Effect of Effluent on Soil Physico-chemical Properties and Tomato (*Solanum Lycopersicum* L.) Growth Performance: The Case of Ambo Mineral Water Factory, Oromia, Ethiopia

Bayisa Duressa[1] and Achalu Chimdi*[1]
*1 Ambo University, School of Natural resources, Department of Natural Resources management, P.O Box 19, Ambo, Ethiopia
***Corresponding Author: Achalu Chimdi; E-mail: achaluchimdi@yahoo.com**

Abstract: *The release of untreated wastewater into the environment can lead to the contamination of crops, and pollution of soils, rivers, streams and other surface water bodies. This study was undertaken to assess the effect of Ambo Mineral Water factory effluent on soil properties, and the performance of tomato crop. Water and soil samples were collected for laboratory analysis. A pot experiment was conducted using tomato as a test crop. The effluent was analyzed for (pH, total alkalinity, bicarbonate* Cl^-*, soluble sodium, total acidity, Total Dissolved Solids, Total Suspended Solids,* Cl^-*, Mg, Ca, total hardness,* NH_4*-N,* PO_4^{3-} *and Sodium Adsorption Ratio). Analysis revealed that the majority of parameters were found within permissible limits for irrigation water quality except for bicarbonate, Magnesium, ammonium nitrogen, and phosphate. Some of the parameters (total alkalinity, soluble Na,* Cl^-*, total dissolved solids, and sodium adsorption ratio) were high in the effluent water. However, Sodium Adsorption Ratio and heavy metals (Pb, Cr, Mn, Zn and Fe) were within permissible limits for irrigation. The effluent was in a range of moderate toxicity hazards of alkalinity, salinity, sodicity, and chloride with high bicarbonate alkalinity hazard hazards. Bulk density, total porosity, exchangeable K, Mg, Ca; total N, and heavy metals in soil solution along the effluent channel did not show significant differences. Soil physicochemical properties (pH, electrical conductivity, exchangeable Na, Exchangeable Sodium Percentage, Soluble* $Cl^{-,}$ CO_3^{2-}*and* HCO_3^-*; and Cr highly significantly increased in the soils along the effluent channel. Cation Exchange Capacity and organic matter decreased in the same channel by 37.46% and 49%, respectively. Tomato local variety treated with five levels of effluent concentrations for irrigation resulted in significantly good growth performance (dry biomass, leaf number, growth rate and heights) at 75 and 100 % effluent water concentrations.*

Keywords*: Effluent, Heavy metals, Soil contamination, Soil properties*, Tomato

INTRODUCTION

Environmental pollution due to increased industrial activities is one of the significant problems (Renu, *et al.,* 2016). Soil and water pollution is strictly related to human activities such as industry, agriculture, burning of fossil fuels, mining, and metallurgical processes and their waste disposal (Guiliano *et al*., 2007). Effluent is an inevitable byproduct of industrial processes. The United States Environmental Protection Agency, US EPA (2006) defined effluent as wastewater (treated or untreated) that flows out of a treatment plant, sewer or industrial outfall. However, industrial wastewater and sludge can be a good organic fertilizer; their treatment and disposal is an environmentally sensitive problem because they may contain heavy metals which could reduce productivity, cause environmental risks (Hossain *et al*., 2009) and human and animal health. Due to shortage of canal for good quality irrigation water, farmers use industrial effluents which are discharged in canal (FAO, 2004) and the use of such effluent for irrigation may introduce some metal ions, which can accumulate in the plants and consumed by humans and animals.

The contamination of soil is often a direct or indirect consequence of industrial activities (Mc Laughlin *et al*., 1999). Soil physicochemical properties are adversely affected by high concentration of heavy metals, rendering contaminated soils unsuitable for crop production (Udom *et al*., 2004, Hernandez-Allica *et al*., 2007). One of the critical wastewater parameter to be considered in the irrigation purpose is the amount of sodium adsorption ratio, SAR (Richards *et al*., 1954), whereas, the application of excess Na without sufficient amount of Ca and Mg may affect soil. Wastewaters carry toxic heavy metals that get introduced into the soil and aquatic system through various processes, prominent among them being irrigation (Khan *et al*., 2015).

Hora is one of the natural mineral water found in West Shoa Zone, Ambo Woreda, and serving as a main water supply for the people living at Senkele and its surrounding, a small district 3 km to Southwest of Ambo town (CSA, 2012). Ambo Mineral Water has been bottling and selling since 1930 and is considered the market leader in Ethiopia. Even though the industry releases wastewater to the surrounding environment each day and there is demand for irrigation, the water has not yet been used and the quality of the wastewater has not yet been determined whether it really fits for irrigation purposes. Tibebu *et al* (2017) analyzed the physicochemical parameters of the Hora water used for the Ambo mineral water factory and indicated its suitability for drinking. However, there is little data about the effluent; its nutrient concentrations; effect on crop growth performance, soil physicochemical properties and surface water quality; suitability for livestock drinking and irrigation purposes. The effluents discharged from factory which contain heavy metals that are toxic to living organisms; necessitating the search for developing appropriate and applicable wastewater treatment technologies. Therefore, this study was focus mainly on the effects of these processed "*Hora*" water effluents on selected soil physicochemical properties, and tomato growth performance and proposes a solution for the management of the effluents by the factory and local farming communities.

MATERIALS AND METHODS

Description of the Study Area: The study was conducted at Senkele Farisi, Ambo Woreda, Oromia National Regional State, Ethiopia, around the Ambo Mineral Water factory and Senkele Sandstone Small Scale Query Site. The zonal capital Ambo town is located 114 Km west of the Addis Ababa and is located at approximately between 8° 47′30″ N–9° 21′30″ N latitude and between 37° 32′30″ E–38° 3′ 15″ E longitude with an elevation of 2101 m above sea level.

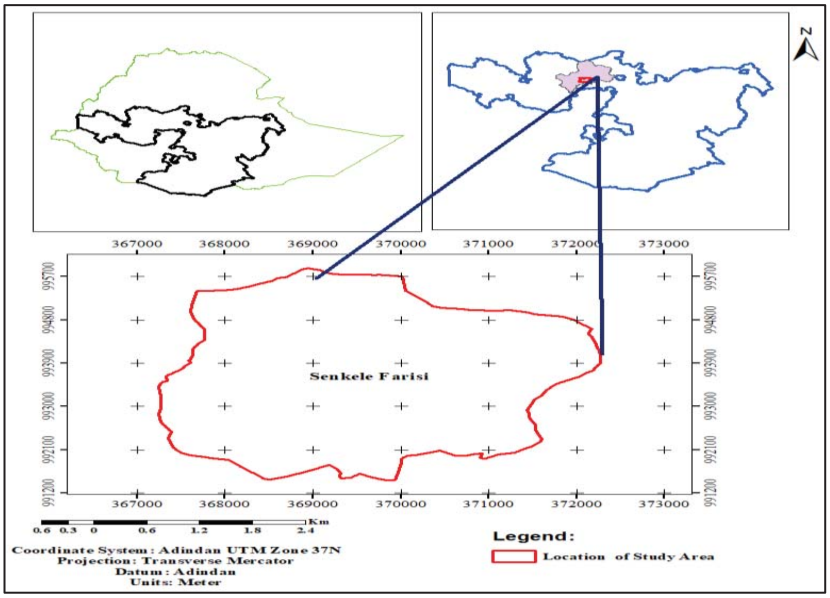

Figure 1: Location map of the study area

The lowest and highest annual average temperature of the study area are 13 and 27 °C, respectively. According to Ambo District Agricultural and Natural Resource Management Office (2002), the woreda enjoys a mild, Afro-Alpine temperate and warm temperate climate with agro climate of Lowland (14.7%), Midland (50%), and Highland (35.3%). The mean annual rainfall of the study area is 1129 mm/year. Clay soil, black/vertisol soil, and sandy soils are the common soil types of the study area that are suitable to a wide range of crops. According to data from the office of Agriculture and Natural Resource Management of Ambo District (2002), common vegetation crops in the study area include tomato (*Solanum lycopersicum*), onion (*Allium cepa*), potato (*Solanum tuberosum*), cabbage (*Brassica oleracea*), lettuce (*Lactuca sativa*), sweet potato (*Ipomoea batatas*), and chili pepper (*Capsicum frutescens)*, whereas, cereal crops like corn *(Zea mays),* and teff *(Eragrostis teff)* comprise the largest proportion of the cropped area. Pea (*Pisum satium),* faba bean *(Vicia faba),* haricot bean *(Phaseolus vulgari*s), flax/linseed (*Linumusita tisimum),* niger *(Guizoita abyssinica)* and rape seed *(Brassica napus)* are common pulse and oil crops of the study area.

Samples Collection, Laboratory Analysis and Pot Experiment

Collection of Effluent Samples: The effluent samples were collected from the outlets of the factory discharge point (outlet) before being discharged in to the soil. Accordingly, three (3) effluent water samples were collected at the same time at 5 days interval.

Collection of Soil Samples: Composite top 20 cm soil samples were taken from the either sides of ditches (along effluent channels) at 200 meters interval in 1000 meter distance in which the effluents flow for analyzing of soil physicochemical properties. Similarly, soil samples from the adjacent farmers' plots/farmers' fields (none polluted vertisol that is none accessible by the effluent discharged) were taken at similar distances and intervals at either side of the channel for comparison of the pot experiment and from unpolluted areas of the farmers' fields used as a control.

Laboratory Analysis of Effluent water samples: Electrical conductivity and pH of the effluent samples were analyzed by digital pH meter as described by (Maiti, 2004). Acidity of the effluent samples was analyzed by Titration method described by (EPA, 2001). Total alkalinity was determined by Titration method (APHA, 1999). Total hardness (TH) and dissolved oxygen (DO) of the effluent samples were determined by Titration with EDTA

(EPA, 2001) and Winkler titration (APHA, 1999) method in mg/L, respectively. The total dissolved solids (TDS) and total suspended solids (TSS) of effluent samples were analyzed by Gravimetric method (EPA, 2001). Chloride (Cl^-) and ammonium (NH_4-N) of the effluent was determined by Argent metric method/Mohr's method via titration of NaCl (APHA, 1999), whereas; phosphate (PO_4^{2-}) was determined by Stannous Chloride Colorimetric Method via UV-Vis (APHA, 1999). Soluble cations in effluent samples (Na^+, $K^{+,}$) were analyzed by Flame Photometry, while, Ca^{2+} and Mg^{2+} where determined by AAS (Maiti, 2004). The SAR of effluent water sample was calculated from the concentrations of Na, Ca and Mg as, SAR= $[Na/ (Mg + Ca/2)^{0.5}]$, in meq/l (FAO, 1992). Heavy metals in effluent samples (Pb, Zn, Cr, Mn, Fe, and Cd) were determined by EDTA extraction method and the aliquots were read by AAS as described by (Lindsay and Norvell, 1978).

Analysis of Soil Physicochemical Properties: The bulk density (BD) of a soil sample was analyzed by using core sample method (Blake, 1964), whereas the total porosity was estimated from BD and the average particle density in % as $(1-\rho b/\rho s)$ where ρb is the bulk density and ρs is the average particle density (2.65 g/cm^3). Electrical conductivity and pH of a soil was determined by digital pH meter at ratio 1:2.5 soil KCl solution (FAO, 2008 and Jackson, 1973). CEC of a soil sample was analyzed by ammonium acetate (NH_4OAc) centrifuge method (FAO, 2008). Exchangeable cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) were analyzed from saturated paste extraction of 1N (NH_4OAc) by AAS for Ca and Mg; and flame photometer for Na and K (Dipak and Abhijit, 2005). Soluble chloride (Cl^-) in a soil sample was determined by titration of Cl^- with mercuric thiocyanate by colorimetric method, whereas; carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) were estimated by Back-titration acid (Dipak and Abhijit, 2005.)Soil organic matter (SOM) was determined by NH_4OAc extraction (Walkley & Black, 1934) method Total N of a soil sample was analyzed by Modified Kjeldhal digestion method (Kjeldhal, 1883) and, available P of soil was determined by Olsen method (Olsen *et al*., 1954). Exchangeable Na percentage (ESP) was calculated as: ESP= Na/ (Na + K + Mg + Ca)*100, (Leticia *et al.,* 2015). Soil micronutrients (Mn, Zn, Pb, Fe, Cr, and Cd) were determined by DTPA extraction method (Lindsay & Norvell, 1978).

Pot Experimental Setup: Pot experiment was set up to analyze the effects of effluent on growth performance of crop and soil properties. Tomato crop, local variety Sembersana was used as a test crop for the experiment. Five levels of effluent concentrations (0 (control), 25 50, 75 and 100 %) dilution with local tap water were used where the control is local tap water. The variety (land race) Sembersana tomato and five effluent rates were combined into 5 treatments and replicated three times in Completely Randomized Design (CRD) in lath house in PVC pots of 20 cm height by 15cm width sizes. The experimental soil was collected from 0-20cm depth, adjacent to the effluent discharge point. The soil was air dried, debris/roots removed and passed through 2cm sieve. The physical and chemical properties of the soils were determined by methods discussed above after planting irrigation water was supplied. The number of irrigations and total volume of water applied was recorded. Pot size 20 cm height by 15cm width sizes was used with three kg air dried soil. The effluent water was applied to tomato during seedling stage and one month after transplanted to the pots in the lath house. Plant parameters recorded were: plant height 10 days from transplanting at 10 days interval; dry biomass, plant leaf number, and plant growth rate (calculated from plant height). The height of a crop was recorded four times after 15 days of transplanting within 10 days intervals.

Data Analysis: The data were analyzed using t-test and SAS statistical software of version 9.3. ANOVA were used to analyze the correlation of the selected parameters of soil properties and tomato growth performance Mean separation was done using Duncan Multiple Range Test (DMRT).

RESULTS

Physicochemical Characteristics of the Effluent: The effluent laboratory analysis results are given in (Tables 1 and 3) for physicochemical characteristics and micronutrients, respectively. The results were to evaluate the suitability of the physicochemical parameters of the effluent for the purpose of the irrigation during of off-season crops. The mean value of pH of the effluent was 8.19 (Table 1) which shows alkaline property. The effluent analysis showed that the mean total alkalinity and total dissolved solids (TDS) were found to be 913.3 and 1673.0 mg/l, respectively; whereas; the acidity of the effluent was 58 mg/l

(Table 1).On the other side, the mean value for TSS was 456.7 mg/l, while the mean value of HCO_3^{2-} in the effluent was 1114.27 mg/l (Table 1). The analysis also revealed the presence of a relatively high concentration of chloride (Cl^-) in the effluent with a mean value of 201.97 mg/l (Table 1). The mean value of total hardness (TH) of the effluent was 420 mg/l. The mean value of NH_4-N in the effluent was 12 mg/l (Table 1). Similarly, phosphate with a mean value of 30 mg/l was highly greater than the restriction set of 0-2 mg/l for irrigation use.

As the result of the effluent analysis (Table 1) revealed that, the mean value of Na concentration was207.81 mg/l. Similarly, the mean values of Mg and Ca cations were 90.70 and 234.25mg/l, respectively. The mean value of SAR of the effluent was 2.91. The proportional ratio of Na to Ca and Mg, the so-called sodium adsorption ratio (SAR) of the effluent, is another irrigation water parameter to determine the sodicity hazard level of Na. The concentrations of Mg and Ca counterfeit the level of sodicity, i.e., when the level of concentrations of Mg and Ca increase, the concentration of Na reduces (Bryan *et al.,* 2007). The SAR value falls within the standard ranges set by FAO (1992). However, crops have different tolerance level towards SAR, the SAR value of 13 is the maximum permissible limit beyond which the productivity and yield of crops decline (FAO, 1992, 2008). When irrigation water containing a high proportion of Na relative to Ca plus Mg is applied to porous, aggregated soil, the Na replaces the adsorbed Ca and causes the soil particles to disperse and form smaller pores (Achalu, *et al.,* 2012).

Table 1: Selected physicochemical parameters of the Effluent

Parameters	**Unit**	**Sample mean value**	**FAO Suitability range for irrigated crop (1992)**
pH	-	8.2	6.5-8.5
ECw	dS/m	2.1	0.7-3
Total alkalinity	mg/l	913.3	-
Bicarbonate (HCO_3^-)	mg/l	1114.2	150-850
Total acidity	mg/l	58.0	-
TDS	mg/l	1673.0	450-2000
TSS	mg/l	456.7	150
DO	mg/l	7.2	-
Chloride (Cl^-)	mg/l	201.9	140-350
Total hardness	mg/l	420.0	50-150
Ammonium (NH_4-N)	mg/l	12.0	5
Phosphate	mg/l	30.1	0-2
Sodium (Na)	mg/l	207.8	900
Potassium (K)	mg/l	10.6	2
Magnesium (Mg)	mg/l	90.7	50-60
Calcium (Ca)	mg/l	234.3	400
SAR*	-	2.9	9-13

ECw=Electrical conductivity of water, TDS=Total dissolved solids, TSS=Total suspended solids, SAR=Sodium adsorption ratio, * =the values of Na, Mg and Ca

Salinity, Chloride, Alkalinity and Sodium Hazard Classification of the Effluent

All the mean concentrations of the effluent parameters except HCO_3^- were in a moderate salinity, sodicity, alkalinity, and Cl^- toxicity and hazard level which are ranged from suitable to semi to moderately tolerant crops Table 2.

Concentrations of Heavy Metal Elements in the Effluent: Analysis results of six selected heavy metals in the effluent were shown in Table 3. High Fe concentration followed by Zn was recorded in the effluent that Cr level being the lowest. The analysis result of the present study revealed that the concentrations for all the heavy metal elements were below the maximum permissible level of 5, 2, 0.1, 0.2 and 5 mg/l for Pb, Zn, Cr, Mn and Fe, respectively, with Pb and Fe far less than the standards set (FAO, 1992); whereas, Cr was found trace. Industrial wastes, acid mine drainage and the corrosion of Fe and steel equipment are potential sources of heavy metals in effluent water (USDA, 2011).

Table 2: Sodium, alkalinity, salinity and chloride hazard level of the Effluent

Effluent Parameters	Concentration means value	Category of toxicity*	Toxicity level*
ECw (dS/m)	2.1	Salinity	Moderate
TDS (mg/l)	1673	Salinity	Moderate
Cl- (mg/l)	201.9	Chloride toxicity	Moderate
HCO_3^- (mg/l)	1114.3	Alkalinity	High
SAR	2.9	Sodicity	Moderate

ECw=Electrical conductivity of water, TDS=Total dissolved solids, Cl^-=Chloride, HCO_3- = Bicarbonate, SAR=Sodium adsorption ratio, (* the toxicity category and level is adopted from USDA, 2011 as cited from Bauder *et al*., 2011)

Table 3: Heavy metal elements concentration in the effluent

Heavy Metals	Unit	Sample Mean Values	FAO Suitability range for irrigated crop (1992)
Lead (Pb)	mg/l	0.05	5.0
Zinc (Zn)	mg/l	0.17	2.0
Chromium (Cr)	mg/l	0.02	0.1
Cadmium (Cd)	mg/l	Trace	0.01
Manganese (Mn)	mg/l	0.14	0.2
Iron (Fe)	mg/l	1.06	5.0

Effect of the Effluent on Soil Physicochemical Properties: The results of laboratory analysis of the soil samples taken from the effluent channel (AECh) and adjacent farmers' fields (AFF) where the effluent had no access to approach the farmers` field are presented in Tables 4 and 5. The mean values of bulk density (BD) of the soil samples and porosity from farmers' fields and the effluent channel showed no significant difference due to the effluent effect on the channel soils. The soil pH of AECh sample was 9.22, while that of AFF was 7.42. The electrical conductivity of saturated extract (ECe) of the soil along the effluent channel which is in direct contact with the soil is found to be highly significantly higher by about 356% compared to the ECe of farmers field soils sampled at the same distance. The mean CEC of the soil samples from AECh is found to be significantly lower by about 37.46% compared to samples from AFF.

Table 4: Mean values for physicochemical properties of soil samples from two fields

	Soil Samples		
	AFF	**AECh**	
Parameters	**Mean + Std. Error**	**Mean + Std. Error**	**P value**
pH	7.4±0.111	9.22±0.074	2.924E-06**
ECe (dS/m)	0.66±0.045	3.01±0.041	2.495E-10**
BD (g/cm^3)	1.41±0.118	1.35±0.032	6.744E-01^{ns}
Total porosity	47.00±5.134	49 ± 5.172	7.45E-01ns
CEC (Cmolc/kg)	20.77±2.056	12.99±1.287	1.574E-02*
Exch. Na (meq/100g)	5.35±0.532	235.87±32.486	2.080E-03**
Exch. K (meq/100g)	6.14±0.929	4.56±0.705	2.160E-01^{ns}
Exch. Mg (meq/100g)	25.44±2.142	28.48±3.954	5.24E-01^{ns}
Exch. Ca (meq/100g)	165.74±21.661	112.74±7.173	6.92E-02^{ns}
ESP (%)	2.75±0.252	60.72±3.487	8.50E-05**
Soluble CO_3^{2-}(meq/l)	1.32±0.080	2.28±0.136	6.629E-04**
Soluble HCO_3^-(meq/l)	0.55±0.340	1.28±0.396	1.25E-03**
Soluble Cl^- (meq/l)	0.40±0.054	0.71±0.105	3.286E-02*
Available P (mg/kg)	5.44±0.816	13.90±4.118	4.33E-04**
OM (%)	3.12±0.275	1.59±0.234	5.31E-04**
TN (%)	0.06±0.010	0.05±0.007	4.281E-01^{ns}

*=Significant, **=highly significant, ns= non-significant at P value of 0.05, AECh=along effluent channel, AFF=adjacent farmers' field, ECe=Electrical conductivity of saturation

extract, BD=Bulk density, CEC=Cation exchange capacity, ESP=Exchangeable sodium percentage, OM=Organic matter TN=Total nitrogen

The mean values of exchangeable Mg, Ca, and K were found to be non-significant on the soils sampled from both sites; whereas high Na concentration was found on soils along the effluent channels and highly significantly higher by about 4309% over soils on adjacent farmers' fields (Table 4). The mean value of ESP of the soil sample from AECh (Table 4), showed significantly higher by 2108% over the soil samples from AFF. The soluble HCO_3^- and Cl^-concentrations along the effluent channel soil showed highly significant increase by about 133% and 77% followed by CO_3^{2-} that has significant concentration increase by about 73% along the channel. The mean value of available phosphorus showed a highly significant increment by about 155% in AECh over AFF soil sample. Reversely, the analytical results showed that the organic matter (OM) content of the soil along the effluent channel has significantly decreased by 49%.

Heavy Metal Elements in Soil Samples: The mean value of analyzed heavy metal elements did not significantly differ except Cr, while, Cd was not detected in the soil sample. The mean value of Cr showed significant increase by 59.88% on AECh as a result of effluent over soil sample from AFF.

Table 5: Values of selected heavy metal elements in soil samples taken from two fields

Mean values of Heavy metals in soil samples (mg/kg)						
AFF						
Mean	Pb	Cr	Mn	Cd	Zn	Fe
+SE	9.25±1.28	17.90±2.79	100.68±5.81	ND	6.34±1.18	1288.94±197.99
AECh						
Mean	Pb	Cr	Mn	Cd	Zn	Fe
+SE	14.29±3.33	28.62±2.96	127.80±11.79	ND	9.26±2.84	1383.22±39.11
P value	**$2.87\text{E-}01^{ns}$**	**$2.99\text{E-}02^{**}$**	**$8.60\text{E-}02^{ns}$**	**-**	**$3.83\text{E-}01^{ns}$**	**$6.63\text{E-}01^{ns}$**

ND=Not detected, **=highly significant, ns=not significant, at p value of 0.05, AECh=along effluent channel, AFF=adjacent farmers' field, SE=standard error

Effects of the Effluent on Tomato Growth Performance: A local tomato variety Sembersana was irrigated with local tap water having different concentrations of (0, 25, 50, 75 and 100%) for 45 days to evaluate the effect of the effluent on growth parameters of the tomato that includes plant height , leaf number, growth rate and dry biomass. Plant height: The result, revealed a high rate of increment in height within a time interval from week 1 to week 4 Table 6. However, there is no significant difference in height between the treatments, except on week 4.

Table 6: Plant height of tomato treated with different levels of effluent concentrations

Plant height (cm)	Treatments					
	T1	**T2**	**T3**	**T4**	**T5**	**Mean**
Week 1	21.42	19.17	17.67	20.5	20.17	19.78^{ns}
Week 2	29.00	26.67	26.00	31.33	33.00	29.20^{ns}
Week 3	36.33	40.33	40.00	45.67	49.67	42.40^{ns}
Week 4	42.00^{c}	48.33^{bc}	52.00^{abc}	57.67^{ab}	61.33^{a}	52.27^{**}

T1=Control, T2=25% EW, T3=50% EW, T4=75% EW T5=100% EW, EW=Effluent Water, **=highly significant & ns=non-significant at p value of 0.05=The same letter (s) in the same column do not vary significantly at p>0.05 (according to DMRT)

At final week, height record showed a significant growth when the highest height was observed on T5 (100%), followed with T4 (75%) and T3 (50%) effluent concentrations. Tomato under 100% effluent concentrations showed greater growth performance in terms of height with a mean value of (61.33 cm), while tomato under 0% effluent recorded the smallest plant height of 42.00 cm Table 6.

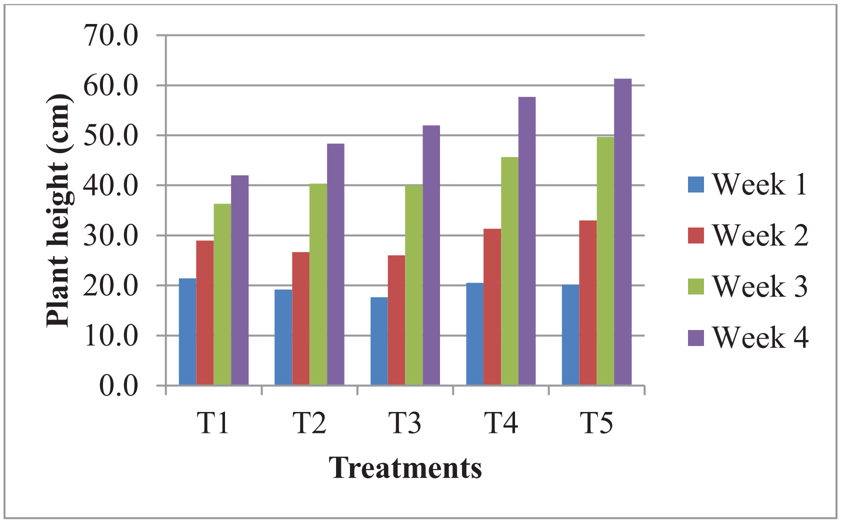

Figure 2: Height of tomato treated with different levels of effluent concentrations

Leaf number per plant: leaf number didn't show significant differences at different concentrations of effluent Table 7. The highest mean value of leaf, 9.67 was observed at the 4th week on 75 and 100% effluent, followed by 8.67 on 3rd week at 75 and 100% effluent concentrations level.

Table 7: Plant leaf number treated with different level of effluent concentrations

Plant leaf (No.)	Treatments					Mean
	T1	T2	T3	T4	T5	
Week 1	4.33	4.33	4.33	4.33	5.33	4.53^{ns}
Week 2	5.33	6	5.67	6.00	6.00	5.8^{ns}
Week 3	7.00	7.67	8.33	8.67	8.67	8.67^{ns}
Week 4	8.00	9.33	8.67	9.67	9.67	9.07^{ns}

T1=Control, T2=25% EW, T3=50% EW, T4=75% EW, T5=100% EW, EW=Effluent Water, ns=non-significant at p value of 0.05

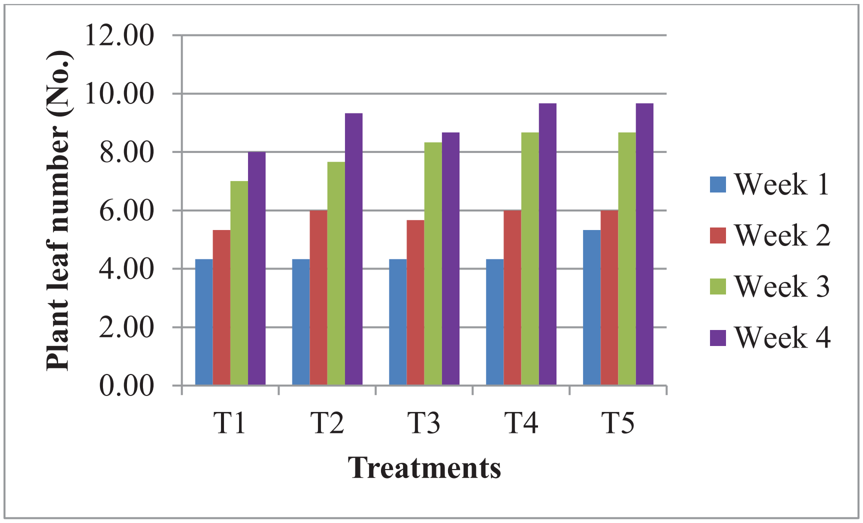

Figure 3: Tomato leaf number treated with different level of effluent concentrations

Plant growth rate: Significant growth rate was observed at Day 2 (2nd round) data recording per day when the plant is at its maximum growing stage. Greatest growth rate 1.67/day in terms of plant height was recorded at T_5 (100% effluent) concentration (Figure 4), whereas, the lowest growth rate data of 0.57/day was observed during day 3 (3rd round) at T_1 (control). Height of the plant over a time (growth rate) showed a significant increment with the concentrations of the effluent. Therefore, the higher growth rate over time from the height of tomato is recorded on 100% concentration followed by 75% effluent concentration level.

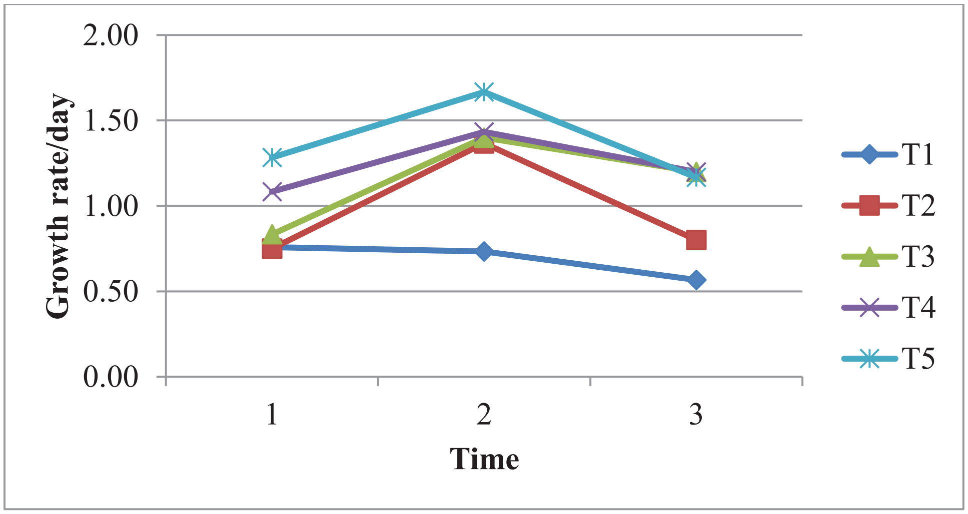

Figure 4: Growth rate of tomato treated with different level of effluent concentrations

Properties of soil after harvest as influenced by Effluent: The mean values of physicochemical properties of soil samples after irrigated with the effluent at different concentrations were summarized in a Table 8 below. Bulk density (BD) of a soil treated with 100% effluent showed a decrement by 4.27% over a control, however, no significant difference was observed at 25, 50 and 75% effluent levels. The decrement of BD from control might be presence of high Na concentrations on exchange sites of soils with 100% effluent treatment. The mean values of a pH of a soil after irrigation showed a highly significant difference with increasing in effluent concentration level. A high pH value of 8.4 was revealed at 100% effluent concentration, while a lower pH value of 6.9 was recorded from the control. This might be due to the alkaline property of the effluent.

Similarly, the mean values of ECe of soil showed a highly significant difference with highest value of 1.31 dS/m analyzed at T_5. The present study result revealed that, the ECe of a soil increased with effluent concentrations. This result is in agreement with Amin (2011) who reported an increase of ECe from 60 to 65.09 dS/m at control and 300 ml of wastewater treatment, respectively. Kumar and Chopra (2011), also presented a 84.13% increase in ECe with 100% concentration. The CEC of a soil samples after irrigated with effluent at five treatments with different concentration levels given in Table 8. The mean value depicted a significant difference within treatments that a high CEC was observed on a control. CEC of a soil sample showed a decrement with an increment of concentrations of effluent. This result is opposite with findings of Kumar and Chopra (2011); that the CEC of soil showed a significant increment from control to 100%. Organic matter of a soil was significantly affected by the effluent. The OM decreased from 2.59 % at control to 2.09 % at 100%. This might be due to decrement of CEC of a soil as the concentrations of effluent increased (Jayanta *et al.,* 2017).

Available P of a soil was significantly affected by the effluent and decreased by 470% from control to 100% effluent level, and no significant mean difference was observed in between T_3 and T_4. The analysis also revealed that, Cl^- in the soil sample treated with different concentrations of effluent showed a significant difference. High Cl^- level in the effluent increased in a soil sample in a parallel way. The increment of effluent concentration from

0% to 100% resulted in increment of Cl^- by 158.62% in a soil solution. This is because of high concentration of Cl^- level in the effluent. Again, this result is similar with findings of Kumar and Chopra (2011) that, Cl^- increased by 292.38% with effluent concentrations. The concentrations of effluent had a significant effect on soil CO_3^{2-} and HCO_3^- (Table 8). Hence, CO_3^{2-} of a soil increased to 4.21 from 2.57 meq/l at 100% and 0% effluent concentrations, respectively. Similarly, there was an increment in HCO_3^- from 0.18 to 1.26 meq/l of soil irrigated with control and 100% effluent, respectively. This result is in line with Kumar and Chopra, (2011), when HCO_3^- and CO_3^{2-} increased by 27.76%, and 43.58%, respectively, from control to 100% effluent. This might be as a result of high HCO_3^- concentration analyzed in the effluent water.

Table 8: Soil properties treated with different effluent concentration levels during irrigation

	Soil Properties													
Treatments	BD (g/cm^3)	pH	ECe (dS/m)	CEC ($Cmol_c$ /kg)	OM (%)	Cl^- (meq/l)	CO_3^{2-} (meq/)	HCO_3^- (meq/l)	Ava.P (mg/kg)	Exch. Na(meq/ 100g)	Exch. K(meq/ 100g)	Exch. Mg(meq /100g)	Exch. Ca(meq/ 100g)	ESP (%)
T_1	1.2^{a}	7.0^{d}	0.6^{e}	18.3^{e}	2.6^{d}	0.9^{e}	2.6^{e}	0.2^{e}	14.9^{a}	5.6^{e}	9.2^{c}	29.1^{a}	62.7^{e}	5.3^{e}
T2	1.1^{cd}	7.8^{c}	0.8^{d}	17.6^{d}	2.5^{c}	1.1^{d}	2.8^{d}	0.4^{d}	12.9^{b}	24.3^{d}	9.4^{b}	26.9^{b}	89.9^{d}	16.1^{d}
T3	1.1^{d}	8.0^{b}	0.9^{c}	16.5^{c}	2.4^{c}	1.7^{c}	3.1^{c}	0.5^{c}	11.6^{c}	31.6^{c}	8.6^{d}	26.3^{b}	95.5^{c}	19.5^{c}
T4	1.1^{c}	8.3^{a}	1.2^{b}	15.5^{b}	2.3^{b}	2.0^{b}	3.4^{b}	0.7^{b}	11.4^{c}	56.2^{b}	9.5^{b}	25.5^{c}	99.7^{b}	29.4^{b}
T5	1.2^{b}	8.4^{a}	1.3^{a}	14.5^{a}	2.1^{a}	2.3^{a}	4.0^{a}	1.2^{a}	10.2^{d}	70.3^{a}	9.8^{a}	24.1^{d}	104.6^{a}	33.7^{a}
Mean	**1.1^{**}**	**7.9^{**}**	**0.9^{**}**	**16.5^{**}**	**2.4^{**}**	**1.6^{**}**	**3.2^{**}**	**0.6^{**}**	**12.2^{**}**	**37.6^{**}**	**9.3^{**}**	**26.4^{**}**	**90.5^{**}**	**20.8^{**}**
LSD (0.05)	**0.0**	**0.1**	**0.1**	**0.7**	**0.1**	**0.1**	**0.1**	**0.1**	**0.5**	**2.6**	**0.2**	**0.7**	**1.9**	**1.4**
CV (%)	**1.9**	**0.9**	**1.5**	**2.2**	**1.4**	**2.9**	**1.7**	**6.4**	**2.2**	**3.7**	**0.9**	**1.3**	**1.2**	**3.5**

LSD=Least Significance Difference among means, CV=Coefficient of variation, T1=Control, T2=25% effluent, T3=50% effluent, T4=75% effluent, T5=100% effluent, BD=Bulk density, ECe=Electrical conductivity of saturated extract, CEC= Cation exchange capacity, OM=Organic matter, Cl^-=Chloride, CO_3^{2-}=Carbonate, HCO_3^-, Ava. P= available phosphorus, Exch. Na, K, Mg and Ca=Exchangeable sodium, potassium, magnesium, and calcium, ESP=Exchangeable sodium percentage

=Different letter (s) in the same column do vary significantly at $p<0.05$ (according to DMRT)

Exchangeable cations analyzed in the soil under different treatments showed a significant difference. Hence, the Na level in the soil sample depicted a highly significant escalation with level of concentration. A very large mean Na value of 70.28 meq/100g was observed at T_5 (Table 8), whereas, the lower mean value was found to be 5.60 meq/100g at T_1 (control). This is escalation might be due to high soluble Na concentration found in the effluent. This is in line with finding of Amin (2011), when Na increased from 1600 (control) to 1826 mg/l when treated with 300 ml wastewater, respectively. Similar study by Kumar and Chopra (2011), and Hanan and Yaling (2017) also showed similar findings in increment of Na with concentrations of effluent. Exchangeable K showed a marginal difference within treatments, that T2 and T4 mean values with no significant difference and T3 with low mean value. In another way, exchangeable Mg and Ca showed highly significant difference within the treatments. Magnesium showed a decrement by 17.10% when the effluent concentration increased from 0 to 100%, whereas, T_2 and T_3 showed no significant difference. Reversely, Ca depicted an increment by 143.97% with effluent concentration level. The present study is in regard with Kumar and Chopra (2011), Hanan and Yaling (2017), and Amin (2011). The increment of Na in the soil also contributed for the highly significantly increment of ESP by 540.95% as the effluent level increased from 0% to 100%.

DISCUSSIONS

The high mean pH value in the effluent might be due to the discharge of used salty ingredients like sodium bicarbonate in the washing of instruments and bottling process of the factory. However, the pH of the effluent is within the range of FAO (1992) guideline and can be used for salt tolerant crops, whereas; the electrical conductivity (ECw), of the effluent water was found to be 2.12 dS/m. This implies that the effluent has high dissolved salts mainly due to various salts used in the factory, in addition to some salt loads contributed from the original spring water used for Ambo mineral water bottling. The ECw in a range of 0.7 to 3 dS/m is recommended by FAO (1992) for various level salt tolerances of crops, and ECw greater than 2 being applied to very salt tolerant crops (USDA, 2011). Therefore, the effluent ECw can be considered safe for semi-salt tolerant crops like tomato (USDA, 2011). The alkalinity of water is a measure of its capacity to neutralize acids (Maiti, 2004), and it is important water characteristic related to ECw and other salts and solids in water. The high alkalinity in the form of $CaCO_3$, CO_3^{2-}, and HCO_3^- restrict plant nutrient uptake by triggering osmotic pressure (FAO, 2008; USDA, 2011); and the presence of high salt concentrations in irrigation water causes plants to exert more energy on extracting water from the soil by decreasing plant available water and cause plant stress (Nikos *et al*., 2003). The high level of salinity of the effluent is related with the pH of an effluent which has an alkaline property. The high preference of livestock in the factory environment for consumption of the effluent water is one indication of the presence of higher salt concentration in the water. TDS levels above about 2000 mg/l are very likely to cause plant growth problems (FAO, 1992; USDA, 2011), however, the current effluent finding, 1673 mg/l was below this maximum limit. As with conductivity issue, high TDS waters need advanced treatment or dilution to make the water useable for irrigation (Williams *et al*., 2016). TDS is highly related to ECw and alkalinity. The lower in acidity might be due to high level of total alkalinity and pH level of the effluent. The mean value for TSS 456.7 mg/l (Table 1), appears to be on the very higher side from water quality point of view, that can possibly, cut down light transmission through the water and so lower the rate of photosynthesis in aquatic flora (Maiti, 2004; ICARDA, 2013).

The mean value of HCO_3^{2-} in the effluent was found to be beyond the permissible level set for irrigation, 150-850 mg/l (FAO, 1992). This maximum HCO_3^- in the effluent might be resulted from carbonate related salts used in factory like sodium bicarbonate ($NaHCO_3$). Excess HCO_3^- can result in damage to leaves where water is applied via sprinkler irrigation; iron deficiencies in some plants; and can increases the Na hazard of water to a level higher than indicated by displacing Ca and Mg in soil solutions (USDA, 2011). The mean concentration of Chloride it was in the range recommended by FAO (1992) for irrigation water. This high value of Cl^- might be a result of waste of food leftovers from the café of the factory washed to the channel, chlorination process to deactivate disease causing microorganisms during bottling process and using Cl^- containing salts like NaCl in the factory. The Cl^- concentration is higher in wastewater than in raw water since sodium chloride (NaCl) is a common article of diet and passes unchanged through the digestive system (APHA, 1999). EPA (2011) states that, Cl^- is found in fresh water; sea water, and wastewater at different concentrations; where sewage contains large amounts of Cl^-, as do some industrial effluents; and high Cl^- levels may render water unsuitable for irrigation. Total hardness mean value of the sample was very high and categorized as very hard water since it is greater than 300 mg/l (EPA, 2011; USDA, 2011). Hence, Ca and Mg contribute to the total hardness of water (WHO, 2011), the presence of high concentrations of Ca and Mg (Table 1) in the effluent contributed to increased hardness of the effluent. A hardness of between 50 and 150 mg/l are recommended for irrigation, and hardness above 150 mg/l can cause foliar staining problems in plants (FAO, 1992; William *et al*., 2016). Ammonia (NH_4-N) is another irrigation water quality parameter and is dependent on pH and temperature of water and indirectly related with DO (USDA, 2011). Excessive quantities of nitrogen in form of ammonium (NH_4-N) exceeding 5 mg/l present or applied in irrigation water may upset production of several commonly grown crops because of over-stimulation of growth, delayed maturity or poor quality (FAO, 1992). Hence, NH_4-N of the effluent was above the maximum permissible level. This level of Na concentration is relatively high as compared to the Mg. This is due to the presence of high Na concentrations in the spring water (Tibebu *et al.,* 2017), naturally and Na containing chemicals used in the factory for softening process. Levels of Na in groundwater vary widely but normally range between 6 and 130 mg/l (APHA, 1999; WHO, 2011; ICARDA, 2013). The concentrations of Mg were beyond the permissible level set as 50-60 mg/l (FAO, 1992), whereas Na and Ca were below the maximum permissible limit of 900 and 400 mg/l, respectively. High Na cations in irrigation water are not recommended due to their high deffloclation properties of soil structure which might affect the permeability and infiltration (FAO, 1992; Bryan *et al.,* 2007). In regards to concentrations of Ca and Mg, University of Massachusetts Amherst (UMA, 2019) states that, the concentrations of Ca and Mg in the range of 40-100 and 30-50 mg/l, respectively, are considered desirable for irrigation water (UMA, 2019), and high Mg levels is often thought to trouble soil infiltration process (FAO, 1992). High Na acts to inhibit plant uptake of Ca, and may result in excess leaching of Ca and Mg from growing media. Acceptable levels of Na and Cl for ornamentals are less than 50 and 140 mg/l, respectively (William *et al.,* 2016), however higher levels may be tolerated depending on crop sensitivity, and Na levels of about 50 mg/l or less are considered acceptable for overhead irrigation (Williams *et al.,* 2016; UMA, 2019).

The larger increment in soil pH which is about 1.8 units is so significant that results due to the effluent effect on soils. The presence of weak acids (HCO_3^-) and strong bases (Na^+) in the soil solution of alkali soils may result in high soil pH as high as pH 10.5 (Jayanta *et al.,* 2017). The high ECe on AECh is the due to high salt load of the effluent that has changed the characteristics of the same soil like that it has changed the pH of the soil reaction. Similar findings were also reported earlier by Chopra, *et al.* (2011), USDA, (2011), and Megha and Kumar, (2015), that irrigation water with high effluent concentrations showed high increment in ECe. Cation Exchange Capacity (CEC) is the total number of exchangeable cations a soil can hold; and the higher the CEC, the more cations it can retain (FAO, 2008). The high Na level observed on AECh soil sample was due to large concentration of Na found in the effluent sample. Again, this finding is in contrary with Hanan and Yaling (2017) study that, exchangeable Ca, Mg, K, and Na also increased, by 198, 116, 148, and 452%, respectively, over nine years of effluent water irrigation. Increased salinity (EC) and Na levels are the greatest risks when using effluent water; however, to a certain degree, these can be managed through appropriate cultural practices such as leaching and adding gypsum (FAO, 1992; Bryan *et al.,* 2007). Another study by Megha and Kumar (2015) also depicted that, very high concentrations of Na that range in 374 to 1563 mg/l in an effluent polluted soil. Exchangeable sodium percentage (ESP) is the ratio of Na to other exchangeable cations (Na, K, Mg and Ca), and is a best soil characteristic to determine level of sodicity hazard (Horneck *et al*., 2007; Leticia *et al*., 2015). The increment of ESP on AECh is resulted from the high level of Na concentration analyzed in AECh. Nonsaline-alkali (sodic) is applied to soils for which the ESP is greater than 15 and ECe is less than 4 dS/m at 25 ^{0}C, with the pH readings usually ranging between 8.5 and 10 (Richards *et al*., 1954) and SAR of greater than 13 (Horneck *et al*., 2007). Therefore, the soils from AECh depicted a sodicity property. Sodicity degrades soil structure by breaking down clay aggregates, which results in more easily eroded soil that is less permeable to water, which then reduces plant growth (FAO, 2008). The Na is not directly harmful to most plants; rather it negatively affects the permeability and infiltration (USDA, 2011). This result coincides with Vipin and Nidhi (2012), that the soils treated with effluent contained ESP value of 15 to 16.80% which depicted that the soil is more sodic property. Therefore, the study indicated that, the soils that are contaminated with the effluent showed a sodic property. The increment of soluble HCO_3^-, Cl^- and CO_3^{2-} is due to the high concentration of HCO_3^- and Cl^- in the effluent water that has contaminated the soil. Based on its concentration in soil, Cl^- as anion can be beneficial and/ or harmful to plant (FAO, 2008), and Cl^- concentrations above a range of 15-50 mg/g in soil are only suitable to very tolerant species. Study by Kumar and Chopra (2011) also showed the increment of soluble anions (CO_3^{2-}, HCO_3^- and Cl^-) over effluent affected soils than a control. Therefore, the finding of this study showed that, the soil samples from AECh were in medium to high alkalinity and chloride hazard as a result of accumulations of these parameters along the channel from the effluent. High mean value of available P in effluent affected soil sample (AECh) might be due to high PO_4^{2-} concentration examined in the effluent (Table 1). This is in regard with the study by Orji and Ayogu (2018), which available P of the soil samples contaminated with effluent, was increased. The decrement of OM on AECh might be due decrement of CEC observed along effluent channels. However, no significant difference was observed on total nitrogen (TN) of a soil sample between both samples, TN showed a decreasing trend on AECh, and this result is in line with Megha and Kumar (2015). Heavy soils (with alkaline pH) provide good storage for trace metals and their supply to plants at a lower rate (Uzaira *et al.,* 2011), and they stated that, this is due to the solubility of most of the trace metals is lower in alkaline and neutral soils than in light acidic soils, which has a great significance on their bioavailability and migration as is evident from the results of the study. This result is dissimilar with the study by Kumar and Chopra (2011), and Hanan and Yaling (2017) that they stated there is a highly significant difference among neutral (control) soils and effluent affected soils.

CONCLUSIONS

The analysis of Ambo mineral water factory effluent was found that the majority of physicochemical parameters are within a suitable range for irrigation purpose. However, the effluent has some alkaline properties with high pH, ECw, TDS, HCO_3^-, Cl^-, and Na as compared to other parameters. The toxicity and hazard level of alkalinity, salinity, sodicity and chloride concentrations were moderate with exception of HCO_3^- alkalinity which was found to be high. This might be due to nature of the *hora* spring water; the use of alkaline ingredients and salts like NaCl and $NaHCO_3$ for different internal processing purposes; and the softening processes in the factory. The effect of the effluent on the soil physicochemical properties showed a significant effect. The bulk density, total porosity, exchangeable Mg, K and Ca, total nitrogen and heavy metal elements (Pb, Mn, Zn, and Fe) showed no significant difference between the soils from effluent channel and farmers' field. The soil pH, ECe, Na, ESP, soluble Cl^-, HCO_3^-, CO_3^{2-}, available P and Cr highly significantly increased in the soil solution and exchange complex in the soil samples collected along the effluent channel, whereas; CEC and OM were found in larger quantities in the adjacent farmers' field soils which were not contaminated by the factory effluent. The effect of the factory effluent used for irrigating tomato crop for 45 days significantly enhanced growth of the crop in terms dry biomass, leaf number, growth rate and heights at 75 and 100% effluent water concentration levels. Significant differences among the soil properties under different concentrations of effluent were observed. Majority of soil properties showed increments with the effluent concentrations from 0 to 100%. Soil pH, ECe, chloride, carbonate, bicarbonate, exchangeable sodium, calcium and ESP highly significantly increased with increment in effluent concentration level in the soil, while organic matter and CEC decreased in the soil with the increase in effluent concentration. Therefore, we recommend for the establishment of appropriate waste water treatment systems and implementation of local and international environmental regulations, public awareness on selection of edible plants grown in high concentration of effluent discharge areas.

Acknowledgment

The authors are grateful to the Ambo University, Ethiopia for their logistic support and unreserved cooperation during the soil sample analysis

Financial support: This work was supported by Ambo University.

Conflict of interest: The authors declare that there is no conflict of interest.

Ethical standards: Not applicable.

REFERENCES

Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadesse. 2012. Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia, Journal *of Biodiversity and Environmental Sciences 2(3), p. 57-71.*

Akinyemi, DS, Olatunji OA, Okeand SO, and Oluyemi TE. (2015). Effects of Industrial Effluent Contamination on Soil Properties, Growth and Yield of Capsicum Chinense Tourn. Federal University of Technology Akure (FUTA) Journal of Research in Sciences. Vol. 11 (2): 253-261

American Public Health Association. (1999). Standard Methods for the Examination of Water and Wastewater. 20th edition. Lenore, S. C., Arnold, E. G., & Andrew, D. E. (Eds). American Water Works Association, Water Environment Federation

Amin M. (2011). Effects of Municipal Wastewater on Physicochemical Properties of Saline Soil. Journal of Biological and Environmental Science, Vol. 5(14):71-76

Blake GR. (1964). In: Methods of Soil Analysis: Bulk Density, Part 1. Black, C.A., Evans, D.D., White, J.L., Ensminger, L.E., & Clark, F.E. (Eds), ASA, Madison, Wisconsin.

Bryan GH, Donald, AH, Robert, GS, Jason WE and Dan MS. (2007). Managing Irrigation Water Quality for Crop production in the Pacific Northwest. Oregon State University, University of Idaho and Washington State University. A Pacific Northwest Extension publication

Central Statistical Authority.(2012). Population and Housing Census of Ethiopia: Results for Oromia Region; Central Statistical Authority. Addis Ababa, Ethiopia

Chhonkar PK, Datta SP, Joshi HC, and Pathak H. (2000). Impact of Industrial Effluent on Soil Health and Agriculture. Journal of Scientific and Industrial Research, 2000. Vol. 59: 350-361

Chopra AK, Sharma MK, & Chamoli S. (2011). Bioaccumulation of organochlorine pesticides in aquatic system--An overview. Environmental Monitoring Assessment, 2011. Vol. 173(1-4):905-16

Dipak S, & Abjihit H. (2005). Physical and Chemical Methods in Soil Analysis. Fundamental Concepts of Analytical Chemistry and Instrumental Techniques. New Age International (P) Ltd Publishers. New Delhi, India

Environmental Protection Agency. (2001). Parameters of Water Quality: Interpretation and Standards. Environmental Protection Agency, Dublin, Ireland.

Food and Agricultural Organization. (1992). Wastewater Treatment and Use in Agriculture. FAO Irrigation Paper 47. FAO, Rome, Italy.

Food and Agricultural Organization. (2004). The State of Food and Agriculture 2003-2004 Report: Agricultural Biotechnology: Meeting the Needs of the Poor. FAO, Rome, Italy

Food and Agricultural Organization. (2008). In: Guide to Laboratory Establishment for Plant Nutrient Analysis. Motsara, M.R., & Roy, R.N. (Eds). FAO Fertilizer and Plant Nutrition Bulletin 19. Italy, Rome

Guiliano V, Pangnanelli F, Bornoron L, Toro L, and Abbruzzese C. (2007). Toxic Elements at Disused Mine District: Particle Size Distribution and Total Concentration in Stream, Sediments and Mine Tailing. Journal of Hazardous Materials, Vol. 148: 409-418

Hanan I and Yaling Q. (2017). Long term Effects of Effluent Water Irrigation on Soil Chemical properties of Sandbased Putting Greens. DOI:10.5772/intechopen.72227

Hernandez-Allica, J, Garbisu C, Barrutia O, and Becerril JM. (2007). EDTA Induced Heavy metal Accumulation and Phytotoxicity in Carbon plants. Environmental Experimental Botany, 2007. Vol. 60 (1): 26-32

Horneck DA, Ellsworth, JW, Hopkins, BG, Sullivan, DM, & Stevens R., (2007). Managing Salt-affected Soils for Crop Production. Oregon State University, University of Idaho and Washington State University. A Pacific Northwest Extension publication

Hossain ML Huda SM and Hossain MK. (2009). Effects of Industrial and Residential Sludge on Seed Germination and Growth Parameters of Acacia auriculiformis seedlings. Journal for Resource,Vol. 20: 331-336.

International Center for Agricultural Research in the Dry Areas. (2013). In: Methods of Soil, Plant, and Water Analysis: A manual for the West Asia and North Africa region. Third Edition. George, E., Rolf, S., & John, R. (Eds). Beirut, Lebanon

Jackson ML. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi

Jayanta K, Rajendiran S, Vassanda C, Dotaniya ML, Samaresh K, and Ashok KP. (2017). Soil Pollution - An Emerging Threat to Agriculture: Environmental Chemistry for a Sustainable World. Published by Springer. Singapore, Singapore

Kjeldahl J. (1983). Neueméthodezurbestimmung des stickstoffs in organischenkörpern. Z. Analalytical Chememistry. Vol. 22: 366-382.

Kumar A. (2011). Effect of Dairy Effluents on Seed Germination and Early Seedling Growth of Pennisetumtyphoides. International Journal of Research, Science and Technology,. Vol. 1 (1)

Kumar V, and Chopra AK. (2011). Alterations in Physicochemical Properties of Soil after Irrigation With Paper Mill Effluent. Journal of Chemical and Pharmaceutical Research. Vol. 3 (6): 7-22.

Kumar V, and Chopra AK. (2011). Impact on Physicochemical Characteristics of Soil after Irrigation with Distillery Effluent. Scholars Research Library, Archives of Applied Science Research, Vol. 3 (4):63-77.

Leticia S, Uttam S, and David EK, (2015) Soil Salinity: Testing, Data Interpretation and Recommendations. The University of Georgia, Fort Valley State University, the U.S. Department of Agriculture

Lindsay WL, and Norvell WA. (1978). Development of a DTPA Test for Micronutrients

Maiti SK, (2004) Handbook of Methods in Environmental Studies: Water and Wastewater Analysis. Volume 1: Second Edition. ABD Publishers. Jaipur, India

Mc Laughlin MJ, Parker DR, and Clarke JM. (1999). Metals and Micronutrients: Food Safety Issue. Field Crop Research, 1999. Vol. 60 (1-2): 143-163

Megha G, & Kumar RR. (2015). Combined Industrial Effluent Effect on Physical and chemical Characteristics of Soil Cultivated with Phaseolus vulgaris. Environment Conservation Journal, 2015. Vol. 16 (1&2):129-132

Nikos JW, Krista EP, and James WB. (2003). In: Basics of Salinity and Sodicity Effects on Soil Physical Properties. MSU Extension Water Quality Program Montana State University. Krista, E. Pearson. (Ed)

Olsen SR, Cole CV, Watanable FS, and Dean LA. (1954). Estimation of Available Phosphorus in soil by Extraction with Sodium Bicarbonate. United States Department of Agricultural Circular, 19: 939

Orji JO, and Ayogu TE. (2018). Effects of Cassava Mill Effluent on Physicochemical Characteristics and Bacterial Flora of Soil in Ezzamgbo Community Ebonyi State, Nigeria. World Journal of Medical Sciences, 2018. Vol. 15 (1): 20-33. IDOSI Publications Person Education Ltd., USA.

Richards RC, Bower CA, Brooks RH, Gschwend FB. (1954). A Comparison of the Effects of Exchangeable Sodium and Potassium upon the Physical Condition of Soils. Soil Science Society of America Journal. Vol.18 (2):130.

Renu, M. Agarwal, K. Singh, (2016) Heavy metal removal from wastewater using various adsorbents: a review, J. Water Reuse Desalin. 7 387–419. https://doi.org/10.2166/wrd.2016.104

Tibebu A, Eyobel, M, and Miresa, T. (2017). Determination of physicochemical parameters of "Hora" Natural Mineral Water and Soil in Senkele Kebele, Oromia Region, Ethiopia. Analytical Chemistry,Vol. 3

Udom BE, Mbagwa SC, Andensodun, JK, and Agbim NN. (2004). Distribution of Zinc, Copper, Cadmium and Lead in Tropical Ultisol after Long-term Disposal of Sewage Sludge. Environment International, Vol. 30(4): 467

United States Department of Agriculture. (2011). Assessing Water Quality for Human Consumption, Agriculture, and Aquatic Life Uses. Natural Resources Conservation Service Environment-Technical Note No. MT-1 (Rev. 2) June, 2011

United States Environmental Protection Agency. (2006). Terms of Environment Beginning with "E". Retrieved 09-06-2010

University of Massachusetts Amherst. (2019). Water Quality for Crop Production. Published on *Center for Agriculture, Food and the Environment*. Online website: https://ag.umass.edu

Vipin K, and Nidhi N. (2012). Effect of Industrial Effluent on Content of Nutrient and Heavy Metals in Plant and Soil. International Conference on Chemical, Bio-Chemical and Environmental Sciences, 2012. Conducted: December 14-15, 2012, Singapore

Walkley AJ, and Black I.A. (1934). An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the chromic acid titration method. Soil Science, Vol.37: 29-38.

William L, Stephen, R, Inge B, and Bill W. (2016). Interpreting Irrigation Water Tests. Penn State Extension. Retrieved: May, 2016

World Health Organization. (2011). Guidelines for Drinking water Quality. 4th Edition.