Evaluation of Groundwater Quality for Irrigation Purposes in Buatni Area, Benghazi, Libya

Mohamed H. S. Ahmida (Corresponding author)
Department of Nutrition, Faculty of Public Health, Benghazi University, Benghazi-Libya,
Tel: 00218925129510 E-mail: hamzasol@yahoo.com

Nagwa H. S. Ammida and Muftah El-Faituri
Environmental Health Department, Faculty of Public Health, Benghazi University, Benghazi-Libya,

Khadija A. El-sharda and Aida Shteiwi
Water Chemistry Lab., General Water Authority, Benghazi, Libya

Abstract

Groundwater samples from the constructed wells in Buatin area (a region of Benghazi city, Libya) were collected during March 2008 to March 2009. The samples were analyzed for their suitability for irrigation purpose. The major cations and anions concentration were measured and the other parameters related to agriculture water quality were calculated. Based on electrical conductivity 6% of Buatni wells have medium salinity hazard, 58% have high salinity and 2% of the wells have very high salinity water. According to sodium adsorption ratio (SAR), almost all wells have excellent to good quality irrigation water. According to residual sodium carbonate (RSC) hazard, 80% of the wells have unsuitable irrigation water quality, 16% have doubtful irrigation and only 4% of wells have good irrigation water quality. Out of United State Salinity Laboratory`s diagram (USSL), Buatni groundwater have classified into 5 classes namely C_2-S_1 (0.5%), C_3-S_1 (60%), C_3-S_3 (0.5%), C_4-S_1 (30%) and C_4-S_2 (1.5%). In conclusion of these results, the majority of Buatni groundwater is suitable for irrigation uses.

Keywords: groundwater analysis, Buatin area, Benghazi, physical parameters, chemical parameters

1. Introduction

Groundwater is the most important source of domestic, industrial and agricultural water supply in the world (Ackah et al, 2011). At present time nearly one fifth of all the water used in the world is obtained from groundwater sources (Hasan, 2008). The main way of using groundwater in the world, accounting of all other consumption is the irrigation purposes. The quality of groundwater is constantly changed in response to daily, seasonal and climatic factors; therefore a periodic monitoring of groundwater is necessary to safeguard its long term sustainability (Adak & Purohit, 2003)

Benghazi is the second largest city in Libya (after the capital Tripoli), it is located in the northeastern region part of Libya (Figure 1). It is the principal city of the Eastern Libya and is one of Libya`s major economic centre, as the city has an important port and there is also an industrial and commercial centre. Benghazi locates between 20^o 03, 50`` to $20^o$, 0` 35`` longitudinal east and 32^o 03 to 23^o 20 latitude north and covers an area of 314 km^2. Benghazi has a Mediterranean climate with warm dry summers and mild winters with occasional rain. Annual rain fall is low; therefore the city local supply is supplement by groundwater transported from the aquifers of south Libya by the *Man-Made River Project* (MMRP). However, the MMRP has not provided the needed water to the population in most areas in Benghazi. The people heavily depend on the groundwater from local wells for drinking, domestic lives and agricultural purposes (Gadalmola& Mohad, 2010; Abdalla, 2003).

The objective of the study is focuses on the evaluation the wells groundwater quality of Buatni area (a

region of Benghazi city, which depended mainly on groundwater as a water supplies-Figure 1) and its suitability for irrigation purposes.

2. Experimental Part

The scope of this paper is limited to the Buatni area. It is a rural area, located in east of Benghazi city (Figure 1). This area undergoes rapid development; it has many farms and factories including factories for construction materials and drinking and stuff foods. The other main activities carried out in Buatni area is agriculture and crop irrigation. The chief crops in this area are barley, fruits (such as fig, grape, pomegranate) and vegetables.

2.1. Water Sampling and Analysis

The water samples were collected from 50 wells of Buatni area; in polythene bottles during the period from March 2008 to march 2009, the date and time were labeled. The water samples were analyzed for different parameters. Temperature and electrical conductivity were measured on the spot itself, using Hanna Auto-ranging microprocessor EC/TDS/^{o}C. The pH was measured using pH-meter (*Ino lab WTW*) equipped with glass combined electrode (*pH-electrode sen Tix 61-B023009AP017*). The other parameters of water were determined in "General Authority Laboratory", Benghazi, Libya, by standard methods of water analysis (Richards, 1956). Calcium and magnesium contents were determined by EDTA titration. Sodium and potassium ions were determined using flame photometer. Chloride ion was determined by silver nitrate titration. Bicarbonate and carbonate ions were determined by acid-base titration. Sulphate ion and nitrate ion contents were determined using spectrophotometric methods (Vierira et al, 1998; Komalenko& Lowe, 1973).

3. Results and Discussion

The water used for irrigation purposes should be of such quality which does not harm the soil and give maximum crop yield. The analyzed physico-chemical parameters of Buatni wells water samples, such as pH; EC; concentrations of some cations and anions are determined and described as shown below:

3.1. Acidity and Bascity

The acidity and basicity of irrigation water is expressed as pH. The desirable limit for pH is from 6.5 to 8.4, which is the normal pH range for irrigation water (Bauder, 2010; Richards, 1954). In our study, the pH of the groundwater samples ranged from 6.39 to 8.87 with an average 7.63. However, most groundwater samples were slightly alkaline; only two wells have water with pH less than 6.5 and 6 wells have water with pH greater than 8.4. Low pH may accelerate the corrosion of irrigation system. High pHs (above 8.4) are due to the presence of high levels of carbonate and bicarbonate ions.

3.2. Carbonate Hazard

Bicarbonate and carbonate contents of irrigation water should be carefully evaluated. The bicarbonate level of irrigation water can increase soil pH. The groundwater with high levels of bicarbonate have tendency to form insoluble salts of calcium and magnesium ions, leaving sodium ion as the dominant ion which affects soil permeability. In the other hand, high level of bicarbonate ion in groundwater may lead to form calcite in drip or micro spray irrigation systems, which leading to decrease the flow rates through orifices. Groundwater with bicarbonate level < 90 mg/L is classified as safe water for irrigation and water samples with bicarbonate levels 90-500mg/L is marginal (Aryres& Westcost, 1985). Many scientific workers were used *Bicarbonate hazard* to describe the effect of carbonate and bicarbonate in irrigation water. Bicarbonate hazard is expressed in terms of Residual Sodium Carbonate (RSC), which calculated by equation {I}.

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \qquad \textit{Equation \{I\}}$$

According to RSC, groundwater for irrigation purposes could be classified as good (RSC< 1.25), Doubtful (RSC: 1.25-2.5) and unsuitable (RSC >2.5) (Sadashivaiah, 2008). Out of Buatni area, 2 wells (4%) have good irrigation water quality, 8 wells (16%) have doubtful irrigation water quality and 40 wells (80%) is unsuitable irrigation water quality.

3.3. Chloride, Sulphate and Nitrate Water Contents

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Chloride ion has a toxic effect to plant, because soil could not adsorb chloride ion. Therefore it takes up by plants and accumulates in leaves, leading to burning or drying leaf tissue. The groundwater with chloride ion contents less than 70mg/L is considered safe for irrigation uses, 70-355mg/L chloride ion contents is slight to moderate. The water with chloride ion content > 355 is considered as severe (Aryres& Westcost, 1985). The chloride ion content of Buatni groundwater is ranged from 15.98 mg/L to 1988 mg/L. The classification of groundwater of selected area for irrigation purposes based on chloride content is shown in table 1. Most groundwater of the selected wells have moderate to severe chloride content.

Sulphate ion is available in nature as calcium sulphate which is known as gypsum. It is essentially plant nutrient. According to sulphate ion level, groundwater are classified to low sulphate content (< 30mg/L), normal sulphate content (30-90mg/L) and high sulphate content (90-180 mg/mL). The sulphate ion content of Buatni groundwater is varied from 12 to 252 mg/L. It found that 6% of samples have low suphate content, 40% of groundwater wells have normal sulphate content, 38% have high sulphate content and 8% of samples have sulphate content greater than 180 mg/mL (table 1).

Nitrate ion is the nature form of nitrogen in soil and ground water. Nitrogen is an essential plant nutrient and stimulates crop growth. Water containing nitrate < 22mg/L is considered as safe water for irrigation and that contain nitrate ion 22-132 mg/L is considered as moderated water, while that contain > 132mg/L are unsuitable water for irrigation. For the analysis of ground water of the studied area, the nitrate ion content is ranged from 6.2 mg/mL to 55.8 mg/mL. 46% of Buatni groundwater is considered as safe water for irrigation, 3% and 1% are considered as moderate and unsuitable water for irrigation, respectively (table 1).

3.4. Electrical Conductivity

The suitability of groundwater for irrigation depends on the effect of mineral constituents (salinity) of the water on both plant and soil. The primary effect of high salinity water on plant growth crop productivity is the inability of the plant to compete with other ions in the soil solution by restricting the taking up of water through modification of osmotic process (physiological drought) (Thorne& Peterson, 1959). The effect of high salinity is often produce smaller plant than one not affected by salinity. In situation of especially elevated salinity, plant tissue may be dying due to occurring necrosis at the leaf edges. Additionally salinity water may lead to accumulation of some elements which can be toxic to plants such as boron, sodium and chloride (Bauder, 2011). The salts also affect the soil structure, permeability and aeration which indirectly affect plant growth. Such effects are called salinity hazard. The salinity can estimated by measuring the electrical conductivity (EC) of water, reported as µs/cm. The EC of Buatni groundwater samples varied from 413-7150 µs/cm. According to the classifications made by United Sates Salinity Laboratory (USSL), the groundwater of the studied area is classified into 4 classes as presented in table (2) (Richards, 1954) (. According to the EC values of Buatni groundwater samples present, there is no sample has low saline, 6% of samples have medium saline, 58% of samples were categorized as high saline and 36% samples were classified as very high saline (Sadashivaiah, 2008).

3.5. Sodium Hazard

Sodium content is an important parameter to determine the groundwater suitability for irrigation. The sodium can influence or replace other cations leading to adsorption of sodium ion in soil cation exchange sites. This cause breaking down of physical structure, sealing the pores of soil making it impermeable to water flow, and dispersion of soil clay which cause the soil to become hard. High sodium content soils are plastic, sticky when wet, prone to form clods and crust on drying (Khodapanah et al, 2009; Nagarajah et al, 1988; Aryres& Westcost, 1985).

The sodium hazard or sodicity hazard is typically expressed as the sodium adsorption ratio (SAR), which is defined by equation {II} (Hasan, 2008).

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}} \qquad \text{Equation \{II\}}$$

Where $[Na^+]$, $[Ca^{2+}]$ and $[Mg^{2+}]$ refer to the molar concentration of Na, Ca and Mg ions respectively in

mol/L.

The calculated SAR values of the studied groundwater are demonstrated in table 3. Based on the USSL classification (Abdalla, 2003), the SAR for groundwater samples of Buatni area is classified as low (90%) and medium (10%). That`s means that Buatni wells water have good quality irrigation water according to sodium hazard.

3.6. Salinity and sodium hazard classification

In order to classify the groundwater for irrigation uses, the USSL diagram has been used (Richards, 1954). According to this diagram, with the reference of EC as an index to salinity hazard and SAR as an index to alkalinity hazard, the water has classified into 16 classes. The groundwater of Buatni were mostly confine to 5 classes, as non of the groundwater samples lie in the first class of salinity hazard and last class of sodium hazard. Buatni groundwater samples fall in C_2-S_1, C_3-S_1, C_3-S_3, C_4-S_1 and C_4-S_2 water classes (table 4). One sample falls in C_2-S_1, with medium salinity hazard and low sodium hazard. This class of groundwater can be used for growing all types of crops on almost all types of soils with good drainage. The majority of Buatni groundwater (60%) falls in the C_3-S_1 quality water class, with high salinity hazard and low sodium hazard. This class of water may be used for growing all type of crops except salt sensitive crops. The second largest area of Buatni groundwater (30%) is covered by C_4-S_1, with very high salinity hazard and low sodium hazard water class. The use of this class of water on soils may cause both salinity and alkalinity problems in long run. The rest of Buatni groundwater samples (2%) fall in C_3-S_3 (high salinity hazard and high sodium hazard) and C_4-S_2 (high salinity hazard and medium sodium hazard) water classes. Such groundwater classes can be used for irrigation only under very special circumstances, for growing high salt tolerant crops.

4. Conclusion

The groundwater samples from Buatni area, of Benghazi municipality, were assessed for the suitability of water quality for irrigation purposes. The results of groundwater of the studied area indicate a moderate to high levels for parameters such as Cl^-, SO_4^{2-} and RSC. Most samples have pH within the permissible limits as per irrigation water quality guidelines. SAR of water samples varied from low to moderate level, where salinity hazard varied from high to very high levels. According to USSL water classification for irrigation purposes, it observed that the majority of samples are within C_3-S_1 class water, which is safely used for agriculture development, but C_4-S_1 and C_4-S_2 water classes need adequate precautions to avoid salinity effects. Additionally, there are other different factors; like soil type, crop type, crop patter, climate, which have an important effects to determine suitability of water for irrigation purposes.
This work may serve as a preliminary study to provide baseline information that may direct future groundwater quality assessment studies in Benghazi city.

References

Abdalla L. M. (2003). Plain Benghazi- National Geography Study. (2nd ed.) Garyounis University Publications, Benghazi, Libya. (*in Arabic language*).

Ackah, M., Agyemang, O., Anim, A. K., Osei, J., Bentil, N. O., Kpattah, L., Gyamfi, E. T.& Hanson J. E. K. (2011). Assessment of groundwater quality for drinking and irrigation: the case study of teiman-oyarifa community, Ga-East Municipality, Gahan. *Proceedings of the International Academy of ecology and Environmental Sciences*, 1 (3-4) 186-194.

Adak, M. D.& Purohit K. M. (2003). Assessment of the water quality in Rijganpur industrial complex-part1: Physicochemical Parameters and Water quality Index. *Poll. Res*., 22 (1) 133-138.

Aryres R. S.& Westcost D. W. (1985). Water quality for agriculture food and agriculture organization of the United Nations. FAO Irrigation and Drainage, FAO, Rome, Italy rev. 1, page 29.

Bauder, J. W., Bauder, T. A., Waskom, R. M.& Scherer T. F. (2011). Assessing the suitability of water (quality) for irrigation salinity and sodium" [online] available: www.ext.colostate.edu.pdf.

Bauder, T. A., Waskon, R. M., Sutherland, P. L.& Davis J. G. (2010). Colorado State University Extension:

Irrigation Water Quality Criteria. [online] Available:www.ext.colostate.edu.pdf.

Gadalmola S. M.& Mohad. E. T. (2010). The impact of The Man-Made River Project in providing domestic water in Benghazi plain, Libya" *IJRRAS* 9 (3) 473-477.

Hasan G. M. (2008). Groundwater Quality For Irrigation in Benghazi Region. *Twelfth International Water Technology Conference (TWTC12)*, Alexandria, Egypt, page 1735.

Khodapanah, L., Sulaiman, W. N. A.& Khodapanah N. (2009). Groundwater quality assessment for different purposes in Eshtehard district, Taharn, Iran. *European Journal of Scientific Research* 136 (4) 543-553.

Komalenko C. G.& Lowe L. E. (1973). Determination of nitrates in soil extracts. *Soil Sci. Soc. Am. Proc.* 37, 660-663.

Nagarajah, S., Emerson, B. N., Abeykoon, V.& Yogalinga S. (1988). Water quality of some wells in Jaffna and Killinochchi with special reference to nitrate pollution" *Tropical Agriculture* 44, 61-73.

Richards L. A. (1954). Diagnosis and improvement of saline and alkai soils:" Agriculture Handbook vol. 60, US Department of Agriculture, Washington D. C., pp 69-82&160.

Sadashivaiah, C., Ramarkrishnaiah, C. R.& Ranganna G. (2008). Hydrochemical analysis and evaluation of groundwater quality in Tumkur Taluk, Karnataka State, India. *Int. J. Environ. Research and Public Heath* 5 (3) 158-164.

Thorne D. W.& Peterson H. B. (1959). Irrigate soils" Constable and Company, London, UK.

Vierira, J. A., Reis, B. F., Kronka, E. A. M., Paim, A. P. S.& Gine M. F. (1998). Multicommulation in flow analysis. Part 6. Binary sampling for wide Concentration Range Turbidimetric Determination of sulphate in Plant digests. *Analatica . Chimica. Acta* 336, 251-255.

Table 1. Content of chloride, sulphate and nitrate ions in groundwater of Buatni area

Cl^- content	No. samples (Sample(%))	SO_4^- Content	No. samples (Sample (%))	NO_3^- Content	No. samples (Sample (%))
Low: < 70	3 (6%)	Low: < 30	3 (6%)	Low: <22	46 (92%)
Medium: 70-355	20 (40%)	Medium: 30-90	20 (40%)	Medium: 22-132	3 (6%)
High: > 355	27 (54%)	High: 90-180	19 (38%)	High: > 132	1 (2%)
		Very high: > 180	8 (16%)		

Table 2. Classification of Buatni groundwater samples based on USSL salinity hazard for irrigation purposes.

Salinity hazard classification	EC ((ms/cm)	Water classification	Number of samples	Sample %
C1: Low conductivity	< 250	Excellent	0	0
C2: Medium conductivity	250-750	Good	3	6
C3: High conductivity	750-2250	Doubtful	29	58
C4: Very high conductivity	> 2250	unsuitable	18	36

Table 3. Classification of Buatni groundwater samples based on USSL sodium hazard for irrigation purposes.

SAR classification	SAR values (eq/L)	Water classification	Number of samples	Sample %
S1: Low SAR	1-10	Excellent	45	90
S2: Medium SAR	10-18	Good	5	10
S3: High SAR	18-26	Doubtful	None	0
S4: Very high SAR	≥ 26	unsuitable	none	0

Table 4. Classification of Buatni groundwater samples according to USSL diagram

Type of ground water	Class of salinity& alkalinity	Number of samples	Sample %
C_2- S_1	Medium salinity-low sodium water	1	0.5
C_3-S_1	High salinity- low sodium water	30	60
C_3- S_3	High salinity-high sodium water	1	0.5
C_4- S_1	Very high salinity- low sodium water	15	30
C_4-S_2	Very high salinity-medium sodium water	3	1.5

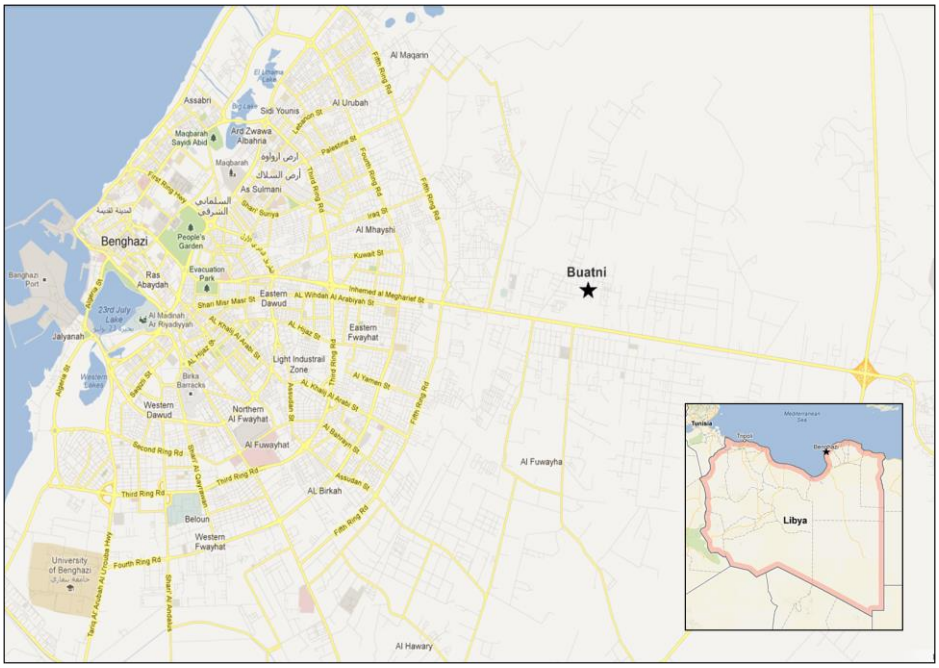

Figure 1. Map showing the location of Benghazi and Buatni area