ISSN 2321 3361 © 2018 IJESC

Research Article **Volume 8 Issue No.7**

The Effect of Cross-Sectional Area and Height of Soil on Primary Wastewater Treatment

Henok Habte[1], Abebe Belay[2], Getahun Kitilla[3], Gelana Amente[4]
MSc(Environmental Physics)[1], Assistant Professor[2], Doctor[3,4]
Jigjiga University[1], Adama Science and Technology University[2]
Wollega University[3], Haramaya University[4]
Haramaya University, Collage of Natural and Computational Sciences, Dire Dawa, Ethiopia

Abstract:
In this study, the effect of cross-sectional area and height of soil on physical water quality and discharge rate of primary wastewater treatment has been investigated. To achieve the goal, two 1.8mm pore sized bar screens (sieves), different cross-sectional area and height buckets (thee each), two plastic drums and SCL soil were prepared. Those drums and buckets were interconnected to each other by metallic pipelines and gate valves in a way suitable for the study. Each bucket was filled with SCL soil up to the desired filter height. The wastewater collected from HU, main campus, students` cafeteria drainage line was added to the filtration system after passing preliminary screening sieves. The data samples from preliminary screening, primary filtered wastewater from each bucket and reservoir water were collected three times a day for consecutive seven days. The flow rate and all basic physical water quality parameters were analyzed using IBM SPSS Statistical version 20 and Microsoft Office Excel 2007. The wastewater treated by CRA and H shown statistical significant difference between preliminary wastewater and reservoir water for all basic water quality parameters except A_2 which did not show statistical significant difference between preliminary wastewater for some parameters like: Turbidity(α= 0.42), pH(α= 0.229), and TDS (α= 0.975). The wastewater treated by h_1 and A_1 gave the highest physical water quality result among the rest but the least FR obtained and wastewater treated by h_3 and A_2 gave the highest FR but the least physical water quality values because of the CRA and H of soil added in each filters buckets. Therefore, the result indicated that the soil filter using CRA and H determine the quality and quantity of effluent discharge.

Key words: Dissolved Solids, Effluent, Electrical Conductivity, Flow rate, Percolation, Turbidiy, Suspended Solids

I. INTRODUCTION

Background of the Study

Water is crucial for all aspects of life, the defining feature of our planet. Life as we know it began in an aquatic medium, and water is still the principal constituent of living organisms. The world is not running out of water, but it is not always available when and where people need it. Ninety seven and a half percent of all water is found in the oceans and of the remaining freshwater (non-saline) only one percent is accessible for extraction and use. Fresh water, rivers, lakes and groundwater are used to irrigate crops, to provide drinking water, and to act as a sanitation system. One of the ways to reduce the impact of water scarcity and pollution is to expand water and wastewater reuse. Recycled or reclaimed water is water that is used more than one time before it passes back into the natural water cycle. Thus, water recycling is the reuse of treated wastewater for beneficial purposes such as irrigation, industrial processes, toilet flushing, or replenishing groundwater basin. Water reuse allows communities to become less dependent on groundwater and surface water sources and can decrease the diversion of water from sensitive ecosystems. Additionally, water reuse may reduce the nutrient loads from wastewater discharges into waterways, thereby reducing and preventing pollution. Treated wastewater may also be used to replenish overdrawn water sources and rejuvenate or reestablish those previously depleted. At present, wastewater undergoes through: preliminary, primary, secondary and/or advanced tertiary treatments before it is discharged either for domestic or industrial uses. But the level of technology utilized within each treatment category influences both the initial capital investment necessary to construct or improve wastewater treatment facilities as well as operation and management costs.

When constructing wastewater treatment plant (WWTP), emphasis should be given to the design cost, the quality and quantity of filtered water obtained. The FR of effluent depends on the CRA of filtration tank, the type of filter media(hydraulic conductivity, k), ΔP, and H. Soils with small pores allow only slow flow of water while materials with larger, less constricted pores permit rapid water flow [7]. The amount of wastewater to be treated depends on the total CRA of filter tank and the H. As the CRA of filter increases, the wastewater to be treated takes more time to pass through (percolate) the filter media so that less amount of water will be treated. The velocity of flow can be reduced by increasing the height of filter media which detains the particle for a longer time in the filtration tank. But better quality of treated water will be obtained by increasing the H [9]. Thus, for a constant volume of filter media, changing (increasing or decreasing) the H affects both the quality and quantity of filtered water obtained. This study was intended to find the combination of CRA and H that result in better flow rate and discharged water of good physical quality to support the water scarcity of HU community, to reuse it for irrigation purpose and to replenish the lake Haramaya which was depleted because of environmental and anthropogenic interventions.

Objectives of the Study

General objective

- To assess the effect of cross-sectional area and height of soil on primary wastewater treatment that results in better physical water quality and high discharge rate.

Specific objectives

- To determine the amount of effluent discharge for a given cross-sectional areas.
- To assess the level of physical purity of primary filtered wastewater.
- To determine the effect of cross-sectional area and height of soil that results in optimum primary wastewater treatment.

II. MATERIALS AND METHODS

Description of the Study Area

This study was conducted at Haramaya University, which is located at 515km east of Addis Ababa, 5km from Haramaya, a town in the East Hararghe Zone. The site is located at an altitude of 2016-2087 meters above sea level with latitude of 9^0N and longitude of 42^0E, and receives a mean annual rainfall of 780 mm [14].

Sample Location

The samples were collected from main campus students` cafeteria wastewater drainage line which is found from cafeteria and dormitories. The reservoir water sample was collected from main reservoir distribution zone whose altitude, latitude and longitude in meters above sea level are: 2059, $9^0$25.410’ N and $42^0$02.102’E respectively. This reservoir water is serving students’ cafeteria and dormitories [11].

Materials and Apparatus

The materials and apparatus used for the study were: different pore size bar screens (sieves), two plastic drums with 200 and 120 liters capacity, six plastic buckets of CRA (A_1= 0.067m^2, A_2= 0.0204m^2, A_3= 0.0576m^2)other three buckets with equal CRA: A= 0.06075m^2, pipe reducers and connectors, SCL soil, different sized metallic pipes, meter ruler, hose valves, gate valves, pipe caps, portable turbidity meter (Jenway model-6035, UK), pH meter (Jenway digital pH meter model-3310, UK), electrical conductivity meter (Jenway conductivity meter model-4310, UK), polyethylene plastic bottle, beakers, stoves, filter papers, hand glove, glass bottles, detergents, spatula, electronic mass balance, graduated cylinder, marker, stopwatch, and Hotbox oven were used.

Experimental Setup: Two 120 and 200 liters capacity drums and six plastic buckets of different CRA were connected to each other as shown in the Figure 1. The first drum, 120 liters, was for preliminary screening, and the second drum, 200 liters, was to minimize turbulence and to maintain constant hydraulic head. Six buckets (three identical and the other three of different CRA) were connected to the pipelines in a horizontal level surface. The three identical buckets of equal CRA (A= 0.06075m^2) and hydraulic head differences of ΔP_1= 0.88m, ΔP_2= 1.02m, ΔP_3= 1.12m were filled with soil at different heights (h_1= 35cm, h_2= 25cm, h_3= 15cm). The remaining three buckets shown on the left hand side of Figure 1 were of different CRA(A_1= 0.067m^2, A_2= 0.0204m^2, A_3= 0.0576m^2) but were filled with soil to equal height of 23.5cm.These all had same hydraulic head difference of ΔP= 1.035m. The experimental setup for primary filtration is as shown in the Figure 1.

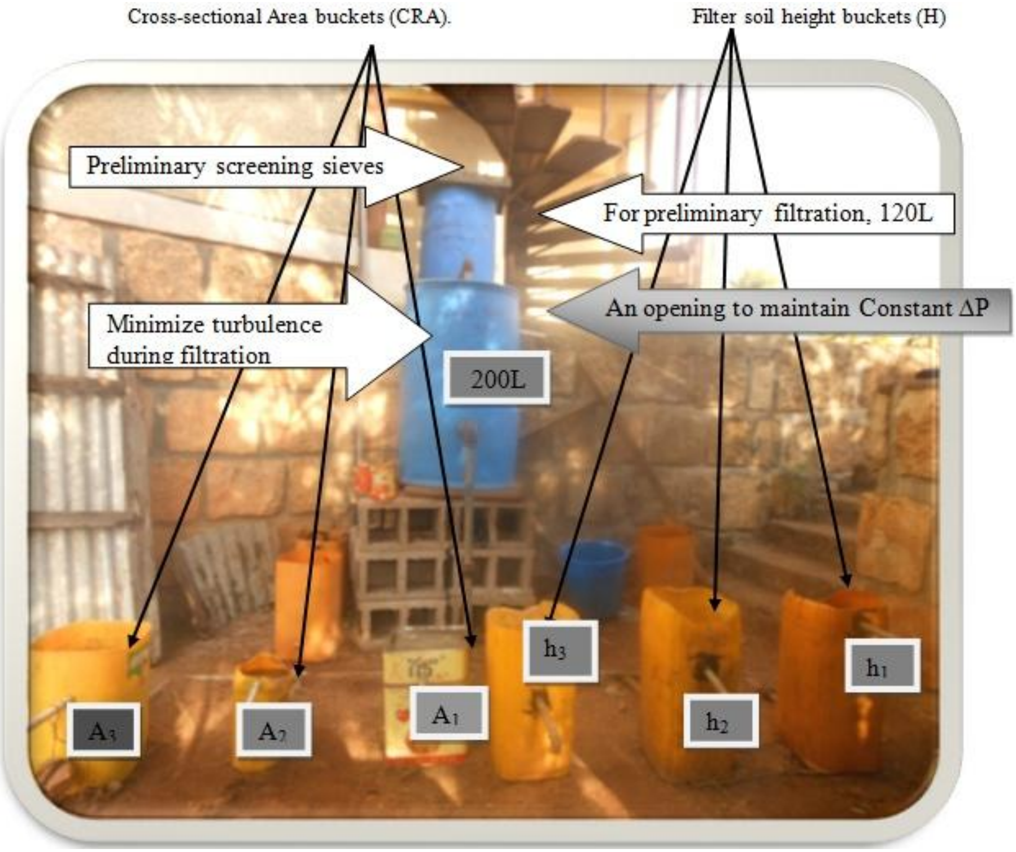


Figure.1. Preliminary screening and primary filtration.

Data Collection and Procedures

Soil sample preparation

The soil sample used for filtration was sieved by 1.8mm diameter pore sized sieves. After sieving, the soil was uniformly mixed and added in each bucket up to required height. The particle size of the soil was analyzed by hydrometric method: Sand= 50%, silt= 20% and clay= 30%.From soil classification textural triangle, the class was observed to be sand clay loam which was recommended by [1] as it has better wastewater filtering ability.

Wastewater sample preparation procedures

The wastewater samples were collected from sewer line by plastic buckets and poured into the first drum (preliminary treatment drum) through double layer screening sieves of 1.8mm diameter to remove large sized objects (sludge) before it passed to the primary treatment buckets [1]. After preliminary screening, sludge separation, the wastewater passed to the second drum. The master control valve was closed until the level of preliminary screened water level in the second drum reached overflow opening and drained through a pre-designed opening. By doing so, constant hydraulic head was maintained throughout the time of data collection. When the water level reached overflowing, the control valve was opened and the preliminary screed water drained through metallic pipelines to the filtration buckets in a desired manner.

Sample data collection

Samples of wastewater that had undergone preliminary screening and the one which was undergoing primary filtration from each bucket were collected in cleaned and marked glass bottles after measuring the volume of filtered sample. The required amount of samples were taken and tested in the laboratory for basic physical water quality parameters like TS, TSS, TDS, turbidity, pH, and EC. The filtration time, soil height, CRA of buckets, ΔP, sludge weight before and after oven dried, and the volume of filtered water at a given time were recorded for every sampling time for each sample type. Sampling was done for all treatments, preliminary wastewater and reservoir water three times a day (in the morning, after lunch and in the evening) continuously for one week. This was because; the predominant amount of wastewater was released from student cafeteria whose physical quality and its discharge rate vary during their meal time and meal type based on menu of each day within a week. The flow entering a WWTP can vary from hour-to-hour, day-to-day, week-to-week and season-to-season.

Methods of Water Sample Analysis for Physical Parameters

The collected water samples were analyzed for determination of physical water quality parameters include turbidity, pH, EC, TS, TSS, TDS [17]. The analytical procedures for each parameter were done according to [8].

Total Solids (TS) of the samples were determined by evaporating 50ml water samples in a preweighed dish and oven drying at 1050C, the increment in weight over that of the empty dish represents the total solids [8].

Mathematically:

$$\frac{\text{Total solids (TS)}}{\text{L}} = \frac{(\text{X}-\text{Y})\times 1000}{\text{sample volume ,ml}} \qquad (4)$$

Where, *X*=weight of dried residue + dish, *Y*=weight of dish, L= Liter

Total suspended solids (TSS) of the samples were determined as shown in Appendix figure 5 by filtering 50ml water samples through a pre-weighed filter and the residue left over the filter was oven dried at 105^0C, the increment in weight of the filter rep resents the total suspended solids [8]. Mathematically:

$$\frac{(\text{TSS})}{\text{L}} = \frac{(\text{X}-\text{Y})\times 1000}{\text{sample volume ,ml}} \qquad (5)$$

Where, *X*=weight of filter residue and *Y*=weight of filter, L= Liter

The total dissolved solids (TDS) were determined by taking the difference between TS and TSS [8]. Mathematically:

$$TDS = TS - TSS \qquad (6)$$

The pH of the samples collected from filter buckets, preliminary and reservoir water were measured using a portable digital Jenway pH meter (Model-3310, UK) equipped with a glass electrode. The calibration was done using standard analytical grade buffer solutions of pH 4.0, 7.0 and 10. The pH data was taken by immersing the probe of portable pH meter in to filtered wastewater sample and recording the readings.

The turbidity of the samples was determined by using portable turbidity meter (Jenway model-6035, UK). The inner part of measuring bottle was washed with distilled and de-ionized water then after the sample was poured into a measuring bottle. The surface of the bottle was wiped with silicon oil (optical grade) and inserted into the turbidity meter and the reading was recorded. EC of the samples was determined using calibrated electrical conductivity meter Jenway conductivity meter (model-4310, UK) by inserting the probe of electrical conductivity meter into the samples till stable reading was obtained and recorded [11].

Data Analysis

The values obtained from the reservoir, preliminary screened and each type of primary filtered wastewater samples were compared and analyzed using pre-designed software, IBM SPSS Statistics version 20 and Microsoft Office Excel 2007. Means of each treatment (h_1, h_2, h_3, A_1, A_2 and A_3), preliminary wastewater (P) and reservoir water (R) were compared and treatment effects were separated using the Tukey test at 5% level of significance to determine the effect of cross-sectional area and height of soil on the physical quality of effluent and discharge rates.

III. RESULTS AND DISCUSSION

Flow Rates of the CRA and H

The volume of filtered wastewater of each bucket for each sample was measured by graduated cylinder. The flow rate (FR) from each buckets were calculated using equation (1) and the time duration for all treatment was 5 minutes. When compared the FR of the three heights of soil filters, the bucket with larger soil filter height had less FR than that of buckets having smaller soil filter heights. This was due to the change in hydraulic head difference (ΔP). Hydraulic head differences (ΔP_1= 0.88m, ΔP_2= 1.02m, ΔP_3= 1.12m) which increases with decreasing the soil filter height (h_1= 35cm, h_2= 25cm, h_3= 15cm) from a constant initial level since it is the driving force for gravity filtration (Hillel, 2004). When the soil height increased, the amount of soil added to the filtration bucket also increased so that the wastewater took more time to percolate through the filter soil.

From the three soil filter heights (h_1, h_2 and h_3), the highest FR was observed by h_3 (30.32L/hr) and the lowest FR obtained from h_1 (20.76L/hr). This implies that as filter soil height increased the FR of the effluent decreased due to the amounts of soil added to the filter buckets through which the wastewater percolated. The less the soil filter height gives more freedom for the wastewater to percolate bottom up and flow through the out let opening but when the H increased the wastewater took more time for percolation so that the FR decreased. The result obtained in this study is similar to [7]. Additionally, from the soil type used for filtration, 50% of the total was sand particle content and the remaining 20% silt and 30% clay that also contributed for variation in FR since soil by itself have hydraulic and water retention characteristics. That means, for a given degree of soil saturation, the hydraulic conductivity increases by several orders of magnitude going from clay to silt clay loam to sand. With small pores, water takes a sinuous path through grains (high resistance to flow), with large pores, the path is less resistance to flow which is also similar to reported by [3]. The other factor was the type of food wastes, cooked and uncooked, released from student cafeteria. The generated result indicated that for the same treatment, the FR varied even from day-to-day (Figure 2) due to daily variability of waste released. Because extreme fluctuations in flow can occur during different times of the day and on different days of the week, estimates are based on observations of the minimum and maximum amounts of water used on an hourly, daily, weekly, and seasonal basis. But after a few days later, the flow rate was tending to decrease because of clogging of filter soil pores by some larger sized particles (suspended solids) retained in it during filtration. The negative slope on flow rate verses days of data collection (Figure 2) show that there was variability and decrease in flow rate from day-to-day due to the type of wastewater released for different meal type and reduction of the soil efficiency to filter at constant rate because of the clogging of pores by those suspended solids from day-to-day.

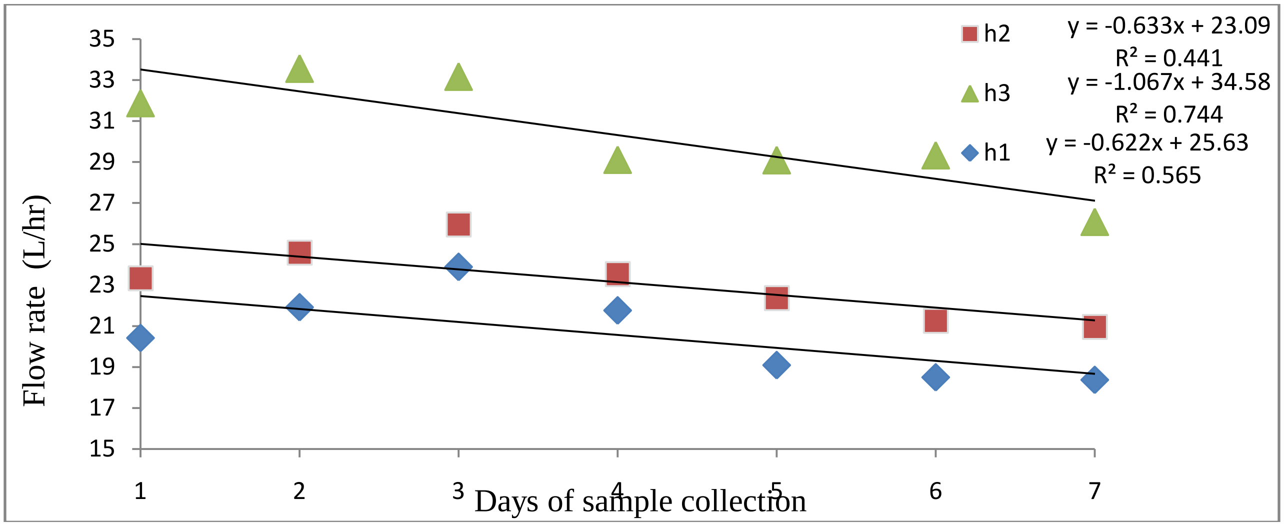


Figure.2. the flow rates of the three heights of soil filters.

Similarly, the remaining three CRA buckets (A_1= 0.067m^2, A_2= 0.0204m^2, A_3= 0.0576m^2) had same hydraulic head difference and height of soil filter ΔP= 1.035m, H= 23.5cm respectively. For each bucket, equal amount of wastewater allowed flowing with constant pressure ($\Delta P/H$) but due to the difference in CRA (the amount of soil added into each buckets), their flow rates were different accordingly after entering into the soil buckets. Those with larger CRA buckets (A_1 and A_3) filtered the wastewater slowly which were 20.541L/hr and 21.485L/hr respectively and that of smaller CRA filter bucket discharged faster, A_2= 41.673L/hr. This was because, the wastewater took longer time to percolate through a soil filter bucket with larger CRA than the smaller since the larger filter bucket contain larger volume of soil particles (sand, silt and clay) each have different compaction, bulk density, moisture ability and water holding capacity that detain the water to percolate through soil, which is similar with the report of [10]. The larger CRA buckets hold much more water than the smaller one so that the upward pressure decreased because of large surface area which pushes the water to come out of the soil containing bucket since the pressure of flowing fluid is directly proportional to the FR (Q) and is the product of velocity and CRA through which the fluid passes as reported by (Fetter, 2001). Even if the driving force $(\frac{\Delta P}{H})$ for three CRA buckets was equal before entering the bucket, because of the difference in CRA, the larger soil bucket experienced less pressure than smaller one. Hydraulic conductivity decreases as the water content and/or soil water pressure head decreases. The other factor was the proportion of clay content (30%), of this proportion the larger CRA bucket contained larger volume of clay than the smaller one which highly affected the hydraulic conductivity (K) and made the flow rate to become less. The other factor was also the alignment of soil pores with each other since the SCL consists of different texture, orientation, pore size, compaction intensity and the like. Since the soil pore sizes for sand, silt and clay are different, the wastewater to be filtered didn't move uniformly. Those all contributed to the variation in the FR. The Darcy's equation (Equation 3) is more appropriate for soil of same type (sand, silt or clay) throughout but here in this experimental work different proportion of the soil were mixed-up. His law does not say discharge through large porous material should be greater than that through smaller porous material but what he identified in his original formula was the factors that affect FR. The physical properties of wastewater also have a contribution on the FR during filtration since the wastewater to be filtered consists of different suspended particles that block the pores of soil during filtration.

The two filter area buckets (A_1 and A_3) have nearly the same values of flow rate throughout. This was because, the two buckets have nearly the same CRA of soil filters whereas the third bucket, A_2, which had highest flow rate because of its smaller amount of filter soil added in it and made the wastewater to percolate easily. In Figure 3 below, the slope of A_1, A_2 and A_3 were negative which shows that there was decrease in flow rate from day-to-day as a result of clogging the pore sizes of filter soil by suspended solids.

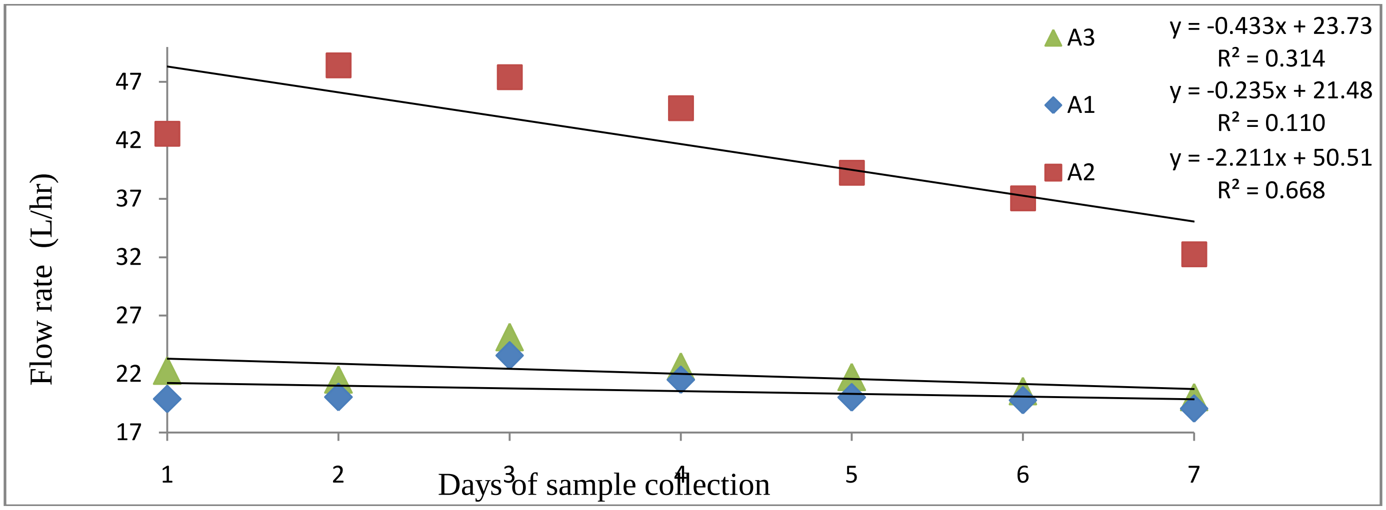


Figure .3. The flow rates of the CRA.

The overall pair-wise mean comparisons show that there was statistical significant difference at 5% between treatments (CRA and H). The variability was due to the amounts of soil added in each buckets (Figure 4). For CRA and H buckets, the larger the soil filters height or/and area have the slower the flow rate but the better the purification result [9]. The slope of all the six treatments (CRA and H) was negative which indicates there was continuous decrease in filtration rate from day-to-day as the result of clogging the pore sizes of the soil (Figure 2 & 3). The coarse media allows wastewater to pass too quickly through the filter without receiving adequate treatment, while very fine media can slow the water movement too much and increase the chance of clogging. The highest and lowest FR were obtained by A_2 (41.673L/hr) and h_1 (20.76L/hr) respectively. This shows that how the CRA and H affect the filtration rates.

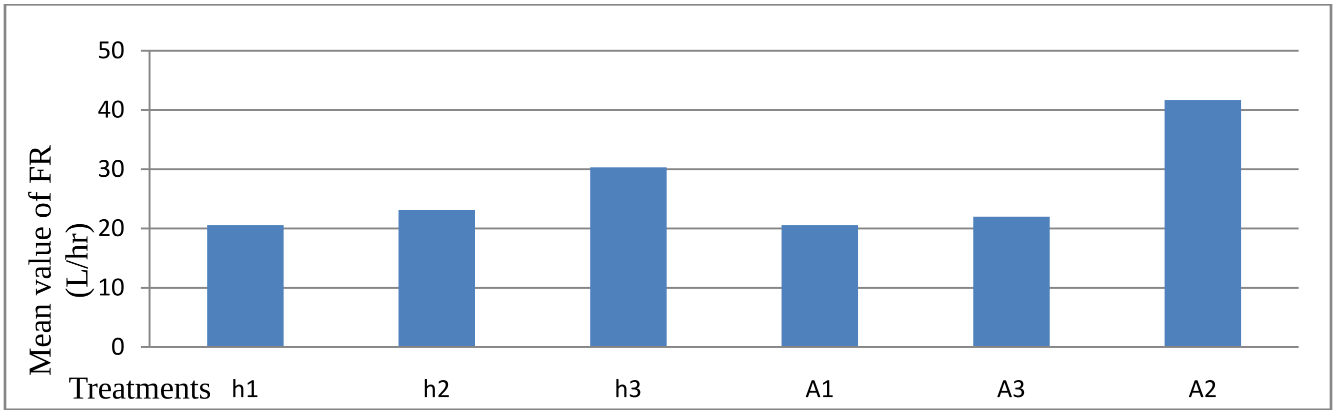


Figure 4: The overall mean flow rates of the CRA and H

pH

The mean pH values obtained from treatments (h_1, h_2 and h_3). The highest and lowest mean values obtained by h_1 and h_3 were 5.95 and 5.20 respectively. This difference in pH was due to the difference in hydrogen ion concentration available within the soil which reacted with ions of the incoming wastewater during filtration. The mean comparison shows that there was no statistical significant different between h_1 and h_2 (α=0.075) but h_3 has statistical significant difference at 5% with h_1 and h_2. Similarly, for the three CRA buckets, the level of pH was different for each treatment depending on the amount of soil added in each filter bucket. The soil composed of ions that react with ions of wastewater which contributes in reducing the acidity of wastewater during filtration. In other cases, the sewer line itself have its own impact on the wastewater to become more acidic because of its long service age in depositing many organic and inorganic wastes in its track lines and corners which combined when the waste flushed through sewer line. Wastewater Treated by A_1 manifested the maximum pH value which was 5.81 whereas A_2 has (5.10) the least quality of pH level. The mean comparisons indicates, there was no statistical significant difference between A_1 and A_3 (α= 0.228) but A_2 was statistically significant with A_1 and A_3. The overall mean comparison between CRA and H buckets indicates that the highest and lowest values of pH were recorded by h_1 and A_2 respectively. Even though the pH level of filtered wastewater reduced to less acidic; still it is not suitable for domestic use and drinking. Preliminary screened wastewater pH value indicates that the waste was more acidic (pH= 4.995). This acidity was due to the age of drainage line which was served for many years and the effect of source wastewater from which the sample was taken. According to the WHO standards [16], the pH standard for drinking water is 6.5 to 8.5. Usually, pH standard for treated wastewater discharge is between 6 and 9 and can vary easily depending on the discharge content. Thus, the wastewater treated by CRA and H buckets didn`t match the WHO standard of drinking water. But it is suitable for toilet flushing and irrigation purpose by taking other parameters into consideration.

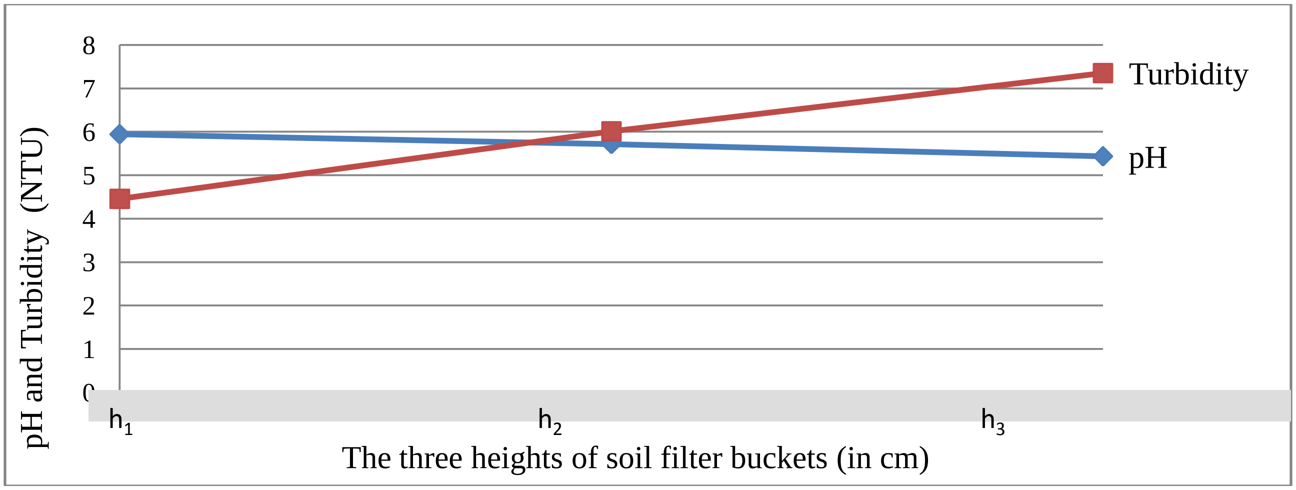


Figure .5. The variability of turbidity and pH for the three H.

Turbidity: The ANOVA table shows that there was statistical significant difference at 5% in turbidity between mean values of wastewater treated by filter soil height (h_1, $h_2$and h_3) buckets. This indicates that the wastewater filtered by different soil filter heights have different capacity to remove suspended solids depending on the amount of soil added in each buckets. When the wastewater moved longer distance through filter soil, more suspended solids were removed and the effluents became less turbid. Turbidity is an indication of suspended solids in the wastewater, wastewater filtered by h_1 gave lowest turbidity level which was 4.47NTU where as h_3 gave the highest turbidity level, 7.36NTU. The wastewater which was treated by soil reduces the level of turbidity by adsorbing/blocking those suspended particles from passing through because of the small soil pore sizes. But the wastewater filtered by h_3 shown least activity in reducing the level of turbidity during filtration due to the small amount of soil added on the filter bucket and highest discharge rate as compared to h_1 and h_2. As reported by [15], high turbidity level usually correlates significantly with microbial load, may support the growth of pathogens and increases chances of infection. Since turbidity is a measure of the cloudiness of water, it indicates water quality and filtration effectiveness [15].

Similarly, the wastewater filtered by CRA buckets show statistical significant difference between A_1, A_2, and A_3. The one with larger CRA reduced the level of turbidity by detaining the contaminants (suspended solids) in a better way than the smaller CRA bucket. But of the three treatments, the highest and lowest values turbidity were obtained for A_2= 7.74NTUand A_1= 4.82NTU respectively. The overall ANOVA show that there was statistical significant difference between CRA and H. The turbidity values in this study failed to comply with the target water quality limit of 0 to 5NTU of no risk for domestic water uses by [17], implying that the wastewater under study was not suitable for domestic uses with reference to turbidity except the wastewater filtered by h_1 and A_1, which were 4.46NTU and 4.82NTUrespectively. As shown in Figure (5 and 6), there was variability in turbidity and pH for each treatment but maximum turbidity and minimum pH was observed by preliminary wastewater where as the reservoir water fulfill the WHO standard of drinking water [17]. The preliminary wastewater consists of different contaminants that were contributing it to become more turbid and acidic as compared to primary filtered effluent. For a long term usage, the quality of primary filtered effluent decreases in its clearness because of closing the soil pore size by suspended solids.

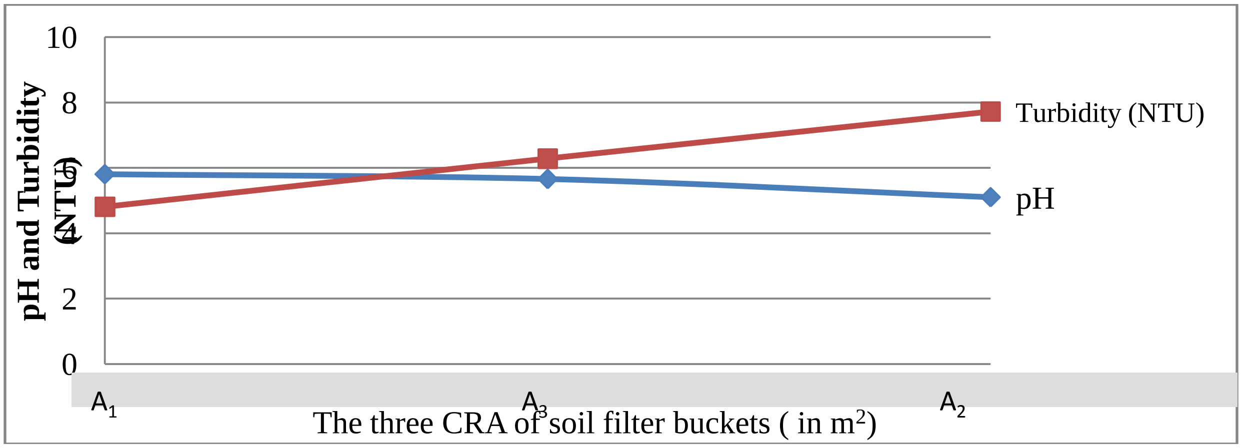


Figure .5. The variability of turbidity and pH for the three CRA.

Electrical Conductivity (EC)

Wastewater filtered by$h_1$had the lowest EC (1492μS/cm) where as the wastewater filtered by h_3 had the highest EC (1661.67μS/cm). This implies, increasing soil height have an effect in reducing the ion concentration of primary filtered wastewater. The more the soil filters height the more the ion concentration available in it. The wastewater composed of different organic and inorganic wastes in solution with water such as: calcium, magnesium, potassium and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides and sulfates, which are all anions that give water its ability to conduct electricity. As reported by [2], the changes in EC of water sample signal changes in mineral composition of water and pollution of water. Similarly, the mean comparison for the three CRA buckets indicate that the wastewater filtered by A_2 gave the highest EC (1729.62μS/cm) whereas the wastewater filtered by A_1 and A_3 gave the least EC (1525.143μS/cm and 1565.10μS/cm respectively). The season A_1 and A_3 have nearly the same value that their difference in their CRA (almost equal amount of soil was added to both buckets). Since EC is an indication of ion concentration (dissolved solids) in the wastewater, the higher the dissolved solids concentration in the wastewater, the greater the EC value will it be. Thus, the larger the CRA bucket contains the higher ions that neutralize, reduces the EC level, the ions in the wastewater during filtration. The TDS and the EC are in a close connection. The more salts are dissolved in the water; the higher is the value of the EC. The majority of solids, which remain in the water after soil filter, are dissolved ions. Sodium chloride for example is found in water as sodium ion and chlorine ion. High purity water contains only H_2O without salts or minerals has a very low EC as reported by [2].The overall ANOVA for the EC of CRA and H buckets indicates as there was statistical significant difference at 5% between them. The variability of EC mean value was dependent on the efficiency of filter soil CRA and H (Figure 7 and 8). EC is used to estimate the amount of TDS rather than measuring each dissolved constituent separately. The values which were obtained from all treatments are in acceptable range for the water irrigation purpose. As recommended by [12], irrigation water having an EC value less than 1.5dS/m is considered to be safe for crops [4].

Total Solids (TS):

Total solids in water generally found in the form of (TSS) and (TDS), a portion that passes through a filter of 2μm or smaller pore sizes [13]. TS of the three H buckets (h_1,h_2,andh_3) were compared and the highest and lowest average values of TS were obtained fromh_3 andh_1, 1427mg/L and 1125.24mg/L respectively. This result shows that the soil filter pores trapped the incoming total solids from wastewater during filtration because the preliminary wastewater TS level was observed to be 2014.3mg/L. The wastewater consists of both suspended and dissolved particles that affect the filter media by blocking and reducing the efficiency of filtration and also enables pathogenic organisms to grow. The higher the soil filters height, the more total solids it removed by its pore sizes. Similarly, the ANOVA table shows that there was significant statistical difference at 5% in total solids between the three CRA buckets (A_1, $A_2$and A_3). The highest and lowest values were obtained from A_2 and A_1, 1745mg/L and 1157mg/L, respectively (Appendix table 6). This difference in TS was because of the removal ability of soil filters added to each bucket (i.e. the larger the CRA of soil filters the more the total solids it removed). Soil is the best media for removal of suspended solids but less efficient in removing dissolved solids. The overall mean comparison shows wastewater treated by A_2 and h_1 gave the highest and lowest TS values1125.238mg/L and 1745.7mg/L respectively. Less TS value implies the better physical quality that the water has and less turbid (Figure 6).

Total Suspended Solids (TSS)

The wastewater treated by the three soil filter heights (h_1, h_2, and h_3) show statistical mean difference with the highest and lowest average value of TSS were recorded by h_3 (481.7mg/L) and h_1 (354.3mg/L), respectively. High concentration of suspended solids (particles floating in the water) can block the filter media pores and results in clogging. As H increased, less concentration of TSS was obtained from the outflow (filtered wastewater). The soil pore size also determined the amount of TSS after filtration since soil is effective in removal of TSS which was reported by [6]. High TSS block sun light from reaching the underwater sea grasses that baby organisms use for protection and also raise water temperature by absorbing solar radiation which reduces the dissolved oxygen.TSS is a good indicator of turbidity in the water that makes the color blurred. For the CRA buckets, the highest and lowest mean values were obtained from A_2 and A_1, 510mg/L and 355.72mg/L respectively. From the three CRA: A_2, the smallest, which made it to have highest flow rate that contributed suspended solids to pass through soil filter pores. Separation of suspended solids from dissolved solids might be affected by the type of filter holder; the porosity, area, and thickness of the filter; and the physical nature, particle size, and amount of material deposited on the filter.

Total Dissolved Solids (TDS)

The ANOVA table shows that there was statistical significant difference between the three heights of soil filter. The wastewater filtered by $h_3$and $h_1$had the highest and lowest TDS values of 945.9mg/L and 770.5mg/L respectively. This was due to the availability of soil ions concentration to trap/adsorb dissolved particles during filtration.SCL reduced the concentration of wastewater`s dissolved solids, which means the smaller pore sized soil contains clay particles with high concentration of ions that served as reaction sites during filtration. According to [17], TDS is made up of inorganic salts, as well as a small amount of organic matter, the ions in the soil react with the ions in the wastewater such as potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium that contribute to the dissolved solids in the wastewater.

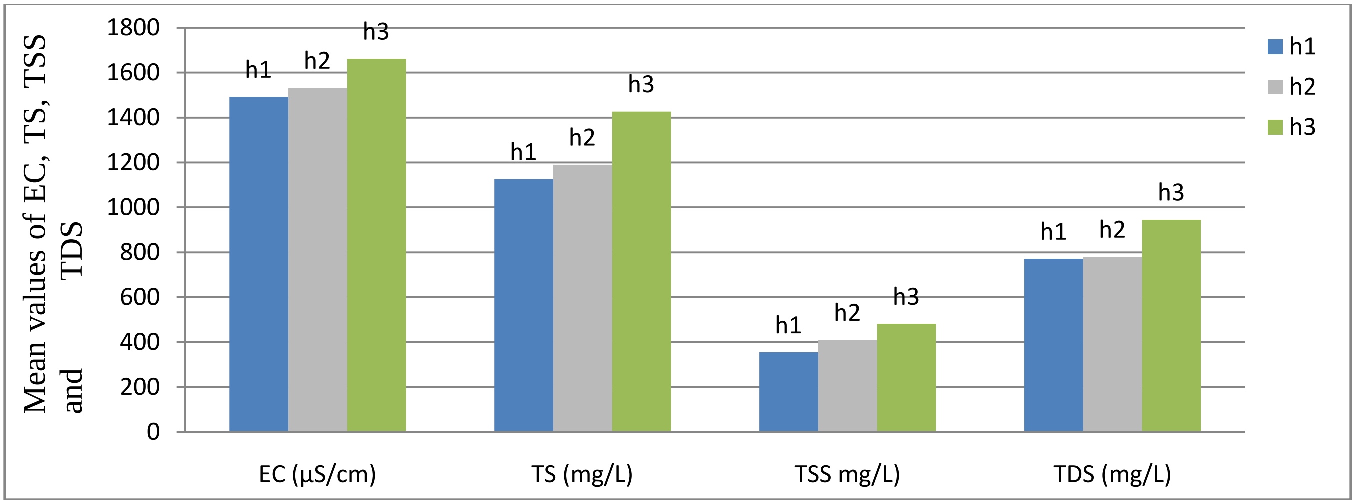


Figure .6. The mean value of EC, TS, TSS and TDS for the three H.

Similarly, Appendix table 9 shows that for the three CRA buckets, the highest value was recorded by A_2 (1235.7mg/L) and the lowest value was obtained from A_1 (801.4mg/L). When the amount of soil added in the filter bucket increased, the quality of filtered wastewater increased that means TDS value decreased (Figure8). This implies that the concentration of ion in the soil had a potential to be combined with ions of incoming wastewater during filtration to reduce the effluent dissolved solids concentration.

As shown in the Appendix table 6, the mean value of all the treatments was shown significant difference between the CRA and H. From the combination, the highest value was recorded by A_2 (1235.7mg/L) and the lowest value was recorded by h_1 (770.953mg/L). TDS is the amount of mineral and salt impurities in the water which tells how many units of impurities are there in the solution; all the solids that cannot be filtered out of the water and which is an important parameter for drinking water because high TDS values may result in a salty taste to the water.

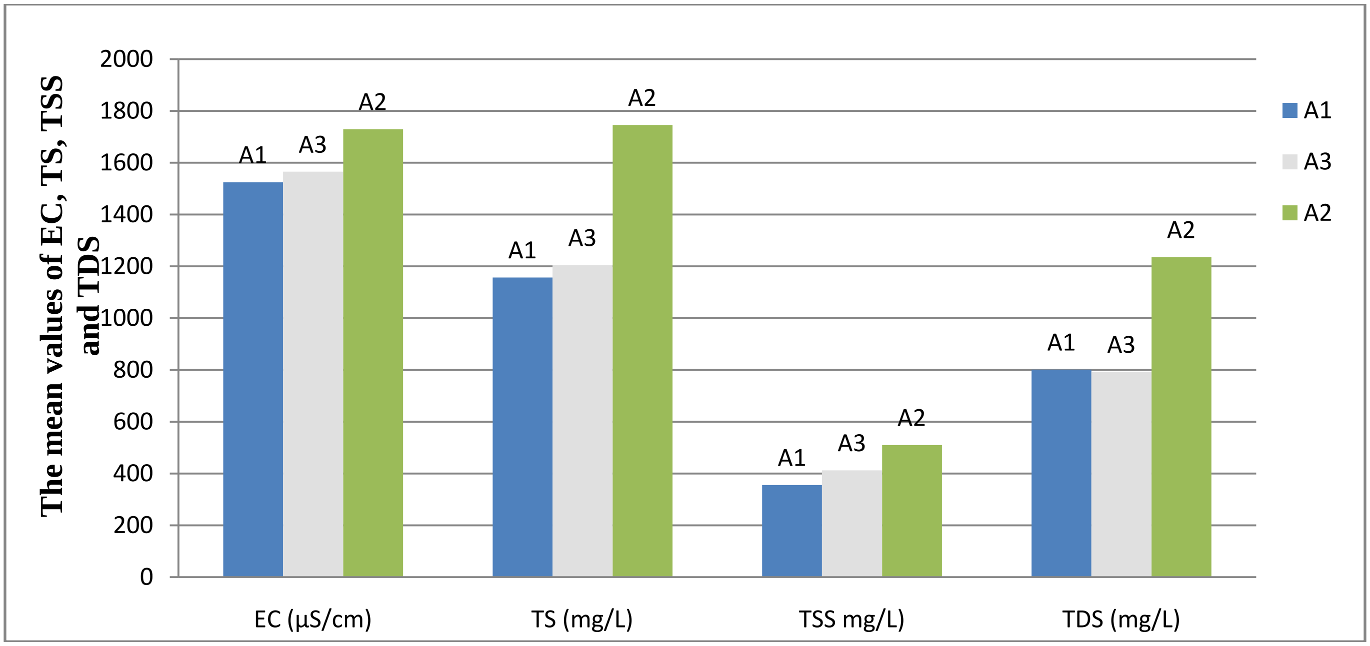
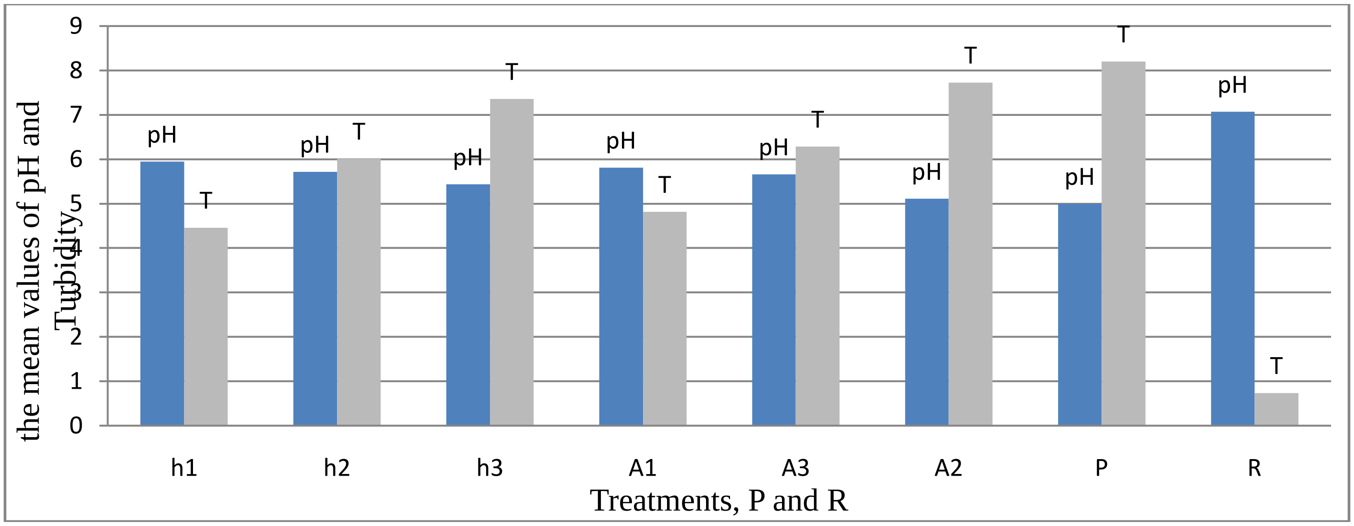


Figure.7. The mean value of EC, TS, TSS and TDS for the three CRA.

Mean Comparisons between P and R with Primary Filtered Effluents

The wastewater treated by CRA and H shown statistical significant difference at 5% between preliminary wastewater and reservoir water in all physical water quality parameters except A_2 which was not showing statistical significant difference between preliminary wastewater for some parameters like: turbidity(α= 0.42), pH (α= 0.229) and TDS (α= 0.975). This was due to the type of wastewater which consisting of more contaminants in the form of suspended and dissolved solids that made the preliminary wastewater more acidic, turbid and electrically not neutral (Figure 9). The wastewater filtered by A_2 was also more acidic and turbid as compared to other treatment buckets. This was because; the amount of soil added in the bucket was small because of its small CRA and the highest FR made the effluent more turbid than the other treatments and less effective in purification (Figure 9). Wastewater filtered by h_1 shown better result in all physical water quality parameters among the others due to the amount of soil available in it and slow FR. The Primary filtered wastewaters do not fulfill the WHO standard of drinking water in all physical water quality parameters but some treatments fulfill the primary discharge standard.



T=turbidity, P=preliminary and R= reservoir

Figure .8. The mean of pH and turbidity for each treatment (CRA and H), P and R.

Additionally, the soil type used for filtration purpose have an effect on the quality of primary filtrated effluent since the SCL consists of high amount of ions that react with ions of wastewater to decrease the concentration, which means the smaller pore sized soil contain clay particles which serve as reaction sites, and also the small pore sizes of the filter soil adsorb/block the passage of contaminants during filtration. The effectiveness of filtration varies with the water residence time (i.e., the length of time the water stays in the soil); longer retention times accelerate the remove of more contaminants. Thus, increasing the CRA and H are effective way of removing suspended solids from wastewater as reported by [9]. When primary filtered effluent from CRA and H compared with WHO physical water quality standard, some parameters meets the standard but others need additional steps to be treated.

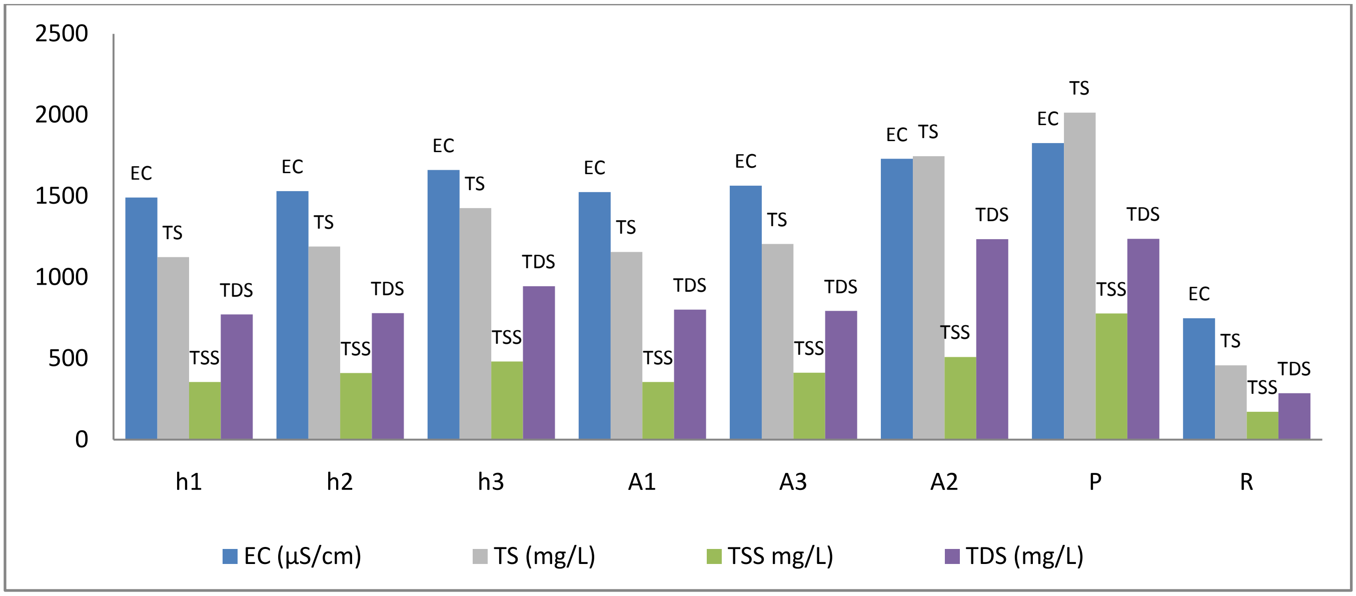


Figure. 9. The mean of EC, TS, TSS and TDS for each treatment (CRA and H), P and R.

IV. CONCLUSION AND RECOMMENDATIONS

Conclusions

From overall results, the wastewater filtered by soil of different CRA and H shown statistical significant difference between preliminary wastewater and reservoir water the wastewater filtered by h_1 and A_1 gave the better result in terms of all basic physical water quality parameter but the least in terms of FR whereas h_3 and A_2 gave the FR rate but the least physical water quality. The extent of filtration quality and quantity was directly dependent on the amount of soil added to each filter buckets. Thus, increasing or decreasing filter soil height and/or cross-sectional area has an effect on physical water quality and flow rates on primary filtration for the wastewater released from same source at constant rates. The more the soil added, the better it will be the effluent water quality since the soil itself is serving as a reaction site to minimize foreign contaminants.

Recommendations

Wastewater treatment by soil filter has great advantage in reducing unwanted entities and contaminants during filtration before discharging to the water body (environment) or reusing it for different purposes. The result obtained from this study depicts that wastewater treated by larger cross-sectional area buckets and higher heights of soil filter have better purification ability of contaminants but they have low FR. The one which were treated by smaller cross-sectional area filter buckets and height of soil filter results better flow rates but least physical water quality. Therefore, depending on the type of wastewater released and the purpose for which the treated water it to be used, higher height of soil and larger cross-sectional area gives effective result in removal of wastewater contaminants. But it is not recommended to use primary treated wastewater for domestic use and drinking purpose unless some other treatment steps have been made. If the wastewater does not contain hazardous chemicals, it is possible to use it for irrigation and toilet flushing purpose after primary treatment. Finally, based on this finding, further research has to be done on biological contaminant removal efficiency of cross-sectional area and height of soil filter.

V. ACKNOWLEDGEMENT

The authors would like to thank all those who involved for the success of this work.

VI. REFERENCES

[1].Abdurahaman Kebede. 2014. Physical characterization of wastewater from HaramayaUniversity. Master`s Thesis, Haramaya Unversity, Ethiopia.

[2]. AWWA (American Water Works Association). 2000. Standard Methods for the Determination of Water and Wastewater. AWWA, Washington DC, USA.

[3].Blanco, CanquiH., Clark, Ganzer, Alberts and Ghidey. 2002. Saturated hydraulic conductivity and its impact on simulated runoff for clay pan soils.Soil Science of American Journal.66:1596.

[4].FAO (Food and Agriculture Organization of the United Nations). 1996. Water Quality for Agriculture, Irrigation and Drainage 1(29) FAO, Rome.

[5].Fetter, C. W. 2001. Applied Hydrogeology, 4th Edition. Prentice–Hall, Upper Saddle River. N.J. Geary, P.M. and Moore. 1999. Suitability of a treatment wetland for dairy wastewaters. Water Science and Technique. 40 (3):179-185.

[6].Henze, H., La Cour, J., Arvin.1998.Wastewater treatment. Prentice Hall of India, USA.

[7].Hillel,D. 2004. Introduction to Environmental Soil Physics. Elsevier Press, USA.

[8]. Hussein, Y. 2013. Onsite wastewater treatment for semi urban areas: Abasan case study. Master`s Thesis of Science in Civil Engineering/Infrastructure. The Islamic University, Gaza.

[9].Isikwue, M.O., S.B., Onoja, and AndrewF., Onyilo. 2011. Effect of Different Vadose Zone Depths on the Purification Process of an Aggregate Laden Soil Infiltration System.Pacific Journal of Science and Technology. 12(2): 479-487.

[10].Junge, T., Gräsle, W., Bensel, G. & Horn, R., 2000. Effect of pore water pressure on tensile strength.Z. Pflanzenernährung und Bodenkunde, 163, Pp 21 – 27

[11].Mebratu Meselge, Gelana Amente and Tesfahun Kebede. 2012. Physical Characteristics of Water Used by Haramaya University and the Effects of Heating and Cooling on the Amount of Extracted Solids. Master's Thesis, Haramaya University, Ethiopia.

[12].Santhi, R.,Natesan, Bhaskaran, A.,Murugappan. 2003. Procedures for Soil Testing and Water Quality Appraisal. Department of Soil Science and Agricultural Chemistry. Coimbatore, India.

[13].Sawyer, C.N., McCarty, P.L. and Parkin, G.F.2003. Chemistry for Environmental Engineering and Science.5th Edition. Tata McGraw Hill, New Delhi, India.

[14].SeifemichaelAbebe, Jema Haji and MengistuKetema, 2014. Impact of Disappearance of Lake Haramaya on the Livelihood of the Surrounding Community: The Case of Haramaya District in Oromia National Regional State, Ethiopia.Journal of Economics and Sustainable Development. Haramaya University, Ethiopia.

[15].USEPA (United States Environmental Protection Agency). 2005. Office of Water: Volunteer Stream Monitoring:A Methods Manual. Washington DC, USA.

[16].WHO (World Health Organization).1993. Guidelines for Drinking Water Quality, V-1: Recommendations, 2ndEdition. WHO,Geneva.

[17].WHO (World Health Organization).2004. Water, Sanitation and Hygiene Links to Health Facts and Figures. WHO, Geneva.