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Evaluation of Jordanian Natural Zeolite for Removing Iron Ions from Underground Water

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ABSTRACT

The content of iron ions (Fe^{+2} and Fe^{+3}) in Jordanian underground water highly exceeds the standard limits in certain places. Since Jordanian water resources are very limited, the removing of these ions by cheap methods is very important. Natural zeolite which is available in Jordan in large amounts is very attractive for this purpose. The objective of this research is to evaluate Jordanian natural zeolite for removing iron ions from underground water. Batch process was used for the evaluation. The concentration of iron ions versus time for different amount of zeolite concentrations and sizes was evaluated. The results indicate that, Jordanian natural zeolite is very effective for removing iron ions from water. The zeolite concentration of about 10g/L is capable of removing almost all iron ions from water in few hours.

Keywords: Jordanian natural zeolite, adsorption, iron ions, underground water.

INTRODUCTION

Jordan is considered one of the poorest countries in terms of water resources, and therefore, it is important to use every source of water to cover the needs of growing demand on water. The contamination of some underground water by iron ions, especially south Jordan underground water, causes a major problem for using this type of water [Water Authority of Tafila/Jordan]. Iron ions cause a health problems (poisoning) when they exceed the limit and the presence of these ions enhance the corrosion of equipment (pipes, pumps, tanks…etc.) Moreover precipitation of these ions restrict or even closes the flow in equipment. The existence of iron ions in underground water can be explained as follows: most soils in Jordan are very rich in iron ions, when it rains, the rain passes through the soil and dissolves some of these ions. If this water finds an underground way to the well, it contaminates the well with these ions. Efficient and cheap techniques for removing iron ions are highly encouraged in Jordan. Several methods can be used to remove iron from water. Adsorption, ionic or cationic exchange are the most predominant cheap methods used for this purpose [Gregg and Kenneth 1982, Barrry and John 1998]. Zeolite mineral has been widely used as an adsorption material, especially in water and waste water treatment [Balanchard et.al.1984, AL Dwairi 2007, Wong 2009].

In Jordan, natural zeolite is available in huge amounts at north-south, central and south as shown in Figure 1 [AL Dwairi 2007]. In extensive studies carried out on Jordanian natural zeolites [Benefield et.al. 1982, AL Dwairi 2007, Reyad 2010] it was found that Jordanian natural zeolites have a surface area comparable to treated commercial zeolites. This great property makes Jordanian natural zeolite a great material for adsorption purposes. Moreover, it was found that Jordanian natural zeolites hold a net negative charge [Ibrahim 1996, AL Dwairi 2007, Reyad 2010] which makes them a suitable adsorption material for positive ions. The electrical forces attract the positive ions and the negative charge on zeolites, so that Jordanian natural

zeolite is expected to be a good adsorption material for positive ions as in the case of iron ions.

The goal of this work was to evaluate Jordanian natural zeolite to remove iron ions from underground water. Since iron contamination of underground water is a predominant problem in southern Jordan, more specifically at Al Tafila area, this research evaluated the Tafila zeolite on its contaminated underground water (AL Tannour well). All tests and measurements were carried out at Tafila Technical University/ Tafila.

EXPERIMENTAL TECHNIQUES

Collections of samples

Three samples of natural zeolite were collected from the Al Hala piles located in south al Tafila/Jordan as shown in Figure 1. The zeolites samples were taken from different locations at the AL Hala piles such that all the area was covered. Table 1 shows the chemical composition of the natural zeiolite at this area [AL Dwairi 2007]. The water from the AL Tannour well located in Wadi El-Hesa area north Tafila was used for this study. The composition of this water is shown in Table 2 [AL Nsoor, 2017].

Preparation of zeolite samples

The zeolite samples were prepared as follows:

1. The samples of natural zeolite were washed by water to remove the dirt.
2. The samples were crushed by jaw crusher and then milled by ball mill to the required size.
3. The milled natural zeolites samples were placed in water so that the impurities existing in the natural zeolite floated on the top of the water, therefore, increasing the concentration of zeolites [AL Dwairi 2007]. The water was then drained and the zeolite is now ready to use.

Table 1. Chemical composition (wt. %) of natural zeolite taken from Al Hala natural zeolite/Al Tafila [AL Nsoor, 2017]

Sample	SiO_2	Na_2O	Fe_2O_3	MgO	Al_2O_3	K_2O	CaO	MnO	TiO_2	P_2O_3	CO_2
1	41.70	0.521	15.50	6.67	15.60	0.94	7.62	0.199	3.28	0.70	6.80
2	40.80	0.670	15.80	7.23	16.90	0.80	6.70	0.210	3.17	0.90	6.10
3	39.60	0.340	16.01	6.89	16.17	0.82	8.10	0.220	3.50	0.81	6.90
Average	40.70	0.510	15.77	6.93	16.223	0.853	7.473	0.210	3.32	0.803	6.60

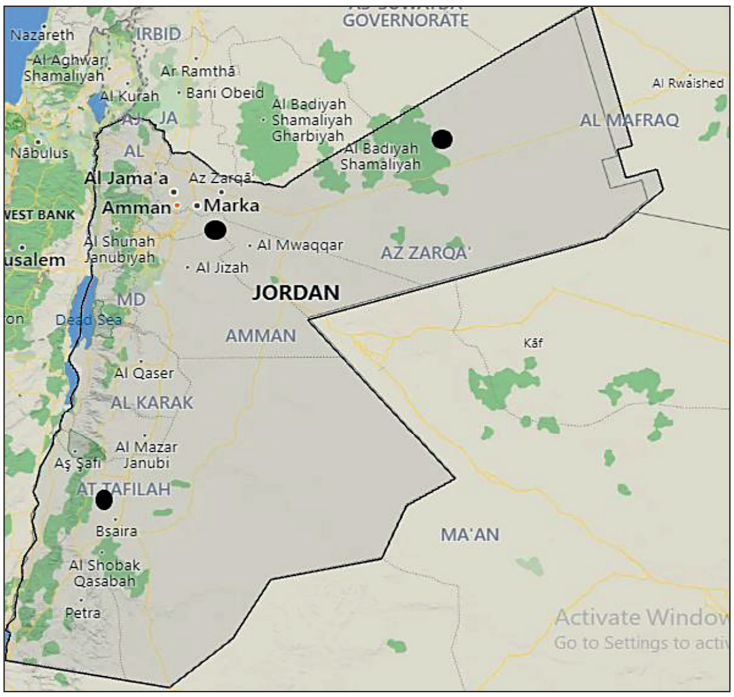

Figure 1. The location of natural zeolite in Jordan (black circles) [AL Dwairi 2007]

Table 2. Chemical composition of the AL Tannour well water and specifications of drinking water in Jordan [Water Authority of Tafila/Jordan]

Parameter		Value	Jordanian drinking water specifications
Chloride Cl^{1-} (mg/cm^3)		0.0	<0.500
Turbidity (NTU)		24.9	< 5.0
Total Dissolved Solids (mg/cm^3)		0.312	< 0.10
Specific Conductivity (µs/cm)		624	<400
pH		7.58	6.5–8.5
NH_4^{1+} (mg/cm^3)		0.00001	<0.0002
Fe^{2+}		0.00151	<0.001
Fe^{3+} (mg/cm^3)		0.00256	<0.001
Total Hardness (mg/cm^3)	$CaCO_3$	0.1001	0.120–0.180
	Mg^{2+}	0.0400	0.020–0.050
	Ca^{2+}	0.0060	0.0010
Total Coliform		<1	<1
Escherichia coli (E. coli)		<1	<1

Experimental procedure of adsorption

Batch process was used to evaluate the adsorption capability of natural zeolite in removing of iron. The procedure was as follows:

1) One liter of contaminated water of the AL Tannour well was added to a magnetically stirred beaker.
2) Natural zeolite is added to the beaker in the required amount. The starting amount of zeolite was 5g.
3) The concentration of iron ions was measured versus time using a spectrophotometer (Type DR 6000 UV-VIS).
4) The above 3 steps were repeated 5 times for different amounts of zeolite added to the contaminated water. The quantities of zeolite ranging from 0–25g with 5g increment were used in these experiments.
5) The mesh size of zeolite was changed and the above mentioned steps were repeated.

RESULTS AND DISCUSSION

Figures 2–5 show the obtained results of using Jordanian zeolite to remove iron ions. The average of the three samples taken from the al Hala piles was plotted in these figures. From these figures, the capability of zeolites in removing iron ions can be seen. Almost all iron ions can be removed by small amount of zeolite in few hours.

In figures 2 and 3, the concentration of iron ions was plotted versus time at different concentrations of zeolites. At the beginning of the adsorption the rate is very fast but at the end of adsorption the rate becomes very slow. This is because at the beginning more sites of adsorption for zeolites are available, and therefore, the rate of adsorption is fast, at the end of adsorption time these sites consumed and thus the adsorption rate becomes slow. For low concentration of zeolite, it takes longer time to remove iron ions, but for higher concentration of zeolites it takes much less time to remove them.

Comparing Figures 2 and 3 it can be seen that iron ion Fe^{3+} needed shorter time than Fe^{2+} ion to remove. This is because zeolite has a negative charge as pointed out in the introduction, and therefore, the attractive forces between zeolite

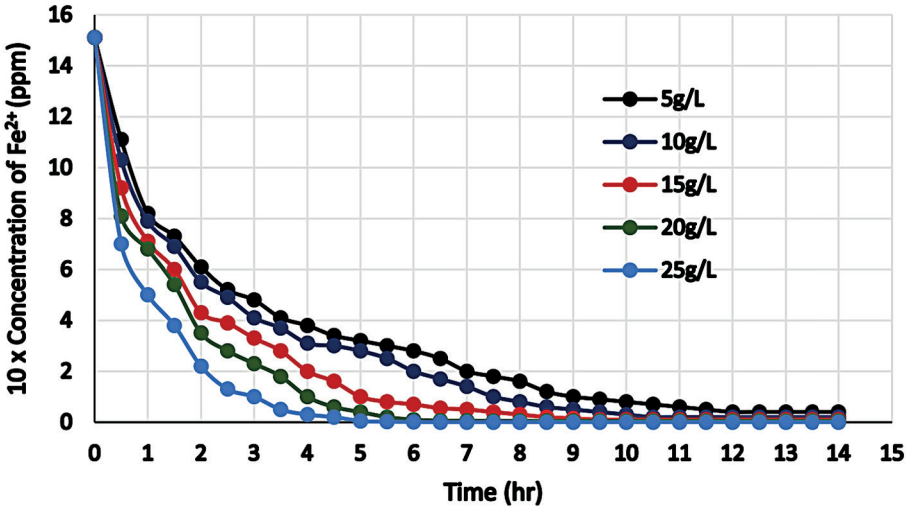

Figure 2. Concentration of Fe^{2+} versus time at different zeolite concentrations. Zeolite mesh size 35/48

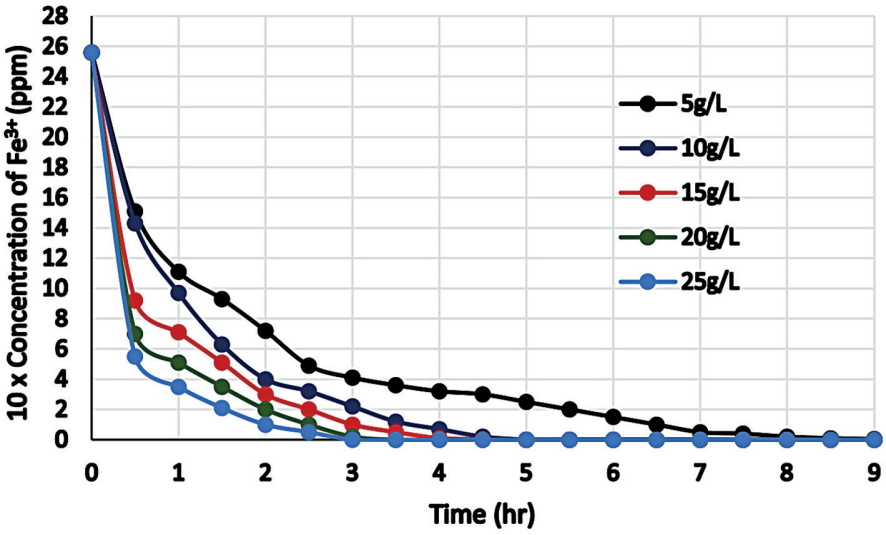

Figure 3. Concentration of Fe^{3+} versus time at different zeolite concentrations. Zeolite size mesh 35/48

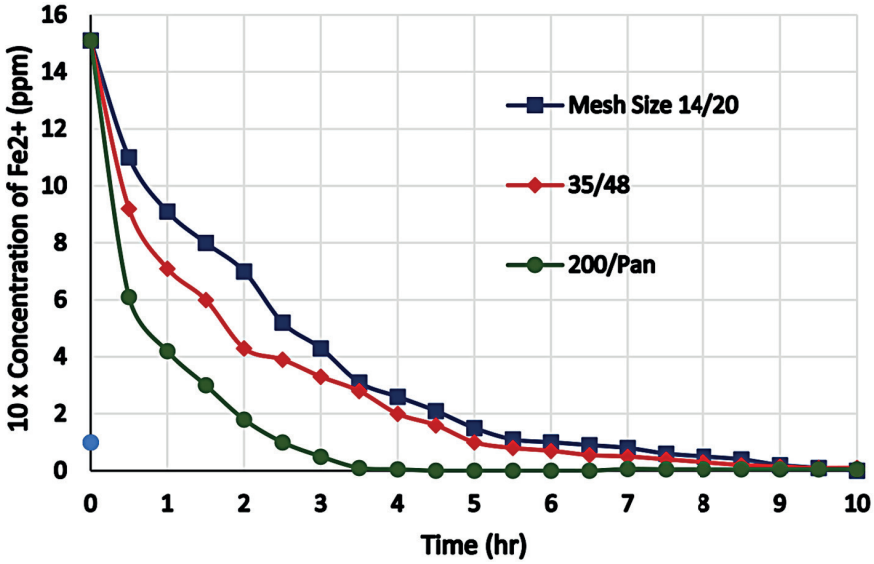

Figure 4. Concentration of Fe^{2+} versus time for different sizes of zeolite. Concentration of zeolite = 15g/L

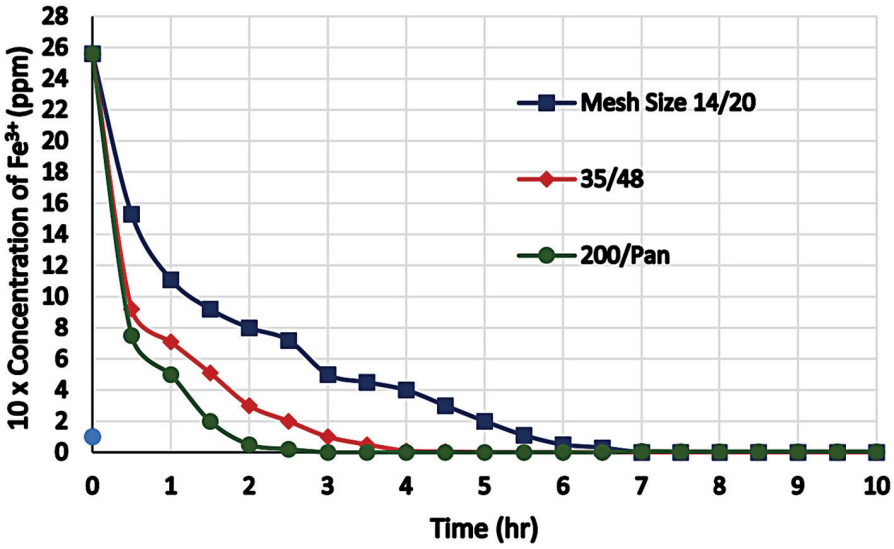

Figure 5. Concentration of Fe^{3+} versus time for different sizes of zeolite. Concentration of zeolite = 15g/L

and Fe^{3+}ion are greater, which makes the process of removing Fe^{3+} faster.

In Figures 3 and 4 the concentration of iron ions was plotted versus time for different sizes of zeolites. It can be seen that as the zeolite size decreased, the adsorption rate becomes faster and the capacity of adsorption also increased. This is because as the size reduced, the surface area of zeolite is increased, and therefore, more sites on zeolites for adsorption are created. This increase in sites makes the rate of adsorption faster and the capacity of zeolite for removing ions increased.

Finally, it can be seen from figures 4 and 5 that, when the size of zeolite decrease, the rate of adsorption of Fe^{3+} is greatly enhanced more than Fe^{2+}. Again, this is because of the increased number of sites of zeolite as well as the more attractive forces between Fe^{+3} and zeolite as pointed above.

CONCLUSIONS

The results indicate that Jordanian natural zeolites can be efficiently used to remove iron ions from water. Few grams of Jordanian Natural Zeolite (10g/L) are capable of removing almost all iron ions from water. With its huge quantities and very low cost in Jordan, natural zeolite is a successful cheap material for removing iron ions from water. After use, the spent zeolite becomes rich in iron ions, which can be used as a fertilizing material.

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