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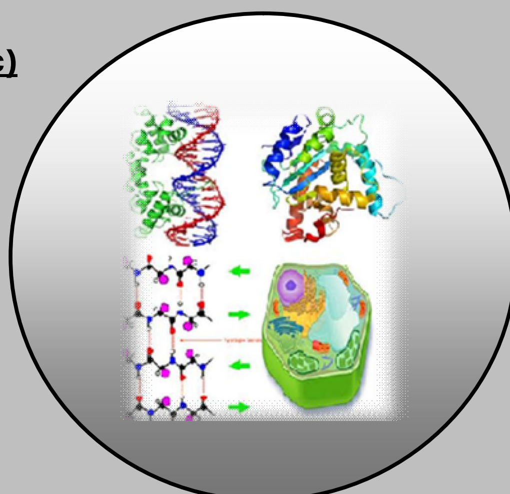

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RESEARCH PAPER

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Physicochemical parameters and indicators of salinity for the assessment of WWTP effluent in the vegetable farming area of sebkha (Nouakchott, Mauritania)

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ABSTRACT

In order to evaluate the WWTP (Waste Water Treatment Plant) effluent using the parameters indicators of salinity to assess the suitability of wastewater for irrigation, the sampling campaigns were conducted between February 2008 and December 2009.
The test results presented in this work showed that these effluents have temperatures reaching 28.7 ° C. The pH oscillates between 7.3 and 7.9. Chlorides, sodium, potassium, calcium, magnesium and bicarbonates have median levels of 950.1 mg/L, 276.1 mg/L, 29.6 mg/L, 131.6 mg/L and 48.2 mg/L and 1053.2 mg/L. The mean values are electrical conductivity (2340 µScm^{-1}), Sodium Adsorption Ratio (5.4), Soluble Sodium Percentage (52.1 %) and Magnesium Adsorption Ratio (36.9 %). The Sodium Adsorption Ratio and electrical conductivity showed that wastewater irrigated at the market-garden of Sebkha oscillates between class C3S1 (high salinity and excellent low hazard alkalization) and C4S1 (very high salinity and the excellent low hazards alkalization).
Keywords: Effluent, Sodium Adsorption Ratio, Nouakchott and Mauritania.

INTRODUCTION

It has been known for years that the quality of irrigation water directly influences the quality of the soil and the crops grown on this soil. In the last century, the demand for agricultural land and products has grown rapidly as a function of population growth. In addition, experts from all disciplines have agreed that factors such as urbanization, industrialization, poor land

management and environmental pollution imposed additional stress on agriculture production. All of these factors have quickly become responsible for the decrease in the amount of land available for agriculture and for the reduction in the quantity and the quality of water to irrigate these lands. A dramatic example for this soil-water quality interaction phenomenon is the salinity problem that is widely experienced in many parts of the world where about 10 million hectares of agriculture land is the lost annually (Tanji, 1990; Kwiatkowski et al., 1995).
The vegetable farming area of Sebkha (**Figure 1**) has been the subject of several studies (Schneider et Gagneux, 1997; Azandosessi et al, 1999; Gagneux et al, 1999; Cissé et Tanner, 2000). The quality of irrigation water is generally evaluated by some factors such as Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and the Magnesium Adsorption Ratio (MAR) (Richards, 1954).

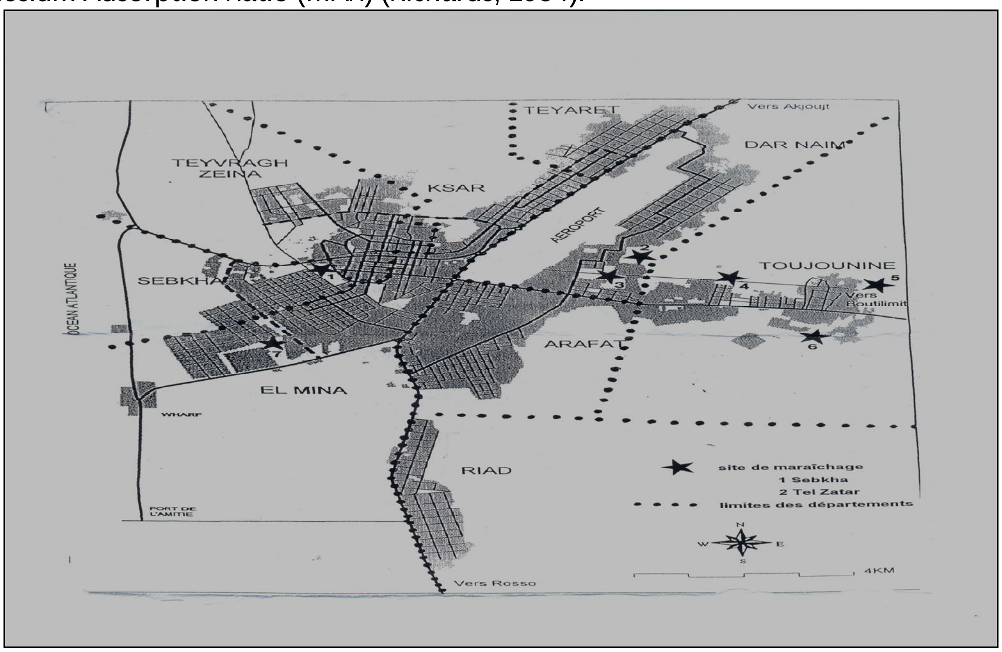

Figure 1. The map of localisation of the vegetable farming area of sebkha.

This study is aimed to assess the quality of effluent from the WWTP of Sebkha through physicochemical parameters and indicators of salinity parameters for to assess the ability of these wastewaters to irrigate vegetables.

MATERIALS AND METHODS

Study Area

The area of present study is the city of Nouakchott is a coastal city, located about 18 ° 07 North Latitude and 16 ° 01 West longitude. Nouakchott is located in the southern part of the Sebkha Ndramcha which locates a sub-ply flush and its level is directly related to that of the Atlantic Ocean. Nouakchott is supplied with drinking water from the well field to Idini, located on the road of hope about 60 km from the city (Mint El Bezeid, 2007).

The city of Nouakchott benefits only 4 % of system sewage through the sewer. This wastewater is transported to the WWTP. The rest of the population uses pit latrines, pits and cesspools, septic tanks or has no drainage system at all (STUDI, 2000).

Sampling and Analysis

The one sampling site is the WWTP where raw sewage drained by some of the city of Nouakchott and some industrial units also connected to the WWTP (Society for a Bottling Company and a Specialized Fishing in the area Sales Cephalopods).

The bimonthly samplings were made at the WWTP during February 2008 to December 2009 (total 36 samples). The physicochemical parameters studied are: temperature, pH, electrical conductivity, chloride, calcium, magnesium, sodium, potassium and bicarbonate. The wastewater samples were collected manually in polyethylene bottles capacity 1 liter. The temperature, pH and electrical conductivity are measured in situ. For the others parameters, the analyses were carried out immediately after sampling to Laboratory Water Chemistry of INRSP (National Institute for Research in Public Health) in Nouakchott. In the Laboratory, all the samples were kept in a refrigerator at a temperature below 4ºC.

The pH and temperature were determined by a pH meter Hanna type. The electrical conductivity was measured by a Hanna conductivity type. The chlorides are measured by volumetric method of Mohr in the presence of silver nitrate solution by using potassium chromate as an indicator. The calcium and magnesium ions were determined by using a solution of disodium ethylenediamine tetraacetic acid (EDTA) (Rodier, 1996). The bicarbonates are analyzed by titration with HCl 0.1 N by using the methyl red as an indicator. For sodium and potassium, a photometer flame atomic emission Corning type is used.

Indicators of Water Quality for Irrigation

Important irrigation water quality parameters include a number of specific properties of water relevant in relation to the yield and quality of crops, maintenance of soil productivity and protection of the environment. These parameters mainly consist of certain physical and chemical characteristics of water that are used in the evaluation of agricultural water quality. Numerous water quality guidelines have been developed by many researchers for using water in irrigation under different condition (Eaton, 1950; US Salinity Laboratory, 1954). However, the classification of US Salinity Laboratory is used commonly. The parameters such as Electrical Conductivity, pH, SAR and SSP were used to assess the suitability of water for irrigation purposes.

RESULTS AND DISCUSSION

The results of present study consisting of descriptive statistics for all characteristics are presented in Table 1. An explanation of the observed characteristics follows in the following sections. The water temperature is an ecological factor that has important ecological repercussions (Leynaud, 1968). It acts on the density, viscosity, gas solubility in water, the dissociation of dissolved salts, as well as the chemical and biochemical reactions, development and growth of organisms living in water and especially microorganisms (WHO, 1987). The average values of temperature recorded oscillate between 26.3 °C and 28.7 °C depicted in **Table 1**. The recorded temperatures are below 35 ° C considered limiting value of direct discharge into the receiving environment (Ministry of Environment of Morocco, 2002).

Table 1. Statistics of the analytical data.

Characteristics	Max.	Min.	Mean
T (°C)	28,7	26,3	27,8
pH	7,9	7,3	7,6
EC (μScm^{-1})	3290	1510	2340
Cl^- (mgL^{-1})	1262,1	682,7	950,1
Ca^{++} (mgL^{-1})	140,2	114,2	131,6
Mg^{++} (mgL^{-1})	54,6	39,3	48,2
Na^+ (mgL^{-1})	308,3	245,5	276,1
K^+ (mgL^{-1})	31,2	28,2	29,6
HCO_3^-(mgL^{-1})	1096,5	992,2	1053,2

This is the concentration of H + in the water. It summarizes the stability of the balance between the different forms of carbonic acid and is related to the buffer system developed by carbonates and bicarbonates (HIMMI et al., 2003). The values of pH varied from 7.3 to 7.9 with an average of 7.6 shown in **Table 1**, which indicates that the treated wastewater is slightly alkaline in nature. The normal pH range for irrigation water is from 6.5 to 8.4. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion (Ayers and Westcott, 1985; Pescod, 1985).

The EC is the most important parameter in determining the suitability of water for irrigation use and it is a good measurement of salinity hazard to crop. The most important negative effect on the environment caused by agricultural wastewater is the increases in soil salinity, which if not controlled, can decrease productivity in long term (WHO, 2005). The primary effect of high EC reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Tatawat and Sing, 2008).

The EC values of experimental samples varied from 1510 to 3290 μScm^{-1} (mean value = 2340 μScm^{-1}) (**Table 1**). These results could be explained by the release of waste water from industrial units connected to the WWTP. The average values of conductivity recorded at the effluent of the WWTP slightly closer to 2700 μScm^{-1} (Ministry of Environment of Morocco, 2002)

The most common toxicity is from chloride (Cl^-) in the irrigation water. The chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue (Pescod, 1985). The obtained chloride ion concentration of the samples varied from 682.7 to 1262.1 mgL^{-1} (mean value = 950.1) (**Table 1**). The concentrations found in wastewater from the effluent of WWTP are greatly exceeding the concentration limit for irrigation water (350 mgL^{-1}) (Ministry of Environment of Morocco, 2002)

The sodium content is, in general troublesome of the major constituents and an important factor in irrigation water quality evaluation. The excessive sodium leads to development of an alkaline soil that can cause soil physical problems and reducing soil permeability (Kelley, 1951).

Furthermore, irrigation water containing large amounts of sodium is of special concern due to absorbed sodium by plant roots which is transported to leaves where it can accumulate and cause injury. The water can be used for irrigation when the concentration of sodium is about 184.0 mgL^{-1} (Abdul-Moneim, 1985). The sodium concentrations varied from 245.5 to 308 mgL^{-1} (mean value = 276, 1) (**Table 1**).

The variations in the alkalinity of wastewater are reconciled with the degree of mineralization viz conductivity, total hardness and pH, which also gives an indication of the degree of oxidation of organic compounds (if the wastewater) (Rodier, 1996). The effluents from WWTP are characterized by average maximum and minimum levels respective bicarbonates 1537.2 mgL^{-1} and 951.6 mgL^{-1} (**Table 1**). The standards recommend a HCO_3^- concentration of 250 mgL^{-1} for water for crop irrigation (Ministry of Environment of Morocco, 2002).

Generally, Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most waters. Both Ca^{2+} and Mg^{2+} ions are associated with soil aggregation and friability, but they are also essential plant nutrients. High concentration of Ca^{2+} and Mg^{2+} ions in irrigation water can increase soil pH, resulting in reducing of the availability of phosphorous (Al Shammiri et al, 1985). Water containing Ca^{2+} and Mg^{2+} higher than 200 mg/L cannot be used in agriculture (Khodpanah and al, 2009). The observed results show that the concentrations of Ca^{2+} and Mg^{2+} varied respectively from 114.2 mgL^{-1} to 140.2 mgL^{-1} and from 39.3 mgL^{-1} to 54.6 mgL^{-1} (**Table 1**).

Sodium hazard is usually expressed in terms of SAR and it can be calculated from the ratio of sodium to calcium and magnesium. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd, 1980). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It has been calculated as follows (Jimenez and Chavez, 1997): SAR = $[Na^+] / [\surd (Ca^{2+} + Mg^{2+})/2]$ where: Na^+, Ca^{2+} and Mg^{2+} are in $meqL^{-1}$. The SAR value of the effluent of WWTP ranges from 5 to 6.2 with a mean of 5.4 (**Table 2**).To control the adverse effects of irrigation on soil and plants, the US Salinity Laboratory (1954) established a scale of quality of irrigation water based on heir EC and SAR. Compared to the CE, water classes are: C1: low salinity with conductivity <250 μScm^{-1}, C2: average salinity with conductivity between 250 μScm^{-1} and 750 μScm^{-1}, C3: high salinity with conductivity between 750 μScm^{-1} and 2250 μScm^{-1} and C4: very high salinity with conductivity between 2250 μScm^{-1} and 5000 μScm^{-1}). Compared to the SAR, the classes of irrigation water are S1: excellent low alkalinization hazards with SAR <10, S2: hazards to good alkalinization acceptable with SAR between 10 and 18, S3: average quality to alkalinization significant hazard with SAR between 18 and 26 and S4: bad quality to the dangers of alkalinization very important with SAR> 26.

The postponement of the analysis results to the scale established by the US Salinity Laboratory (1954) shows that wastewater irrigated market-garden at the perimeter of Sebkha oscillates between class C3S1 and C4S1.

The SSP was calculated by Todd (1980), with the following equation: SSP= (Na + K) 100/ (Ca+ Mg + Na + K) where all the ions are expressed in $meqL^{-1}$. The water with SSP greater than 60 percent may result in sodium accumulations that will cause a breakdown of the soil's physical properties (Halliwell et al, 2001). The calculated values of SSP varied from 48.6% to 55.9% with a mean of 52.1% (**Table 2**) indicating moderate degree of restriction on the use of this wastewater in irrigation.

When the concentration of sodium ion is high in irrigation water, Na^+ ion tends to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. This exchange process in soil reduces the permeability and eventually results in soil with poor internal drainage (Ayers and Westcott, 1985). Irrigation with waters that have high concentrations of Na^+ ion relative to divalent cations may cause an accumulation of exchangeable Na^+ on soil colloids (Halliwell et al, 2001).

Another indicator that can be used to specify the magnesium Hazard (MH) is proposed by reference (Raghunath, 1987) for irrigation water as in the following formula: MAR= Mg x 100/ (Ca + Mg) where, Ca^{2+} and Mg^{2+} ions are expressed in $meqL^{-1}$. If the value of MAR is less than 50, then the water is safe and suitable for irrigation (Khodapanah et al, 2009). The MAR values range between 31.5 and 39.4%, with a mean of 36.9 (**Table 2**) and the treated wastewater can be classified with few exception as suitable for irrigation use.

Table 2. Calculated irrigation quality characteristics.

Characteristics	Max.	Min.	Mean
SAR	6,2	5	5,4
MAR (%)	39,4	31,5	36,9
SSP (%)	55,9	48,6	52,1

CONCLUSION

The Mean values of CE of the SAR of SSP and the MAR are respectively 2340 μScm^{-1}, 5.4, 52.1% and 36.9%. The Sodium Adsorption Ratio and electrical conductivity showed that wastewater irrigated at the market-garden of Sebkha oscillates between class C3S1 (high salinity and excellent low hazard alkalization) and C4S1 (very high salinity and the excellent low hazards alkalization). The study of the physicochemical parameters and indicators of salinity of the WWTP effluent shown the existence of pollution resulting in high salinity can have a negative impact on soils and crops of Sebkha gardener.

Therefore, the use of these effluents would be possible only after the reduction of salinity, which could be done by dilution of effluents (Ben Ghedella et al, 2001). But dilution could be a disadvantage since it amounts to the use of drinking water that you want to save. The salinity of the effluent could be reduced by reverse osmosis, but this treatment is expensive (Bowman et al, 2002). Finally we could water the plants selectively so as to apply the effluent on the salt-tolerant species (Brown and Glenn, 1999; Lin et al, 2001).

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