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Development of an Economic Fe & Mn Removal System for Ground Water in Egypt

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الملخص العربى :

تعد تقنيات إزالة الحديد (Fe) والمنجنيز (Mn) ضرورية للاستخدام الآمن للمياه الجوفية وبالجودة المطلوبة, يخضع اختيار تقنية معينة للعديد من العوامل التي تشمل جوانب الجودة في ازالة الحديد والمنجنيز والمعايير الاقتصادية الي جانب الظروف البيئية والمناخية الموجودة بجمهورية مصر العربية حيث يتم استخدام العديد من تقنيات إزالة الحديد والمنجنيز حاليا والتي توفر العديد من المؤشرات لمقارنة التكنولوجيا وتقييمها.
في هذا البحث ، تم عمل حصر ودراسة لتقيم الوضع الحالي للأنظمة الموجودة , وتم استعراض المميزات الرئيسية لأنظمة إزالة الحديد والمنجنيز من المياه بإيجاز، ومن ثم اختيار النظام الاقتصادي المناسب بناءا علي عمل تحليل دراسة الوضع الحالي لأنظمة ازالة الحديد والمنجنيز من المياه. تم عرض السمات الرئيسية للنظام المقترح, والذي يشتمل على تطوير نظام تهوية جديد كمرحلة أولى لإزالة الحديد متبوعا بالأكسدة الكيميائية للمنجنيز ، والتصفية ، والترشيح ، والتطهير. يتم تقديم الخصائص التقنية النموذجية ومؤشرات التكلفة لمعالجة مياه الحديد والمنجنيز المطورة بسعة 50 متر مكعب / ساعة.

Abstract:

Iron (Fe) & Manganese (Mn) removal technologies are essential for safe utilization of marginal quality ground water. The selection of a particular technology is governed by numerous factors comprising quality aspects, treatment role, economic criteria and related reliability issues. In Egypt, numerous Fe & Mn removal technologies are currently in use which avails numerous indicators for technology comparison and evaluation. In this paper, the main features of the existing systems for Fe & Mn removal from potable water are briefly reviewed. The need for developing an appropriate Fe & Mn removal system based on analyzing the current practices are identified. The main features of a proposed system are presented. The system comprises the development of a new aeration system as a first stage for Fe removal followed by Mn chemical oxidation, clarification, filtration and disinfection. The system has the merits of low energy requirements, low chemical consumption and low footprint.
Typical technical characteristics and cost indicators are presented for a developed Fe & Mn water treatment plant with a 50 m^3 /hr capacity.

Keywords: Ground Water, Fe & Mn, Oxidation, Removal and Treatment.

1. Introudation

Based on present demand expectations, the water shortage will increase and the current water resources (surface water, renewable ground water, desalinated water, treated wastewater,…etc) may not adequately cover the future needs. One of the solutions for water shortage will be through the optimal abstraction of safe ground water especially from the deep water layers. Moreover, ground water is becoming very important as a buffer for alleviating water shortages under fluctuating supply or demand. Thus, the demand for ground water necessitates development of water treatment technologies to remove contaminants. The ground water is found in Egypt in Nile valley, Delta, Western Desert and Sinai, and its abstraction is almost 11.56 billion m^3/year. According to Environmental Protection Agency (EPA) guidelines for public water supplies, Fe & Mn are considered secondary contaminants. The maximum allowable contaminant level for Fe is 0.3 mg/l and 0.05 mg/l for Mn.

Packages for reliable technologies are available to remove dissolved Fe & Mn from water sources. Aeration, for instance, can be an effective low cost method for Fe oxidation. Water is passed down a series of porous trays by gravity to provide contact between air and water. Aeration towers also remove sulfides and volatile organic chemicals.

There are commercially established methods for treating water containing these contaminants. They comprise phosphate compounds, ion exchangers, water softeners, oxidizing filters, aeration (pressure type) followed by filtration, and chemical oxidation followed by filtration. The most commonly used techniques are coagulation and filtration, sequestration, ion exchange, oxidation and filtration.

Typically, important factors for Fe & Mn removal include: Fe & Mn concentration, pH, hardness, dissolved oxygen and presence of Fe & Mn bacteria.

2. Background

2.1. Scientific Basis for Fe & Mn Removal from Ground Water

Dissolved Fe & Mn are easily oxidized to a solid form using different treatment oxidation methods as follows:

1- Chemical oxidation followed by separation of suspended solids, which can be achieved with different oxidants (air, potassium permanganate, ozone, chlorine, hydrogen peroxide with or without ultraviolet).

2- Oxidation and filtration in one step using green sand filters.

3- Removal of Fe & Mn from ground water by ion exchange technique.

4- Biological treatment methods for Fe & Mn removal from ground water.

Survey and evaluation of technologies used for Fe & Mn removal of some Egyptian treatment units were achieved. Main indicators of this investigation include,” but not limited to the following”:

a- Holding Company for Water and Wastewater (HCWW)

Implemented more than 80 treatment plants to remove Fe & Mn from ground water in different governorates (Beni Sweif, Gharbeya, Sharkeya, Kaliubya, New valley…&

others) as listed in Table (1). Capacities of these units ranged from 20 to 125 l/s of ground water. The treatment plants have been implemented using three types of technologies:

1. Air and chemical oxidation of Fe & Mn

Oxidation of Fe is conducted in aerating towers (multi – trays) or aerating tanks provided with air diffusers and air compressors. After addition of $KMnO_4$ for Mn oxidation, water is directed to the clarifier before filtration and finally disinfected with chlorine gas.

2. Biological treatment:

In this method, Fe is oxidized first in aeration tower, then oxidation of Mn is performed using natural bacteria which is continuously grown on fixed surface in the biological filter. Finally the filtered water is disinfected.

3. Oxidation with $KMnO_4$:

The pH is firstly adjusted using lime followed by aeration, settling and addition of $KMnO_4$ for Mn oxidation then filtration and disinfection.

Table (1) Implemented (or Under Construction)
Water Treatment Plants for Fe & Mn Removal

Location	***Capacity (l / s)***
Sharkeya	20 - 100
Gharbeya	25 – 100
Kaliubya	100
Beheira	40 – 100
Menufya	100 – 125
Giza	100
Beni Sweif	35 – 70
Kena	100
Sohag	100 - 125

a- **Kaha Company for Chemical Industries [Military Production Authority** (Factory 270)]
Implemented many treatment plants using imported and developed technologies. The company applied local technology to decease the capital and operating costs using the following arrangement:

- Fe removal stage by air oxidation and primary settling.
- Mn Removal stage by chemical oxidation and final settling.
- Disinfection and sand filtration.

The product water analysis showed that ground water quality satisfies the Egyptian legislations and standards for more than 8 years.

3- Implementation of Pilot Scale Physico-chemical Treatment

A flow sheet for the pilot scale treatment process is illustrated in **Figure (1).** Experiments were conducted using synthetic solution similar to underground water containing Fe & Mn . Also, oxidation treatment is applied using solutions of different salinities (up to 1500 ppm) using air and $KMnO_4$ for Fe & Mn removal, respectively.

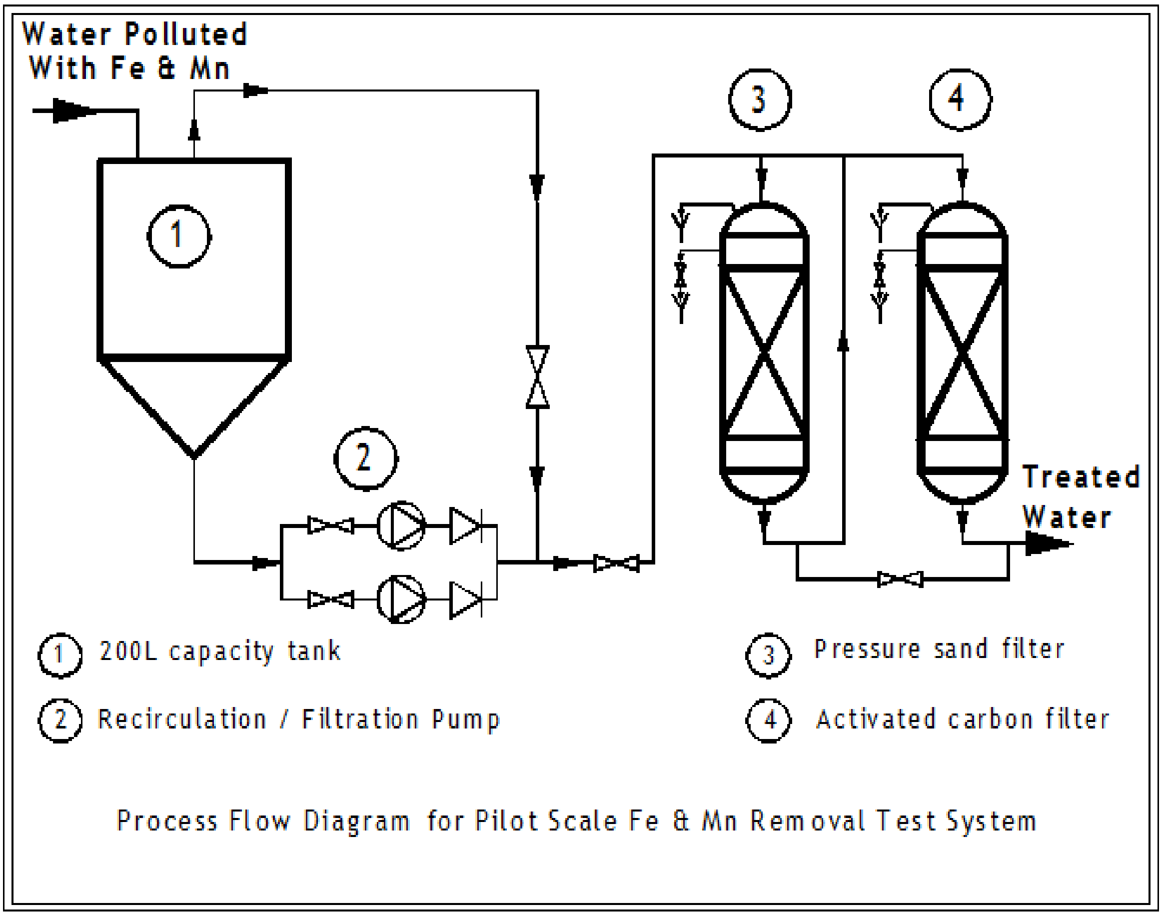

Figure (2) Pilot Scale Treatment Unit

The pilot treatment unit is illustrated in **Figure (2).** The results of the physico-chemical oxidation for iron and manganese treatment are tabulated in **Table (2).** Starting with feed water containing 5 ppm Fe & (0.5 – 2) ppm Mn at different salinities ranging between 300 ppm & 15000 ppm, removal of Fe & Mn has been achieved by applying physico-chemical oxidation using air and $KMnO_4$ followed by sand and carbon filters.

Product water quality reveals maximum Fe & Mn removal efficiency (more than 98%) at salinity 1000 ppm. It decreases to less than 93% by increasing salinity to 1500 ppm.

Table (2) The Results of Physico-chemical Oxidation for Fe & Mn Treatment

Exp. No.	Concentration (mg/l)		pH	Cond. µs/cm	Concentration (ppm) NaCl
	Fe	Mn			
1					
❖ Feed	5.00	-	8.6	500	
❖ After Sand Filter	0.3	-	8.3		300
❖ After Carbon Filter	-				
2					
❖ Feed	4.04	0.40	8.8	500	
❖ After Sand Filter	0.11	0.02	7.7		300
❖ After Carbon Filter	0.07	0.02			
3					
❖ Feed	4.2	1.00	7.2	3400	
❖ After Sand Filter	0.69	0.21	7.2	3500	1000
❖ After Carbon Filter	0.07	0.03	9.2	3800	
4					
❖ Feed	3.69	1.2	7	4400	
❖ After Sand Filter	1.06	0.24	7.6	3480	1500
❖ After Carbon Filter	0.25	0.01	8.9	3470	
5					
❖ Feed	4.06	2.05	7	3570	
❖ After Sand Filter	0.47	0.31	7.9	2990	1500
❖ After Carbon Filter	0.33	0.14	9.3	3140	

3.1- Proposed Technology for an Economic System

Table (3) presents a comparison between the applied technologies in Egypt and the proposed technology outlined in this study.

The main treatment steps of the proposed system could be summarized by the following sequential unit operations:

1. Feeding of raw water under pressure with lime solution injection.
2. Air oxidation of Fe to obtain insoluble oxides.
3. Addition of $KMnO_4$ dose with stirring for Mn oxidation.
4. Settling of insoluble Fe & Mn oxides.
5. Filtration through sand and carbon filters.

The treatment procedure is illustrated in the process flow diagram (PFD) **Figure (3)**.

Table (3) Comparison between the Applied Technologies in Egypt and the Proposed Technology

Item	Some Adopted Technologies	Proposed Technology
Technology Description	• Aerobic treatment in open towers and addition of an oxidizing agent (KMnO4), clarification, filtration and disinfection. • Aerobic treatment to oxidize Fe by using air blowers, addition of an oxidizing agent, filtration and disinfection. • Biological treatment to oxidize Mn .	• Aerobic treatment with pressurized pumped water and venturi system, pH adjustment with lime, oxidation with $KMnO_4$, clarification, filtration and disinfection.
Capital Cost	• Relatively high construction cost of concrete towers for clarification and filtration basins. • Guided by actual project cost, $conc^n$ cost for 30 l/s. = L.E 4.34 millions	• Relatively low cost for eliminating electro-mechanical systems and depending on natural aeration, pressurized water and using a compact system for clarification and filtration. • $conc^n$ cost estimates for 30 l/s. capacity (including mechanical, electrical and civil work = LE 3.64 millions
Operation and Maintenance	• Tendency to collect dirt and dust in open towers. • The concrete open towers should be constructed in a clean remote area. • Large foot print • The concrete towers	• Relatively low chemical consumption due to unification of Fe & Mn oxidation in one unit operation. • Need for limited number of technical operators. • Low foot print
Treatment Efficiency	• Biological treatment needs to be continuous for treated water quality monitoring (chemically and bacteriologically).	• Relatively high treatment efficiency. • Has the advantage of high reliability for the oxidation dependence on natural source free from dust. • pH adjustment with low cost chemical (lime) leads to increasing the treatment efficiency of Fe & Mn removal.

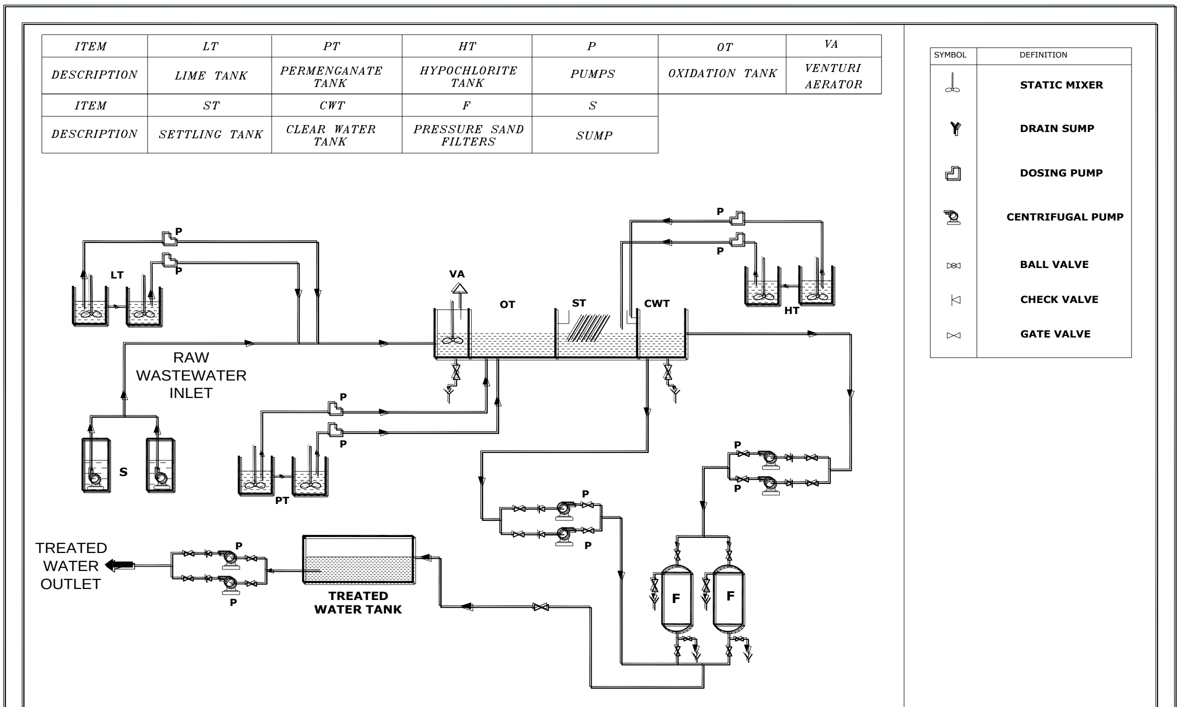

Fig. (3) PROCESS FLOW DIAGRAM for The Proposed Fe & Mn Removal Plant 50 m^3/h

The advantages of the proposed system are:

a- Adjustment of raw water alkalinity leads to an efficient oxidation of Fe by air & Mn using an oxidant.

b- Using a venturi for aeration improves the aeration and saves the power consumption and construction cost (in comparison to tower and mechanically aerated systems).

c- Addition of an oxidizing agent after Fe oxidation increases Mn oxidation efficiency and provides better economics for the treatment process.

d- Clarification is very efficient due to the mutual effect of both Fe & Mn oxides on each other during settling.

e- Oxidation and clarification take place in one tank having different compartments. This reduces the area needed for the treatment station and saves the construction cost.

The main criteria for the design of the proposed system are outlined below:

a- Capacity of the proposed treatment unit 50 m^3/h (1000 m^3/d or 15 l/s)

b- Specifications of inlet water

- Fe conc^n : 5 mg/l
- Mn conc^n : 2 mg/l
- pH : 7.2 – 8.3
- Dissolved solids : 1000 mg/l
- Total hardness : 300 mg/l ($CaCO_3$)

c- Specifications of treated water

- Fe conc^n : less than 0.1 mg/l
- Mn conc^n : 0.1 mg/l

4- Conclusions

1- Fe & Mn treatment units in Egypt are of capacities ranging from 20 to 125 l/s depending on air oxidation of Fe then chemical oxidation of Mn using $KMnO_4$ followed by clarification and / or filtration under pressure.
2- An adopted technique for Fe & Mn removal by biological oxidation is applied in some new treatment stations in Egypt.
3- The most efficient systems applied in Egypt are those depending on chemical and physical treatments.
4- Based on pilot scale experimental results, a proposed economic system for removal of Fe & Mn in ground water was developed.

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