International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

Effectiveness of Sewage Treatment System and its Irrigation Potential: the Case of Main Campus of Hawassa University, Ethiopia

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Abstract **- This research evaluated the performance of sewage water treatment system and also assessed its suitability for irrigation. Salient water quality parameters were determined at different stages of the treatment process and compared with the standard. The treatment unit comprised of anaerobic, facultative and maturation ponds in two series. Sampling were done in different time periods from 2014-2016. The university main campus produced an average of 320m^3 of wastewater per day. The effluents of the treatment system are discharged to nearby land whenever there is overflow from the system. After treatment BOD, COD and SS were reduced by 76, 45 and 53 percent respectively. Treatment performance has been on increasing trend since 2014. Water quality analysis revealed that the treated wastewater is slightly alkaline in nature. Percentage treatment efficiency of the pond for BOD, sulfide, Total Suspended solids, COD, Nitrate, Nitrite and Total Nitrogen were satisfactory. However, the effluent TSS concentration was higher than standard set by the EPA standards for treated effluents. In present conditions, the treated water can be used for irrigation purpose with some moderate restrictions. Even though EC and TDS permit to irrigate fruit trees and fodder crops, there is a risk of soil degradation due to high value of SAR. In such cases high efficiency irrigation systems are recommended rather than flood irrigation. Also, irrigation with treated waste water increased nutritive elements in soil that can be source of nutrition for plants. Continuous use of treated sewage water for irrigation will make the soil acidic. Analysis of other soil parameters indicates that there is an increase in nitrogen, phosphate and potassium nutrient levels considerably to benefit crop production but increase in soil EC is a serious concern.**

Key words: Sewage water, Treatment efficiency, Irrigation, Soil properties.

I INTRODUCTION

Wastewater irrigation is substantially a growing worldwide practice. Globally, around 20 million hectares of land are irrigated with wastewater and this figure is likely to increase during the next few decades. Wastewater irrigation has been practiced with several drivers. One, in water scarce areas (arid and semi-arid climate zones) the limited water source have insignificant contribution to support agricultural production, thus the direct or indirect use of wastewater is one way of sustaining agricultural production. Two, cities of low and middle income countries with rapid urban expansion produce a large volume of wastewater and this attracts farmers to enhance their agricultural practice with irrigated agriculture. Moreover, the rapid population growth results in market demand rise for vegetables which cannot be transported longer distance and encourages farmers near cities to grow vegetables. Three, the direct use of wastewater in some cases is driven by its ready availability compared with the huge cost needed to construct irrigation structures. Four, availability of plant essential nutrients from the biodegradable constituents of wastewater attracts farmers to use it for agriculture. In that sense, it enables farmers to reduce the expenditures on fertilizer and better production can be achieved. In some cases up to 37% increase in harvest is possible when raw wastewater is applied compared to freshwater irrigation with chemical fertilizer (Martijn and Redwood, 2005). The value of wastewater for crop irrigation has also been recognized in India, China and lately, the Middle East (Pescod and Alka 1988). In Egypt, acute shortage of water necessitates the development of new water sources. The supplies of sewage water effluent progressively increase with increasing the population. At present, land application of wastewater is considered to be the best solution for disposal problems. It is a low-cost method for the disposal of wastewater; land application permits the reclamation and reuse of valuable resources such as water and nutrients from sewage (Abdel Ghaffar et al. 1985, Wang 1984).

Despite its positive contribution to stimulate agricultural production, unwise use of wastewater for irrigation has associated adverse impacts on environment public and animal health. Wastewater mostly comprised of organic matters, nutrients, heavy metals, pathogens and other miscellaneous constituents. The direct discharge of wastewater into nearby streams without pre-treatment will modify the natural water constituents. When the mixed water is used for irrigated agriculture, the wastewater constituents flowing to the field interferes beneficially or harmfully to the crop, environment public and animal health. When the concentration of harmful water constituents goes beyond the acceptable level, it has associated adverse effect on the crop, growing environment, public and animal health.

Pond systems are commonly employed for municipal sewage purification, especially in developing countries, due to its cost effectiveness and high potential of removing different pollutants. Oxidation ponds are designed to achieve different forms of treatment up to three stages in series, depending on the organic strength of the input waste and effluent quality objectives. Usually, classical oxidation ponds consist of an anaerobic pond, followed by primary or

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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secondary facultative ponds. The aim of this study is to evaluate the performance of Waste water treatment system in the main campus of Hawssa University and to determine its potential for irrigation.

Sewage water from Hawassa University is disposed in a nonproductive manner. This results in drainage problems and environmental degradation particularly during rainy season. Water logging condition occurs in the surrounding low lands during rainy season due to continuous recharge of ground water from the oxidation ponds. On the other hand, if this water is diverted for irrigation, the nearby hill side lands can be cultivated under rain fed condition. During dry spells, supplemental irrigation is must for annual crops like banana/sugarcane to boost yield and coping uncertainty of rainfall due to climate change. After construction of the oxidation ponds, performance evaluation of the treatment system has not been carried out to verify whether the pollutant levels are within the permissible limits of EPA or not and improve its operation. At present the treated water from the system is disposed to underground by seepage and percolation. To make use of this water for irrigation purpose, it is necessary to study its quality parameters and suitability for irrigation. This research deals with how best the pollutants are treated and the unutilized resource of sewage water can be utilized productively for suitable irrigation methods thereby enhancing water productivity and avoiding environmental degradation.

The main objective of the study is to study the performance of oxidation ponds in reducing the pollutants of sewage water and its suitability for irrigation. The specific objectives of this study are to evaluate the operational performance of oxidation ponds with respect to selected quality parameters, to estimate irrigation potential of treated waste water, to analyze suitability of treated sewage water for irrigation and its impact on soil parameters.

II MATERIALS AND METHODS

2.1 Description of the Study Area

Hawassa town is the capital of the Southern Nations, Nationalities and People Region (SNNPR) Hawassa City Administration and Sidama zone. It is located at a distance of 273 km South of Addis Ababa. The geographic coordinates of the town are approximately 7º 03' latitude North and 38º 29' longitudes East. Sewage water from the student's hostel buildings in the main campus is first diverted to septic tanks to remove the solids and then diverted to stabilization pond and a series of oxidation and polishing ponds. There is a possibility for utilizing the treated sewage water for irrigation purpose in the nearby hill side lands. Based on physical observation, soils on adjacent hillside land is generally sandy loam with low humus and are more permeable. They dry fast even after a heavy rain. The cultivated crops are maize, onion, tomato, potato and sugarcane under rainfed and irrigated conditions.

2.2 Climate and topography

Hawassa has warm temperature which varies between 10ºC in winter and 30ºC in summer. The mean annual precipitation is 958mm. Hawassa is situated at the Eastern shore of Lake Hawassa close to the eastern fault belt of the central part of the Main Ethiopian Rift Valley in a large volcano-tectonic collapse. It lies on the plain between Lake Hawassa and Chelelaka wetland with general slope towards Lake Hawassa. The average elevation at is 1700m and that of the lake surface is 1680m. Rain is more intensive during the four rainy months of June to September such that more than 80% of the rain falls during this period. The university farm land is formed of gentle and undulating hills, surrounding by ranges of hills with different altitudes.

2.3 Sewage Treatment system – Oxidation ponds

The daily time schedule in the student's hostel for water usage causes wide fluctuations in effluent volume and strength. To maximize treatment plant efficiency it is necessary to operate it at constant flow rates with relatively consistent untreated wastewater composition. To achieve this objective a balance or equalization tank is essential, the size being governed by local operating conditions and the necessity of accommodating peak flows.

Ponds and tanks are one of storage options and combinations that can be considered for managing increasing water resources variability (McCartney and Smakhtin 2010). From the student's hostel buildings which accommodate more than 5,000 students, average sewage discharge of 5.8 to 8.1 (500 to 700m^3/d) litres per second is estimated (Directorate of constructions, HU). This water is collected by many septic tanks constructed as part of primary anaerobic treatment removing macro particles. The effluent from these septic tanks is collected and delivered to sewage treatment plant (STP) located at a distance of around 1km. The STP (Fig 1) comprises of a series of lined earthen tanks of different capacities starting from equalization pond followed by oxidation and polishing ponds. The sewage water is treated both by physical and biological treatment to reduce the suspended solids and Biochemical oxygen demand to the acceptable levels. The treated effluent is then delivered to irrigate the low lying agriculture lands. Since all the rainwater from the surrounding high lands accumulates in the low lands thus making them water logging causing nuisance and environmental pollution and affecting the crop yield particularly during rainy season.

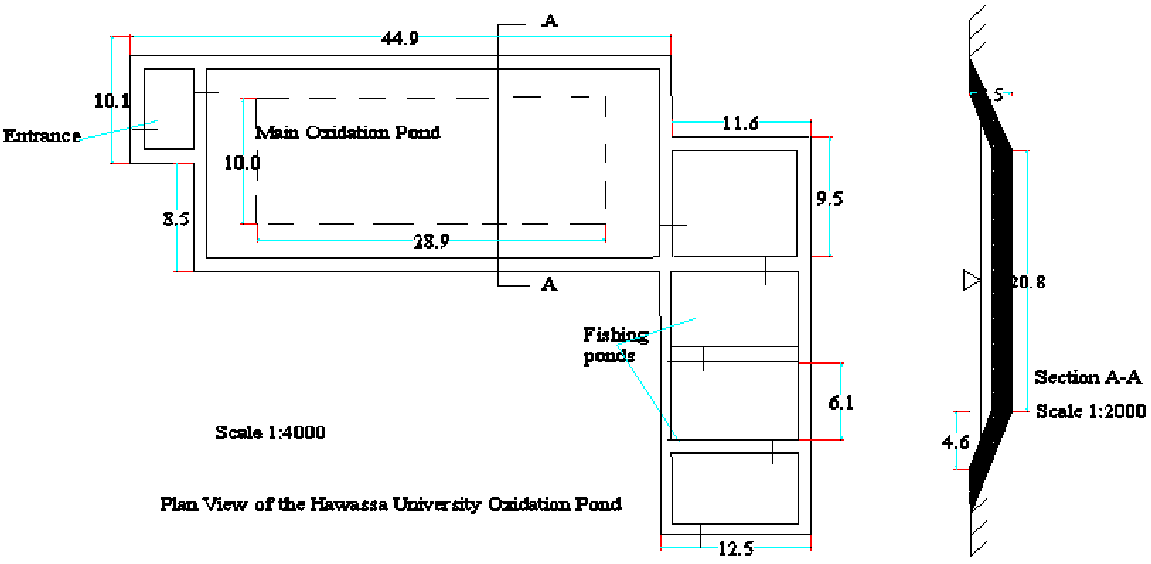

Fig 1 Layout of treatment system

2.4 Crop Water Requirements

To estimate the crop water requirements and irrigation water requirement of selected crop CROPWAT software for windows was used. The input climate parameters Rainfall, temperature, humidity, solar radiation, wind velocity and pan evaporation data obtained from Meteorological station of Hawassa were used for the research.

2.5 Work plan

The project was planned and divided into following work elements:

Work element 1: Monitoring of WWTP and its performance evaluation

Samples were collected from waste water treatment plant at different sampling points of the system and characterize for parameters BOD5, COD, SS, TDS, Sulfide, NH3, Nitrite, Nitrate, Chloride, Total Nitrogen and Electrical conductivity etc.

Work element 2: To estimate the crop water & irrigation demand of selected crop and suitability of treated sewage water for irrigation.

Climate data was analyzed to estimate the peak crop water demand of sugarcane plant and observations were also made on soil quality parameters to find the impact using treated sewage water if used for irrigation on soil parameters. Treated sewage water quality has been compared with standard water quality requirements for irrigation.

2.6 Water Sampling and analysis

Grab water samples were collected from STP and monitored for three years during peak functioning month of the university. Six sets of samples comprising of Raw effluent [P-1] Equalization pond [P- 2] Oxidation pond [P- 3] Polishing pond 1 [P- 4] Polishing pond 2 [P- 5] Treated Effluent [P- 6] were collected and analyzed for the water quality parameters. Samples for BOD, COD, Nitrogen, Phosphorus, Chlorides and Solids etc were analyzed in accordance with the procedure laid down in Standard Methods for the Examination of Water and Wastewater (APHA 2005). Total Suspended Solid (TSS) and Total Dissolved Solid (TDS) were determined by gravimetric method (dried at 103degree C). Biological Oxygen Demand (BOD) was determined by the 5 Day BOD test while Chemical Oxygen demand (COD) was determined in the laboratory by the standard Open Reflux Method. Other tests such as Conductivity (EC) and pH were directly measured in situ using portable measuring devices (HANNA instruments, HI 9811, portable pH-EC-TDS METER, Italy). Note that before each measurement, the pH meter was calibrated with reference buffer solution. Each analysis was carried out in triplicate and then the mean value was taken.

Samples were analyzed to determine the concentration of selected elements in the pond effluent so as to compare with recommended limits and to determine the overall efficiency of the whole treatment system. Treatment efficiency was calculated from reduction of concentration to initial concentration and expressed in percentage. All samples were collected and transported within ice box and analyzed within 6 hours of collection for chemical examinations. Soil samples from sewage disposal land and nearby cultivated land were also analyzed. Soil sample were taken at 30 to 60 cm depth in three different locations. Totally six samples were collected and tested for Na^{++}, K^{+}, SAR, pH, EC, TOC, available phosphorous and Total nitrogen. Organic carbon was determined using the Walkley-Black method. Phosphorus (P) content determination was done using the colorimeter method using sodium hydrogen carbonate extract (Adepetu et al, 2000). Exchangeable bases were extracted by the ammonium acetate extraction technique and determined by flame photometry (Adepetu et al, 2000). The total nitrogen was determined using Kjeldal method while pH was determined using 1:2.5 $CaCl_2$ dilution method (Adepetu et al, 2000)

International Journal of Engineering Research & Technology (IJERT)
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2.7 Sewage flow measurement

Sewage flow was measured on daily basis during three weeks of the study period. Flow was measured by volumetric method in the manhole of the incoming sewage flow pipe system as shown in the figure 2 below.

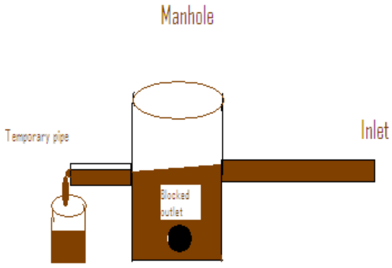

Fig 2 Sewage flow measurement

III RESULTS AND DISCUSSION

3.1 Sewage flow and retention time

Sewage flow from the university main campus shows hourly and daily variation. Since most water consumption occurred in the weekends, maximum flow rate of 43cubic metre per hour was observed on Saturday morning hours and in the afternoon reduced to 16 cubic metre per hour. Except Tuesday, in all the remaining days flow of around 7cubic metre per hour was observed. Effluent flow rate depends on the rate of water supply to the hostel facilities. Weekly average flow of 16.78 cubic metre per hour was observed. In the current situation, water supply is unpredictable on daily basis and so the weekly average is considered for pollutant load estimation since it is more appropriate for estimation purpose according to the experience of maintenance department of the university. Based on average flow rate and pond volume, retention time of water in each pond is derived as in the table.

Water retention time influences the natural purification processes like sedimentation, oxidation and reduction process. Providing sufficient retention time facilitates good treatment efficiency in removing suspended solids and reducing BOD. Since major portion of the treatment occurs in the facultative pond, it has a long retention time of 87 hours to handle the incoming pollutants followed by maturation and fish ponds with average retention time of 10 hours.

Anaerobic, facultative and maturation ponds are the three major types of pond in a sewage treatment pond (STP) system. These ponds are normally arranged in series to achieve effective treatment of raw wastewater (Marais, 1974). Anaerobic and facultative ponds are employed for BOD removal, while maturation ponds remove excreted pathogens. A series of anaerobic and facultative ponds can treat wastewater to a sufficient degree to allow it to be used in a restricted way for irrigating crops. It has been argued that such pond systems remove nematode eggs significantly by sedimentation (WHO, 1989). Maturation ponds are normally used if the treated wastewater is to be used for unrestricted crop irrigation complying with WHO guidelines of less than 1000 faecal coliforms (FC) per 100 ml (WHO, 1989). Maturation ponds have also been used when stronger wastewaters with high concentrations of nutrients (nitrogen, phosphorus) are to be treated prior to surface discharge (Mara, 1997) inferring that the treated water has scope for irrigation.

TABLE 1 POND DETAILS AND WATER RETENTION TIME

Treatment Series	Pond Type	Average surface area, m^2	Depth, m	Volume, m^3	Retention Time, Days (Av flow rate $16.78m^3/hr$)
Treatment system	Anaerobic pond	31.5	2.5	78.75	0.196 (4.69 hrs)
	Faculative pond	490.1	3	1470.3	3.65 (87.6 hrs)
	Maturation pond	78	3	234	0.58 (13.95 hrs)
	Fish pond I	61	3	183	0.45 (10.9 hrs)
	Fish pond II	61	3	183	0.45 (10.9 hrs)
	Fish pond III		3	183	0.45 (10.9 hrs)

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Barjenbrach and Erler (2005) reported that, there are several causes for deterioration of the purification performance; such as unsuitable design of the pond; incomplete mixing of aerated pond; type of preliminary treatment; insufficient maintenance and increased organic influent loads. In our study, although, the retention time is sufficient in the ponds, moderate removal of BOD, COD was observed. The poor removal in maturation pond may be due to some defects in the design of the ponds. The entrance of wastewater to different ponds was from one point. It means bad distribution of the wastewater and bad mixing with the microorganisms in the pond. Also, the increase in the detention time more than recommended may lead to the death of algae and then decrease of the efficiency of the ponds. Modifications of the design of the pond by adding some additional points for entrance of wastewater to the ponds to make complete mix in the different ponds are needed.

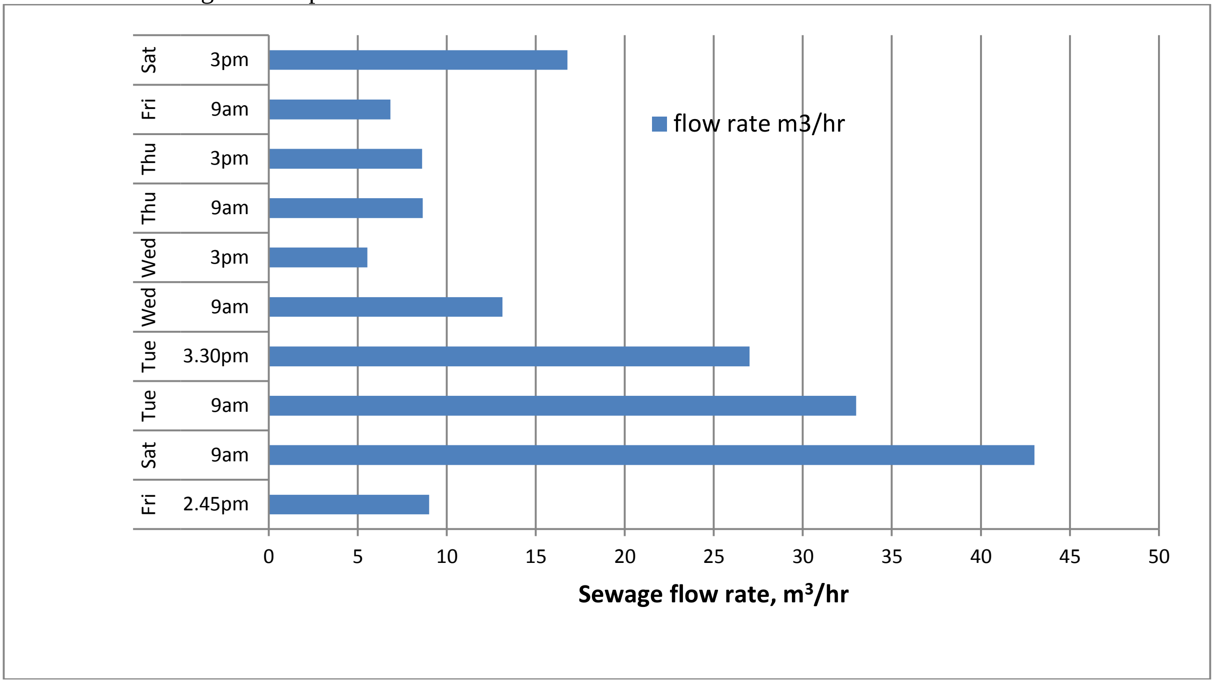

Fig. 3 Sewage flow rate variation

3.2 Raw Sewage water quality

Both BOD and COD are on the increasing trend since 2014 inferring the possibility of higher pollutants due to increasing student population and more usage of laboratories. This leads to more biodegradable wastes resulting higher BOD/COD ratio of 0.74 which results more opportunity to decompose the biodegradable pollutants by oxidizing the organic components of pollutants. Relationship between volumetric BOD loading and pond temperature for designing anaerobic ponds implies that the volumetric BOD loading shall be less than $100g/m^3/day$ to avoid anoxic conditions in the pond. The maximum volumetric BOD loading of $350g/m^3/day$ has been set to avoid the risk of excessive odour in anaerobic ponds (Mara et al. 1997a). For average temperature of 10 degree Celsius, volumetric organic loading rate for the in fluent is 100g/m3/day which is recommended for the design of anaerobic pond. With average observed influent BOD of 200 ppm and inflow of 320m3/day, required anaerobic pond volume is 150 m3 to provide better hydraulic retention time. Maximum expected BOD reduction is 40% as against the actual observed average value of 25% inferring the need to increase the size of anaerobic pond to improve the efficiency.

TABLE 2 RAW WATER BOD AND COD

Period	BOD, ppm	COD, ppm	BOD/COD Ratio
Dec-14	128.0	312.0	0.41
Feb-15	201.3	411.0	0.49
Jan-16	256.0	348	0.74

The biodegradable nature of the sewage water from the university is getting increased as one of the major impact of the growth of the university. This implies the scope for good treatment efficiency of the oxidation ponds.

3.3 Performance evaluation of treatment system

3.3.1 Trend of BOD and COD in treatment ponds

Oxidation ponds are used for removal of pollutants under natural conditions. Theoretically pollutants are expected to be decreased when the influent water passes through a series of treatment ponds. However there is a possibility of increase in the organic load in the treatment ponds if the ponds are not operated with proper cleaning mechanism particularly to remove the floating dead algae. Domestic sewage water normally rich in nutrients and it results in excess growth of microalgae thereby increasing additional oxygen demand both during their growth period and after death. This could be a reason for increased BOD and SS in Oxidation pond and fish ponds even though the influents are with lower BOD and SS. Mahassen et al, (2008) reported that anaerobic effluent indicated a BOD average value of 229 mg L^{-1}, the facultative effluents 180.7 mg L^{-1} and maturation effluents 145.3 mg L^{-1}. The removal efficiencies of this parameter were 22, 21.1 and 19.6% in anaerobic, facultative and maturation effluents respectively. Further they observed mean values of TSS in treatment system were 283.3 mg L^{-1}, 214.3 mg L^{-1}, 176.3 mg L^{-1} and 157.8 mg L^{-1} in influent , anaerobic , facultative , maturation effluents and the reduction of TSS was 24.4, 17.7 and 10.5% in anaerobic, facultative and maturation ponds respectively. This is comparable with the results obtained in sewage treatment system of university.

It is observed that BOD value is lower in December as compared to February 2015 and Jan 2016. This is due to the effect of long rainfall season in September to November and leads to dilution of contaminants and lowers the BOD. The treatment system performed well to reduce the BOD well within the permissible limit prescribed by EPA, Ethiopia. In case of SS and COD, the treatment system reduces the pollutants in oxidation and maturation ponds but allowed to increase by the end of the treatment and exceeds beyond the permissible limits. The main reason for this process is due to continuous stagnation of the influent in all the ponds since most of the time there was no free outflow from the system. Entered water is lost by evaporation and percolation through the leakages slowly. Free out flow occurs rarely only when there is heavy usage of water in the university.

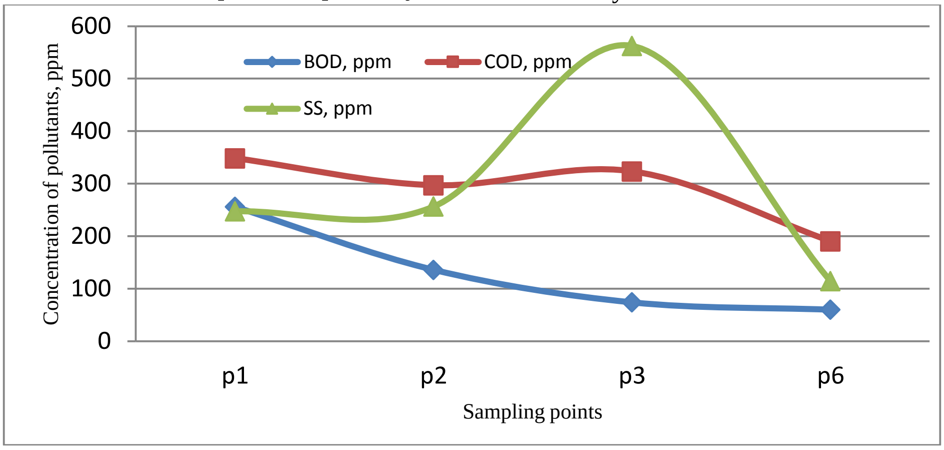

Fig 4 BOD, COD and SS of raw water in Jan 2016

BOD removal in anaerobic ponds depends on various environmental conditions, including the quality of the raw wastewater. If the pH of the raw wastewater is beyond the permissible range of ~6.6 to 7.8, BOD removal by methanogenic bacteria will be reduced significantly. This will consequently increase the influent BOD into the facultative pond.

3.3.2 Pond wise removal percentage

Removal efficiency of 30 to 40 % was observed on BOD and COD in maturation ponds whereas above 50 % removal of SS was observed in fish ponds. In equalization and oxidation ponds negative % removal COD, SS and BOD, SS were observed inferring an increased trend. This indicates there is an increase in pollutants particularly suspended solids in oxidation ponds. Two reasons can explain this increasing trend. First is poor maintenance of both the equalization and oxidation ponds. Particularly for many years the equalization pond is not desludged. Secondly, the floating dead algae was not cleaned in the oxidation pond on daily basis. During the study lot of floating dead algae was observed. Among all the three years of study, during Jan 2016, the removal percentage of BOD, COD and SS were good enough to make the treatment system more efficient despite the increasing pollutant load. Maximum of 80% removal of suspended solids was observed in maturation and fish ponds.

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ISSN: 2278-0181
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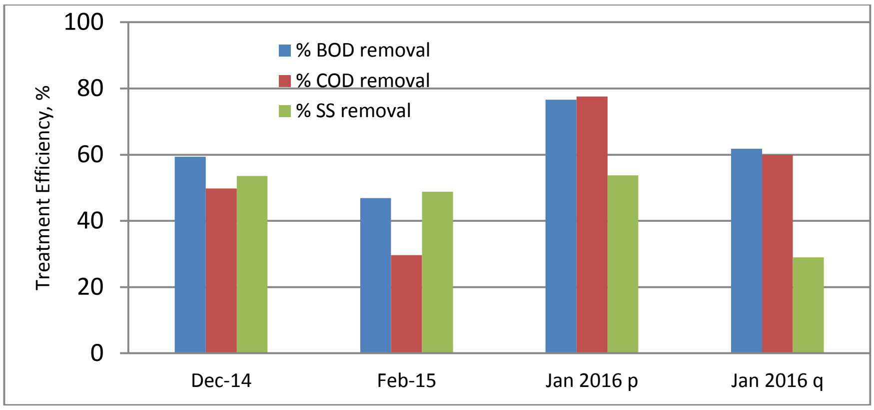

Fig 5 Overall treatment efficiency for BOD, COD and SS

Regarding overall pollutant removal efficiency, maximum of more than 75% was observed for BOD and COD in the first treatment system in 2016 whereas in the second treatment system about 60 % removal efficiency was observed in both BOD and COD. Coming to suspended solids removal efficiency 54% and less than 30 were observed in first and second treatment system respectively in 2016. All the three pollutants removal efficiencies were lower as compared to other years. This indicates that despite higher incoming BOD, COD in the year 2016, removal efficiencies were good due to the proper maintenance of the treatment system. In 2014 and 2015 only one treatment line was under operation but in 2016 both treatment lines were under operation resulting higher treatment efficiency of BOD, COD and SS. The incoming sewage water from the university needs to be diverted optimally to both the treatment lines to increase the performance of the system. Verification of the design of the system reveals that with current flow rate of sewage, capacities of both the systems are sufficient to reduce the pollutants. Still, further scope of improving the treatment efficiency is possible since more than 85% efficiency is reported in Hawassa hospital sewage water treatment system. And that is possible by regular maintenance of the treatment system. BOD and COD of the treated effluent remains well within the permissible standard of EPA whereas suspended solids concentration needs to be contained within the limit and care should be taken to reduce the algal bloom.

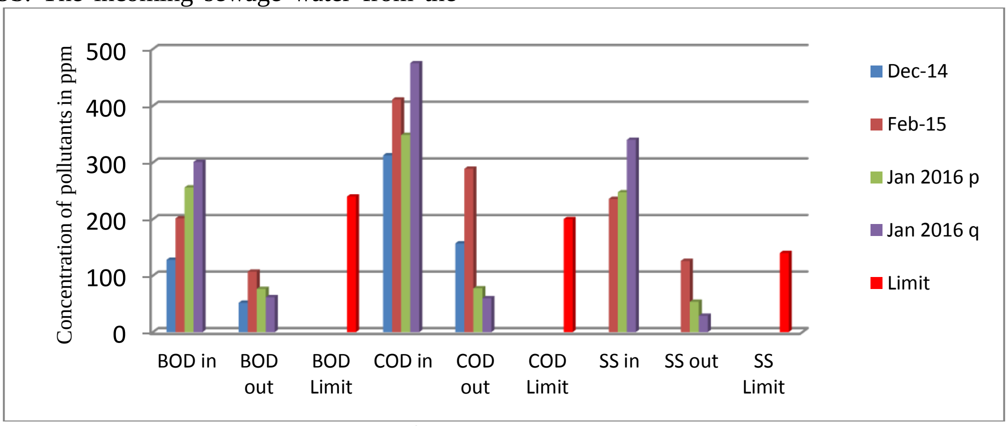

Fig.6 Comparison of BOD, COD and SS with Standard limits

3.3.3 BOD/COD Ratio

For better treatability, the BOD /COD ratio should be greater than 0.5 (Metcalf and Eddy, 2003). The BOD /COD ratio of the wastewater received at treatment pond was 0.74 in 2016 and less than 0.5 was observed in 2014 resulting poor removal efficiency of BOD and COD. This indicates that organic substances with low biodegradability have been in use in the university much more than inorganic materials. Except the chemicals from the laboratories, most of the inorganic materials are removed adopting proper solid waste disposal facilities. Such characteristics of university wastewater showed less resistance toward conventional oxidation.

For better treatability, the BOD /COD ratio should be greater than 0.5 (Metcalf and Eddy, 2003). Most of the values of BOD/COD ratio of treated water in all the three years of study remained around 0.5. This indicates the possibility of further treatability of water in terms of BOD and COD reduction thereby opening a scope of enhancing treatment efficiency of the system. Along the treatment chain of ponds, BOD/COD ratio shows a declining but fluctuating trend. This is mainly due to fluctuation of BOD due to overgrowth of microalgae and floating dead algae.

TABLE 3 PERCENTAGE REDUCTION OF BOD/COD RATIO AT DIFFERENT STUDY PERIODS

Period	Dec-14	Feb-15	Jan 2016 p	Jan 2016 q
% Reduction	27.66	36.2	58.11	42.85

p and q – treatment line 1 and 2 respectively

Due higher removal efficiency observed in 2016, BOD/COD ratio exhibits high reduction percentage between raw and treated sewage water. Year 2014 observes lowest reduction of 27.66% due to poorly treated effluent as reasoned earlier.

3.3.4 Algae and other parameters

Algae count was made in April randomly and found as 0.8 to 1 million cells per ml. More groups of cells were observed and in each group 3 to 7 cells were found indicating clumps of dead cells. This occurs mainly due to effect of ammonia gas present in all the ponds. Algae count data are used to assess the release of oxygen generation and influence on the design review which will be done later. Algae measures are included as an approximation of total phytoplankton abundance and also as an indicator of energy inputs into the system through primary productivity. Algae content in maturation ponds were high but decreased than that in facultative pond as a result of grazing of phytoplankton by zooplankton and also by death of algae. In influent, the algae content was at its minimum because of high content of suspended solids which obscure light responsible for photosynthesis and the zooplankton count was relatively high in this site of stabilization pond. The algae biomass and its productivity cause a marked diurnal and vertical variation in the levels of dissolved oxygen, pH, sulphide and ammonia. It has been observed that when carbon dioxide is taken up faster than bacterial respiration can supply, the concentration of carbon dioxide drops causing a dissociation of the bicarbonate ion to form carbon dioxide and alkaline hydroxyl (Mara and Pearson, 1998). This raises the pH levels in facultative ponds. Pearson et al. (1987c) observed a rise of pH in facultative ponds exceeding 9.0 and this is important in killing faecal coliforms. Ammonia and sulphide toxicity have been observed to be pH-dependent (Konig et al. 1987). As the pH of a facultative pond increases, the unionized form of ammonia increases while sulphide production decreases. The effect of this toxicity is to inhibit algae growth and production and these mechanisms are thought to be self-sustaining (Konig et al. 1987). Other parameters viz TDS, Sulphide, NH_3, total phosphate, Nitrate, nitrite, TN, EC were observed using EPA facility and the removal % are 38, 76, 93, 68, 34, 100, 78 and 37 respectively. Most of parameters exhibit declining trend in physic chemical parameter concentration when water passes from stabilization pond to final polishing pond except chloride which increased after treatment. In general most of the pollutants are reduced after the treatment. During these periods of Dec 2014 and Feb 2015 no much rain was observed. Whereas during observation made in May 2016 considerable rainfall occurred and reversed the declining trend of pollutants to increasing trend. The rain and corresponding runoff entry through the sewage outlet possibly diluted the pollutants in the beginning of the treatment ponds. This could be one of the reasons for getting increased concentration of most of the pollutants towards the end on the treatment. The rainfall resulted more inflow into the stabilization pond and diluted the pollutants. The rate of dilution decreased towards the end of the treatment. Even in rainy season no free outflow from the treatment system was observed. This could be true for confined sewage treatment system without regular outflow.

3.4 Irrigation Potential of sewage water

3.4.1 Rainfall data analysis

Annual average rainfall considering 5, 10 and 20 year data shows a decreasing trend due to impact of climate change. The rate of decrease in rainfall is 1.76% and 8.9% based on 10 and 5 years average. This implies that the rate of decrease is increasing year by year resulting severe impact on agriculture and land management practices. To cope with this decline in rainfall, suitable strategies should be followed in crop scheduling and water management. Owing to increasing population and food demand new water resources and appropriate water application methods need to be evolved. Five year monthly average rainfall reached a new low figure in June and September, alarming possibility of short spells of water scarcity. In the month of May, it reached highest value of 135mm. These extremities in both high and low ends lead to ore vulnerability to drought and flood damages. For irrigation system design, peak crop water demand of sugarcane and effective rainfall are to be considered. Considering 5 year averages compared to 20 year average values of these parameter are absolutely different. To cope with the existing short spells of water scarcity, it is recommended to design the irrigation system considering 5 year average values of both rainfall and other climate parameters to estimate crop water demand and irrigation demand.

3.4.2 Design Irrigation demand

Being a long duration crop (Sugarcane), it needs total crop water demand of 1400mm for Hawassa climate conditions. Both 5 year and 20 year average monthly rainfall data are analysed to estimate effective rainfall and irrigation demand. Considering medium sandy loam soil, the net irrigation water to be applied in the root zone to replenish 30% depletion is calculated as 48.6mm. For 90% irrigation efficiency, gross irrigation depth of 54mm is to be applied. Considering peak crop water demand of 5.5mm/day for the case of 5 year average climate data, the root zone can retain moisture to favour 9 days irrigation interval. But to be more efficient, drip irrigation needs more frequency of water application. So, 3 days of irrigation interval is selected for the design of the drip irrigation system. Peak irrigation demand of 2.7mm/day is observed for 20 year average data with planting date in January whereas 4.6mm/day is observed when planting is in June. Maximum irrigation demand of 795mm is needed for 5 year average data whereas it is 7.5% less for 20 year climate data. This clearly reveals recent climate conditions demand increased irrigation as compared

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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to the past years. Considering the effect of climate change, designing the irrigation system to match recent average climate data of at least 5 years will be more appropriate. This will equip our irrigation system better adapted to climate changes.

3.4.3 Irrigation with treated sewage water

Globally, around 20 million hectares of land are irrigated with wastewater and this figure is likely to increase during the next few decades (Hamilton et al., 2007). Wastewater irrigation has been practiced with several drivers. One, in water scarce areas (arid and semi-arid climate zones) the limited water source have insignificant contribution to support agricultural production, thus the use of treated wastewater is one way of sustaining agricultural production through supplementary irrigation.

Depending on the two planting season as analysed with climate data, peak irrigation demand of sugarcane plantation is 4.7mm per day. If the treated sewage water is applied for irrigation through further pressure sand or disc filtration systems, with available average daily treated water of 320 m^3, about 6 hectares of sugarcane plantation can be irrigated productively with application efficiency of 85% and meeting the peak crop water demand during dry season. In furrow irrigation system about 3.5 hectares can be irrigated without further investment on filtration system. Availability of plant essential nutrients from the biodegradable constituents of wastewater attracts farmers to use it for agriculture. In that sense, it enables farmers to reduce the expenditures on fertilizer and better production can be achieved. In some cases up to 37% increase in harvest is possible when raw wastewater is applied compared to freshwater irrigation with chemical fertilizer (Martijn, 2005).

3.4.4 Irrigation water quality

Raw and treated water quality was examined through the following basic parameters: pH, Electrical Conductivity, Total Dissolved Solids, Chloride, SAR, BOD and COD which were used to assess the suitability of water for irrigation purposes. The average value of pH was 7.8 which indicate that the treated sewage water is slightly alkaline in nature. The normal pH range for irrigation water is from 6.5 to 8.4. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion (Ayers and Westcot 1985, Pescod 1985).

Electrical conductivity is the ability of water to pass electric current in a solution. Total dissolved solid is a measure for the soluble substances in the water. Total dissolved solid includes both organic and inorganic molecules and ions mainly cat ions of calcium, magnesium, sodium, and potassium as well as carbonate, bicarbonate, chloride sulphate and nitrate ions. When the ionic content of water increases, the conductivity will also increase. The ionic contents are mainly the result of dissolved salts; hence the high electric conductivity indicates the presence of large concentration of salts and dissolved chemicals. Electrical conductivity (EC) is the most important parameter in determining the suitability of water for irrigation use and it is a good measurement of salinity hazard to crop as it reflects the TDS in wastewater. The most important negative effect on the environment caused by agricultural wastewater is the increases in soil salinity, which if not controlled, can decrease productivity in long term (WHO 2005). EC values of treated waste water varied from 1100 to 1300 µS/cm (mean value = 1200 µS/cm) while TDS values varied from 545 to 675 mg/L (mean value = 610 mg/L) indicating slight to moderate degree of restriction on the use of this wastewater in irrigation due to salt build-up in soils and its adverse effects on plant growth (Ayers, 1985). Furthermore, the results indicted also that this type of water can be used on the soils with restricted drainage. Special salinity control management with selection of good salt tolerant plants is required. However, irrigation water with conductivity in the range of 750-2250 µS/cm is permissible for irrigation and widely used. Satisfactory crop growth is obtained under good management and favorable drainage conditions but saline conditions will develop if leaching and drainage are inadequate. It is clear that irrigation using saline water can add salt concentration to the soils and a problem may be occurred due to the increase in concentration that is harmful to the crop or landscape. Therefore, it is necessary to combine the use of wastewater with practices to control salinization, such as soil washing and appropriate soil drainage (WHO, 2005). The primary effect of high EC reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Tatawat and Singh, 2008). Among the two treatment lines, Treatment line 1 performs better in reducing the TDS and EC whereas in treatment line 2 due to operational and maintenance problems, it performs poorly in reducing TDS and EC. SAR and chloride values were increased in both the treatment lines. This is mainly due to the fact that in both the systems most of the time the water gets stagnated resulting increase in concentration of dissolved salts due to continuous evaporation of water.

TABLE 4 REMOVAL EFFICIENCY OF SELECTED IRRIGATION WATER QUALITY PARAMETERS

	Treatment line I			Treatment line 2		
	Raw	Treated	Removal eff %	Raw	Treated	Removal eff %
TDS, ppm	878.0	540.0	38.4	814.0	666.0	22.7
EC µmhos/cm	1762.0	1107.0	37.2	1638.0	1337.0	18.4
SAR	25.5	31.0	-21.5	27.0	36.0	-21.8
chloride, ppm	135.0	189.0	-40.0	130.0	151.0	-13.9

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

Sodium hazard is usually expressed in terms of Sodium Adsorption Ratio (SAR) and it can be calculated from the ratio of sodium to calcium and magnesium. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd, 1988), since it is more closely related to exchangeable sodium percentages in the soil than the simpler sodium percentage (Tiwari, 1988). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious.

Continued use of water having a high SAR leads to a breakdown in the physical structure of the soil. Sodium is adsorbed and becomes attached to soil particles. The soil then becomes hard and compact when dry and increasingly impervious to water penetration. Fine textured soils, especially those high in clay, are most subject to this action. The SAR and EC values of the treated wastewater reflect that it should be severely restricted for surface irrigation system since it reduces the infiltration rate of the soil. Highly efficient irrigation systems are recommended if the treated sewage water needs to be used for irrigation to avoid soil degradation. The effects of the high SAR percentages are that the soil hydraulic system is affected, as aggregates will begin to break down resulting in poor soil structure. This will make the soils less productive as they will be sticky when wet and crusty when dry making tillage operations very difficult (Ayers, 1985, Affullo, 2009)

The most common toxicity is from chloride (Cl^-) in the irrigation water. Cl^- is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the Cl^- concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity), and progresses from the tip back along the edges as severity increases. Excessive necrosis (dead tissue) is often accompanied by early leaf drop or defoliation (Pescod 1985). The obtained Cl^- ion concentration of the samples varied from 130 to 224 mg/L representing slight to moderate degree of restriction on the use of this wastewater in irrigation (Ayers, 1985). While, according to USSL classification of irrigation water, the effluent samples can be used for moderately tolerant plants (WHO 2005).

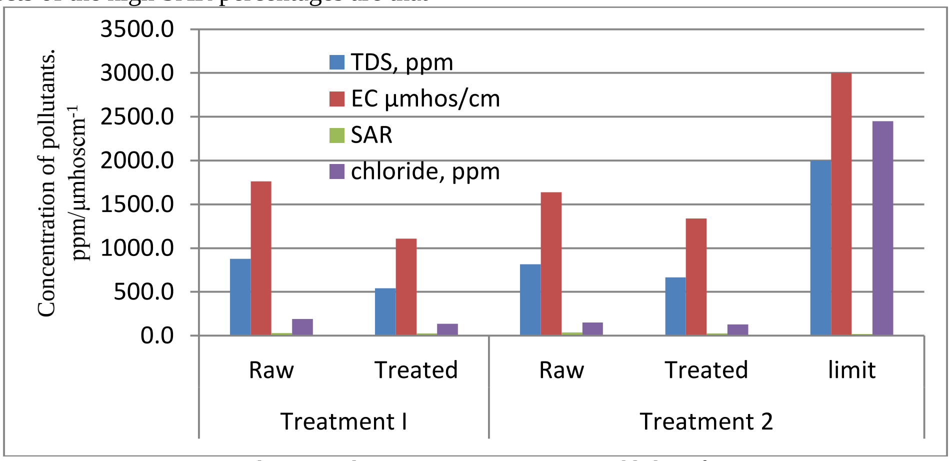

Fig. 7 Treated water quality parameters against permissible limit for irrigation

Except SAR and Chloride, all other parameters are well within the permissible limits recommended for irrigation water. According to the guidelines of Pescod, (1992), BOD and SS also favors possibility of using the treated sewage water for irrigating fruit trees and fodder crops. For other crops BOD and SS should be less than 20ppm which is the requirement for irrigating vegetable crops. Moreover, it should be noted that BOD meets the standard requirement for treated sewage water whereas suspended solids do not so as such the treated waste water cannot be disposed into natural water bodies. This indicates that the performance of the treatment system in the university campus needs to be improved in terms of operational efficiency despite having adequate capacity of the ponds system.

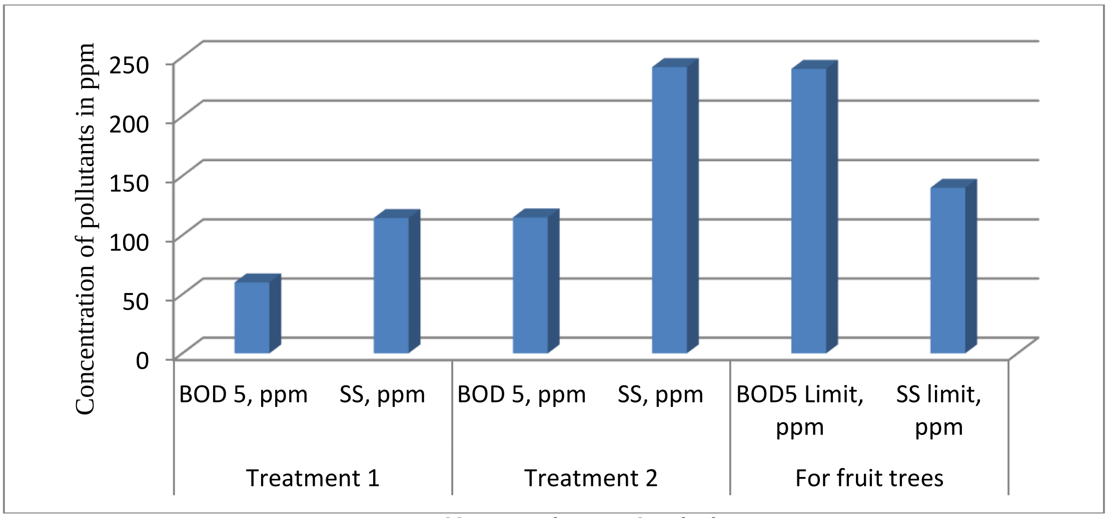

Fig. 8 Permissible Limits of BOD and SS for fruit trees

3.5 Soil parameters

The treated sewage water is disposed on available uncultivated land near the treatment system. Soil test was conducted on both land disposal site and nearby cultivated area. Selected soil chemical properties show that there is significant difference in parameters like electrical conductivity and available phosphorus as compared to other parameters between the two sites.

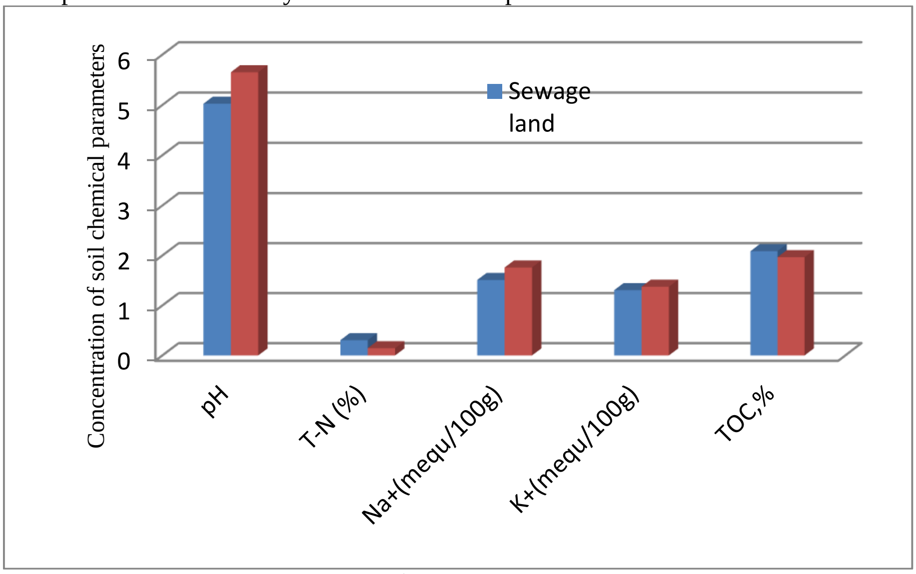

Fig 9 Soil chemical properties of Sewage disposal and Normal cultivated land

Analysis of variance of results shows that except pH and EC values vary significantly between sewage disposed and cultivated fields. But all parameters increased in soil where the treated sewage water was disposed when there is an over flow from the treatment system. Electrical conductivity of sewage disposal land exhibits 91.69% increase followed by total Nitrogen and available phosphate with 52.46 and 43.93 % respectively. This is mainly due to high nutrient contents of the treated sewage water. Continuous deposition of organic materials in the soil results an increased total carbon percentage and reduced pH making the soil acidic in nature. This infers the need of lime application to neutralize the acidic nature if irrigated with the sewage water.

TABLE 5 SOIL CHEMICAL PARAMETERS

	pH	EC µS/cm	T-N (%)	Av-P mg/kg	Na+(mequ/100g)	K+(mequ/100g)	TOC,%
Sewage land	5.025	501	0.305	32.43	1.51	1.305	2.085
Normal land	5.65	41.65	0.145	18.185	1.76	1.375	1.965
% increase/ decrease	-11.06	91.69	52.46	43.93	14.20	5.09	5.76

Typical concentrations of nutrients in treated waste water effluent from conventional sewage treatment processes are 50 ppm Nitrogen and 10 ppm Phosphorus. With an

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

application rate of 5000 m^3/ha/year, the fertilizer contribution of the effluent would be N - 250 kg/ha.year and P - 50 kg/ha.year. Thus, all of the nitrogen and much of the phosphorus and potassium normally required for agricultural crop production would be supplied by the effluent. Further, other valuable micronutrients and the organic matter contained in the effluent will provide additional benefits.

Soil EC is strongly affected by application treated sewage water for irrigation purpose. EC value of soil from sewage disposal field differs from crop cultivated field at 5% significance level. Existing salinity levels and amount of salt contained in the treated sewage water need to be closely monitored to prevent salinity problems, especially in arid climates. Electrical conductivity levels can serve as an indirect indicator of the amount of water and water-soluble nutrients available for plant uptake such as nitrate-N. Areas of saline soils need to be identified and managed differently from areas of non-saline soils. Soil microorganism activity declines as EC increases. This impacts important soil processes such as respiration, residue decomposition, nitrification and denitrification. Soils with a high concentration of sodium salts (sodic conditions) have additional problems, such as poor soil structure, poor infiltration or drainage, and toxicity for many crops since very high SAR value of the treated sewage water. EC values less than 1 dS/m, soil are considered non-saline and do not impact most crops and soil microbial processes. At present the EC value of the sewage disposal land is 0.5dS/m and in continuous usage in the long run EC readings greater than 1 dS/m, are possible due to accumulation of salts and will impact important microbial processes, such as nitrogen cycling, production of nitrous and other N oxide gases, decomposition and increased nitrogen losses. EC values above 1.0 dS/m increase production of nitrous oxide (N2O) gas from denitrification under anaerobic conditions (90% or more water-filled pore space) by over 15 to 315 fold with relatively high nitrate levels. Nitrous oxide is nearly 300 times more potent than carbon dioxide (CO_2) as a greenhouse gas and depletes ozone in the upper atmosphere. (Smith and Doran, 1996) and Adviento-Bore et al.,(2006). This alarms possibility of N_2O formation in the long run from the soil.

IV CONCLUSIONS

The average sewage water flow from Hawassa University main campus reaching the oxidation ponds was 16m3/hr in 2016. The characterization of the untreated sewage water of the university showed that many parameters were higher than the prescribed limit as compared to EPA guidelines. The results provide strong evidence that the water of these drains is not suitable for irrigation without treatment. The raw sewage water is subjected to oxidation ponds treatment facility to reduce the pollutants before discharging into land disposal since there is no any natural river nearby. The present sewage treatment system was introduced so that pollution load can be minimized and the water can be used for beneficial purposes. Interpretation of physical and chemical analysis revealed that the treated wastewater is slightly alkaline in nature. In conclusion, the percentage treatment efficiency of the pond for BOD, sulfide, Total Suspended solids, COD, Nitrate, Nitrite and Total Nitrogen were satisfactory. However, the effluent TSS concentration was higher than standard set by the EPA standards for treated effluents. The treatment efficiency of the pond for some of the trace elements was satisfactory. Treatment performance has been on increasing trend since 2014. Maximum of 75% BOD reduction was achieved in 2016 leaving scope for further improvement of the system by carrying out regular maintenance activities particularly removal of sludge in stabilization pond and removal of dead algae floating in the ponds. In present conditions, the treated water can be used for irrigation purpose with some restrictions. Even though EC and TDS permit to irrigate fruit trees and fodder crops, there is a risk of soil degradation due to high value of SAR. In such cases high efficiency irrigation systems are recommended rather than flood irrigation. With present flow rate of water maximum of 7 hectares of sugarcane plantation can be irrigated meeting its peak crop water requirement. Continuous use of treated sewage water for irrigation will make the soil acidic. Analysis of other soil parameters indicates that there is an increase in nitrogen, phosphate and organic carbon nutrient levels considerably to benefit crop production but increase in soil EC is a serious concern demanding soil reclamation by leaching the accumulated salts when it goes beyond the limit. Therefore, the sustainable use of treated wastewater in agriculture can be beneficial to the environment in such a way that minimizes the side effects on the quality of downstream water resources, but it requires the control of soil salinity at the field level.

Based on these results that proper management of wastewater irrigation and periodic monitoring of quality parameters are required to ensure successful, safe and long term reuse of wastewater for irrigation. It is recommended as a matter of high priority that treated wastewater is considered and made a reliable alternative source in water resources management. Agricultural wastewater reuse can effectively contribute to fill the increasing gap between water demand and water availability particularly in semi-arid areas. In future, further work is needed to examine organic and toxic constituents in wastewater and more intensive sampling and studies to measure any change of chemical elements in wastewater, irrigated soil and plant. Also, irrigation with domestic waste water increased nutritive elements in soil that can be source of nutrition for plants. The findings may give applicable advice to commercial farmers and agricultural researchers for management and proper use of water.

ACKNOWLEDGEMENT

The authors highly acknowledged the Institute of Technology, Hawassa University, Ethiopia for financial support. The authors also express appreciation to staff members of School of Biosystems & Evironmental Engineering and maintenance department of Hawassa university main campus sewage system for their holistic support throughout the experimental work.

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