ASSESSMENT OF THE IMPACT OF INDUSTRIAL EFFLUENTS ON THE QUALITY OF IRRIGATION WATER AND CHANGES ON SOIL CHARACTERISTICS (A CASE OF KOMBOLCHA TOWN)

Eskinder Zinabu [1], Eyassu Yazew [2] and Mitiku Haile [3]

[1] MSc, Kombolcha ATVET College, P.O. Box 56, Kombolcha, South Wollo, Ethiopia
E-mail: eskyak@yahoo.com
[2,3] PhD, Mekelle University, P.O. Box 231, Mekelle, Tigray, Ethiopia
E-mails: eyasuet@yahoo.com , gualmitiku@yahoo.com

ABSTRACT

In the town of Kombolcha, which is found in the northern parts of Ethiopia, there are several industries that drain their liquid waste to the nearby rivers. To assess the impacts of the liquid waste on irrigation water quality, samples of water and soil were collected three times from three rivers that are locally named River Leyole, River Worka and River Borkena. The rivers are used as sources of irrigation water for the near by farmlands. Parameters of pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, $CO_3^{=}$, HCO_3^{-}, BO_3^{-3}, and SAR were monitored in the irrigation water and the soils of the respective irrigated farmlands. Significance concentration differences ($P \leq 0.05$) of these parameters was detected in the two industrial effluents recipient rivers (River Leyole and River Worka) from which most of the town's farmlands are irrigated, when compared against the control river water (River Borkena). The mean values of the parameters in each irrigation water sources samples were also compared with most applicable standards of Irrigation Water Quality to evaluate their irrigation suitability. River Leyole and River Worka are proved to be polluted as compared to River Borkena. Significant quality difference ($P \leq 0.05$) was observed in pH value and Na^{+} concentrations between the River Borkena and effluent contaminated irrigation water of River Leyole. Besides, Na^{+}, HCO_3^{-} and SAR were found beyond the safe limits to use irrigation. Irrigation water from River Worka was found to be significantly different ($P \leq 0.05$) from the control irrigation water in Na^{+}, Mg^{+2} and SAR and the Na^{+} concentration, the value of pH and SAR have been identified to surpass the normal condition to use for agriculture. The chemical parameters in the irrigation water were also seen to be accumulated to change the soils characteristics of the farmlands.

Keywords: Irrigation water quality, River Leyole, River Worka, River Borkena, Soil characteristics

INTRODUCTION

With the ever increasing demand on irrigation water supply, farmlands are frequently faced with utilization of poor quality irrigation water. In many parts of Ethiopia, waste water, which are disposed to wells, ponds, streams and treatment plants, are used as a source of irrigation water as well as for drinking (Alemtsehaye, 2002). But, the continued application of poor quality irrigation water can reduce the yield of farmlands. Water quality for agricultural purpose is determined on the basis of the effect of water on the quality and the yield of the crops, as well as, the effect on the characteristic changes in the soil (FAO, 1985). The most commonly encountered soil problems used as a basis to evaluate water quality are those related to the salinity, water infiltration rate, toxicity and a group of other miscellaneous problems (Richardson, 1954).

Kombolcha is one of the few towns in Ethiopia with a relative greater number of large-scale manufacturing plants including Textile Factory, ELFORA-Meat Processing Factory, Tannery, BGI-Brewery Factory, Steel Product Industry and Flour Factory. On top of this, the town is selected to be an industrial town by Amhara National Regional State of Ethiopia, which indicates the industrial development and its associated pollution risk will increase in the future. The existing industries have been discharging their wastes into the surrounding environment, in particular to the near by river. According to the local woreda agriculture office report (2006), more than 25,000 farmers are diverting the effluent contaminated rivers water to irrigate about 2695 ha of farmlands in order to grow different crops including cereals, vegetables and fruits. In addition, the latest report from the local agricultural administration office explains that despite the fact that many farmers and enterprises have used the local rivers for irrigation since long time ago; no study has been conducted yet on the chemistry of the polluted river water for its irrigation suitability. In Kombolcha, perhaps the most important factor in predicting and managing farmland soil is the quality of irrigation water being used.

The main intention of the study is to provide concrete information on the magnitude of the industrial liquid wastes and help farmers and policy makers to take the necessary corrective measures on time. The impact of industrial liquid wastes on the irrigation water quality was assessed by examining the concentrations of Na^+, Ca^{2+}, Mg^{2+}, BO_3^{-3}, $CO_3^=$, HCO_3^-, Cl^- and values of pH and SAR in the polluted irrigation rivers water through laboratory analysis. Soil samples were also taken to assess the quality of the irrigation water effect on the irrigated farm soils properties.

MATERIAL AND METHODS

Location of Study Area

The study area is found in the town of Kombolcha which is located on the north central part of Ethiopia placed immediately south east of Dessie in the Amahara region at $11^o06'$ north latitude and $39^o45'$ east longitude. River Borkena crosses the town emerging from the east and running to the west direction. In its way all through the town, it receives effluents indirectly through its tributaries rivers named Worka and

Leyole. Most of the factories are found closely together in the middle of the town near by the tributary rivers of Borkena.

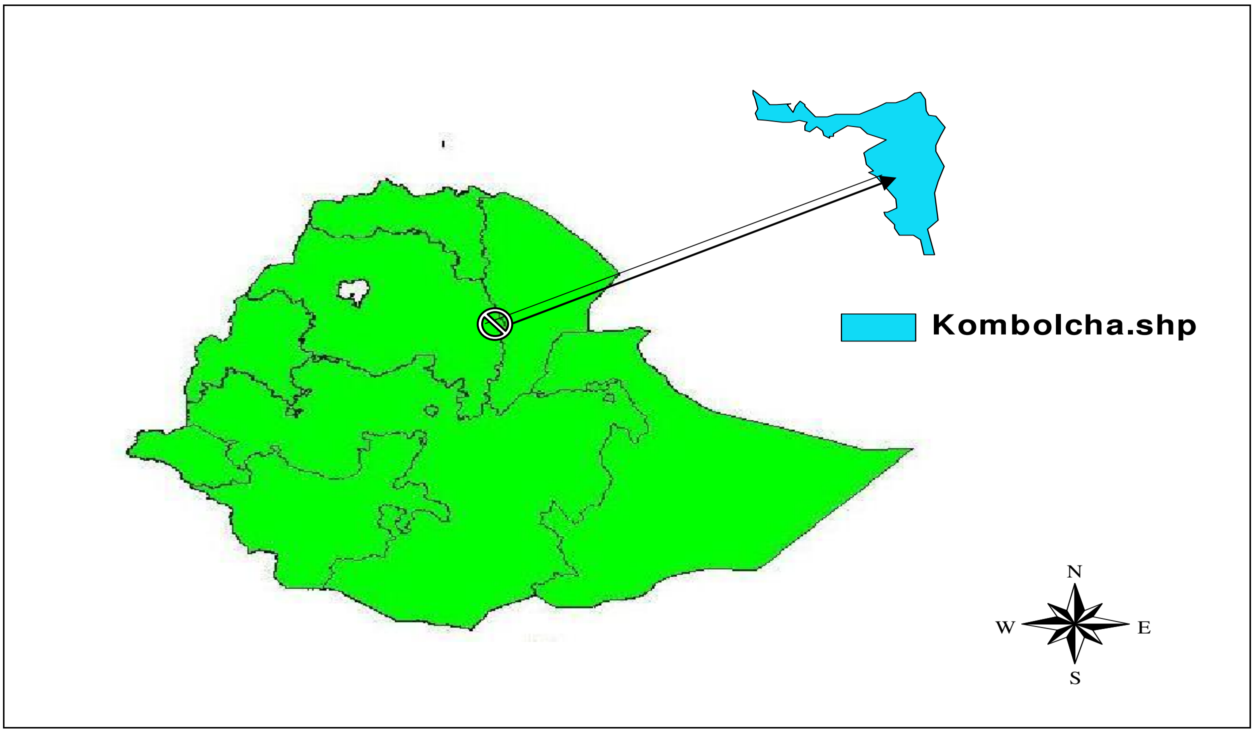

Figure 1 Location of the Kombolcha town in Ethiopia

Figure 2. Excess solid and liquid industrial wastes surfaced over the irrigation water of Leyole River

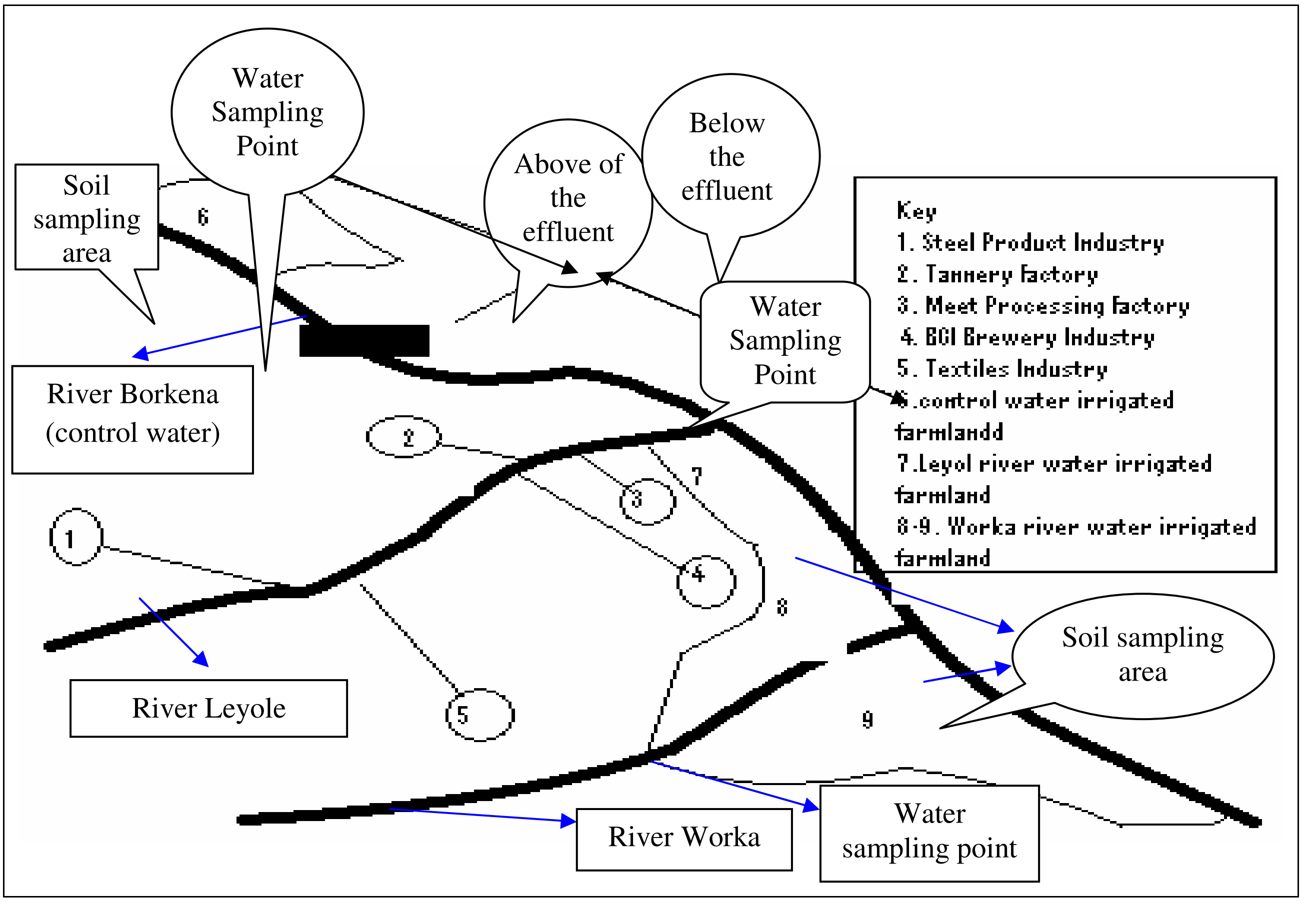

Figure 3. Sketch of factories, irrigation source rivers and irrigated farmlands in relation to effluent points

Methods

Samples of irrigation water and farmland soils were collected in three phases with in the irrigation period of the study area. FAO'S standard methods and calibrated instrumentation were used during sample collection activity.

Sampling site selection: Based on the outlining of the irrigation sites and waste disposal points, three areas were selected to take water and soil samples viz. a farmland (control) above of the effluent points which is irrigated by effluent free water of River Borkena and two farmlands below of the effluent points which are irrigated by effluent contaminated rivers water (River Leyole and River Worka). One liter of water sample was collected per each location in a plastic bottle thoroughly cleaned by distilled water. All samples were collected by grab method i.e. just taking each sample independently at once. The plastic bottle was rinsed with the water to be sampled just before sample collection and was labeled and recorded on the Water Information Sheet. The mean values of the parameters in the control irrigation water source and the effluent contaminated water of the other rivers were compared with the most recognized and applied standards set by FAO (1985). The soil samples of the respective irrigated farmlands were also considered to assess the extent of the impacts of the effluent contaminated irrigation water on the characteristics the soils. Samples were taken from the center of shovel slice in a 30cm by 30cm core. The chemical parameters that have been measured in the diverted irrigation water were also determined from the soil samples of the selected irrigated farmlands. Both surface and subsurface soil samples were taken once from the fresh water irrigated farmland (control) at the upper and three times from the effluent mixed irrigated farmlands at the lower of the effluent points through out the irrigation period of the study area. TDS, ESP and SAR were computed following the formulas stated in FAO soil bulletin 42. Chlorides, nitrogen-nitrate, sulfate, chromium and some samples of phosphate were found to be below the detection limit in the first phase samples analyses.

Water samples: 9 water samples were taken from January 2007 to June 2007. The sampling frequency was in three phases throughout the irrigation season. In first phase, additional parameters were analyzed other than the mentioned ones in the internationally accepted irrigation water quality guidelines by FAO (1976c; 1985) in order to have a better understanding on the water quality characteristics. The chemical variables analyzed in the second and third phase were made to stick only to those recommended in the FAO standard guidelines.

Samples were taken from two sites. One is from a main diversion channel (from the fresh water of River Borkena) above the effluent points. These samples served as background and were non effluent contaminated; the others were from the main channels at lower of the effluent points which were diverted from industrial effluent recipient rivers, i.e. are locally named River Leyole and River Worka. The samples were collected at the same location in all phases of samples collection from the irrigation surface water sources of the selected farmlands. Samples collection was conducted immediately after the factories discharge their effluents in to the near by rivers in order to take advantage of the effluent presence in the collected irrigation water samples. The samples were stored in refrigerator at less than 4°C temperature till it was delivered to the laboratory for analyses. All samples were transported in ice box to suppress chemical changes and delivered with in two days for an immediate analysis.

Soil samples: Before sample collection, site characterization and soil profile descriptions were done by close observation and examination of dug pits on the study areas. First, the surface characteristics were recorded. Then, the soil description was made according to the Guidelines of FAO (1990). Nine composite surface soils samples and 21 subsurface soils samples were taken from the farmlands irrigated by the above three sources of irrigation water in the irrigation period of the study area. The control soil samples were taken from a farmland placed upper of the effluent points which were irrigated by fresh water (effluent free). The other two areas are found below the effluent point and were irrigated by the effluent contaminated river water of River Leyole and River Worka.

Composite surface soils: taking samples using shovel slices was repeated randomly at 20 different spots with in the demarcated farmlands. The collected samples were put in a plastic bucket and thoroughly mixed and at the end, 500gm of soil is removed as the composite sample representing the whole field. The samples were made to air dry for a few days and transported for laboratory analyses in plastic bags. While soil sampling, areas of back furrows or dead furrows, old fences rows, areas used for manuring or hay storage and livestock feeding, small gullies, slight depressions, terraces, waterways or unusual areas were all avoided.

Subsurface soil samples: A pit, in all of the three demarcated sampling areas, was dug to take subsurface soil samples; a depth of 90 cm pits was dug at the selected farmlands. A sample of 500gm soil was removed in each 30cm sections downward. The morphological and other characteristic of the soil was examined in the dug pits which were large enough to allow observations. Sampling from the boundaries of the horizons was avoided. The soil description was done based up on the method of FAO Guidelines for soil description. The subsurface samples were air dried and transported along with the surface soil samples with in a few days in plastic bags. All soil, surface and subsurface, samples in the plastic bags were labeled and recorded by codes on the Soil Information Sheet.

Physico-chemical determination of soil and water samples: pH values were read on ORION model SA720 pH meter with a standard solution calibrated at pH values of 4.7 and 9.2. Electrical Conductivity was read on EC meter InoLab (WTW series) which was calibrated using 0.01NKCl standard solution. The cations Na^+, K^+, Mg^{+2}, and Ca^{+2} were determined by atomic absorption spectrometer (Varian SP-20). $CO_3^=$ and HCO_3^- were measured by titration using phenolphthalein and methyl orange indicators respectively. Chloride was titrated by Argentometry methods. The instrument used for phosphate, nitrate and sulfate measurement was UV visible spectrophotometer. All analyses followed the standard procedures as outlined by USSL staff (1954). TDS and SAR were calculated by formulas as it is suggested in FAO Soil Bulletin 42 (1985).

Data analysis and interpretation techniques: To make irrigation suitability evaluation and quality difference comparison, the values of the chemical variables of lower farmlands irrigation water and soil samples were taken after computing the average of the three phase samples collected in one irrigation period (start, middle and last irrigation times). At the upper farmland (background), a single variables measurement of soil was taken at the starting period of the irrigation season. These values were used for testing of significant irrigation water quality changes due to industrials effluent discharge in to the irrigating rivers. The most widely applicable irrigation water quality guideline, which is set by FAO, was selected for suitability evaluation. The assumptions made by the selected guideline were then evaluated against the local conditions and it was generally found that most of the assumptions of the chosen guideline for evaluation of irrigation water quality of the rivers are the same to the actual conditions of the study area. There are no as such wide deviations between the assumptions of the guideline and the related local conditions study area. Finally, the values were compared to their respective standards recommended by the internationally accepted guideline in order to evaluate their degree of restriction on use for irrigation.

Since water samples were taken from three different rivers located above and below the effluent points, the test statistics for the significant quality difference in water samples was run by The Independent-Samples T Test. The absence of irrigation practices at the upstream parts of the wastes draining rivers (River Leyole and Worka) forbids the easiest and rather straight forward quality changes between upstream and downstream water samples due to the intrusion of effluents. Besides, as all the three rivers originate from the same neighboring catchments areas with more or less the same geological and biophysical characteristics, the quality of the rivers water is assumed to be the same unless otherwise another external element, like the industrial effluents, is introduced in the rivers. To overcome the mentioned limitation, water and soils samples were taken from another neighboring site with non effluent contaminated river water (River Borkena) and irrigated farm soils.

SPSS VERSION-13 software has been employed to run the test. The T Test procedure produces two test of difference between water samples parameters in the two distinct rivers under investigation. One test assumes the variances of each parameter in the two rivers samples are equal. The Levene Test Statistics tests this assumption. Based on this test, for a significance probability (at $P \leq 0.05$) of greater than 0.1, equal variances in the rivers is assumed. Other wise it is ignored and the second test which assumes unequal variance is taken. The frequency of sample variables measurements were three, and the hypothesis was tested at significant level ($\alpha = 0.05$).

RESULTS AND DISCUSSIONS

Quality of irrigation water: The water samples that have been analyzed to measure the levels of electrical conductivity, sodium, chloride, calcium, magnesium, carbonate, bicarbonate, pH and boron. In addition, sulfate, phosphate, nitrogen-nitrate, fluoride and chromium were added to asses their levels in the first phase of sample collection. The measured values of the parameters were recorded three times over the six months. Some of the parameters, like nitrate, chromium and sulfate, were found to be below the detection limit of the laboratory instruments. Other important parameters like TDS and ESP were computed by the formulas stated in FAO Soil Bulletin 42 (1985). The adjusted SAR (adj R_{Na}) was recalculated using the using the most updated equation.

The T test for the pair of upper control water and Leyole irrigation water shows that the mean of Na^+, Cl^-, HCO_3^-, B^{+3} concentrations and the value of EC are greater at the latter (See Table 1). On the contrary, the concentration of Ca^{+2}, $CO_3^{=}$ and the value of pH were lesser at the latter. Mg^{2+} was found to be the same in both rivers' irrigation water. Statistically, it was seen that there is a significant difference (at $P \leq 0.05$) in mean pH value and Na^+ concentrations between the two sampling locations. Other water parameters (EC, Cl^-, HCO_3^-, SAR), though they indicated appreciable difference in concentrations, they were found to be significantly not different in concentration when compared in the two irrigation water rivers. The T test for the pair of control fresh water and Worka river irrigation water also reveals that there is a significant (at

$P \leq 0.05$) quality difference between them in Na^{+}, Mg^{+2} concentrations and SAR (Table 2). The other mean parameters (Cl^{-}, $CO_3^{=}$, HCO_3^{-}, B^{+3}, and pH) were found not significantly different in the two rivers. Chemical parameters, like electrical conductivity, sodium, chloride, bicarbonates, boron, pH, and SAR were found to be at higher concentration in the effluent mixed irrigation water of River Worka in relative to the background effluent free water. The comparison between the two effluents contaminated rivers by the T Test shows all chemical variables but chloride ions are not different significantly (at $P \leq 0.05$).

Table 1. Independent Samples T-Test for the upper background fresh irrigation water and the Leyole River of lower area

Parameter	Unit	Control Irrigation Water	Leyole Irrigation Water	Levene's Test for Equality of Variance			T- test for equality of means					
				Assumption on variance equality	F	Sig.	T	df	Sig. (2 -tailed)	Mean Difference	95% Confidence Interval of Difference	
											Lower	Upper
EC	dS/m	0.48	1.62	Equal	13.5	0.02	-2.07	4	0.107	-1.143	-2.672	0.39
				Unequal			-2.07	2.02	0.173	-1.143	-3.496	1.21
Na^+	me/l	1.32	8.11	Equal	5.77	0.1	-2.81	4	0.048	-156.33	-310.8	-1.9
				Unequal			-2.81	2.02	0.105	-156.33	-393.3	80.6
Cl^-	ppm	17.33	36.33	Equal	3.20	0.15	-2.02	4	0.114	-19	-45.18	7.17
				Unequal			-2.02	2.15	0.173	-19	-57.05	19.05
BO_3^{-3}	ppm	1.63	6.26	Equal	2.70	0.18	-1.31	4	0.262	-0.85	-2.66	0.96
				Unequal			-1.31	3.01	0.283	-0.85	-2.92	1.22
CO_3^{-2} HCO_3^-	me/l	3.25	8.06	Equal	3.82	0.122	-2.168	4	0.096	-438.47	-1000.0	123.11
				Unequal			-2.168	2.016	0.841	-438.47	-1302.2	425.2
pH		8.38	7.14	Equal	4.08	0.11	3.23	4	0.161	1.23	0.17	2.3
				Unequal			3.23	2.3	0.069	1.23	-0.21	2.7
Ca^{+2}	me/l	2.47	2.15	Equal	1.41	0.300	0.63	4	0.565	6.33	-21.72	34.39
				Unequal			0.63	3.41	0.570	6.33	-23.75	36.42
Mg^{+2}	me/l	1.48	1.48	Equal	7.14	0.056	0.000	4	1.000	0.000	-10.14	25.83
				Unequal			0.000	2.322	1.000	0.000	-13.79	10.14
Adj. R_{Na}		1.05	7.43	Equal	10.4	0.032	-2.23	4	0.090	-12.35	-27.76	13.79
				Unequal			-2.23	2.01	0.156	-12.35	-36.08	11.38

Table 2. Independent Samples T-Test for River Borkena (Control) and Industrial effluent polluted River Worka

Parameter	Unit	Control river water	Worka river Irrigation Water	Levene's Test for Equality of Variance			T- test for equality of means					
				Assumption on variance equality	F	Sig.	t	Df	Sig. (2 -tailed)	Mean Difference	95% Confidence Interval of Difference	
											Lower	Upper
EC	dS/m	0.48	1.26	Equal	9.47	0.037	-2.752	4	0.050	-0.77	-1.55	0.07
				Unequal			-2.752	2.05	0.108	-0.77	-1.96	0.41
Na^+	me/l	1.32	8.48	Equal	2.5	0.190	-7.573	4	0.002	-164.7	-225.04	-104.3
				Unequal			-7.573	2.14	0.014	-164.7	-252.45	-76.9
Cl^-	ppm	17.33	25.0	Equal	11.6	0.027	-0.500	4	0.650	-7.67	-51.16	35.83
				Unequal			-0.050	2.051	0.672	-7.67	-73.48	58.15
$B0_3^{-3}$	ppm	1.63	5.28	Equal	1.180	0.338	-1.148	4	0.315	-0.67	-2.29	0.95
				Unequal			-1.148	3.272	0.328	-0.67	-2.44	1.10
$CO_3^=$ HCO_3^-	me/l	3.25	4.07	Equal	10.94	0.030	-.227	4	0.831	-41.6	-549.7	466.50
				Unequal			-.227	2.059	0.841	-41.6	-807.63	724.43
pH		8.38	8.80	Equal	11.263	0.028	-0.214	4	0.841	-0.427	-5.97	5.11
				Unequal			-0.214	2.011	0.850	-0.427	-8.97	8.11
Ca^{+2}	me/l	2.47	2.3	Equal	0.126	0.741	0.368	4	0.732	3.33	-21.83	28.49
				Unequal				3.72	0.733	3.33	-22.59	29.26
Mg^{+2}	me/l	1.48	0.98	Equal	1.000	0.374	3.286	4	0.030	6.00	0.93	11.07
				Unequal			3.286	3.448	0.038	6.00	0.59	11.40
Adj. R_{Na}		1.05	7.63	Equal	4.485	0.102	-4.543	4	0.010	-9.91	-15.97	-3.85
				Unequal			-4.543	2.082	0.042	-9.91	-18.96	-0.87

Table 3. Mean values of soil sample chemical parameters of farmlands that are irrigated by three rivers

Water parameter	Unit	Control water irrigated soils				River Leyole irrigated soils				River Leyole irrigated soils			
		Composite surface samples	Soil profile samples			Composite surface samples	Soil profile samples			Composite surface samples	Soil profile samples		
			0– 30 cm	30-60 cm	60-90 cm		0-30 cm	30-60 cm	60-90 cm		0-30 cm	30-60 cm	60-90 cm
Electrical conductivity	dS/m	0.017	0.034	0.043	0.044	0.0413	0.046	0.035	0.049	0.038	0.036	0.018	0.033
TDS	ppm	10.88	21.76	27.52	28.16	29.44	29.44	22.4	31.36	24.32	23.04	11.52	20.736
Sodium	me/l	4.32	3.48	3.48	4.34	17.38	13.04	13.6	13.88	11.01	6.95	14.5	17.35
Chloride	ppm	B.D.L.	B.D.L	B.D.L	B.D.L	71	B.D.L.	51.3	B.D.L.	57	-B.D.L	66.33	B.D.L
Borate	ppm	B.D.L.	0..185	0.234	0.24	2132	-	1290.	-	B.D.L.	-	2555	-
Carbonate	me/l	0	0	23.96	23.9	23.53	34.12	28.85	26.62	39.93	0	11.11	0
Bicarbonate	me/l	27.85	78.26	59.88	95.87	74.82	79.89	62.22	89.44	68.64	52.46	36.02	69.78
pH		7.44	8.28	9.19	9.23	9.08	9.36	9.33	9.2	8.27	7.69	8.32	7.51
Calcium	me/l	29.98	69.9	68.85	70.85	64.28	109.2	48.93	97.15	65.91	41.26	27.96	89.13
Magnesium	me/l	14.74	14.75	18.03	18.03	15.85	19.12	11.47	20.19	15.82	14.21	7.11	21.25
Adj. RNa		1.5	1.22	1.15	1.39	6.03	3.99	5.33	4.12	3.79	2.5	7.07	5.22
ESP	%	8.83	3.93	3.77	4.65	17.73	17.76	18.39	10.56	11.87	11.15	29.24	13.6

Table 4. Mean values of water parameters verses with potential degree of restriction for irrigation

Water parameter	Unit	Degree of restriction (Source: Biswas et al., 1998; FAO SOIL BULLETIN 55, 1985)			Control water (effluent free water)	Leyole river water (effluent contaminated)	Worka river water (effluent contaminated)
		None	Slight to moderate	Sever			
Electrical conductivity (EC)	dS/m	< 0.7	0.7 - 3	> 3	0.4807	1.6237	1.26
Total Dissolved Solids (TDS)	ppm	< 450	450 – 2,000	> 2,000	307.65	1039.17	806.4
Sodium (Na^+)	me/l	SAR < 3	SAR: 3 - 9	SAR: > 9	1.32 Adj. RNa 0.94	8.11 Adj. RNa 7.71	8.48 Adj. RNa 8.18
Chloride (Cl^-)	ppm	< 140	140 - 350	> 350	17.33	36.33	25
Borate (BO_3^{+3})	ppm	< 3.8	3.8 – 10.88	> 10.88	1.63	6.26	5.28
Carbonate ($CO_3^{=2}$)	me/l	Normal range: 0 – 0.2			0.16	0	0.104
Bicarbonate (HCO_3^-)	me/l	Normal range: 0 -10			4.76	12.04	6.02
pH		Normal range: 6.5 – 8.4			8.37	7.14	8.8
Calcium (Ca^{+2})	me/l	Normal range: 0 - 40			2.47	2.15	2.3
Magnesium (Mg^{+2})	me/l	Normal range: 0 – 9.87			1.48	1.48	0.98
Adj. RNa		< 6	6 - 9	> 9	1.05	7.43	7.63

Effect of industrial effluent on selected soil properties of irrigated farmlands: the suitability of water for irrigation is evaluated based on its potential to create hazardous soil conditions to crop growth. Thus the impacts of the applied irrigation water were evaluated in terms of salinity, water infiltration, specific ion toxicity and related miscellaneous problems.

I. Salinity: The mean electrical conductivity of River Borkena's water was 0.4807 dS/m and this can be classified as none restricting for irrigation. The concentration of electrical conductivity of River Leyole and River Worka irrigation water increased to1.624 dS/m and 1.260 dS/m respectively (Table 5). Based on the standards of FAO (1985), these concentrations indicate a potentially slight degree of restriction to use for irrigation (Table 4). The salinity concentration of all irrigated farm soil at the upper areas was found to be less than even 0.05 dS/m (Table 3); this is justified by the low salinity of the applied irrigation water and the practice of surface irrigation methods which help to leach down salts in the rooting depth. However, there was an increase in the level of salinity at the lower area farm soil with 0.0413 dS/m and 0.038 dS/m for each effluent contaminated irrigated farmlands as compared to 0.017 dS/m of upper fresh water irrigated farmlands. This indicates that the polluted irrigation water of River Leyole and River Worka is elevating the salinity of the lower areas farmlands soils.

II. Water infiltration: since EC values of all rivers are was not found enough cause permeability problem, the salinity of all irrigation sources is not a factor to cause infiltration problems. The concentration of sodium as compared to calcium and magnesium, which is measured in terms of sodium adsorption ratio (SAR), was found to be less or none restricting in the control irrigation water; however, in the effluent contaminated water of Leyole and Worka rivers, which was detected be 7.71 and 8.18 respectively, it was found high and is potentially restricting (Table 4 and 5). The effect of high SAR water irrigation is noticeable in the soil samples of the irrigated farmlands causing excessive exchangeable sodium percentage (29.24%) in the lower farmlands soils relative to the upper area farm field which has only a maximum ESP of 8.83%.

Table 5 Concentrations contrast of Electrical Conductivity, Sodium Ions and Adj. Sodium Ration in the three rivers sources of irrigation water

Source of Irrigation	Electrical Conductivity (dS/m)	Sodium Ions (me/l)	Adj. Sodium Ratio	Remark
River Borkena	0.48	1.32	1.05	Control/Background
River Leyole	1.62	8.11	7.43	Effluent Contaminated
River Worka	1.260	8.48	7.63	Effluent Contaminated

III. Specific ion (sodium and chloride) toxicity: The ions of primary concern were chloride, sodium and boron ion toxicity because these ions are usually related to water toxicity and industrial wastes in arid and semi-arid areas (FAO Soil Bulletin, 1985). But the toxicity effects need to be explained by taking into account indicator crops, which is not the intention of this particular study. However, the assessment of these ions in the water and soils of the irrigated farms could show the general trends with the associated risks of toxicity.

The mean concentration of chloride was quite low in all irrigation water sources and the restriction on use for irrigation is none. The soil samples possessed the smallest (below detection limits) content of chlorides too. At the lower of the effluent points, a little higher reading was obtained in both surface soil samples of Leyole river irrigated farmlands and sub surface soil sample of River Worka irrigated farm fields.

The mean sodium ion concentration of the upper control water of the Borkena river was determined to be less (30.33 ppm / 1.32me/l) and none restriction on use. But the levels in effluent mixed water of Leyole (186.67 ppm / 8.11me/l) and Worka (195 ppm / 8.48me/l) rivers were higher and can pose moderate restriction on use for irrigation (Table 4 and 6). Accordingly, the soil samples of the downstream farms displayed 160% to 400% increment of sodium ions as compared to the upper farmlands soil samples. The increased level of sodium at the lower of the effluent point's irrigation water and farmland soils can be attributed to the presence of caustic soda, for the purpose of washing, in the effluents of Kombolcha Textiles, ELFORA Meat Processing and BGI brewery factories. Besides this, the existence of high bicarbonates in the effluent mixed of the two rivers cause Ca^{+2} and Mg^{+2} to form insoluble minerals leaving Na^{+} as the dominant in solution.

At the upper fresh irrigation water of the River Borkena, the mean boron concentration was 0.3 ppm and is none restricting to irrigation. At the lower areas, it was highest (1.15 ppm) in River Leyole which is slight to moderate restriction on use. In the irrigation water of River Worka, it was 0.97 ppm and is near to slightly restricting on use for irrigation (Ayers and Westcot, FAO 1985). All soil samples at the lower areas were below the detection limits, but on areas lower of the effluent points, some samples were indicating that boron is introduced in the surface and subsurface soil of the fields. This could be because of the presence of boric acid in the effluents from the tannery factory.

Table 6 Concentrations contrast of Chloride ions and Borate in the three rivers sources of irrigation water

Source of Irrigation water	Chloride anions (ppm)	Borate (ppm)	Remarks
River Borkena	17.33	1.63	Control
River Leyole	36.33	6.26	Effluent Contaminated
River Worka	25.00	5.28	Effluent Contaminated

IV. Miscellaneous: These include measurements of bicarbonate, carbonates, calcium, magnesium and pH of the water. The mean concentration of bicarbonates in Leyole river irrigation water (734 ppm/12.03me/l) was exceptionally high and is beyond the accepted level. But the concentration in control River Borkena and Worka rivers irrigation water was 290.67 ppm (4.76 me/l) and 367 ppm (6.01 me/l) (Table 7) respectively and is in the normal range of concentration for use in irrigation (Table 4). The bicarbonates ion conditions in the water of the irrigation rivers led to have the same proportional distribution of bicarbonate content in the soils of the irrigated farmlands with highest accumulation in Leyole river irrigated farmlands (4873.67ppm/ 79.9 me/l) and lowest in farmlands irrigated by the fresh water of the control river (Table 7). The increased levels of this ion in the soil can be attributed to the long term application of the effluents. The level of carbonates, calcium and magnesium in the irrigation water samples of the three sources were all in the normal range and do not show a notable difference between upper and lower of the effluent point's soil and water samples.

Mean pH of the River Borkena (Control) and River Leyole water were found to be 8.37 and 7.14 respectively (Table 7), which is both considered to be in the normal range for irrigation. The average pH in the irrigation water of Worka was 8.8 and is beyond the safe limits (Table 4). The higher value of pH in River Worka is perhaps attributed to the presence of carbonates ions in the water. The soil samples of the upper areas farm fields indicated that pH value increases with the soil depth. The presence of high bicarbonates in the River Leyole water can justifies higher pH values in the soil solution. The sediment loads from industrial solid wastes of the tannery, textiles and steel product factories was seen to fill canals and ditches that are diverted from River Leyole causing costly dredging and maintenance problems.

Table 7 Concentrations contrast of miscellaneous parameters in the three rivers sources of irrigation water

Source of Irrigation	Carbonate ions (me/l)	Bicarbonate ions (me/l)	pH	Calcium ions (me/l)	Magnesium ions (me/l)
River Borkena	0.16	4.76	8.37	2.47	1.48
River Leyole	0.00	12.04	7.14	2.15	1.48
River Worka	0.10	6.02	8.80	2.30	0.98

CONCLUSION AND RECOMMENDATION

Through this study, it is clear that the industrial waste has substantially changed the irrigation water quality diverted from the two rivers and consequently, some chemical elements also increased in the soil of the irrigated farmlands. EC of Leyole and Worka rivers was differentiated to be a slightly restricting. As onion is a major vegetable grown in local area, based on Ayers (1977) prediction; if the irrigation water is used continuously, the prevailing EC values might causes a potential 10% yield decline. Leaching is needed to avoid the associated long term risks.

According to Mass (1987), some of the crops grown in the local farms irrigated by Leyole River (like onion, carrot, potato and cucumber) would also be sensitive to the prevailing concentration of BO^{-3}. Notably, the Na^+ and SAR content of Leyole and Worka rivers were higher and would pose permeability problems (surpassed the safe limits). Since the root system of most crops develop best in the upper 30 cm of the soil (FAO Soil Bulletin 55, 1985), the existing higher SAR levels of irrigation water in the soils render problems of drainage, tillage and surface crusting and these could affect crop yield. The existence of Vertisol also pronounces the effect of low infiltration because of the swelling and shrinkage of soil containing clays minerals and the subsequent collapse of soil pores (Levy and Miller, 1997). If sprinkler irrigation method is applied in the future, the concentration of Na^+ could also cause foliar injury on the growing local vegetable like tomato, pepper, potato and maize (Mass, 1990).

The higher HCO_3^- concentration in Leyole river irrigated soil solution can harm the mineral nutrition of plants, since excesses HCO_3^- affects the uptake and metabolism of nutrients. Higher soil pH (9.08 – 9.36) values was found in Leyole river irrigated farmland soils. Such values of pH in farm soils may have a profound effect on availability of plant nutrients, as micronutrients, for instance; iron, manganese, zinc, copper, and cobalt are less available at a pH > 8.5 (Ayers and Westcott, FAO 1985).

All chemical parameters analyzed in the surface composite soil samples were found to be higher in farmlands irrigated by effluent mixed irrigation water of the two rivers. This indicates that the trend of the chemicals, which are important for suitable irrigation, is alarmingly increasing. The problems seems exacerbate in the town farmlands soil type, as Ayers and Westcott (1985) state low quality irrigation water is hazardous on clayey soil (particularly in Worka irrigated farmlands), while the same water could be used satisfactorily on sandy and/or permeable soils.

Since quality of water is an important priority for both environmental and economic reasons, it is vital that the fate of wastewater effluent in the surrounding rivers is to be well understood. Soil permeability problems (excessive Na^+ and SAR) can be improved by blending the fresh water of the Borkena River with the effluent contaminated water, in particular to Leyole River. Blending proportion and implementation could be guided by the local agricultural administration. Other practices that can be done at individual farm level may include cultivation and deep tillage, increasing duration of irrigation, changing the direction of irrigation to reduce slope, collecting and recirculation of run off water, using organic residue, using soil or water amendments (gypsum, elemental sulfur etc.) and changing irrigation water supply.

Because of insufficient research fund, it was not able to see the effects of heavy metals on crops but analysis of effluents only by the parameters selected under this research study is not adequate. Heavy metals, Organic and synthetic pollutants are suspected to be discharged with the liquid wastes and are rarely analyzed and thus it demand further investigation to assess their effects on the activity of soil microorganisms, crop productivity and crop quality.

Assessment on the trend of the farmlands yield should be conducted in order to have better perspective of the effluents impact on soils. It also creates awareness (to factories officials and farmers) of the problems, thereby urging to seek for corrective measures. Recent reports from the health center (2006) of the town indicated that the nearby community is frequently exposed to upper respiratory tract infection, asthma, malaria and skin diseases. Studies need to be conducted on the water quality and emission value of particulate matter in to the air in order to asses their clear impact on health. Since Kombolcha is chosen as a city of industrialization by the Amhara National Regional State of Ethiopia, all concerned bodies must focus on appropriate industrial waste management strategy and integrated with the industrial development.

REFERENCES

Alemtsehaye Birru. 2002. Assessment of the fertility and pollution status of irrigated vegetable farms around Addis Ababa city. Final Report. Addis Ababa Agricultural Office, Addis Ababa, Ethiopia.

Ayers R.S. 1977. Quality of Water for Irrigation. Journal of the Irrigation and Drainage Division. ASCE. Vol. 103. No. IR2. P. 140.

Ayers, R. S. and D. W. Westcott, FAO 1985. Water Quality for Agriculture. Irrigation and Drainage Paper No. 29, Rev.1.Food and Agriculture Organization of the United Nations. Rome, Italy.

Biswas, A, 1998. Environmental Planning Management and Development. pp. 208-402.

FAO. 1985. Soil Bulletin 42, Soil Survey Investigation for Irrigation. Agriculture Organization of The United Nation. Rome, Italy.

FAO. 1985. Soil Bulletin 55, Guidelines: land Evaluation for Irrigated Agriculture. Agriculture Organization of the United Nation. Roma, Italy.

FAO. 1998. Conservation and Development of Dry Land Resources. Land and Water Digital Media Series No. 2 (CD-ROM). Rome: FAO.

Levy GJ, Miller WP (1997) Aggregate stability of some southern US soils. Soil Sci Soc Am J 61:1176–1182.

Mass (1987) Salt Tolerance of Plants. CRC Handbook of Plant Science in Agriculture. B.R. Cristie (Ed.). CRC Press Inc.

Mass (1990) Crop Salt Tolerance. Agricultural Salinity Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.

Richardson, L. A. (ed.) 1954. Diagnosis and Improvement of saline and alkaline Soils. United States Department of Agriculture. Agriculture Handbook No. 60. Washington, D.C., USA.

U.S. Salinity Laboratory Staff, 1954. Diagnosis and Improvement of Saline and Alkali Soils. D.C., USA.

Westcott, D. W. and R. S. Ayers. 1985. Irrigation Water Quality Criteria, In G. S. Pettygrove and T. Asano (eds.) Irrigation with Reclaimed Municipal wastewater: A Guidance Manual.