
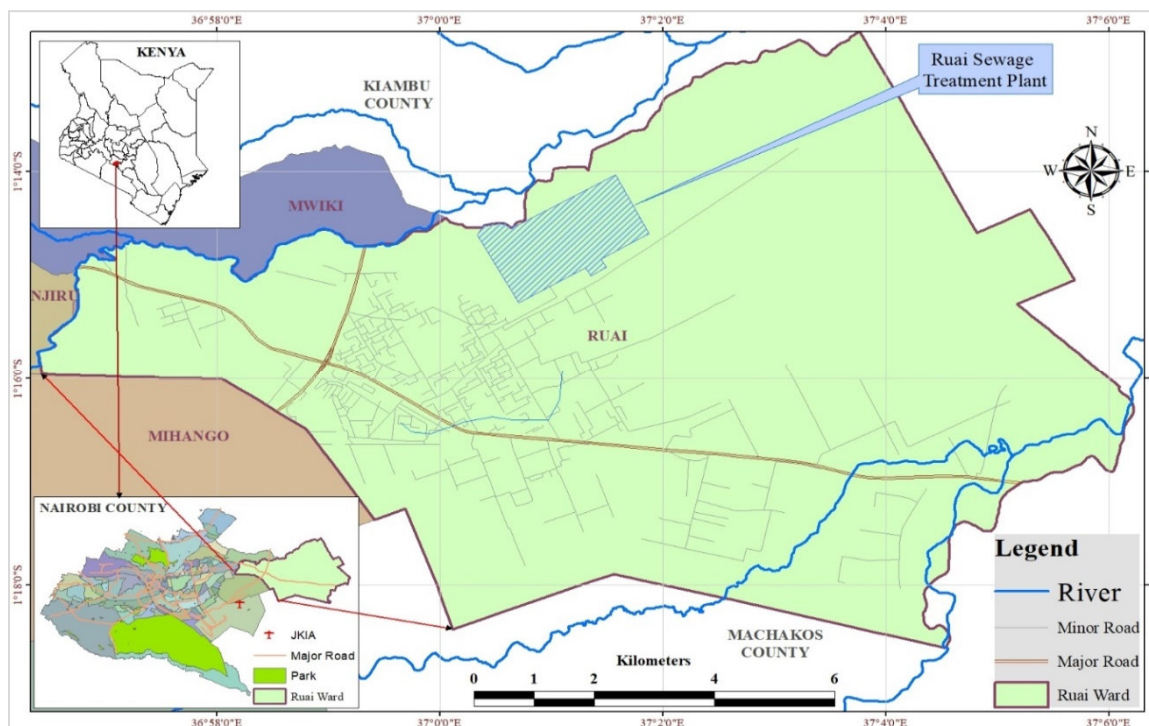
Figure 1: Map of the Study Area
Source: Author

2.1 Research Design

The study involved an analytical design where physicochemical data on the status in the quality of the treatment of wastewater were collected, prepared and analysed in accredited science laboratories (Njagi 2013).

2.2 Treated Wastewater Sampling, Preparation and Analyses

2.2.1 TWW Samples Collection

Samples of the TWW discharged at DESTW were collected from the three outlets coded in the study as sites A, B and C (Figure 2). This was done thrice - consistent with a similar study in (Raschid-Sally et al., 2004) - during the study period (between February and April, 2019) to reduce errors in sampling processes and to establish any changes in the status of the TWW at different times.

Grab method was used to collect samples of the TWW as recommended by Pitt (2007) and as used in a similar study by Sewe et al., (2013) from the three discharge points. A grabbing plastic bottle was used to collect samples which were then transferred into one litre conical flasks. According to Koffi et al., (2014) water sample for assessing water quality is collected in plastic bottles. Prior to use, the grabbing plastic bottle and the conical flasks were cleaned by pre-soaking them overnight with 10% nitric acid and rinsed with distilled water as described in Nzeve (2015). The samples were collected manually in the middle and mid-depth of the channels as recommended (Koffi et al. (2014). Three samples were collected, and transferred into three separate conical flasks. The three samples from the conical flasks were then homogenized to form one litre composite treatment sample (Njagi, 2013). The flasks with the composite samples were then labelled to indicate sample number, date of sampling and the sampling site and put in an cooler box at a temperatures of at least 4^0C (Nzeve 2015).

The samples were then transported to the DESTW laboratories and University of Nairobi's (UoN) chemistry and biological laboratories where they were stored at 4^0C awaiting subsequent laboratory analysis as stipulated in El Moussaoui et al., (2017).
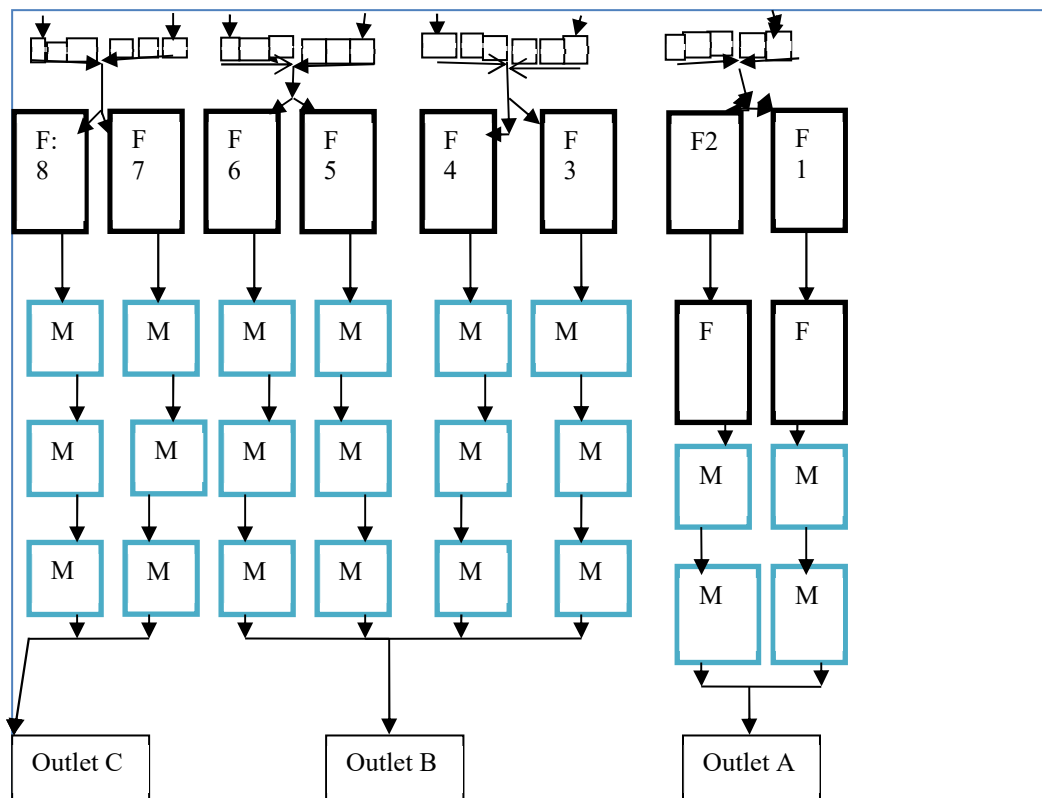
Figure 2: Schematic layout of DESTW Stabilization Ponds and the Outlets
F = facultative ponds, M= maturation ponds,
Source [DESTW, Secondary information, February 20, 2019]

2.2.2 Laboratory Preparations: Standard and Working Solutions

Stock standards solution of 1000 parts per million (ppm) - [1ppm is equivalent to 1mg/l] - for each of the heavy metals were prepared from the metal salts (Analytical grades) using nitric acid as described in Hack (1992) and Nzeve (2015). This was followed by the preparation of the corresponding working standards solutions, ranging from 0.05ppm to 20ppm as each case required from the stock solutions by appropriate serial dilutions with distilled water (Hack 1992). Blank solutions (de-ionized water) were also prepared.

2.2.3 Laboratory Analyses

TWW samples were analysed for 18 parameters which were selected based on their importance in wastewater treatment and reuse for irrigation as was done in a similar study (Kihila et al., 2014). They included 8 heavy metals [lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni) and iron (Fe)]; three macronutrients [nitrates as nitrogen (N), phosphate as phosphorous (P) and potassium (K)] and 7 environmental characteristics [microbes; faecal coliforms (FC) and total coliforms (TC), BOD, COD, TS, pH and chlorides]. UoN's chemistry and biological laboratories analysed metals, nutrients and microbes while DESTW laboratories performed the remaining environmental parameters.

Laboratory analyses for estimating the concentration of the metals in the TWW were carried out using atomic absorption spectrometer (AAS) using the respective hallow cathode lamp (Hack 1992; Eaton et al. 2005; Koffi et al. 2014; Amare et al. 2017; El Moussaoui et al., 2017). To determine the instrument signal response to changes in concentration, calibration was done using working standard solutions of known and increasing concentrations for each metal (analyte element) in the study as stipulated in Hack (1992) and Amare et al., (2017). By measuring the signals of the working standards, the AAS constructed a suitable calibration curve of response/absorbance versus concentration. The AAS used this suitable graph to determine concentrations of unknown analyte as described in Hack (1992); Nzeve (2015) and Skudi, as cited in Mathenge (2013). Analytical samples, blanks and duplicate samples were run in parallel for each analysis. All the samples were analysed in triplicate.

Nutrients were analysed using a visible/ultra violet (UV) spectrophotometer (calorimeter) as described in Hack (1992). The samples for determining nitrate levels were first digested with conc. sulphuric acid, a catalyst and distilled water. A Nessler's reagent was added in every analysis and the mixture run in a UV spectrophotometer at an absorbance of 425nm. Procedure for determining the levels of phosphate in the sample involved 1). Stock solution (100ppm) was prepared and then diluted to obtain working standards of 10ppm, 20ppm…up to 90ppm. $1cm^3$ reagent (molybdovanadate) was then added to each standard. 2) Preparation of samples where 1 ml of the reagent was added to 10 mls of the each sample and 3) running the standards, samples and blank solutions in a

UV/visible spectrophotometer (calorimeter) at a wavelength of 470nm (Hach 1992). Potassium levels in the sample were determined following the same methods used for the analysis of heavy metals.

Biochemical oxygen demand (BOD) was determined using a 5-day digital BOD test at 20 °C as described in Eaton et al. (2005) and Amare et al., (2017). For Chemical oxygen demand (COD) determination, the sample was mixed with 1.5 ml potassium dichromate solution and 3.5ml sulphuric acid (catalyst) in a Rota mixer digester for two hours. The mixture was allowed to cool and then titrated with phenolphthalein indicator (Eaton et al., 2005). A standard solution (distilled water) was used. Chlorides levels were determined by titration method with silver nitrate solution and acidified potassium dichromate solution as the indicator. A standard of sodium chloride solution was used. Conversion of units of measurement of chloride determined from ml to mg/l was done as follows:

$$\frac{mg}{l} chloride = \frac{(A - B) * Normality\ of\ \text{AgNO3}\ sample * constant}{ml\ of\ sample}$$

Where: A = sample titre, B = blank titre and constant = 35450.

The pH of the wastewater was measured using a portable pH meter. Total solids (TS) were analysed as follows: metallic crucibles were dried at 150^0 overnight, and then cooled in a desiccator and each weighed (W_1). 50mls of TWW sample was put into an empty dry metallic crucible and dried for 12 hours, cooled and weighed (W_2) (Eaton et al. 2005; Koffi et al. 2014). The procedure was done in triplicate. TS (mg/l) were calculated according to Aminot and Chaussepied as cited in Koffi et al., (2014) as follows:

TS = [(W_2-W_1) * 1000]/sample volume (ml).

Bacteriological laboratory analyses were undertaken following the plate count method (Hack, 1992). Two growth media were used namely Eosin methylene blue agar for indication of faecal coliform (FC) and MacConkey agar for enumeration of total coliform (TC) as recommended in Hack (1992). 1 ml of each sample (A, B and C) was serial diluted up to 10^5. Then 0.1ml of the last 3 dilutions was transferred on to the growth media and using a sterile spread rod they were spread uniformly. The plates were then incubated at 37^0c for 48 hours and the colonies that developed were enumerated. For the TC all the plates which had more than 300 colonies were discarded.

2.3 Statistical Data Analysis

Data from laboratory analyses were statistically analysed using both the Ms Excel and the SPSS (Version 20.0) software. Descriptive analyses (that is, mean and standard deviations) were done and presented in tables. The mean level of concentration of each parameter in the study was also compared with the set standards by NEMA and WHO or Food and Agriculture Organization (FAO) where available in order to ascertain safe use of TWW. At the same time, the resultant concentration levels for the parameters of TWW were subjected to a one-way analysis of variance (ANOVA) followed by Tukey HSD or Games-Howell multiple comparison tests where applicable. The resulting *F* statistic and its corresponding significant level (*p*) in each case were used to determine the significance of the differences of their mean levels, both within the site and between the sampling sites in the study. The means were deemed significantly different when $p \leq 0.05$ and insignificant when $p > 0.05$ at 95% confidence interval.

A one-way ANOVA is a hypothesis test that determines whether there are any significant differences among the means of three or more independent (unrelated) populations or categories (Shayib 2013). The independent groups (categorical) in the study were the three sampling sites whereas the dependent variable at scale level as stipulated in Norušis (2008) and Nolan and Heinzen (2011) was the mean level of each of the treated wastewater parameters analysed. The null hypothesis tested in the study was that the population values for mean levels of each of the TWW parameters were the same for the three sites of wastewater at DESTW (Norušis, 2008).

According to Shayib (2013) and Norušis, (2008), the methodology of ANOVA is based on the following assumptions: (1) each sample of size *n* is drawn randomly and is therefore independent of the other samples, (2) the populations are normally distributed as ANOVA is a relatively robust procedure for violations of the normality assumption (Shayib, 2013), (3) the populations from which the samples are drawn have equal variances. This means that:

$$\sigma_1^2 = \sigma_2^2 = \cdots = \sigma_k^2\ for\ k\ populations.$$
Where σ² is the variance of populations 1, 2…. to k

The ANOVA produces an F statistic, the ratio of the variance among the means to the variance within the samples (Shayib, 2013; Norušis, (2008) :

$$F = \frac{Mean\ squared\ for\ between - group\ variation}{Mean\ squared\ for\ within - group\ variation.}$$

The following procedures were followed in conducting the one-way ANOVA): (1) Cleaning the data, (2) Checking and testing the assumptions of one-way ANOVA. The study used the Shapiro Wilk test for testing normality as it is more appropriate for small sample sizes, more powerful than the K-S test even after the Lilliefors correction, has good power properties as compared to a wide range of alternative tests and is also an omnibus test in most situations (Öztuna et al., 2006; Razali and Wah 2011; Ghasemi and Zahediasl 2012). For numerical

variables with skewed distributions, the Kruskal–Wallis rank sum test was then used as described in (Ghasemi and Zahediasl, (2012) and Salkind, 2007). It is the non-parametric analogue of a one-way ANOVA (McDonald 2014). In practice, the analysis of variance is not heavily dependent on the normality assumption (Norušis, 2008).

Levene test statistic was used for homogeneity testing (Norušis, 2008; Ghasemi and Zahediasl 2012). (3) Calculating the respective F ratio and its associated significant probability (p) value and (4) Conducting post hoc procedures using the Tukey HSD and Games-Howell tests for equal variances assumed and not assumed respectively where a significant difference ($p \leq 0.05$) had been found in the preceding ANOVA analysis (Salkind, 2007). Tukey HSD which assumes homogeneity works for any number of groups with roughly equal sample sizes whereas Games-Howell is a separate variance version of Tukey test (Elder, 2009). Following Kruskal-Wallis rank tests, pairwise comparisons tests were done to ascertain where any significant differences in distributions occurred.

3. Results and Discussion

The statistical results of the study are presented systematically as follows: Descriptive statistics comprising the means and standard deviations of the concentration levels of the parameters of the TWW sampled. Inferential statistics follows; starting with the results of tests of the assumptions of the one-way ANOVA (normality of the raw data and homogeneity of variances) and then the results of one-way ANOVA and post hoc procedures. Results of Kruskal–Wallis rank-sum test for the skewed data closes the section.

3.1 Descriptive analyses of qualitative status of TWW

Table 1 shows the mean levels of the parameters studied in each site, their overall average and comparisons with NEMA and international recommended standards (where applicable) for safe use, as discussed below.

3.1.1 Environmental Parameters

The means of most of the environmental parameters in the study [pH, TS, BOD, COD, Chlorides and microbes; FC and TC), were similar in the three sites except a slight difference which was noted among the mean levels of BOD and FC. For instance, mean level of BOD of TWW from site B was 106.71mg/l compared to both C of 71.43mg/l and site A at 62.1 mg/l. The mean counts of FC in all the three outlets differed.

The results further show both compliance and non-compliance with the standards among the parameters. Among the parameters that complied with the NEMA recommended standards (given in brackets) for safe use includes, TS [888.0 mg/l (1230 mg/l)], chlorides [137.0 mg/l (250) mg/l], and pH [8.3 (6.5-8.5)] while BOD [80 mg/l (30 mg/l)], and COD [278.0 mg/l (50 mg/l)] were above the recommended standards. The results for the BOD and COD were consistent with finding of a study by Sewe et al., (2013) on the efficiency of DESTW which reported that the BOD-5 and COD in the final effluents failed to meet not only the design expectation but also the required water quality regulations of Kenya for discharge to the surface water and environment. This is an indication of inefficiency of the treatment process appropriated (Kihila et al., 2014) for a while now. One reason for this is the fact that the ponds have not been de-sludged since construction as noted in a previous study by Sewe et al., (2013). The average mean colonies of TC [2.1 x10^5 (1000 colonies per 100mls)] were above the recommended standards. This poses a health risk to the users of TWW in Ruai and consumers of agricultural produce resulting from its use.

3.1.2 Heavy Metals

The mean concentration levels of each of the heavy metals studied were relatively similar in the three sites except those of iron (Fe) and lead (Pb). Further, except for lead [0.158 mg/l], the levels were below the NEMA'S standards (0.1mg/l) for safe use. In this regard, the TWW from DESTW in Ruai was safe for use in relation to the heavy metals in the study except lead.

3.1.3 Nutrients

While the mean levels of potassium and phosphate were relatively similar in the three sites, there was a large variation in the mean of nitrate in site C (50.8mg/l) from the other two (around 38 mg/l). The mean levels of phosphate (3.0mg/l) complied with the NEMA recommended standards (30 mg/l) for safe use while those of nitrate (42mg/l) exceeded the threshold limit (10 mg/l). These findings are similar to those in a study by van der Hoek et al., (2002) who found that the level of nitrogen in the wastewater was too high and therefore could lead to excessive vegetative growth.

Table 1: Mean Concentration Levels of Parameters of TWW in Comparison with Recommended Standards

Parameter	Site A mean levels ± SD (mg/l)	Site B mean levels ± SD (mg/l)	Site C mean levels ± SD (mg/l)	Average levels ± SD (mg/l)	NEMA (mg/l)	WHO* / FAO** Standards (mg/l)
Cd	0.054±.007	0.058 ± .009	0.063±.013	0.058±.010	0.1	0.01**
Cr	0.091±.068	0.104±.023	0.089±.032	0.094±.047	2.0	0.1**
Cu	0.056±.012	0.061±.005	0.058±.013	0.059±.009	1.0	0.2**
Fe	0.442±.087	0.272±.072	0.402±.087	0.372±.107	10.0	5.0**
Pb	0.294±.056	0.196±.028	0.071±.034	0.158±.105	0.1	5.0**
Ni	0.090±.057	0.095±.073	0.175±.117	0.117±.087	0.3	0.2**
Mn	0.678±.151	0.654±.058	0.754±.014	0.695±.098	10.0	0.2**
Zn	0.035±.006	0.037±.005	0.051±.026	0.041±.016	0.5	2.0**
K	1.33±.531	1.448±.68	1.47±.543	1.42±.556	N/A	
Nitrate	38.4±14.8	38.0±12.9	50.8±27.5	42.4±18.8	10.0	
Phosphate	3.14±0.9	3.15±0.35	2.74±.19	2.98±.59	30.0	
Chlorides	132.8±13.5	139.6±4.3	138.3±9.8	136.9±9.9	250	
pH[a]	8.6±.25	8.2±.10	8.1±.08	8.3±.25	6.5-8.5	6.5-8**
TS	858.9±72.1	899.6±29.8	905.5±53.0	888.0±56.2	1230.0	
BOD	62.1±16.4	106.7±46.1	71.4±11.6	80.1±33.8	30.0	
COD	286.0±60.2	277.3±28.7	271.4±27.9	278.2±40.4	50.0	
FC[b]	6.0±6.0	10.0±3.0	27.0±7.0	14.0±11.0	Nil.	1000.0 /100ml***
TC[b]	218667.0 ± 59651.0	210167 ± 60407	211167 ± 41845	213333 ± 51478	1000.0 /100ml	

Note. [a] pH scale (range 1-14), [b] Levels of coliforms (FC= faecal coliforms and TC= total coliforms) are measured in counts per 100 milliliter. N/A = Not available, *source: Mara, (2001), **source: Adapted from Pescod, (1992), *** No standards recommended for cereal and fodder crops, pasture and trees but ≤ 1000/100ml for irrigation of crops likely to be eaten uncooked and public parks.

3.2 Inferential Statistical Analysis

3.2.1 Results of Normality Test

Results of the Shapiro-Wilk normality tests for levels of Cd, Fe, Ni, Zn, TS, pH, COD and nitrate (in all the three sites) had their p-values greater than 0.05 (Appendix A, Table A.1). This indicated absence of sufficient evidence to reject the null hypothesis for a test of normality which states that the data is normally distributed. Hence, the assumption of normality was not violated. Consequently, these data were subjected to one-way ANOVA test as explained below. However, the data for Cr (site B), Cu (site C), Mn (sites A and B), Pb (site C), K (sites B and C), Chlorides (site B), BOD (site B), Phosphate (site A), FC (site A) and TC (site B) were not normally distributed as their p-values were less than 0.05. Hence, we rejected the null hypothesis for this test of normality necessitating the use of the Kruskal–Wallis rank-sum test to separate their differences as described in Ghasemi and Zahediasl, (2012) and Salkind, (2007).

3.2.2 Results of Homogeneity Test

As Table 2 shows, the results from Levene tests for homogeneity of variances indicated that the null hypothesis which states that the variances in the three discharge sites of TWW were equal could not be rejected for Cu, Fe, Pb, TS, COD and TC. However, the tests showed statistical significance ($p \leq 0.05$) for the variances of the groups for Cd, Cr, Ni, Mn, Zn, K, BOD, pH, Chlorides, Nitrates, Phosphates and Faecal coliforms. Hence, the null hypothesis was not accepted. So, where necessary, it was reasonable to use post hoc procedures that assume and don't assume equality of group variances (Norušis 2008).

Table 2: Results for the Levene Test of Homogeneity of Variances

Parameter	Levene Statistic	df1	df2	Sig.	Parameter	Levene Statistic	df1	df2	Sig.
Cd	6.287	2	15	.010	Nitrate	74.383	2	9	.000
Cr	6.023	2	8	.025	Phosphate	27.983	2	15	.000
Cu	2.147	2	6	.198	FC	7.524	2	15	.005
Fe	0.097	2	15	.909	TC	1.705	2	15	.215
Pb	1.198	2	5	.376	TS	2.544	2	21	.102
Ni	4.737	2	14	.027	Chloride	5.175	2	21	.015
Mn	494.70	2	15	.000	pH	6.056	2	21	.008
Zn	3.777	2	14	.049	BOD	9.63	2	18	.001
K	3.749	2	15	.048	COD	3.065	2	21	.068

Note. Significance level used is .05

3.2.3 Results of One-way ANOVA

Table 3 shows results of a one-way ANOVA test. It was computed to test the null hypothesis that the population values for mean levels of each of the TWW parameters (whose data were normal as earlier explained) were the same for the three sites of discharge of the treated wastewater at DESTW as described in Norušis (2008). Results showed no statistically significant difference in the levels of Cd, Ni, Zn, TS, COD and nitrates in all the three sites. For these parameters the null hypothesis of the study could not be rejected. However, there was a statistically significant difference in the levels of Fe [$F(2, 15) = 7.06$] and pH [$F(2, 21) = 15.98$] among the three discharge sites of TWW at $p \leq .05$. In this regard it was unlikely that the mean levels of the two parameters in the TWW from the three sites were the same. The null hypothesis was therefore rejected, and based on Levene test results, Tukey HSD procedure was carried out for Fe while Games-Howell procedure was used for pH in order to pinpoint exactly where the differences occurred.

Table 3: One-way ANOVA of Mean Levels of the Parameter of TWW among the Three Sites at DESTW

Parameter	df	F	p	Parameter	df	F	p
Cd	(2,15)	1.105	0.357	TS	(2,21)	1.739	0.200
Fe	(2,15)	7.056	0.007	pH	(2,21)	15.979	0.000
Ni	(2,14)	1.751	0.210	COD	(2,21)	0.248	0.782
Zn	(2,14)	1.922	0.183	Nitrate	(2,9)	0.557	0.591

Note. Statistical significant at the $p \leq 0.05$ levels

Tukey HSD test results as presented in Table 4, showed a significant mean difference ($p \leq .05$) for Fe between site A ($M = .442 \pm .087$) and B ($M = .272 \pm .072$) as well as between site B ($M = .272 \pm .072$) and site C ($M = .402 \pm .087$). However, there were no statistical differences between the site A and C ($p = 0.685$). On the other hand, the Games-Howell tests revealed significant mean difference ($p \leq .05$) for pH between site A ($M = 8.6, SD = .25$) and site B ($M = 8.2 \pm .10$) and between site A ($M = 8.5 \pm .25$) and site C ($M = 8.1 \pm .08$). There were no differences between the means for pH at sites B and C. This implies that variations exist in the performances of the treatment processes among the corresponding series at DESTW.

Table 4: Output of Multiple Comparisons Tests

		Fe Tukey HSD					pH Games-Howell		
(I) site	(J) site	Mean Difference (I-J)	Std. Error	Sig.	(I) site	(J) site	Mean Difference (I-J)	Std. Error	Sig.
A	Site B	.170*	.047	.007	A	site B	.366*	.096	.010
	Site C	.040	.047	.685		site C	.425*	.093	.004
B	Site A	-.170*	.047	.007	B	site A	-.366*	.096	.010
	Site C	-.130*	.047	.037		site C	.059	.046	.425
C	Site A	-.040	.047	.685	C	site A	-.425*	.093	.004
	Site B	.130*	.047	.037		site B	-.059	.046	.425

Note. *. The mean difference is significant at $p \leq 0.05$

Results of a Kruskal-Wallis test (Table 5) showed that there was no statistically significant difference (with $p > .05$) in distribution of levels of Cr, Cu, K, Mn, chlorides, phosphates and TC across categories of the sites. So we did not have sufficient evidence to reject the null hypothesis, that the distributions were the same. See details of ranks in Appendix B, Table B.1. This indicates no significant variations in the performances of the treatment processes among the corresponding series at DESTW.

However, the test showed a statistically significant difference ($p \leq 0.05$) in distribution of levels of Pb, BOD and FC across the categories. Corresponding pairwise comparisons tests shows significant differences (at $p \leq 0.05$) in the distribution of BOD between site C and site B, as well as distribution of FC between sites A and Site C and between site B and site C, (Appendix B, Table B.2). This indicates that the treatment processes for the removal of pathogens and breakdown of organic matter (BOD) differed across the respective series at DESTW (Mara (2001).

Table 5: Results for Kruskal-Wallis Test

Test Statistics[a,b]

Parameter	Chi-square	df	p	Parameter	Chi-square	df	p
Cr	.247	2	.884	Phosphate	.649	2	.723
Cu	.318	2	.853	Chlorides	1.512	2	.469
Pb	6.072	2	.048	BOD	7.132	2	.028
Mn	3.789	2	.150	FC	11.986	2	.002
K	.573	2	.751	TC	.266	2	.875

Note. a. Kruskal-Wallis Test, b. Grouping Variable: Site.

4. Conclusion and Recommendations

This study revealed that the TWW currently discharged at DESTW contained parameters (all the heavy metals in the study except lead; TS, Cl and pH) that are at a non-harmful degree with respect to NEMA's safety standards for use and unacceptably high loads of BOD, COD, nitrates and both faecal and total coliforms which constitute a great health concern. There was also a remarkable difference in the quality of TWW discharged among the three outlets of TWW at DESTW with respect to parameters such as Fe, Pb, pH, BOD and FC. This indicates a marked difference in the performance of the treatment processes among the corresponding series at DESTW. With 12 out of 18 parameters tested in the study falling within safety bounds, the overall status in quality of TWW can be said to be about 67% safe for use. In this regard, the DESTW seems to have great potential for producing TWW that is safe for reuse, however, the current status in quality of the TWW imply a partial inefficiency toward that end. Hence, this marginal water is not entirely safe for reuse in its current state in terms of quality and its usage poses human health and environmental risks which can impact negatively on sustainability of people's livelihoods.

Therefore, there is need for sustained proper care and maintenance of wastewater processes at DESTW's WSP, in order to produce appropriate quality marginal water that meets all the NEMA's recommendations for wastewater reuse in, say, crop irrigation, instead of just being disposed of as noted in Keremane and Mckay (2006). Perhaps also, its time the idea of a constructed wetland (CW) system was actualized at DESTW to supplement the WSP one for better removal of pathogens and nutrients prior to releasing the effluent into water supplies as recommended in Cakmak & Apaydin, (2010). According to Kihila et al., 2014, with the integration of the treatment technologies and proper operation of the system more better quality effluent can be availed whereby organic load can be reduced significantly and relatively significant amounts of nutrients can be made available for irrigation.

In the meantime, based on the observed effluent quality, restricted irrigation may be employed for growing crops that are eaten when cooked. Crop restriction is one of the health protection measures applied on farms to reduce the risk of contamination for exposed consumers, especially for crops eaten raw (Mahjoub et al., 2016). Both public and environmental health risks associated with TWW reuse in Ruai need to be assessed, managed, monitored and reported on a regular basis in order to sensitize the public on the status of its quality for the purpose of minimizing the negative impacts.

Relevant policies, institutional mandates, and control regulations should be formulated or reviewed, legislated and enhanced to include and ensure that TWW use is part of the integrated management of urban water. This would be in line with an observation made that wastewater is a water resource management and that water quality issue and its reuse is an important option for integrated water resources management in (Bahri, 2009 and Oyebode 2015). Water reclamation and recycling are considered as key components of water and wastewater management policies around the world (Keremane and Mckay 2006).

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Appendix A

Table A.1: Results of Shapiro-Wilk Tests of Normality

Parameter & Site		Shapiro-Wilk			Parameter & Site		Shapiro-Wilk		
		Statistic	df	*p*-value			Statistic	df	*p*-value
Cd	A	.926	6	.546	TS	A	.948	8	.691
	B	.883	6	.281		B	.974	8	.929
	C	.854	6	.169		C	.945	8	.658
Cr	A	.837	5	.157	Chlorides	A	.949	8	.702
	B	.750	3	.000		B	.811	8	.037
	C	.980	3	.727		C	.942	8	.628
Cu	A	.943	3	.538	pH	A	.927	8	.488
	B	.963	3	.630		B	.916	8	.396
	C	.750	3	.000		C	.930	8	.519
Fe	A	.971	6	.899	COD	A	.967	8	.874
	B	.941	6	.664		B	.889	8	.228
	C	.966	6	.862		C	.969	8	.889
Pb	A	n/a			BOD	A	.969	7	.894
	B	n/a				B	.729	7	.008
	C	.743	4	.033		C	.956	7	.787
Ni	A	.972	6	.903	Nitrates	A	.798	4	.100
	B	.895	6	.347		B	.831	4	.170
	C	.842	5	.169		C	.780	4	.071
Mn	A	.724	6	.011	Phosphates	A	.784	6	.042
	B	.723	6	.011		B	.935	6	.621
	C	.943	6	.686		C	.901	6	.380
Zn	A	.993	6	.996	FC	A	.767	6	.029
	B	.901	6	.377		B	.851	6	.161
	C	.803	5	.086		C	.928	6	.565
K	A	.832	6	.111	TC	A	.873	6	.240
	B	.734	6	.014		B	.754	6	.022
	C	.754	6	.022		C	.973	6	.912

Note. Sig. level at $p \leq .05$; n/a= levels were below detection limit

Appendix B

Table B.1: Kruskal-Wallis H test results showing site and ranks

Parameter	Sample 1-Sample 2	Test Statistic	Std. error	Std. Test statistic	Sig.	Adj. Sig
Pb	Site C-site B	3.000	2.109	1.423	.155	.464
	Site C-site A	5.000	2.109	2.371	.018	.053
	Site B-site A	2.000	2.435	.821	.411	1.000
BOD	site A- site C	-2.714	3.310	-.820	.412	1.000
	site A- site B	-8.643	3.310	-2.611	.009	.027
	site C- site B	5.929	3.310	1.791	.073	.220
FC	Site A-site B	-2.167	3.066	-.707	.480	1.000
	Site A-site C	-10.083	3.066	-3.288	.001	.003
	Site B-site C	-7.917	3.066	-2.582	.010	.029

Table B.2: Kruskal-Wallis results of pairwise comparisons

Parameter	Site	N	Mean Rank	Parameter	Site	N	Mean Rank
Cr	A	5	6	Chlorides	A	8	10.00
	B	3	6.67		B	8	13.88
	C	3	5.33		C	8	13.63
Cu	A	3	4.33	pH	A	8	19.63
	B	3	5.17		B	8	10.5
	C	3	5.5		C	8	7.38
Pb	A	2	7.5	Phosphates	A	6	10.08
	B	2	5.5		B	6	10.33
	C	4	2.5		C	6	8.08
Mn	A	6	9.5	FC	A	6	5.42
	B	6	6.5		B	6	7.58
	C	6	12.5		C	6	15.5
K	A	6	8.17	TC	A	6	10.42
	B	6	10		B	6	9.00
	C	6	10.33		C	6	9.08
BOD	A	7	7.21				
	B	7	15.86				
	C	7	9.93				

Note.   1. Each row tests the null hypothesis that the sample 1 and sample 2 distributions are the same,
2. The significance level is .05.