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Salinity assessment of irrigation water and soil for al-seleit agricultural scheme (Sudan)

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Abstract
This study was conducted to measure the effective parameters that, determine irrigation water quality and agricultural soil characteristics at, Alseleit Agricultural Scheme. Depending on the cultivated crop type, soil and irrigation water samples were collected from ten farms. Minerals content of soil and water samples were measured by (ICP) spectroscopy. Salinity parameters $SO_4^{=}$, Cl^-, and NO_3^- were determined by UV-VIS spectrophotometry. Sodium adsorption ratio was calculated for water and soil samples. Water samples showed minerals content mean as, Ca (43.82ppm), Mg (11.61ppm), Si (21.89ppm), K (3.80 ppm) and Na (0.87ppm). Micro nutrients and toxic minerals showed very low availability. Only one sample showed significantly high Fe (59.2ppm). Soil minerals content means were, Ca (15,999.9ppm), Mg (6,552.8ppm), K (2,183.74ppm), Na (1,781.32ppm), Mn (510.22ppm), Ni (65.51ppm), Ti (4,817.9ppm), Zn (43.24ppm), and significantly high Fe content (mean 29,168.6ppm). The mean values of toxic minerals, Al, Ba, Sr and V, were relatively high in soil samples. Both water and soil samples showed low $SO_4^{=}$, Cl^-, and NO_3^- content. SAR mean value was (16.21meq) for soil and (0.161meq) for irrigation water samples.

Keywords: SAR, sodicity, RSC, potential salinity, ECw, soil fertility

Introduction

The competition for water resources is much more intense worldwide. To avoid a global water crisis, farmers will have to increase their productivity to meet the growing demand for food (Chartres and Varma, 2010) [1]. Fertility of soil is itssr ability to enhance plant growth (Tisdale *et al*; 1985) [11]. Therefore fertility is a complex range of chemical, physical and biological parameters that should be optimized as a base of good management practices (Meyer and clowes 2011, Amolo *et al*; 2017) [21, 20]. Effects of soil and irrigation water on crop quality and production may be classified as: Salinity effects, Sodicity hazard, Sodium adsorption ratio, pH and alkalinity.

Salinity effects

The term salinity refers to, the major inorganic ions in water and aqueous soil extracts, especially Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-, CO_3^{2-} and HCO_3^-. Salinity can be quantified as, total minerals concentrations, or as, electrical conductivity (US Salinity Laboratory Staff, 1954, FAO Irrigation and Drainage Paper 57, Rome 1999). Salinity measurements can provide a general guidance about crops yield. Plants can tolerate salinity up to certain levels, without, measurable loss in crop yield. This is known as threshold level. At salinity levels greater than the threshold, crops yield reduces linearly as salinity increases (Shabbir A. Shahid *et al*; 2009) [22]. Salinity and sodium adsorption ratio are, the two most common water quality factors that, influence infiltration rate (Mohamed SA El Marazky1 *et al*; 2018) [17]. Irrigation water salinity is measured as electrical conductivity (ECw). The main effect of (ECw) in crop productivity is inability of plants to compete with ions for water in soils solution. This is known as physiological drought. Irrigation water with high (ECw) reduces yield potential (Ayers, *et al*; 1994) [3]. If the developed salinity is not properly managed in time, a complete failure of crop may occur (Shabbir A. Shahid, *et al*; 2009) [22]. Salinity can develop naturally, or when human activities disturb natural ecosystems (NSW, 1983-1991, Omer A. M. Gibla *et al*; 2016) [24].

Sodicity hazard

In soil clays exchangeable sodium may replace, calcium and magnesium, causing dispersion of soil particles (Asadollah fardi *et al*; 2010). Irrigation water of poor quality, may affect crops by accumulating salts in the root zone, leading to, less permeability of soil due to, excess sodium or calcium leaching. Therefore irrigation water with high sodium can adversely affect soil structure and reduce water movement into and through the soil (Omer A. Gibla; 2007) [6]. These conditions may decrease the hydraulic conductivity in fine-textured soil, leading to Na imbalance and crop yield reduction, because of excessive sodium accumulation which is referred to as Sodicity (Gholamreza Asadollahfardi *et al*; 2013) [5]. As aresult the actively growing plant roots may not get adequate water (Ayers *et al* 1994) [3].

Sodium adsorption ratio

Sodicity of irrigation water and soil is known as sodium adsorption ratio (SAR), which can be defined as the relative concentrations of Na to the sum of Ca^{2+} and Mg^{2+} ions in a sample (Oster *et al*; 1980). It is mathematically written as:

$$SAR = \frac{Na+}{\sqrt{\frac{1}{2}[Ca^{2+} + Mg^{2+}]}}$$

SAR is a standard diagnostic parameter in the management of sodium affected soils. Water with high SAR may require soil amendments to prevent long-term soil damage (Dwarf 1996) [13]. Sodium ions (Na^+) in water can displace (Ca^{2+} and

Mg^{2+}). According to Reeve *et al*; (1954) the suitable SAR value was reported to be (< 3) and soil problems will occur when it is (> 9). SAR value of 8 was also reported to be satisfactory, the ranges from 12-15 are marginal and the value above 20 is very disadvantageous (USDA, 2017; Ayers and Tangi 1981)

Some studies use sodium and potassium adsorption ratio (SKAR), to measure the change in relationship between, soluble ions and rainfall (P. Sarah 2004) [15]. Soils can be easily cultivated if Ca and Mg are the dominant cations (Asadollahfardi *et al*; 2010) [4].

Effects of **pH and alkalinity**

Acidity and basicity of water are normally expressed as pH values (T.A. Bauden *et al*; 2014). The normal pH range of irrigation water is from (6.5 to 8.4), but pH values higher than (8.0) are often caused by high (HCO^-_3) and ($CO_3^=$) content, which is known as alkalinity of water. Alkaline water could intensify the impact of high (SAR) water that, results in sodic soil conditions (Mass 1990). Water with abnormal pH value, may need further evaluation, because, pH outside the normal ranges may cause, nutritional imbalance or may contain toxic ions (T.A. Bauden *et al*; 2014). Low salinity water (ECw < 0.2 ds/m) sometimes has a pH outside the normal range and very low buffering capacity. Such water causes few problems for soils or crops but it may rapidly corrode pipelines, sprinklers and control equipments (R.S. Ayers and D.W. Westcot 1989, 1994). Depending on alkalinity hazards irrigation water quality can be expressed as residual sodium carbonate (RSC meq/l). RSA can be calculated as:

$$RSC = \left[HCO_3{}^- + CO_3{}^{2-}\right] - \left[Ca^{2+} + Mg^{2+}\right]$$

RSC must not be much higher than (1.0) and preferably less than (0.5). USDA follows the adjusted SAR (8) for calculating water sodicity (S. M. Lesch, D. L. Suarez 2012). Alkaline soil with (pH > 8.5), is a clay soil with poor structure and low infiltration capacity. It has unfavorable physicochemical characteristics, because, the presence of sodium carbonate, leads to soil swelling and difficult clarification. It is also referred to as alkaline sodic soil (US Salinity Lab Handbook 60, Kella and David, 2010). Each plant species achieves maximum growth in a particular pH range.The majority of edible plants can grow in soils with pH ranging from (5to 7.5).

The specific anions

These are Cl^-, B, $SO_4{}^{2-}$ and $NO_3{}^-$ Chloride content below (70ppm) is generally safe for all plants, but at (70-140ppm), sensitive plants may be affected. When chloride content of irrigation water reaches (141-350ppm), tolerant plants will be affected and some problems may occur when chloride content is above 350ppm (Mass 1990). Boron is essential to plants in low amounts but, it is toxic at higher levels. Although sulfate ions are major contributor to salinity in irrigation water, most crops need enough sulfates for maximum production. Nitrate ions can be important source of nitrogen for most plants.

Agricultural soil

Soils are often treated as a three state system of solids, liquids and gases (Mc Carthy David, 2006). Plants roots naturally, increase soil salinity as they uptake water and exclude salts (GAMA Program 2010). The excluded salts will gradually build up around the roots, and must be periodically “flushed” from the root zone or plant death may occur. More salts can be dissolved from soil, as irrigation water percolates downward (GAMA Program 2010). Salts can damage crops, affect plant growth, degrade drinking water, and damage industrial equipment.

The study area

Alseleit agricultural scheme is located in the North-Eastern part of Bahri city in Khartoum state, as one of the important irrigated schemes that, contribute in food supply. The scheme depends on surface irrigation system, to produce orange, lemon, grapefruit, palm date, cantaloupe, okra, tomatoes, medicinal plants and berseem. It is also concerned with dairy, poultry, fish farming and protected home systems.

Methodology

From ten farms cultivated with different types of crops, three samples were randomly collected at, the beginning, middle and the end of each farm. Equal amounts from each three samples were mixed to obtain ten composite samples. Ten (10) water samples were obtained from irrigation pumps in each farm. Minerals contents of soil and irrigation water samples were measured by (ICPOES725ES). UV-VIS Spectrophotometry was used for determining Cl^-, SO_4^{2-} and NO_3^-.

Results and discussion

The macro-minerals showed different concentrations in water samples (Figure 1). Ca was ranging from (31.15 to 115.9ppm), as the most available mineral in the ten samples, followed by Mg (7.720 to31.95ppm), K (2.679 to 8.425ppm). Na showed very low concentrations (0.3118 to 2.357). The significantly low P content (0.004732 to 0.5005ppm), may be due to the fact that, phosphorus containing compounds in earth crust are normally, sparingly water soluble. Fe concentrations were clearly different, with a significantly high value in sample (No.1) as (59.250ppm) and lower value in sample (No.2) as (0.000763ppm), with a mean (7.17ppm). Silicon was relatively high in all samples, with a mean value as (21.89ppm) and a highest value in sample (No.1) as (131.2ppm). Silicon availability in surface water may be expected, since earth crust is dominated by silicon containing compounds.

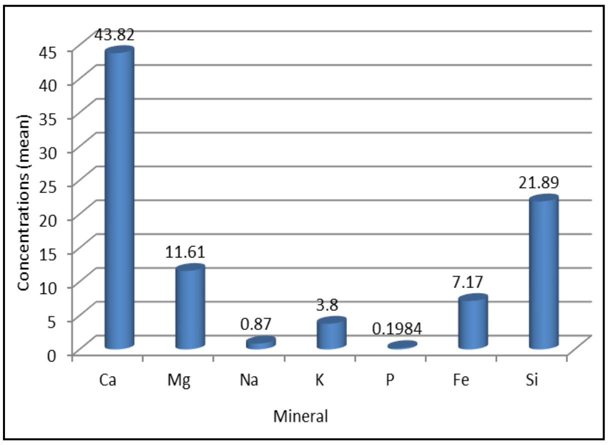

Fig 1: Macro minerals in water samples (ppm)

The essential micro-minerals showed very low availability in all water samples (Figure. 2). Most of these minerals have no importance in irrigation water and their low availability may be an advantage from, quality point sight of view, because the products may not contain risky levels of minerals from irrigation water sources.

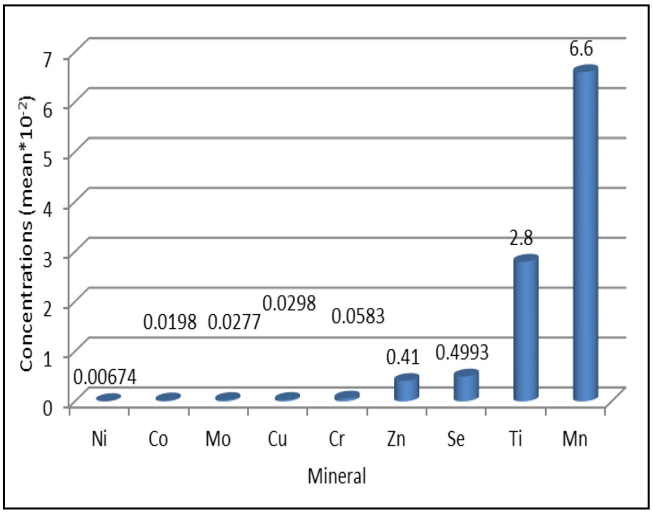

Fig 2: Micro minerals in irrigation water samples (ppm)

The ten irrigation water samples, showed very low availability of As, Cd, Be, Ba, Pb, Sb, Sn and Li (Figure 3). Aluminum concentrations were different in the ten samples with a mean value of (1.54ppm). Be and Cd were the lowest in all samples. These findings may indicate that, the water sources used in AlSeleit Scheme are of good quality and safe for general uses, irrigation, and human consumption.

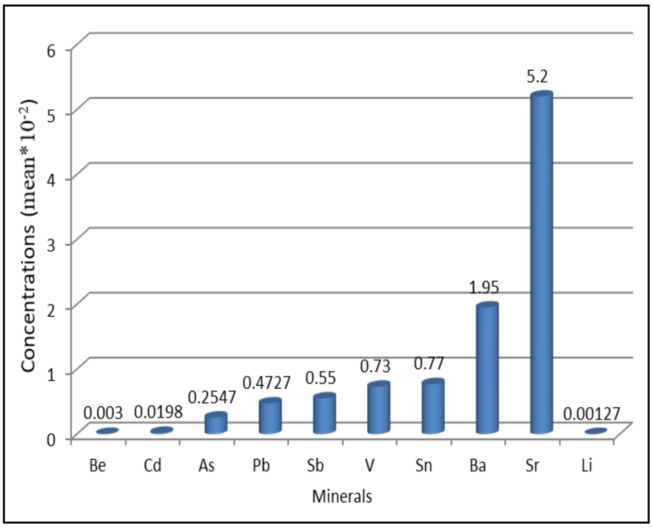

Fig 3: Toxic minerals content of water samples **(**ppm**)**

The ten composite soil samples were very rich with, Ca, Mg, K, Na, and P (Figure 4). The high Ca and Mg content may be an indication of clayey soil formations. K and P concentrations may be quite enough to satisfy the requirements of the different cultivated plants. Na was relatively high and that may result in some sodicity problems. The significantly high availability of (Fe) may indicate that, the geological formation of the area is dominated by iron containing compounds in addition to that of Ca and Mg.

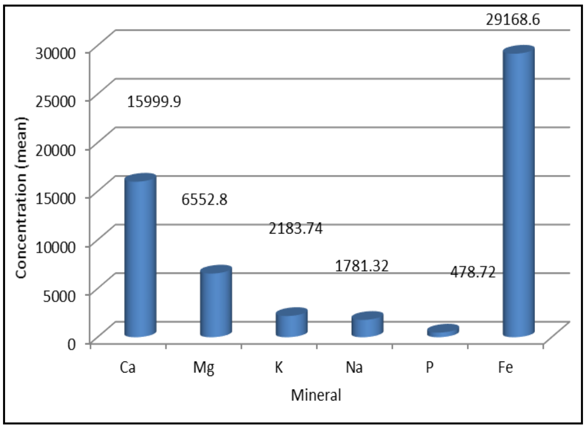

Fig 4: Macro minerals content of soil samples (ppm)

The minerals, Mn, Ni, Zn, Cu and Co were relatively high in soil samples. This may satisfy the general demand of the cultivated plants growth. Cr showed different concentrations, ranging from very low (0.000583ppm) to significantly high (81.70ppm), with a mean value as (31.72ppm). This may need more research investigations for the availability of chromium rich ores in the study area. Se and Mo as real trace minerals showed low concentrations in all soil samples.

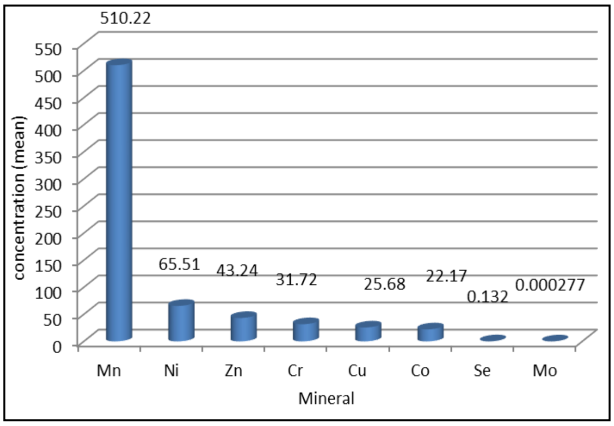

Fig 5: Micro minerals content of soil samples (ppm)

The toxic minerals Be, Sn, Sb, Pb, and Cd, showed very low availability in all soil samples. Arsenic (As), showed different concentrations and relatively high mean value (8.14ppm). Ba and Sr levels may be risky. B content was fair, because the element is important for plants at certain levels. The trace minerals (V) and (Li) showed unexpected, relatively high concentrations in the ten soil samples.

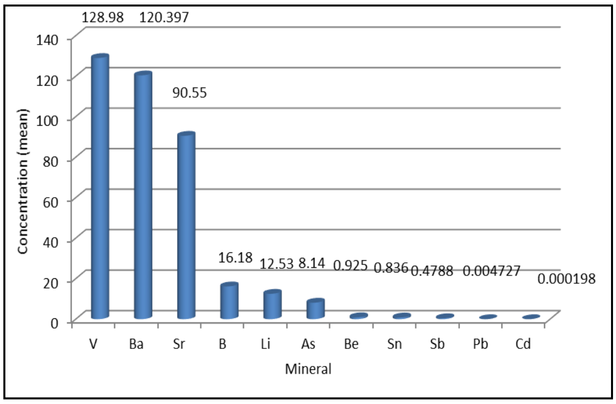

Fig 6: Toxic minerals in soil samples (ppm)

SO_4^{2-} (Table 1). Therefore this water may be described as, low salinity water. Because sulfate concentrations were higher than that, of chlorides and nitrates, this water may be classified as sulfate water. Mass (1990) reported that, water with chloride content below (70ppm) is safe for all plants. One water samples showed nitrate concentration as (12.20ppm), which was higher than the permissible range (10 ppm), as reported by (T. A. Bauder *et al*; 2014). It may be concluded that, nitrate and sulfate contents of Alseliet irrigation water were within the permissible limits.

Table 1: Cl^-, NO_3^- and $SO_4^=$ content of irrigation water (ppm)

Anion	Highest concentration	Lowest concentration	Mean
Cl^-	10.60	2.00	4.67
NO_3^-	12.20	2.70	6.57
$SO_4^=$	25.32	8.96	14.2

The ten irrigation water samples showed low concentrations of CI-, NO_3^- and Chlorides and nitrates showed relatively low concentrations in all soil samples.

Only one sample showed chloride content as (8.90ppm) and nitrate as (16.68ppm). Sulfate concentrations in the ten composite soil samples, were ranging from (9.93 to 66.49ppm). When compared with Ca and Mg (Figure 4), sulfate concentrations may indicate that, the soil composition is dominated by calcium and magnesium sulfate, taking in consideration that ($MgSO_4$) is more soluble than ($CaSO_4$).

Table 2: CI^-, NO_3- and SO_4^{2-} content of soil samples (ppm)

Anion	Highest value	Lowest value	Mean
Cl^-	8.90	1.50	3.41
NO_3^-	16.68	0.12	2.39
$SO_4^=$	66.49	9.93	42.5

The lowest SAR value for Irrigation water samples was (0.0685) and the highest value was (0.483), with a mean value as (0.161). These SAR values were less than that recommended by Reeve.*et al*; (1954) which is (<3).

Table 3: SAR values of irrigation water and soil samples (Meq/l)

SAR	Highest value	Lowest value	Mean
In irrigation water	0.483	0.0685	0.161
In soils	32.00	10.11	16.21

SAR values of soil samples were significantly high, when compared with that of irrigation water. They were ranging from (10.11 to 32.00) with a mean value as (16.21). It was reported that, agricultural soil problems will occur when SAR value is (> 9) and SAR value of 8 may be satisfactory. The ranges from 12-15 were reported as marginal and the value above 20 is very disadvantageous (Reeve *et al*; 1954, Ayers and Tangi 1981, and USDA, 2017)

Conclusion

Alseleit Agricultural Scheme irrigation water is good for plants growth from quality criteria sight of view. Cl^-, NO_3^- and $SO4^{2-}$ contents of irrigation water were relatively low when compared to that of calcium and magnesium. This may suggest that, the irrigation water is mainly bicarbonate water, since calcium and magnesium bicarbonates are readily soluble salts. The high concentrations of Ca^{2+}, Mg^{2+}, and $SO_4^=$ may be considered as, geochemical indication to suggest, that, Al-Seleit Scheme soils are dominated by gypsum, calcite, magnecite, dolomite or magnesium sulfate.

- SAR values for soil samples were different, and this may affect the growth of some plants and crops yield.

Recommendations

1. Further qualitative and quantitative studies may be needed to determine the effects of SAR on crops production in the area.
2. Geochemical background investigations may be required to give clear information about salinity, alkalinity and sodicity of the agricultural soil throughout Al Seleit scheme area.
3. SAR determination should be considered as an essential parameter for determining irrigation water and agricultural soil characteristics in future research.

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