

Seasonal and Spatial Water Quality of Awash River for Irrigation at Dubti/Tendaho, North Eastern Ethiopia

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Abstract
Salt affected soils are common in the irrigated arid and semi arid regions where irrigation with poor quality water is a common practice. In all irrigation farms, particularly at Dubti/Tendaho state farm, clear information on Awash River water quality for irrigation is lacking. Therefore, this study was conducted at Dubti/Tendaho state farm to investigate seasonal and spatial variations of irrigation water quality in Awash River. Water samples were collected from four sampling sites (dam to field) in monthly interval from September 2013 to August 2014. Relevant data were collected and interpreted as per the irrigation water quality guidelines. The result showed that pH, electrical conductivity (EC), sodium adsorption ratio (SAR) and adjusted sodium adsorption ratio (adj.SAR) were beyond the permissible limit in Autumn and Summer. The residual sodium carbonate (RSC) and bicarbonate (HCO_3^-) were unsuitable in all seasons except in Spring. Sodium percentage (Na %) was permissible in Winter and Spring whereas doubtful in Autumn and unsuitable in Summer seasons. Sodium toxicity was severe in Summer and Autumn (>9 meq l^{-1} SAR) while slight to moderate in Winter and Spring (3 - 9 meq l^{-1} SAR) seasons. However, chloride (Cl^-) hazard was safe (< 4 meq l^{-1}) in all seasons except Summer which showed slight to moderate. Spatially, an increasing trend on Cl^-, pH and Na% from the dam to the end of field drain water(FDW) whereas a decreasing trend on EC, Na, Mg, Ca, K, HCO_3^-, total dissolved solids (TDS), SAR, and RSC were observed. The results revealed that irrigation water quality was highly saline and toxic in Summer and Autumn whereas slight to safe in Winter and Spring seasons. Hence, it is possible to infer that the planting date of crops should be adjusted in Winter and Spring seasons when the quality of irrigation water becomes safe.
Keywords: Awash River, irrigation water quality**,** Electrical conductivity, pH, residual sodium carbonate, sodium adsorption ratio , toxicity, water quality parameters
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1. INTRODUCTION

Land degradation by salinization is often a common phenomenon in arid and semi-arid regions where irrigation with poor quality water is practiced (FAO, 2000). Furthermore, the most serious salinity and sodicity problems are being faced in the irrigated arid and semi arid regions of the world where irrigation is essential to increase agricultural production to satisfy food requirements (OWWDSA, 2007). Predominantly, saline soils are naturally formed and pedogenetically slow. However, the process is induced and augmented by irrigation where saline water is used (Wanjogu *et al*., 2004). For instance, in Kenya, one of the countries in east Africa, about 26,000 ha of irrigated soils are considered salt affected due to poor quality water, poor drainage and irrigation management systems (Mugwanja *et al*., 1995).

In Ethiopia, approximately 11 million ha of land is salt affected (saline, saline sodic and sodic) and mainly concentrated in the Rift Valley and Wabi Shebelle River Basin (Fentaw, 2007). According to the same author, of the 4,000 ha of irrigated lands at Melka Sedi, about 40.0, 16.98 and 0.02% were saline, saline sodic and sodic, respectively. Out of the 170,000 ha under irrigation by state farms in Awash Valley and in Central Rift-Valley lake area, almost 10% (11,000 ha) area of land have already gone out of production (Hawando, 1995).Thus, considering irrigation water quality is an important issue for modern irrigated agriculture management, especially for countries such as Ethiopia where arid and semi arid climatic zones occupy over 60% of the total land area (OWWDSA, 2007).

According to Szabolcs (1989), all the irrigation water sources contain potentially injurious salt levels and nearly all dissolved salts are left in the soil after the applied water is lost by evaporation from the soil. Unless the salts are leached from the root zone, sooner or later, it will accumulate in quantities which will partially or entirely prevent growth of most sensitive crops (FAO, 1988; Bohn *et al*., 2001). The use of poor water quality for irrigation can create problems like toxicity, poor water infiltration, degradation of soil physical properties and other miscellaneous problems that lead to reduction in crop production (Banderi *et al*., 2012). Thus, evaluating the quality of irrigation water is the most important undertaking (Ghassemi, *et al*., 1995). The chemical composition of surface and river water is basically governed by natural processes like precipitation, weathering processes, soil erosion and anthropogenic effects (Giridharan *et al*., 2009). These processes are spatial and seasonal dependent that may affect the irrigation water quality due to the variations in chemical concentrations and compositions of major anions and cations (Hamilton *et al.* 2005;Khadka and Khanal, 2008; Mtethiwa *et al*., 2008; Juang *et al.,* 2009; Pejman *et al*., 2009).

Ethiopia has an estimated 2.7×10^6 ha of irrigable land, in which most of the irrigation developed to today is located in the Awash basin but the irrigation water management is under problem (FAO, 2003; 2012). Soil salinity degradation due to irrigation water challenges in Ethiopia in general and Afar region (including the study area) in particular have been given less emphasis because its damaging effects are often not immediate but comes gradually with the continuous accumulation of salts. Due to erratic pattern of rainfall, both large commercial state and small scale farms use River Awash for irrigation without paying attention to its quality and impacts on land and crop losses. However, According to Ouyang *et al*. (2006) and Jha *et al. (*2010), irrigation water quality could vary both temporally and spatially in the transport pathways on agricultural activities. Owing to different factors such water runoff, discharge from ditches and creeks, groundwater seepage, atmospheric deposition, urban and industrial wastes, spatial and temporal variation on Awash River is predictable (Juang *et al.,* 2009; Pejman *et al*., 2009). Thus, knowledge of these variabilities helps to adjust the proper planting date of crops to maximize yield. However, information regarding the irrigation water quality of Awash River near to Dubti/Tendaho is very limited. Therefore, to establish water quality management program and adjust the planting date of crops, seasonal and spatial changes of water quality must be considered (Ouyang *et al*., 2006; Garizi *et al*. 2011).

Although, WWDSE (2004) studied the Awash River water quality near Dubti/Tendaho state farm with limited parameters, its spatial and seasonal variation, the causes of water quality deterioration, and the severity effects of water salinity in irrigated lands have not been investigated and well documented. Therefore, in filling this gap, the objective of this study was to investigate seasonal and spatial quality of Awash River for irrigation near Dubti/Tendaho area.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted at Dubti/Tendaho state farm, Afar National Regional State (ANRS (Figure 1). Geographically, it is located between 11° 39'0'' - 11° 48'0''N latitudes and 041° 6'0'' - 041° 12'0'' E longitudes with an altitude range from 339 – 381meters above sea level (m. a. s. l.) and slope varies from 0.03 - 0.3%.

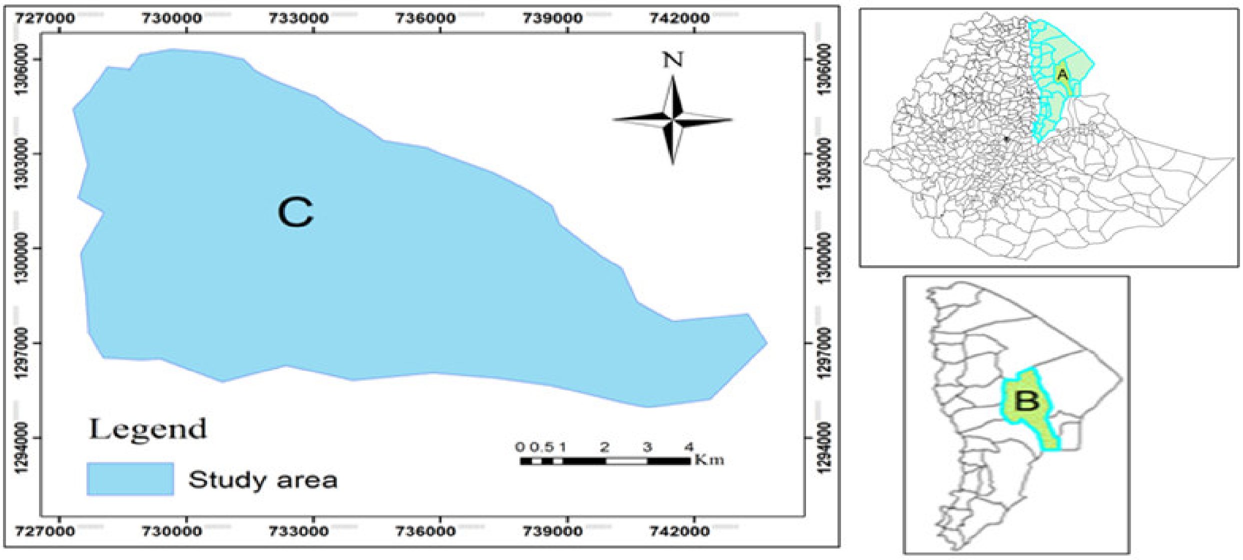

Figure 1.Map of the study area: The Afar region in Ethiopia (A) ; Dubti district in Afar region (B); Dubti/Tendaho Estate Farm (C)

The area is characterized by bimodal rainfall patternwith mean annual precipitation of 222 mm. The annual mean minimum and maximum temperatures are 22.6 and 48.8 ^{0}C, respectively (Figure 2) with an average of 35.7 ^{0}C and the meanannual evapo-transpiration (ET) was 2854.1 mm (Dubti meteorological station).

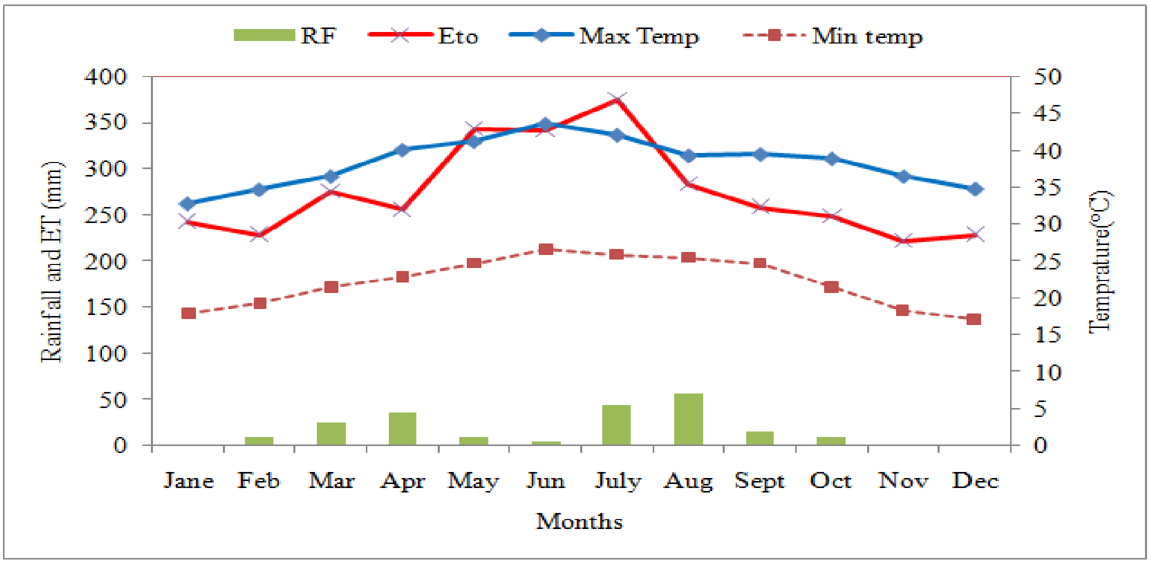

Figure 2. Mean monthly rainfall, evapotranspiration, maximum and minimum temperature of the study area (1986 – 2014) (Dubti Meteorological Station, 2014)

Soils of the study area fall into five main soil units of Solonetz (39.35%),Calcisols (28.34%), Solonchak (14.55%),Vertisols (13.89%)and Fluvisols (3.88%) with most of them characterized by massive soil structure which is attributed to the dominance of exchangeable sodium (WWDSE, 2004;Sileshi, 2015).

2.2. Sampling Site Selection and Water Sampling

Water samples were collected monthly from September 2013 to August 2014. According to the Ethiopian season classification, the months were divided in to four seasons; Winter (December – February), Spring (March – May) Summer (June – August) and Autumn (September – November).Water samples were taken from four sampling sites. These were diversion point from the dam (DFD), diversion point from main canal to primary canal (PC1) (i.e. about 17 km far from the dam), diversion point to the farm from the tertiary canal (TERC) (i.e. about 21 km far from the dam), and water that drain from the farm (FDW). The sites were selected purposefully for all months. Accordingly, water samples were collected using plastic container from each site in a year (a total of 48 representative samples).

Figure: Soil sapling point across Awash River basin

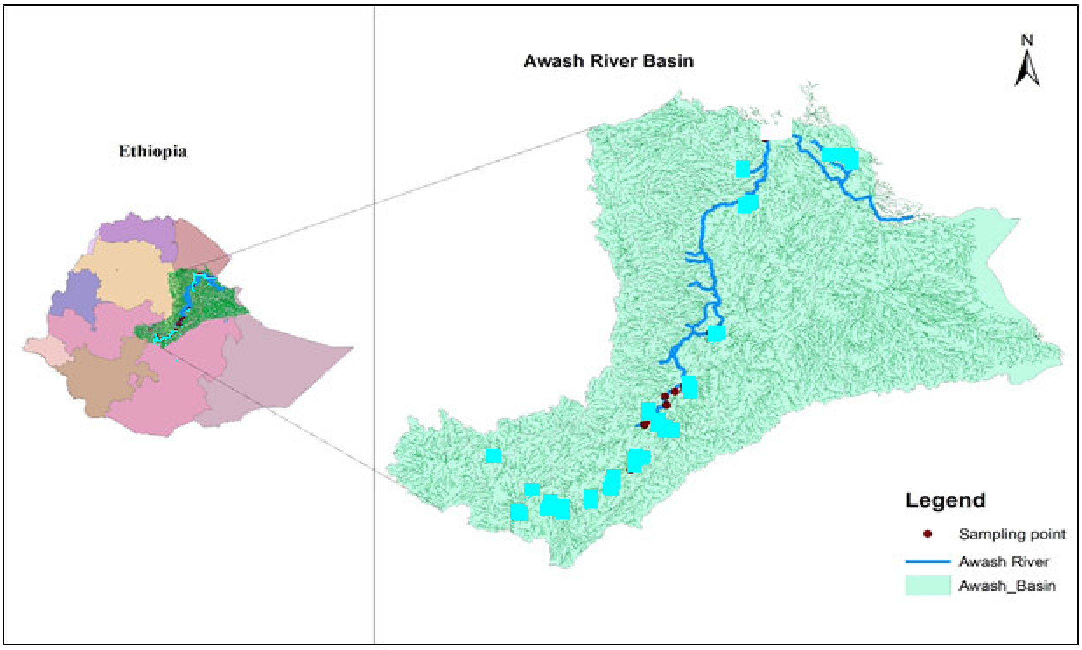

Figure 3: Water sampling point from Awash River around Dubti/Tendaho state farm

The collection and handling of the irrigation water samples were in accordance with the procedures outlined by the Richards (1954). To assess irrigation water quality, sodium percentage (Na %), SAR, pH, EC, TDS, and basic cations (Ca, Mg, Na and K) and anions ($CO_3^{2,}$ HCO_3^- and Cl^-) were analyzed. Water pH and EC were measured using pH meter and conductivity meter, respectively (Chopra and Kanwar, 1976). Sodium and K were determined by flame photometer (Chapman, 1965). Calcium and Mg were determined titrimetrically using atomic absorption spectrometer while Cl^- was determined by silver nitrate titration method (Hesse, 1971). Carbonate and HCO_3^- were estimated using standard sulphuric acid (Venkate and Vediappan, 2013). Sodium adsorption ratio (SAR) and adjusted SAR (adj.SAR) of irrigation water were calculated using the procedures set by Miller and Gardiner (2007) and Dewis *et al.* (1988), respectively. Sodium adsorption ratios (SAR) and adj.SAR of the irrigation water samples were computed as:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{.................................Eq1}$$

And

$$Adj.SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}\left[1 + \left(8.4 - PHc\right)\right] \quad \text{..............Eq2}$$

where, concentrations of all the constituents are given in meq l^{-1}.

Residual sodium carbonate content of the irrigation water samples was calculated from the concentrations of Ca^{2+}, Mg^{2+}, HCO_3^- and CO_3^{2-} ions given in meq l^{-1} as follows (Landschoot, 2007):

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad \text{...............Eq3}$$

where, all the ionic concentrations are expressed in (meq l^{-1}) of the respective ions.

Percent sodium was calculated based on the chemical variables of water samples (Singh *et al*., 2005).

$$Na\% = \frac{Na^+}{Na^+ + Ca^{2+} + Mg^{2+} + K^+} \times 100 \text{....................} Eq4$$

The different salinity and sodicity hazard classes of the irrigation water and their use for irrigation purposes were interpreted based on Richards (1954) and FAO (1985) irrigation and drainage paper. Moreover, to determine the suitability of irrigation water quality, SAR and Na% were calculated and plotted based on Wilcox diagram (1948).

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2.3. Statistical Analysis

Water samples were analyzed and interpreted as per the irrigation water quality guidelines using descriptive statistics. Accordingly, mean values of irrigation water quality were computed to compare the findings with relevant evaluations of water quality guidelines for irrigation suitability.

3. RESULTS AND DISCUSSION

3.1. Seasonal Dynamics of Irrigation Water Quality

3.1.1. pH, electrical conductivity and sodium adsorption ratio

The mean pH of Awash irrigation water varied from 7.78 to 8.72 in which the lowest and highest values were recorded during Spring and Autumn, respectively (Table 3.1). As per irrigation water quality guidelines proposed by Bauder *et al.* (2010) and FAO (1985), the pH of the water sample around Dubti/Tendaho state farm was beyond the normal range (> 8.4) in Autumn season. The reason might be the addition of waste effluents having high alkaline contents from upper stream of River Awash basin through erosion in summer and the residual impacts of those waste materials in Autumn when the dilution effect is less prominent. This suggestions are supported by Pejman *et al*. (2009) who stated that waste water discharge materials added to water during domestic water use, such as detergents and soap-based products are often alkaline which can increase the pH of water. The other reason might be due to the entry of Lake Basaka which has high concentrations of HCO_3^- and pH in to River Awash through erosion in summer and its residual impact in Autumn season. In evidence to this, Megrsa (2009) reported that the mean concentration of HCO_3^- and pH of Lake Basaka is 20.65 meq/l and 9.58, respectively and some times deliveretely it has been drain to River Awash to decrease the volume of the Lake.

Table .1.Seasonal dynamics of pH, electrical conductivity, sodium adsorption ratio and adjusted sodium adsorption ratio of River Awash water around Dubti/Tendaho state farm

Seasons	EC(µScm^{-1})	pH	SAR(meql^{-1})	adj. SAR(meql^{-1})
Autumn	853	8.72	9.00	21.89
Winter	700	8.08	3.43	10.54
Spring	737	7.78	3.66	6.91
Summer	880	8.40	12.13	25.45

.Furthermore, based on the irrigation water quality guideline set by Richards (1954), the EC of River Awash water near Dubti/Tendaho state farm sites fall under doubtful class (750 - 2250 µScm^{-1}) in Autumn and Summer while good (250 - 750 µScm^{-1}) in Winter and Spring seasons. This seasonal variation might be due to high evaporation in Summer and Autumn. Similarly, Kirda (1997) indicated that the concentration of salt in rivers, lakes and manmade reservoirs may increase towards the end of summer. WMO (2013) also reported that the salinization of surface and River water is increased due to high evaporation in arid and semi-arid regions during summer season. Accordingly, Singh *et al.* (1999) recommended that the irrigation at the planting and germination stage may be managed with safe water and unsafe irrigation water might be used only at a later stage of plant growth. Hence, at Dubti/Tendaho state farm, the planting date should be arranged in winter and spring seasons when the salinity level of the irrigation water is in the range of safe.

According to Richards (1954) evaluation guide line, the irrigation water quality near Dubti/Tendaho state farm was excellent (< 10 meq l^{-1} SAR) in all the seasons except Summer which was in the range of good (10- 18 meq l^{-1} SAR) (Table 3.1). Based on a more strict evaluation of irrigation water quality in terms of SAR value suggested by SAI (2010), the awash river water being used around Dubti/Tendaho falls in the range of severe (> 5 meq l^{-1} SAR) in Autumn and Summer, and high (4 – 5 meq l^{-1} SAR) and significant (2 – 4 meq l^{-1} SAR) in Winter and Spring seasons, respectively. This could be attributed to the leaching of salts by erosion during the high rainfall Summer from across Awash River basin may laden the water with salts. The other main reason could be the impacts of Lake Basaka and factory wastes around the basin which have high concentration of Na^+ resulting in high SAR in River Awash particularly in Summer season through erosion. In corroboration to this, Megersa (2009) reported that factory wastes which are found in River Awash basin and Lake Basaka have 57.03 and 307.0 meq/l SAR, respectively. Hence, during its pathway from long distance the volume of the river flow decreases substantially and the velocity also decreases significantly, as a result the suspended salts will have time to settle. Furthermore, dilution factors also decrease with decreasing in flow volume and high evaporation condition in Summer and Autumn seasons. Similar studies by WMO (2013) revealed that in arid and semi-arid areas, the salinization process in water bodies can be aggravated by the inflow of leaching salts with water from irrigated soils and increasing evaporation during the dry season.

Regarding adj.SAR, the results of all the water samples near Dubti/Tendaho state farm taken from different sites in different seasons fall under severe (> 9 meq l^{-1} adj.SAR) category during all the seasons except in Spring which was in the range of significance level(6 – 8 meq l^{-1} adj.SAR). This hazard levels also fall under similar category with SAR except little variation in Winter and Spring seasons. According to FAO (1985) irrigation water quality interpretation guideline, the $CO3^{2-}$ and HCO_3^- contents of water samples of the study area indicate that there is a tendency to precipitate Ca^{2+} and Mg^{2+} to the irrigated soil from the applied water.

3.1.2. Bicarbonate and Carbonate hazard levels

As the ratings suggested by SAI (2010), the River Awash around Dubti/Tendaho state farm irrigation water quality in terms of HCO_3^- concentration were beyond the permissible limit(> 244 mg L^{-1}) in all seasons except in Spring which was in the range of safe (Table 3.2). Although the hazard level in all seasons except in Spring which was under the same category, the results increased by two fold from the maximum permissible limit in Summer. This might be due to high ET rate in Summer season. This result was in consent with the result of Philip (2014) who reported that HCO_3^- and CO_3^{2-} ions are formed as a consequence of CO_2 reactions with various components in the water sources when the temperature is high in arid and semi-arid regions. The other reason could be due to the entery of Lake Basaka to River Awash particularly in summer season. This is because of that as Summer is rainy season, the volume of the lake becomes increased and it drains to the River Awash. In confirmation to this, Megersa (2009) reported that the HCO_3^- level of Lake Basaka is about 20.65 meq/l.

Table .2.Seasonal dynamics of bicarbonates, carbonates,sodium percentage and residual sodium percentage of irrigation water from River Awash used at Dubti/Tendaho state farm

Season	HCO_3^- (mg L^{-1})	Co_3^{2-} (meql^{-1})	Na%	RSC (meql^{-1})	Cl^- (meql^{-1})
Autumn	320.66	3.21	79.77	6.07	2.82
Winter	405.45	1.11	56.60	3.80	2.67
Spring	219.40	0.27	57.02	0.22	2.03
Summer	496.13	Nil	82.20	5.27	4.23

The other reason for the increment of HCO_3^- hazards might be due to the fact that as Summer is a rainy season in the study area, the components of limestone and dolomite which contain the sources of HCO_3^- could be washed from the surroundings by surface runoff and enter in to River Awash. Analogously, Boyd (2000) indicated that the main sources of HCO_3^- and CO_3^{2-} ions are limestone and dolomite and those ions may increase the concentrations of Na in lakes and rivers in rainy seasons by precipitating Ca^{2+} and Mg^{2+}ions.

On the other hand, based on FAO(1985) evaluation guide lines, River Awash irrigation water quality near Dubti/Tendaho state farm, the CO_3^{2-} concentration was unsuitable (> 1 meql^{-1} CO_3^{2-}) during Autumn and Winter while which was in the range of safe (< 1 meql^{-1} CO_3^{2-}) in Spring and Summer seasons. The high concentration of CO_3^{2-} in Autumn and Winter might be as these seasons are dry (no rainfall) throughout the basin of River Awash, there is a decreasing of water volume and velocity in the River, as a result the suspended salts and waste effluents that comes by erosion during summer will have time to settle. Furthermore, the dilution factors also decrease with decrease the inflow volume of water.

Similar to these findings, Ogedengbe and Akinbile (2010) reported that alkalinity levels of the industrial effluent increased from the value of 175 mg /l to 230mg /l at point of discharge and downstream area of Ibadan in Nigeria due to untreated direct effluents discharge into stream of Ona River. According to the same authors, high alkalinity levels are usually associated with the high concentration of bicarbonates and carbonates from effluents and leachates during Summer season when rainfall is sufficient for the leaching of waste effluents and then settled when the volume of the River becomes decrease in dry seasons.

3.1.3. Sodium percentage and residual sodium carbonate

Based on the ratings set by Wilcox (1955) evaluation guides, the irrigation water quality of River Awash around Dubti/Tendaho state farm area was within the permissible range(40 – 60 Na%) in Winter and Spring while it was doubtful in Autumn (almost 80 Na%)and unsuitable (> 80 Na%) in Summer seasons (Table 3.2). As it is also indicated in the Wilcox diagram (Figure 3.1), Na% values of River Awash water samples revealed that in Spring and Winter the quality of water was fair while in Summer and Autumn seasons it falls under poor category. The possible reasons might be due to the mixing of Lake Basaka and factory wastes through erosion in Summer to River Awash and also the remaining of its residual impact in Autumn. In confirmition to this, Megersa (2009) founded that the concentration of Na^+ in factory wastes found in River Awash basin and Lake Basaka is about 57.03 and 159.7 while the concentration of Ca^{2+} is 1.59 and 0.38 meql^{-1}, respectively. Thus, if the concentration of Na ion is high in irrigation water, it displaces Ca and Mg ions and opens the room for the ominancy of Na ion (Belkhiri *et al*., 2010; Arshid *et al.,* 2011).

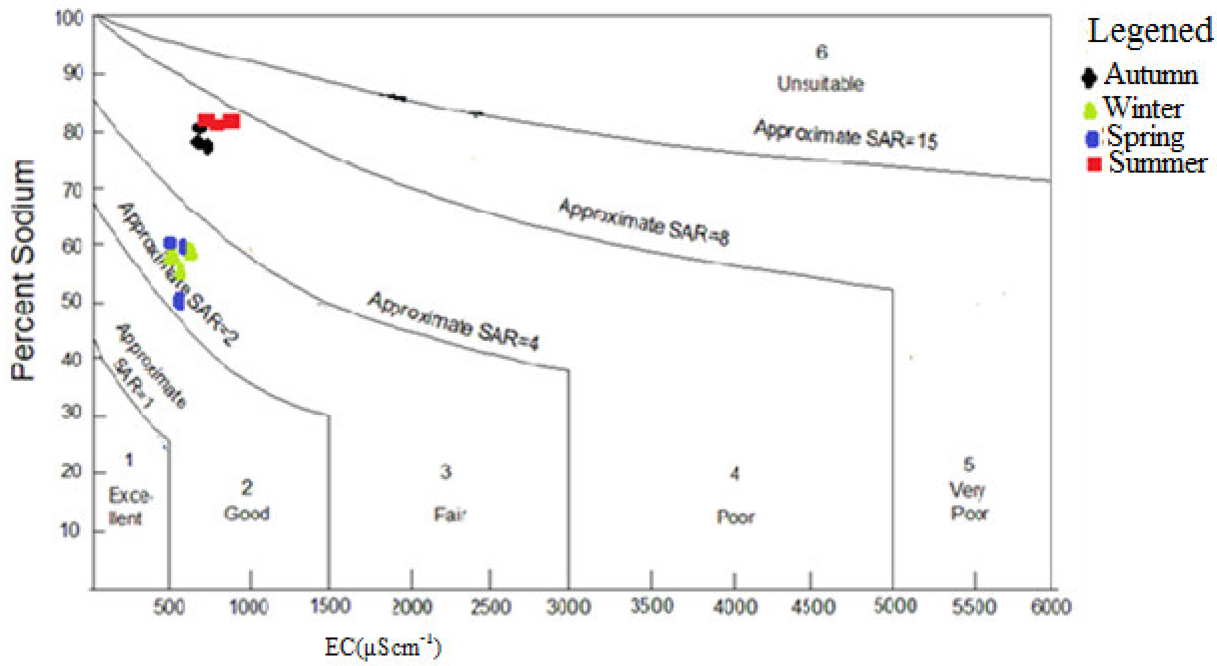

Figure 4. Rating of River Awash water samples on the basis of Wilcox's (1948) electrical conductivity and sodium percentage

The seasonal variation in RSC of the River Awash water used for irrigation around Dubti/Tendaho state farm was observed. Accordingly, the ratings proposed by Aghazadeh *et al*. (2010), the water quality of the River was unsuitable in all seasons (>2.5 meq l^{-1} RSC) except in Spring which was in the range of good (< 1.25 meq l^{-1} RSC). This might be due to the precipitation of Ca and Mg ions with excess HCO_3^- present in water. These results were in parity with that of Rengasamy *et al*. (2010) who elucidated that CO_3^{2-} and HCO_3^- of Ca and Mg are insoluble and precipitate out of solution whereas their compounds with Na are soluble and as a result when used for irrigation, Ca and Mg precipitated to form compounds with CO_3^{2-} or HCO_3^- leaving excess Na ions in the soil.

Naseem *et al.* (2010), Nishanthiny *et al.* (2010), and Obiefuna *et al.* (2011) reported that if the land is irrigated with high RSC, it becomes infertile and results in salt build up which in turn may harden soils due to the deposition of excess HCO_3^-. Accordingly, the result of RSC indicates that the study area may face similar problems since the water quality is unsuitable in all seasons except during spring.

3.1.4. Sodium hazard in terms of sodium adsorption ratio and chloride

Based on FAO (1985) evaluation guidelines, the irrigation water quality of River Awash in terms of Sodium hazard around Dubti/Tendaho area (Table 3.2) showed severe Na toxicity in Summer and Autumn (> 9 meq l^{-1} SAR). The Na hazard was in the range of slight to moderate level in Winter and Spring (3 – 9 meq l^{-1}SAR) seasons. The possible causes might be due to the dominance of Na relative to Ca and Mg as a result of high concentrations of HCO_3^- and CO_3^{2-} ions due to waste water effluents and mixing of Lake Beseka by surface runoff during Summer and Autumn seasons. Similarly, Saumitra *et al.* (2005) reported that the presence of high concentrations of Na% in irrigation water is due to the precipitations of Ca and Mg ions as a result of $HCO3^-$ and CO_3^{2-} ions present in the irrigation water.

On the other hand, as to FAO (1985) and Hopkins *et al.* (2007) evaluation guidelines, River Awash water quality in terms of chloride (Cl^-) toxicity around Dubti/Tendaho state farm fall under safe category (<4 meq l^{-1} Cl^-) in all seasons except summer (4 - 10 meq l^{-1} Cl^-) which showed slight to moderate toxicity hazards. The different toxicity level in summer season could be attributed to the effects of sewage wastes due to surface runoff from urban areas and other geologic processes that entered to the River. These results were in agreement with that of Saumitra *et al.* (2005) who reported that large variation of Cl^- concentrations in irrigation water is due to geochemical processes and contamination by sewage wastes. According to Prabu *et al.* (2011) the possible sources of Cl^- could be domestic and municipal sewage water that contaminates the river through domestic and sewage water intrusions. Fasil *et al.* (2013) also reported that major sources of waste water effluents, slum, and domestic and municipal sewage water are discharging to upper River Awash from industrial areas of Mojo oil and Akaki tanners' factories. The other possible reason might be the entery of Lake Basaka in which high concentration (>39meql^{-1}) (Megersa, 2009) of Cl ion to River Awash. Thus, the increments of Cl^- during Summer season might be caused by the washing of those waste effluents from industrial areas and Lake Basaka directly entering to River Awash.

3.1.5. Impacts of irrigation water quality on infiltration rate

Based on interpretation guide line suggested by FAO (1985) andAyers and Westcot (1989) the infiltration impacts of SAR and ECw were in the range of slight to moderate (6 – 12 meq l^{-1} SAR and 0.5 – 1.9 dsm^{-1}ECw) in all seasons except in summer which is in the range of severe (12- 20 meq l^{-1} SAR and < 1.3 dsm^{-1}ECw). This could be due to high concentrations of Na than any other cation in water as a result of high concentrations of HCO_3^- ion. These high concentrations of HCO_3^- ions precipitate the Ca and Mg ions as either calcium carbonate ($CaCO_3$) or magnesium carbonate ($MgCO_3$) and open the room for the dominancy of Na on the exchange sites and resulting soil dispersion and crusting which in turn hinder water infiltration to the soil. Similar studies by SAI (2010) revealed that high HCO_3^- ions combined with Ca or Mg will precipitate as carbonates when the soil solution concentrates in dry conditions and resulting to infiltration problems.

3.2. Spatial Variations of Irrigation Water Quality

The annual mean values of pH, Cl^- and Na% were increasing from the dam to end of tertiary canal (Table 3.3). The increase of pH and Na% could be due to high concentrations of HCO_3^- relative to Ca and Mg ions. These results were in agreement with that of Dar *et al.* (2014) who stated that the presence of HCO_3^- ions causes alkalizing effect and increase pH by dissociating Ca and Mg in irrigation water.

Table.3. The mean annual spatial variability of pH, electrical conductivity, cations, anions,total dissolved solids, sodium percentage, sodium adsorption ratio, and residual sodium carbonate of irrigation water from River Awash used at Dubti/Tendaho state farm

Descriptions			Cations (meql^{-1})				Anions (meql^{-1})						Meql^{-1}
Location	pH	EC dsm^{-1}	Na	Ca	Mg	K	Co_3^{2-}	Hco_3^-	Cl^-	TDS	Na%	SAR	RSC
DFD	8.22	0.81	8.94	2.76	0.88	0.17	1.11	6.34	2.85	515.20	67.02	7.43	4.01
PC1	8.29	0.80	8.76	2.10	0.93	0.16	1.13	5.75	2.93	510.40	69.13	7.27	3.88
TER	8.37	0.78	8.69	2.05	0.68	0.16	Nill	5.63	2.93	496.00	70.70	7.32	3.64
FDW	7.76	0.95	10.40	2.11	2.43	0.27	Nill	8.36	3.83	606.40	66.45	7.26	4.37

NOTE: DFD* diversion from dam; FDW* field drain water; PC1* primary canal one; TERC* tertiary canal

On the other hand the possible causes for increasing Cl^- concentration might be due to domestic and urban wastes from offsite areas and the nearby towns of Logia and Dubti as a result of surface runoff. Similarly, Prabu *et al.* (2011) revealed that Cl^- concentrations in the downstream was four times higher than the upper stream water samples due to the contamination of river through domestic and sewage water intrusions. Furthermore, Venkatesharaju *et al.* (2009) found that the most important source of Cl^- in water is the discharge of domestic and sewage inflow and other anthropogenic sources. On the contrary, parameters of EC, Na, Mg, Ca, K, HCO_3^-, TDS, SAR, and RSC were recorded higher in the diversion dam compared to the primary and tertiary canals which could be due to the dilution, precipitation and purification of some concentrated dissolved solids. These results were in line with that of WMO (2014) which indicated that as distance from the source increases, some variables will be reduced by self-purification, deposition and adsorption. The carbonate alkalinity is negligible at the end of the tertiary canal and field drain water throughout the study. Hence, the high pH (total alkalinity) recorded in this study is mostly due to the presence of HCO_3^-.

In field drain water, pH, CO_3^{2-}, Na% and SAR were decreased and the level of EC, Na, Mg, Ca, K, HCO_3^-, Cl^-, TDS, and RSC were found to be higher (Table 3.3). Perhaps, the increment of HCO_3^- might be due to the application of chemical fertilizer mainly of Urea ($CO(NH_2)_2$) and consequently the increase in HCO_3^- resulted in high RSC. However, the increase in EC, Na, Mg, Ca, K, Cl^- and TDS might be due to high ET of infiltrating water in to the soil. This suggestion was supported by Glover (1996) who reported that part of the irrigation water infiltrating into the soil is removed in a pure state by ET and much of the remaining water with its increased salt load will subsequently become drainage water.

4. CONCLUSIONS

Spatial and seasonal variations have a significance influences on Awash River irrigation water quality which is a water source for Dubti/Tendaho state farm. The irrigation water quality was found to be highly problematic in Summer and Autumn; whereas it become moderate and safe in Winter and Spring seasons. The major reason for the poor quality of water in Summer and Autumn could be the mixing up of factory wastes and Lake Basaka to Awash River by surface runoff in Summer and in Autumn the dilution factor decreases with decrease in flow volume resulted in high concentration of salts in it. Spatially, variations in water quality from dam to irrigated lands were observed and this suggests the need for blocking the entry of Lake Basaka to the River and proper management of waste effluents contaminating in the upper streams of Awash River. Therefore, to overcome the effects occurred at early crop establishment phases, the state farm should adjust the planting date to Winter and Spring seasons when the salinity levels of the irrigation water becomes safe.

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