REMOVAL OF IRON FROM WATER USING HYDROGEN PEROXIDE

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ABSTRACT

The presence of iron is probably the most common water problem facing by consumers. So, the aim of this study was to assess the efficacy of hydrogen peroxide to remove iron (Fe2+) from water. Water with high content of Fe2+ (20 ppm of iron II) was prepared in the laboratory using Iron(II) sulfate heptahydrate (FeSO4.7H2O), then treated with 0, 0.1, 1, 3, 5, 10 and 20 ppm of hydrogen peroxide as the final concentration in the solution for contact time 5, 10, 20, 30 and 60-minute. Results showed that the average of removal ratio of Fe2+ was 85%-96% at the normal pH range of drinking water. The recommended dose of hydrogen peroxide was 0.1 ppm as a final concentration for 20−minute contact time. The study proved that hydrogen peroxide successfully used for Iron II removal and consider as economic and eco-friendly solution.

Keywords: Hydrogen peroxide, Heavy metals, Water, Iron removal, Oxidation

INTRODUCTION

All of us believe that there is no life without water, in the fact it is well-known that clean water considers the absolutely essential thing for the people (Kroehler, 2013). In the past, rain was one of the main sources of freshwater because it forms rivers and lakes. Rain is commonly polluted by various pollutants that we add to our atmosphere. Enough renewed, clean and obtainable drinking water is a basic requirement for the life of all organisms on the earth's surface (Ahuja, 2013).

Heavy metals (such as arsenic, zinc, manganese, aluminum, cadmium, lead and others) cause many health problems if they are found in drinking water at concentrations higher than permitted (Kroehler,2013) and (Fernández-luqueño *et al.*, 2013).

Heavy metals are widely different in their chemical properties, also it is important in our everyday life, as well as in high-tech applications. This gives chance for heavy metals to reach and enter into our aquatic food chains from different anthropogenic natural weathering sources (Tripathi & Ranjan, 2015).

Contamination basically from mining wastes, landfill, wastewater, industrial waste, particularly from the electroplating and metal finishing (Huang *et al*., 2016).

The problems are becoming larger because metals have ability to be transported with sediments, and can bio-accumulate in the food chain (Fernández-luqueño *et al*., 2013).

Besides that, iron in an industrial water lead to many problems such as corrosion of boiler water, cooling water lines due to the presence of high concentrations and also membranes stations damage reverse osmosis if not get rid of iron in the feed water (Sharma, 2015). The world health organization (WHO) recommends that iron concentration in drinking water should be less than 0.3 mg/L (WHO, 1996). The European commission directive recommends that iron in water supplies should be less than 0.2 mg/L

(Council Directive /EC, 1998). The Egyptian limits for iron in drinking water is 0.3 mg/L (Law 48, 2003).

Iron usually exists in two oxidations states, ferrous (Fe^{+2}) and ferric (Fe^{+3}). Several methods such as lime softening, ion exchange, activated carbon, oxidation, precipitation, bioremediation and membrane process have been used for the removal of iron from water (Cho, 2005).

Hydrogen peroxide is considered as ecofriendly substance and has highly oxidation capacity. So, it was used to remove heavy metals from industrial wastewater (Weakley, 2009). It is one of the most powerful oxidizers known, stronger than chlorine, chlorine dioxide and potassium permanganate (Ayres *et al*., 2013).

Hydrogen peroxide can be converted to hydroxyl radical (OH.) with reactivity second only to fluorine. However, literature review indicated that very few studies has been conducted to find out the effects of factors that contribute to hydrogen peroxide decomposition in wastewater treatment. Such factors include contact time, pH and H_2O_2 dose. Hence, the objective of this study to investigate the concentration of hydrogen peroxide and contact time required to remove the Fe^{2+} ions from water.

MATERIAL AND METHODS

1. Chemicals: The reagents and synthetic solutions used in this study were all prepared by use of analytical grade chemicals, which were supplied from MERK Co. as follows: Iron (II) sulfate heptahydrate, Nitric acid, Sodium Hydroxide and Hydrogen peroxide 30% W/V.

2. **Instruments:** Inductively Coupled Plasma-Emission Spectrometry (ICP-ES) (Perkin Elmer optima 3000, USA) for Iron analysis. 2. pH meter (ORION model 7l0A). 3. Analytical balance, Mettler Toledo model AL 104. 4. Digital Thermometer, Conductivity Meter / TDS Meter, HANNA, model HI993310. model: Checktemp - HI98501. 5. Conductivity Meter / TDS Meter, HANNA, model HI993310.

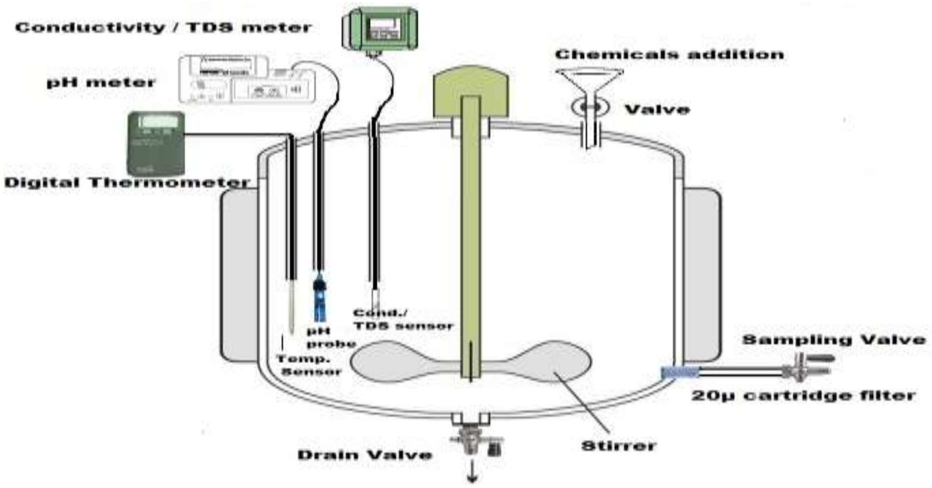
3- **Preparation of various H^2O^2 concentrations:** The amount taken from the stock solution of H^2O^2 to prepare different concentration as required concentration explained in Table (1).

Table (1): Preparation of different concentrations of H2O2

Stock solution of H_2O_2	**V from H_2O_2 stock solution ml**	**Water with high content of iron**	**The final concentration of H_2O_2**
H_2O_2 30%	0.3 ml	999.7 ml	100 ppm H_2O_2
H_2O_2 30%	3 ml	997 ml	1000 ppm H_2O_2
100 ppm	1 ml	999 ml	0.1 ppm H_2O_2
1000 ppm	1 ml	999 ml	1 ppm H_2O_2
1000 ppm	3 ml	997 ml	3 ppm H_2O_2
1000 ppm	5 ml	995 ml	5 ppm H_2O_2
1000 ppm	10 ml	990 ml	10 ppm H_2O_2
1000 ppm	20 ml	980 ml	20 ppm H_2O_2

4- **Preparation of water with high content of iron II:** To prepare 1 liter of water contained high content of iron II, 0.1837 gm. accurately weighted from Iron (II) sulfate heptahydrate FeSO4.7H2O and dissolved in a little quantity of distilled water then completed to one liter by distilled water, one drop added from nitric acid to be sure all Iron(II) sulfate heptahydrate is dissolved.

5- Treatment: For bench-scale experiments, synthetic samples of Iron (Fe+2) had been used instead of real water samples. All these experiments had been carried out in reactor followed with 20µ cartridge filter with capacity of 1 liter and variables studied include pH, contact time and H_2O_2 concentrations as shown in Fig. (1).



Figure(1): Bench scale reactor combined with 20 µ filter

RESULTS AND DISCUSSIONS

1. Removal of iron without H_2O_2

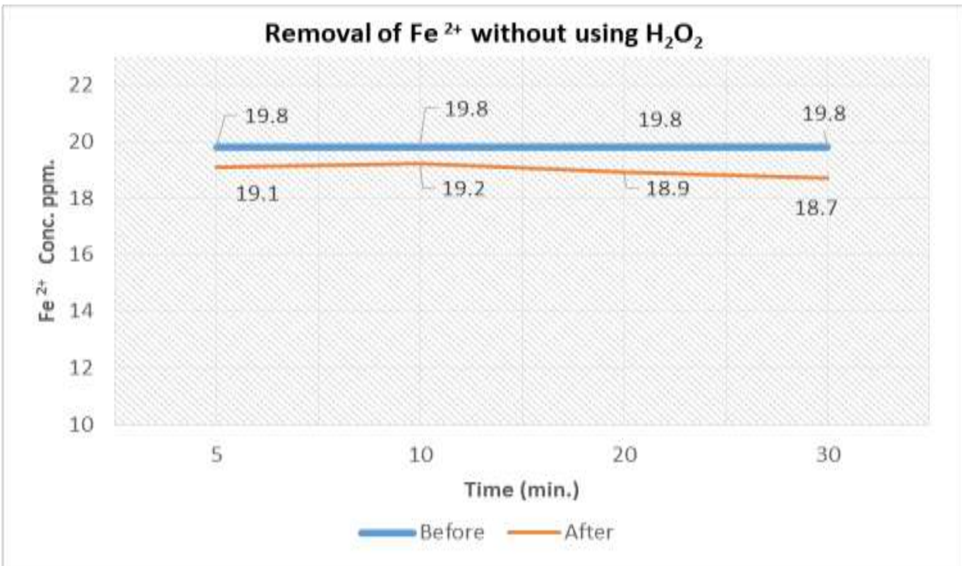


Figure (2): removal of fe $^{+2}$ without using h_2o_2

The removal of iron from the prepared water without any addition of H_2O_2 as a control for the other parameters to check the effect of H_2O_2 under different concentrations, after 5, 10, 20, 30 and 60-minutes, the removal percentage of iron II was 1.5, 3.5, 3.0, 4.5 and 5.6% respectively as shown in Fig. (2).

2. **Removal of iron with 0.1 ppm H2O2:** The removal of iron from the prepared water with 0.1 ppm of H_2O_2 after 5, 10, 20, 30 and 60 minutes were studied, the removal percentage of iron II were 83.8, 84.3, 85.4, 85.9 and 85.9% respectively as shown in Table (2).

Table (2): Removal of Fe^{2+} with o.1 ppm H_2O_2

S.no	Fe II conc. Initial	Conc. of H_2O_2	Contact time (min)	Fe II conc. Final	Remv.%
1	19.8	0.1	5	3.2	83.8
2	19.8	0.1	10	3.1	84.3
3	19.8	0.1	20	2.9	85.4
4	19.8	0.1	30	2.8	85.9
5	19.8	0.1	60	2.8	85.9
Mean	19.8			2.96	85.1
Min	19.8			2.8	83.8
Max	19.8			3.2	85.9
S.D	0			0.18	0.92

3. Removal of iron with 1 ppm H2O2

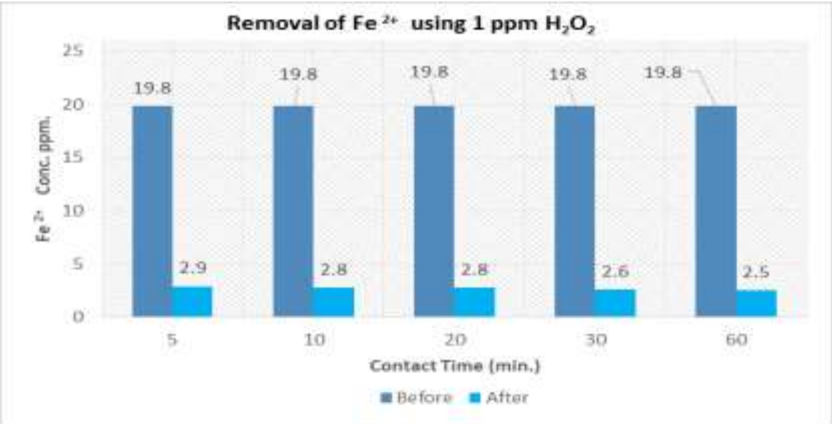


Figure (2): Removal of Fe^{2+} using 1 ppm H_2O_2

The removal of iron from the prepared water with 1 ppm of H_2O_2 after 5, 10, 20, 30 and 60 minutes were studied, the removal percentage of iron II were 85.4, 85.9, 85.9, 86.9 and 87.4 % respectively as shown in Fig. (3).

4. **Removal of iron with 3 ppm H_2O_2:** The removal of iron from the prepared water with 3 ppm of H_2O_2 after 5, 10, 20, 30 and 60 minutes were studied, the removal percentage of iron II were 88.9, 89.4, 89.9, 89.4 and 89.9 % respectively as shown in Table (3).

Table (3): Removal of Fe^{2+} with 3 ppm H_2O_2

S.no	Fe II conc. Initial	Conc. of H202	Contact time (min)	Fe II conc. final	Remv.%
11	19.8	3	5	2.2	88.9
12	19.8	3	10	2.1	89.4
13	19.8	3	20	2	89.9
14	19.8	3	30	2.1	89.4
15	19.8	3	60	2	89.9
Mean	19.8			2.08	89.5
Min	19.8			2	88.9
Max	19.8			2.2	89.9
S.D	0			0.08	0.42

5. **Removal of iron with 5 ppm H_2O_2:** The removal of iron from the prepared water with 5 ppm of $_2O_2$ after 5, 10, 20, 30 and 60 minutes were studied, the removal percentage of iron II were 91.9, 92.4, 91.9, 92.9 and 92.9 % respectively as shown in Fig. (4).

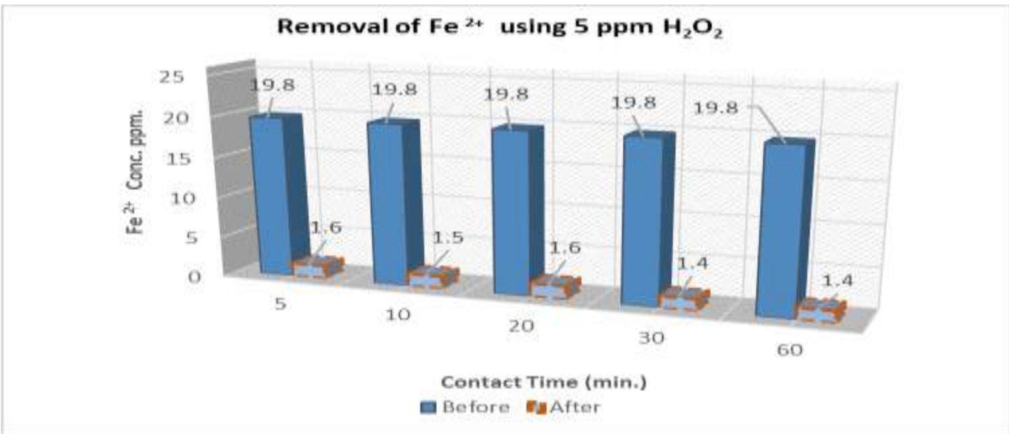


Figure (3): Removal of Fe $^{2+}$ using 5 ppm H_2O_2

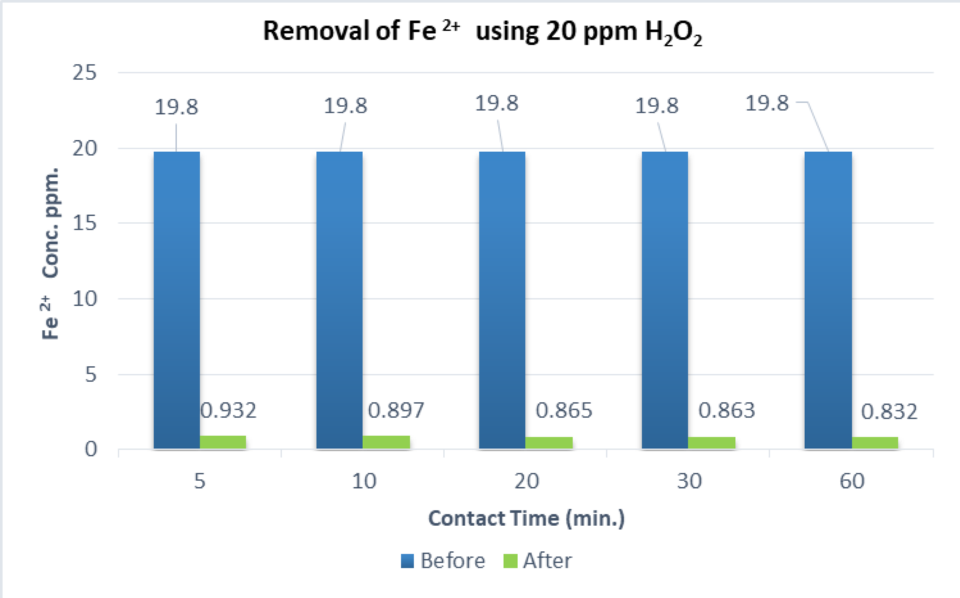
6. Removal of iron with 10 ppm H2O2

Table (4): Removal of Fe^{2+} with 10 ppm H_2O_2

S.no	Fe II conc. Initial	Conc. of H_20_2	Contact time (min)	Fe II conc. final	Remv.%
21	19.8	10	5	1.2	93.9
22	19.8	10	10	1.2	93.9
23	19.8	10	20	1.3	93.4
24	19.8	10	30	1.2	93.9
25	19.8	10	60	1.1	94.4
Mean	19.8			1.2	93.9
Min	19.8			1.1	93.4
Max	19.8			1.3	94.4
S.D	0			0.07	0.36

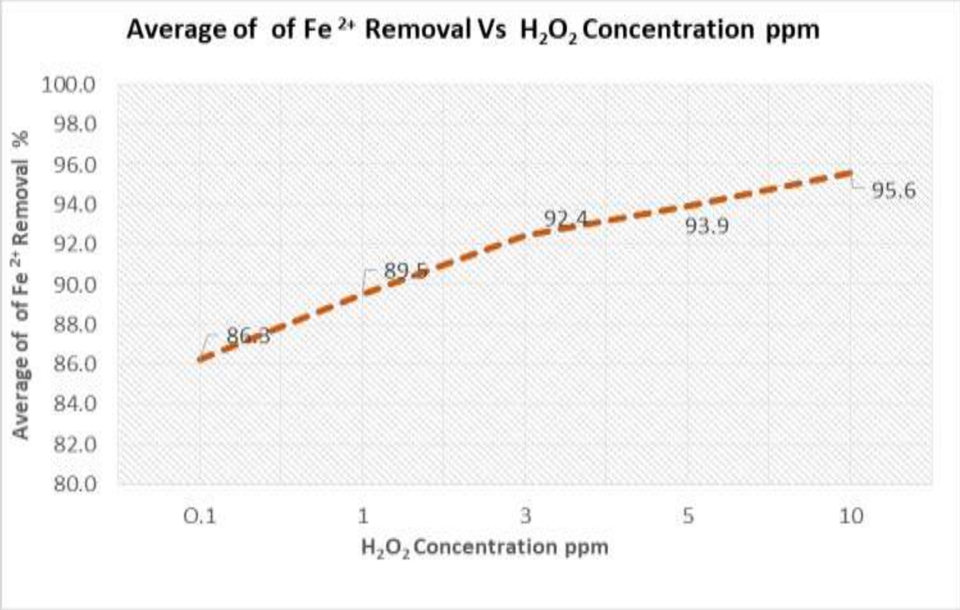
The removal of iron from the prepared water with 10 ppm of H2O2 after 5, 10, 20, 30 and 60 minutes were studied, the removal percentage of iron II were 93.9, 93.9, 93.4, 93.9 and 94,4 % respectively as shown in Table (4).

7. **Removal of iron with 20 ppm H2O2:** The removal of iron from the prepared water with 20 ppm of H_2O_2 after 5, 10, 20, 30 and 60 minute were studied, the removal percentage of iron II were 95.5, 95.5, 95.6, 95.6 and 95.8 % respectively as shown in Fig. (5).



Figure(4): Removal of Fe^{2+} using 20 ppm H_2O_2

8. **Average of removal of iron with H_2O_2:** The average of removal of iron from the prepared water with H_2O_2 for 0, 0.1, 1, 3, 5, 10 and 20 ppm of H_2O_2 in different contact time were calculated using SPSS v20 software. The average of removal percentage of iron II were 3.6, 85.1, 86.3, 89.5, 92.4, 93.9 and 95.6 % respectively as shown in Fig. (6).



Figure(5): Average of Fe^{2+} removal Vs H_2O_2 Conc. ppm

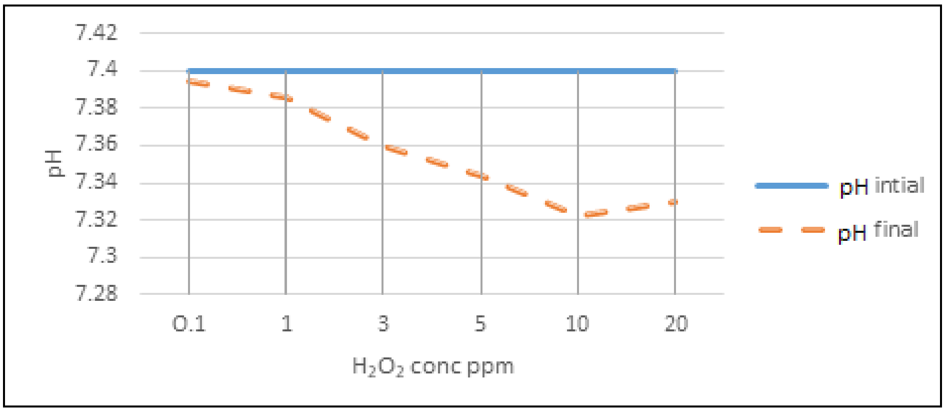
9. Removal of iron with H2O2 in different pH media

Table(5): Removal of Fe^{2+} with H_2O_2 in different pH media

pH	Fe^{+2} bef.	H_2O_2 ppm	Time min.	Fe^{+2}Aft.	removal %
3	20	20	5	19.3	3.5
5	20	20	5	6.88	65.6
7	20	20	5	2.68	86.6
9	20	20	5	0.5	97.5

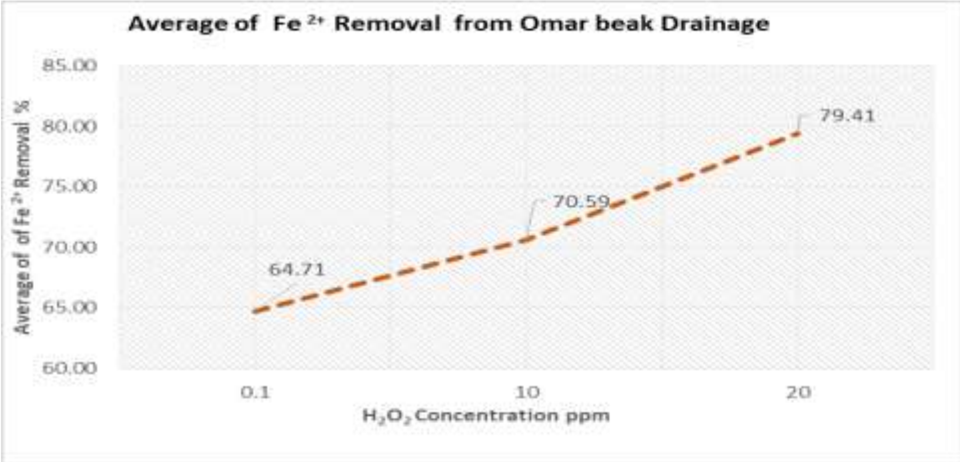
The removal of iron from the prepared water with H_2O_2 in different pH with 20 ppm of H_2O_2 for 5 minutes at pH 3, 5, 7 and 9 were studied, the removal percentage of iron II were 3.5, 65.6, 86.6 and 97.5 % respectively as shown in Table (5).

10. Change in pH:: The results showed that slight change in pH values toward decrease the values, averages of values. The maximum change was from 7.4to 7.32. So it proves that the change of pH values not affect the usage of water and not need any other process to adjust pH again as shown in Fig (7).



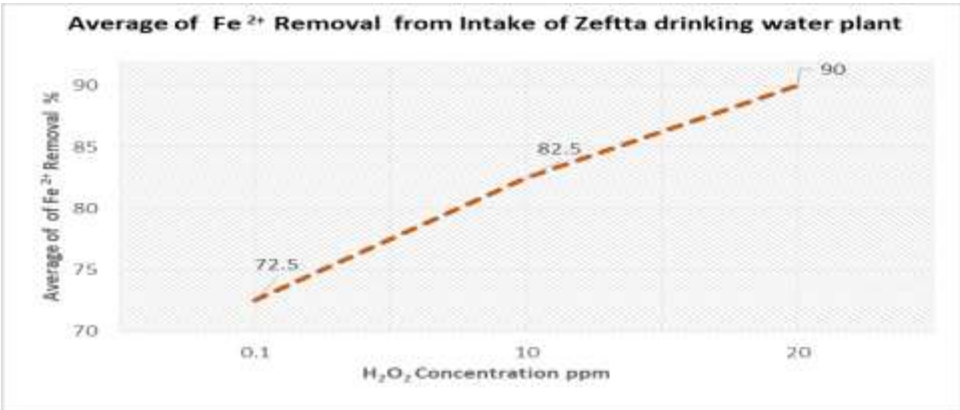
Figure(6): Change in pH

11. Application on real water: Samples taken from a real water from Omar Beak drainage and applied the hydrogen peroxide on it, the Fe2+ decreased from 0.34 ppm to 0.12, 0.10, 0.06 ppm with 0.1, 10, 20 ppm H_2O_2, the removal percentage was 64.71, 70.59, 79.41 % respectively with 20-minute contact time as shown in Fig. (8).



Figure(7): Average of Fe $^{2+}$ removal from Omar beak Drainage samples

Samples taken from real water from intake of Zeftta drinking water treatment plant and applied the hydrogen peroxide on it, the Fe^{2+} decreased from 0.40 ppm to 0.11, 0.07, 0.04 ppm with 0.1, 10, 20 ppm H2O2 the removal percentage was 72.50, 82.50, and 90.0 % with 0.1, 10, 20 ppm H2O2 respectively with 20 minutes' contact time as shown in Fig. (9).



Figure(8): Average of Fe $^{2+}$ removal from Intake of Zeftta drinking water plant Samples

Effect of H^2O^2 concentration: The result leads to a relationship between hydrogen peroxide concentration and the iron removal percentage. The average of removal percentage of iron II were 3.6, 85.1, 86.3, 89.5, 92.4, 93.9 and 95.6 % respectively with 0, 0.1, 1, 3, 5, 10 and 20 ppm of H_2O_2 as shown in Fig. (6).

Effect of Contact time: The result leads to a relationship between contact time with hydrogen peroxide and the iron removal percentage. The average of removal percentage of iron II were 95.5, 95.5, 95.6, 95.6 and 95.8 % respectively after 5, 10, 20, 30 and 60 minute as contact time with 20 ppm H_2O_2 as shown in Fig. (5).

Effect of pH: Result proved that the pH can be considered as a key factor in the iron removal with hydrogen peroxide. The removal percentages of iron II were 3.5, 65.6, 86.6 and 97.5 % respectively at pH 3, 5, 7 and 9 with 20 ppm of H_2O_2 for 5 minutes as shown in Table (5).

These results meet the theoretical expectation which showed that 1.01 ppm of H_2O_2 required removing 1 ppm of Fe^{2+} as cited in iron and manganese removal handbook.

CONCLUSION

In the present study, the removal of iron (Fe^{+2}) from water using hydrogen peroxide was found to be effective. The removal ratio was increased with increasing the contact time. Hydrogen peroxide had a very slight effect on pH changes, the average of pH changes from 7.40 to 7.32. The results obtained from real samples show that hydrogen peroxide can be used effectively in the removal of iron from water.

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إزالة الحديد من المياه باستخدام فوق أكسيد الهيدروجين

[١]

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المستخلص

يعتبر وجود الحديد في مياه الشرب المشكلة التي تواجه أكثر المستهلكين، لذلك هدفت الدراسة لتقييم فاعلية فوق أكسيد الهيدروجين في إزالة الحديد من المياه المحضرة معملياً ذات المحتوي العالي من الحديد (٢٠جزء في المليون) والتي تم تحضيرها بإستخدام كبريتات الحديدوز المائية ومن ثم تمت معاملتها بفوق اكسيد الهيدروجين بحيث كانت التركيزات النهائية في المياه ٠، ٠،١، ١، ٣، ٥، ١٠، ٢٠ جزء في المليون من فوق أكسيد الهيدروجين وتم قياس الحديد قبل الإضافة وبعد الإضافة بزمن تلامس ٥، ١٠، ٢٠، ٣٠، ٦٠ دقيقة. أوضحت النتائج أن متوسط نسب إزالة الحديد تتراوحت بين ٨٥ % – ٩٦ % في نطاق الرقم الهيدروجيني الطبيعي لمياه الشرب (٧،٤) وكانت أقصي إزالة مع إستخدام تركيز ٢٠ جزء في المليون من فوق أكسيد الهيدروجين مما يؤكد علي أن التركيز عامل هام جداً في عملية الإزالة. كذلك زدات نسب الازالة بزيادة زمن التلامس وتكاد تكون الازالة طفيفة بعد

مرور ٢٠ دقيقة من اضافة فوق أكسيد الهيدروجين مما يستوجب الحفاظ علي زمن تلامس ٢٠ دقيقة علي الأقل عند استخدام هذه الطريقة في إزالة الحديد من المياه .كما تم متابعة التغيرات في الرقم الهيدروجيني مع كل تركيز مستخدم من فوق أكسيد الهيدروجين واتضح أن التغيرات في الرقم الهيدروجيني طفيفة حيث كان الانخفاض من ٧،٤٠ الي ٧،٣٢ علي أقصي تقدير .من النتائج التي توصل لها البحث يوصي بإستخدام تركيز ٠،١ جزء في المليون وزمن تلامس ٢٠ دقيقة مع التأكد من أن الرقم الهيدروجيني للمياه من ٧ – ٨ .

الكلمات الدالة: فوق أكسيد الهيدروجين، المعادن الثقيلة، مياه الشرب، إزالة الحديد، الأكسدة.