Manganese removal from ground water using expanded polystyrene beads as filtering media

أزاله المنجنيز من المياه الجوفية باستخدام خرز البوليستيرين المتمدد كوسط ترشيحي

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الملخص العربي

المياه الجوفية تشكل مصدر مهم للمياه ، ولكن في بعض الأماكن يوجد بها بعض العناصر مثل المنجنيز بتركيز أكبر من المسموح به في مواصفات مياه الشرب وتصبح حينذاك هناك ضرورة لتنقية تلك المياه لتصبح صالحة للشرب وللاستخدام المنزلي. كثر البحث العلمي في عملية ترشيح المياه لإزالة مركبات المنجنيز ولكن القليل منها الذي اهتم باستخدام وسط ترشيح غير الوسط التقليدي (الرمال وفحم الأنثراسيت) . هذا البحث يدرس استخدام خرز الفوم كوسط ترشيحي لإزالة المنجنيز من المياه الجوفية ، وحيث أن كثافته اقل من كثافة المياه لذا تسمى مرشحات الوسط العائم . يتميز خرز الفوم كوسط ترشيحي بديل عن الوسط التقليدي كالرمل بأنه يحتاج إلى كمية مياه غسيل اقل (تقريباً 1% من المياه المرشحة) ولا يحتاج إلى مضخات خاصة للغسيل حيث أن هذه عملية تتم في نفس اتجاه الجاذبية بعكس المرشحات التقليدية. تم تصميم وإعداد جهاز معملي بمعمل الهندسة الصحية بكلية الهندسة – جامعة المنصورة لإجراء عمليه البحث ودراسة إمكانية استخدام خرز الفوم كوسط ترشيحي. تم استخدام مياه مصنعة بها تركيزات المنجنيز من 0.50 إلى 4.50 مجم / لتر وتم أكسدتها باستخدام هيبو كلوريد الصوديوم ثم إمرارها على عمود الترشيح بسرعات تتراوح من 3 إلى 5 متر / الساعة.وقد تبين أن استخدام خرز الفوم كوسط ترشيحي للمياه الجوفية نظام ناجح نسبيا حيث وصلت متوسط نسبة أزاله المنجنيز إلى 85.48% وأزاله العكارة الناتجة عن المنجنيز إلى 76.16%.

Abstract

Ground water is considered an important source of drinking water but in many cases it contains manganese with concentration higher than the standards limits. Therefore purification of ground water is necessary to be adopt to drinking water standards. The scientific research is increased in filtration processes but a little of them has been changed the conventional media as sand and anthracite to other filtration media. This research studies using polystyrene bead as a filtration media to remove manganese from ground water. Since the density of this media less than water density that is called floating media filters. This media has some advantages over conventional media in many things as it wants a little quantity of washing water (around 1%) of filter product, doesn't need separate washing pumps that because the washing process is in the same direction of gravity.

The experimental work was designed and run in the laboratory of Sanitary Engineering, Faculty of engineering – Mansoura University to study the possibility of using polystyrene beads as filtering media to remove manganese from ground water. Synthetic water was used having manganese concentration from 0.50 to 4.50 mg/l and was oxidized by sodium hypochlorite and then passed it through filtration column with velocities ranged from 3.0 to 5.0 m/hr.

The conducted study cleared that the using of expanded polystyrene beads as filtering media to remove manganese from ground water was successful. The average removing manganese percentage was 85.48% and turbidity removal with 76.16%.

Keywords

Expanded polystyrene beads, Filtering media, Filtration, Manganese removal, Ground water.

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Introduction

The main objective of water purification is the production of safe and appealing water for human consumption with respect to capital and operating cost. In Egypt, ground water is one of the main resources of drinking water. Ground water may have many impurities of different salts such as iron and manganese with concentrations that can cause some problems. Manganese causes brownish-black stains on laundry, porcelain, dishes, utensils, glassware, sinks, fixtures and concrete. Manganese also causes turbidity of water. Manganese and turbidity in drinking water should not exceed 0.4 mg/l, 1.0 NTU respectively according to Egyptian standard.

There are many methods of removing iron and manganese from ground water such as:

Ion exchange: It should be considered only for the removal of small quantities of iron and manganese because the presence of higher concentrations of iron and manganese will cause rapid fouling as well as rapid clogging of the used resin [1, 10].

Lime softening: Lime softening is highly effective in removing iron and manganese; the high pH achieved insured essentially complete precipitation of any iron and manganese in the raw water [1, 10].

Removal by aeration followed by filtration: In this method oxidation can be accomplished with dissolved oxygen, added by either natural or artificial aeration. This method is suitable for iron removal only because manganese is more difficult to oxidize by aeration unless the pH is raised to about 9.5[1,10].

Removal by chemical oxidation followed by filtration: The basic process of this method is the oxidation of iron (II) and manganese (II) by chemical oxidants such as molecular oxygen, potassium permanganate, or chlorine dioxide, and then subsequent removal by precipitation and/ or filtration.

Filtration is considered the final polishing process in water purification train. In practice, there are many types of filters which can be classified according to kind of media, direction of flow, rate of filtration and driving force. In recent time, expanded polystyrene beads are used as filtering media and its filters are named floating media filters.

Floating media filters differ from the conventional sand filters in many ways. First, because of the density of the synthetic filter-media (expanded polystyrene beads) is 0.015-0.10 gm/cm^3, a retaining grate is placed at the top of the filter in order to maintain the media inside the filter in submerged state. Secondly, by increasing the diameter of the grains(beads) its density decreased and vice versa, so under the action of Archimedes floating force, the grains of filter media are sorted downward for size, with the grain of large size at the top of the filter and grain of the small size at the bottom. So, the direction of downward filtration simply coincides with the direction of a uniform decrease in pore size through the filter depth. Thirdly, floating media filters are washed with down-flow water, therefore the media -expands downward and the gravitational force direction of the deposited solids coincides with the direction of wash water, so that the required volume of wash water is less than that for sand filters [2,3, 4]. Floating media filters are also claimed to have high retention capacity with low head loss development compared to the conventional sand filters [5].

This research aims at the determination of the efficiency of the expanded polystyrene beads media filter to remove manganese from raw water by using chemical oxidations.

Material and methods

a) Pilot plant

To conduct the experimental work of this study, the pilot plant was installed in the laboratory of sanitary engineering in the faculty of engineering in El-Mansoura

University. The experimental pilot plant as shown in figure (1) consisted of the following main parts: Feeding tanks, constant head tank, filtration column with diameter of 135 mm, piezometric tubes for measuring head losses through the filter media and valves with different diameters.

b) Filter media

The filter media used in this study was the expanded polystyrene beads **(1.60-2.00 mm)** with depth about 1.00m. This was the smallest available beads size in Egyptian market. The density of this type is **33.77 kg/m^3.**

c) Synthetic water

Synthetic water was prepared in the laboratory using tap water and manganese sulfate ($MnSO_4$) and sodium hypochlorite (NaOCl) was used for oxidation. Filtration process was run through up flow direction.

d) Instruments and measurements:

Atomic Absorption Spectrometry: was used to measure the concentration of manganese in (mg/l). Its model was Varian (fast sequential atomic absorption spectrometer) (AA240FS).

Nephelometric turbidimeter was used to measure the water turbidity, in nephelomitric turbidity unit (NTU). Its model was Orebro HELLIGE (TB200IR).

e) Comparison criteria (k_s) and (X) factors

Two comparison criteria were used to evaluate and comparing the filter runs. The first criterion was the theoretical depth index (Ks). This criteria was assumed to be direct proportion to depth of filtering media and inversely proportion to the average raw water turbidity, filtration rate and length of filter run. The theoretical depth index criterion can be expressed by the following form [6]:

$$Ks= \phi . D / R . t . C_O$$

Where:

ϕ = constant of the proportionality

D = Media depth, m

R = Rate of filtration, m/hr

t = Run length, hr

C_o = Average turbidity of raw water, NTU

The constant of the proportionality ϕ depends upon the technological characteristics of the filter such as the type and size of the filtering media, the number of layers, the direction of the filtration process . . . act. When making comparison between a set of runs conducted in the same filter, this constant can be neglected and the value of the theoretical depth index criterion can be calculated by using the following expression:

$$K_s= D / R . t . C_O \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

From this expression it is clear that as the value of the theoretical depth index (K_s) decreased, the depth of the filtering media was more utilized and a higher quantity of turbidity can be removed. So, the lower theoretical depth index (Ks) value, means that a better combination of the variables appeared in expression(1) have been already realized.

The second criterion was the filter capacity (X), NTU - cubic meter of turbidity removed per meter of head loss [7, 8]. The filter capacity can be calculated by the following expression:-

$$X= (C_o - C_e) . R . a . t / h \ldots\ldots\ldots \quad \ldots(2)$$

Where:

C_o = Average turbidity of influent water, NTU

C_e = Average turbidity of filtrate water, NTU

R = Rate of filtration, m/hr

a = filter area, m^2

t = run length, hr

h = head loss due to solid accumulation, m

From expression (2), it's clear that the increasing X value means the increasing of filter productivity.

The design of the pilot plant allowed the measuring of the monitored variables such as concentrations manganese, turbidity, head loss, total dissolved solids, conductivity and pH

Results and discussion

The process of removal manganese ions includes two stages. First stage was oxidation of manganese sulfate and convert manganese ions from soluble form (Mn^{+2})

to insoluble form (Mn^{+4}). Second stage was filtration through up flow direction.

Two independent variable parameters (flow rate & inlet manganese concentration) have been studied. The flow rate was in the range 3 - 5 m/hr, inlet manganese concentration was 0.5-4.5 mg/L. The experiments were planned in 24 runs classified in three groups as shown in tables (1, 2, 3)

A. Group (1)

In group No. (1) ten runs were conducted with flow rate of 3.0 m/hr and influent manganese concentrations from 0.5 mg/l to 4.50 mg/l as shown in table (1).

B. Group (2)

In group (2) six runs were conducted with flow rate of 4.00 m/hr. and influent manganese concentrations from 0.75 mg/l to 4.50 mg/l as shown in table (2).

C. **group no (3)**

In group (3) eight runs were conducted with flow rate of 5.00 m/hr. and influent manganese concentrations from 0.50 mg/l to 4.50 mg/l as shown in table (3).

Results show that, at rate of filtration 3.0 m/hr and influent Mn^{++} concentration 0.50 – 4.50 mg/l the effluent concentration was in range 0.12 to 0.34 mg/l with removal efficiency 66.6 to 95.56%. Similarly, at rate of filtration 4 & 5 m/hr the Mn^{++} effluent concentration was in range 0.13 to 0.40 mg/l with removal efficiency 70.0 to 92.2%.

The Mn^{++} effluent concentration in all runs was acceptable according to Egyptian standard. But for turbidity the issue was different where at rate of filtration 3.0 m/hr the influent turbidity was in range 6.0 to 83.4 NTU and effluent turbidity was in range 1.43 to 4.40 NTU with removal efficiency 69.23 to 94.72%. Similarly, at rate of filtration 4 & 5 m/hr the effluent turbidity was in range 1.85 to 9.50 NTU with removal efficiency 56.0 to 93.83%. In all runs, the turbidity was not acceptable with respect to Egyptian standard. The failure of filter to produce filtrate with turbidity less than 1.0 NTU may be due to the size of media was relatively big and/or the absence of coagulant addition.

It can be also observed that there was a direct correlation between inlet manganese and turbidity as shown in Fig. (2), and efficiency of manganese and turbidity removal as shown in Fig. (3).

From tables 1-3 it was observed that at highest efficiency of manganese and turbidity removal the (Ks) value was the lowest one and (X) factor was the highest value.

Figure (4) show a comparison between the average values of Ks and X factors at different rate of filtration, from which it was clear that when the effluent concentration of Mn^{++} was acceptable, in the runs with higher filtration rate, the media was more utilized, higher quantity of Mn^{++} was removed and the filter productivity was increased.

Conclusions and recommendations

According to the laboratory studies, the following conclusions and recommendations could be drowning.

1. The expanded polystyrene beads of grain size 1.6- 2.0 mm with filtration rate up to 5.0 m/hr succeed to reduce the oxidized Mn++ of concentration 0.5 – 4.5 mg/l to be less than or equal 0.40 mg/l and fail to reduce the turbidity below than 1.0 NTU.
2. More research work with smaller beads grain size and/or by using coagulant before filtration is needed to produce water with turbidity agree with the standards of drinking water.

References

[1] American Water Works Association (AWWA) (1999). Water quality and treatment, a handbook of community water supplies, fourth edition, and L. J. Borowitzka (eds.), Microalgal biotechnology. Cambridge

[2] Baumann, E. R (1979) "Precoat filtration. In water treatment plant designed" R, L. Sanks ann arbor, ann arbor science.

[3] Ben Aim R., Shanoun A., Visvanthan C., and Vigneswaran S.(1993). "new Filtration Media and Their Use in water treatment. Proc". world Filtration Congress ,Nagoya, Japan, pp. 273-276.

[4] Hisham K. EL-Etriby, Myrzakhmetov Mmenlibai (1997). "Sewage tertiary Treatment using floating Media Filters". Second international water technology conference, Alexandria ,Egypt.

[5] Ngo H. H, and Vigneswaram S(1998). "process Optimizing of a combined system of floating Media and sand filter in prawn farm Effluent treatment". wat. sic. tech. ,vol. 38, No 4-5, pp. 87-39.

[6] Jorba, M. G. (1992) " Expanded Polystyrene Filters" Stroizdat Moscw. (in Russian Language)

[7] Fadel, A. A., El-Etriby, H.K.," Evaluation of the Direct Filtration under the Egypt ion Conditions" , Mansoura Engineering Journal (MEJ) Vol.14, No. 1, June 1989.

[8] El-Naggar, H. A. (2004) "Water Filtration through Expanded Polystyrene Beads" Faculty of Engineering , Mansoura University,. In Partial Fulfillment of Requirements of Master of Science.

[9] Slim Z., Nelu P., Jean P., and patric S.(1998) ."Process Control for nutrients removal using lamella sedimentation and floating media filtration". wat. Sci tech ,vol. 38, No.3, pp. 227-235

[10] Professor T J Casey Aquavarra Research Limited 22A Brookfield Avenue Blackrock County Dublin Ireland www.aquavarra.ie may(2009.)

Table (1) Results of runs of group No. (1) That conducted at R.O.F =3.0 m/hr.

No. of run	Mn^{++} mg/l		Turbidity, NTU		Run length (hr.)	Head loss ΔH, cm	Removal efficiency %		Ks factor $\times 10^{-3}$		X factor	
	inlet	outlet	Inlet	outlet			Mn^{++}	Turbidity	Mn^{++}	turbidity	Mn^{++}	turbidity
1	0.50	0.12	8.00	1.43	8	6	76.00	82.12	83.30	5.20	2.08	36.07
2	0.75	0.25	9.75	3.00	8	8.5	66.60	69.23	55.55	4.27	2.01	27.25
3	0.95	0.13	9.85	1.44	7	11	87.30	75.83	50.10	4.88	2.11	11.58
4	1.20	0.3	11.00	3.07	7	17	75.00	72.00	39.68	4.30	1.58	14.00
5	1.50	0.34	9.00	2.50	8	17	77.30	72.20	27.77	4.62	2.34	13.12
6	2.15	0.15	18.20	1.80	8	22	92.66	90.03	19.37	2.29	3.10	25.50
7	3.00	0.25	55.60	3.80	8	29	91.66	93.16	13.88	0.74	3.25	61.30
8	3.20	0.21	59.50	3.66	8	30	93.43	92.85	13.00	0.70	3.32	61.36
9	4.00	0.18	74.10	4.20	8	38	95.55	94.33	10.40	0.56	3.39	62.17
10	4.50	0.2	83.40	4.40	8	43	95.56	94.72	9.25	0.49	3.39	62.32

Table (2) Results of runs of group No. (2) That conducted at R.O.F =4.0 m/hr.

No. of run	Mn^{++} mg/L		Turbidity, NTU		Run length (hr)	Head loss ΔH, cm	Removal efficiency %		Ks factor x 10^{-3}		X factor	
	Inlet	outlet	Inlet	outlet			Mn^{++}	turbidity	Mn^{++}	turbidity	Mn^{++}	turbidity
1	0.75	0.13	4.65	2.10	7	10.7	83.30	79.56	47.6	7.68	2.33	9.54
2	1.15	0.17	12.20	1.85	7	17.2	85.20	84.83	31.10	2.92	2.28	24.09
3	2.00	0.24	12.40	3.20	7	30	88.00	74.19	17.90	2.88	5.00	12.27
4	3.00	0.35	18.60	2.65	7	43	88.30	79.56	11.90	1.92	2.46	13.78
5	4.00	0.35	73.70	5.00	7	60	90.00	93.21	8.92	0.48	2.41	45.8
6	4.50	0.40	83.00	5.60	7	67.5	91.11	93.83	7.93	0.43	2.43	45.91

Table (3) Results of runs of group No. (3 that conducted at R.O.F =5.0 m/hr.

No. of run	Mn^{++} mg/L		Turbidity, NTU		Run length (hr)	Head loss ΔH, cm	Removal efficiency %		Ks factor x 10^{-3}		X factor	
	Inlet	outlet	Inlet	outlet			Mn^{++}	Turbidity	Mn^{++}	turbidity	Mn^{++}	turbidity
1	0.50	0.14	8.00	3.50	8	2.8	70.00	56.00	50	3.12	7.14	91.50
2	0.75	0.17	9.12	1.43	7	4.2	77.00	71.40	38.1	5.71	6.80	42.261
3	1.00	0.20	10.00	2.30	7	11.2	80.00	76.60	28.5	2.85	3.50	34.21
4	2.00	0.26	14.00	4.00	8	12.1	87.00	71.40	12.5	1.78	8.20	47.27
5	2.50	0.43	54.00	9.50	5	14.1	82.40	81.85	16	0.74	5.2	112.1
6	3.00	0.30	58.00	9.50	8	15.2	90.00	83.60	8.3	0.43	10.6	185.5
7	3.50	0.26	72.00	9.25	8	13.2	92.20	87.20	7.14	0.34	13.9	272.3
8	4.50	0.40	78.10	8.90	8	25.2	90.80	88.50	5.55	0.32	9.20	157

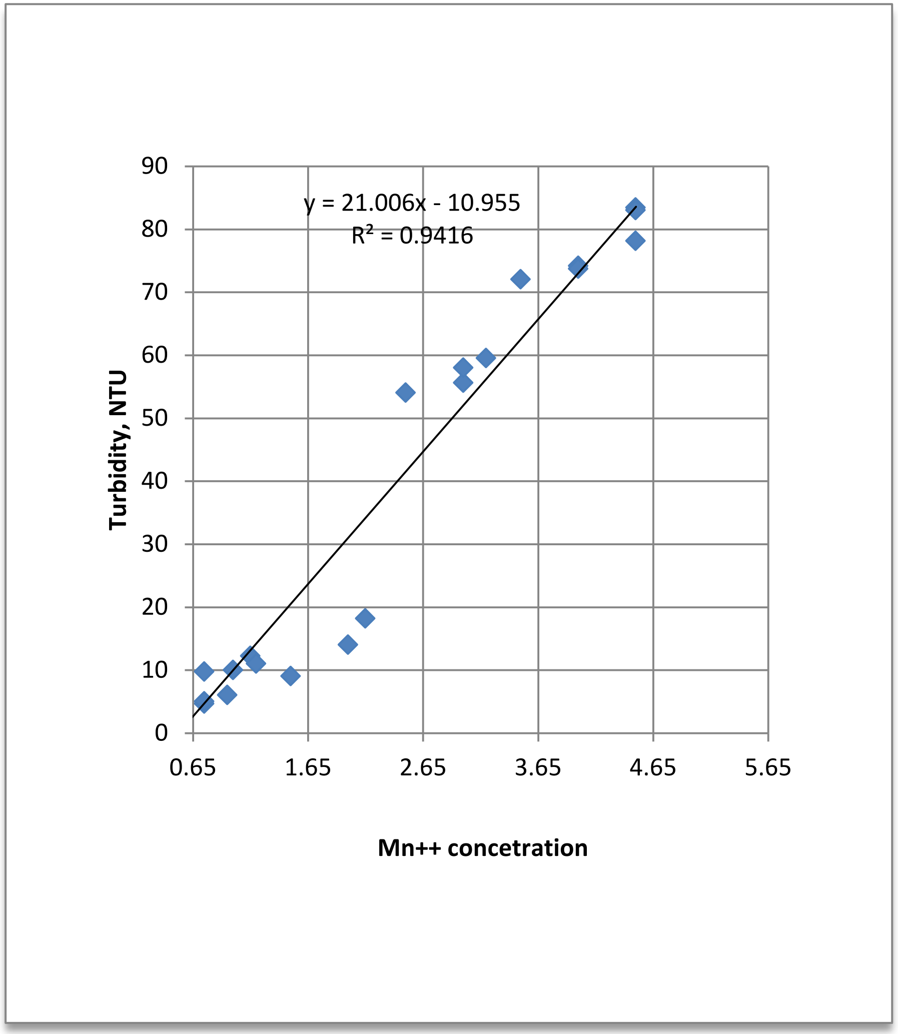


Fig. (2) The correlation between inlet turbidity and Mn^{++} concentration

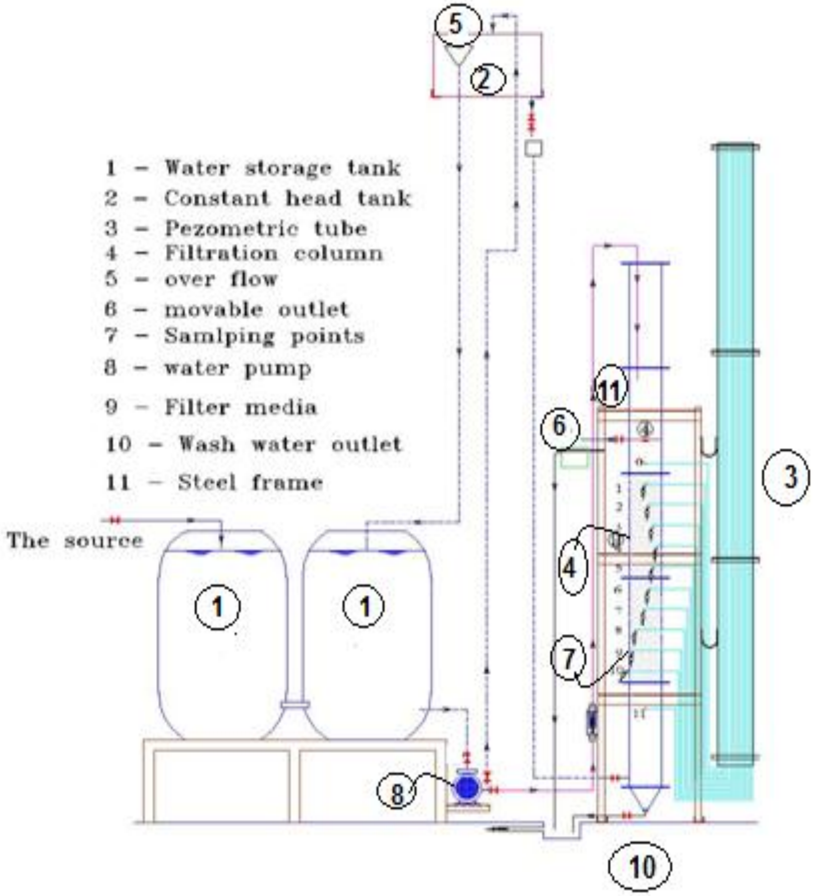
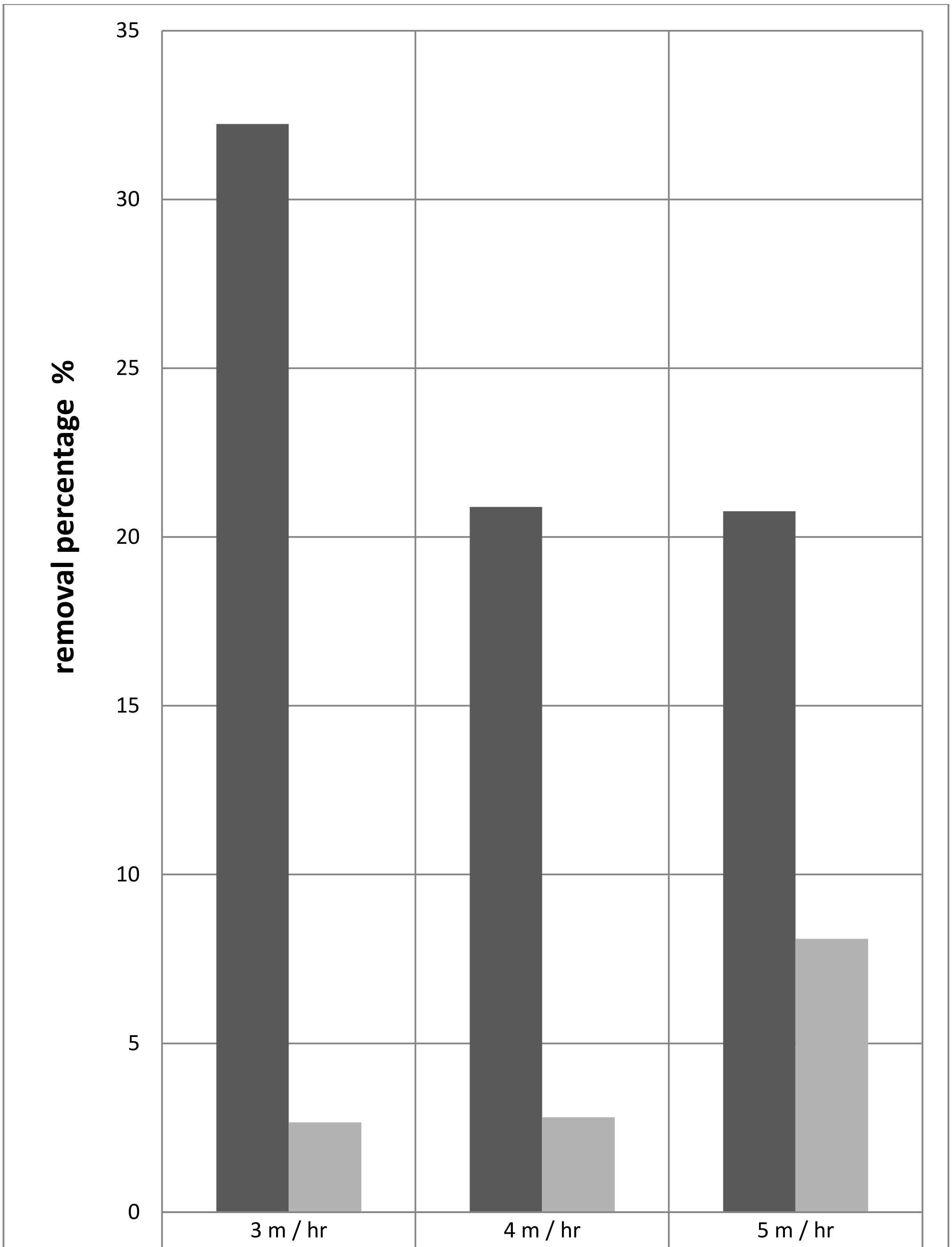


Fig.(1) Experimental Pilot Plant Components and Arrangemen



	3 m / hr	4 m / hr	5 m / hr
Ks factor	32.23	20.89	20.76
X factor	2.66	2.81	8.1

Fig. (3) Comparison between the average values of Ks and X factors at different rates of filtration

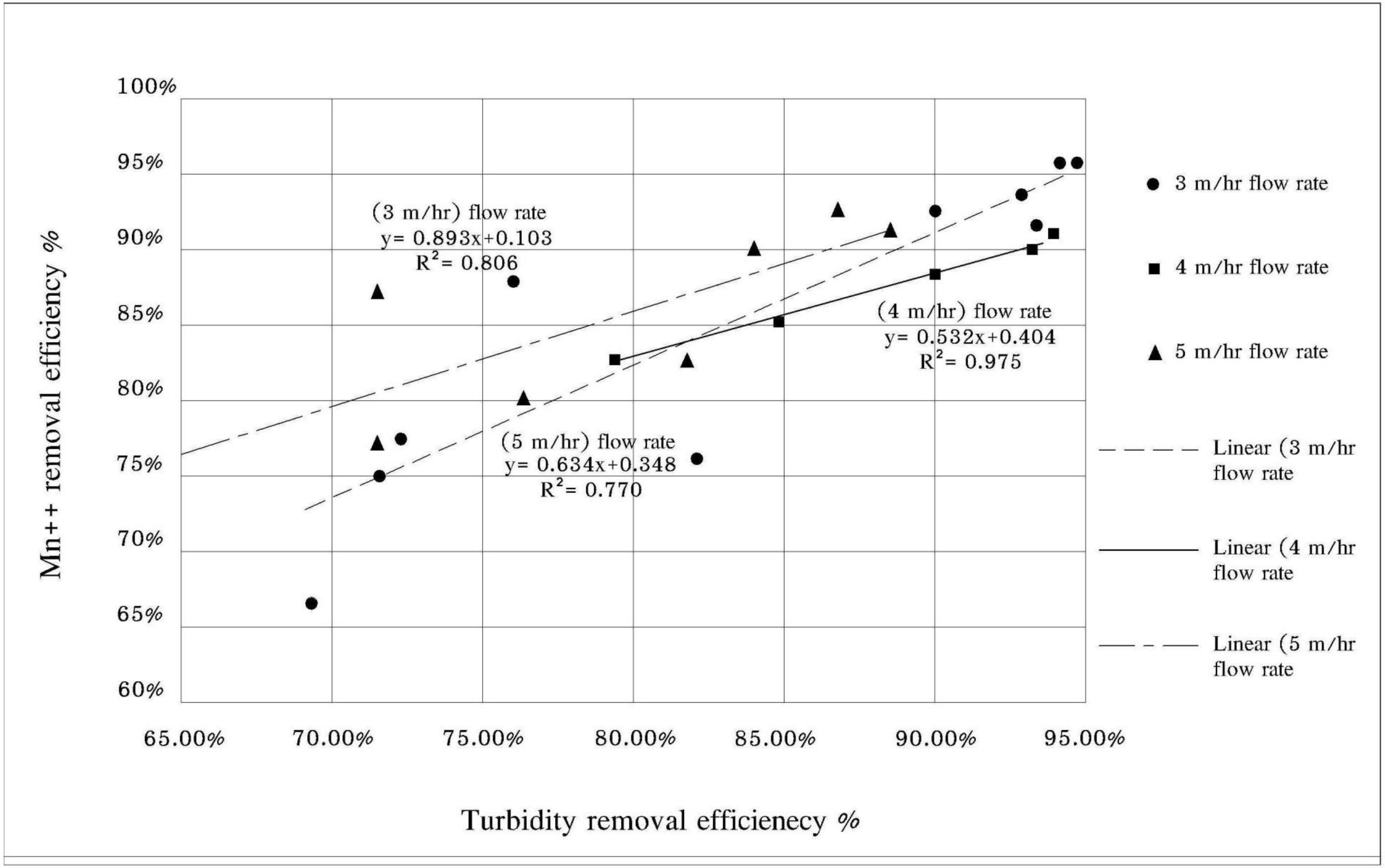


Fig . (4) The correlation between the percentage of removal of manganese and turbidity at rate of fillration (3.0 m/hr ,4.0 m/hr and 5.0 m/hr)