Optimum pH for Iron Removal in Groundwater Using Powdered Activared Carbon Coagulant

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ABSTRACT

The objection to high concentrations of iron in groundwater is due to its objectionable colour, taste and odour. Iron is concentrated in water by contact with rocks and minerals and it is understandable that it is usually groundwater supplies that may require treatment for high levels of iron. The optimum pH for the removal of iron in ferruginous water was investigated. The investigation involved an analysis of the treatment through carrying out the standard jar test experiment for the determination of residual iron of the supernatant. The experimental results showed that the optimum iron removals were achieved at pH of 5.2 to 8.4 with the optimum pH of 6.34 and the dose of about 25 mg/l with an almost 87.5% removal rate. The concentration of residual iron in treated water by Powdered Activated Carbon (PAC) under optimum coagulant conditions was 0.12 mg/l, which can completely comply with the permissible limit of 0.30 mg/l. The data obtained from this experimental research hopefully is going to provide useful technical information for possible full domestic applications to remove and reduce the undesirable excess iron from any groundwater sources to its acceptable standard permissible limit.

Keywords: *iron removal, optimum pH, Powdered Activated Carbon (PAC) coagulant*

Introduction

Groundwater is a major source of water supplies and groundwater extracted from an aquifer is usually low in suspended solids and practically bacteriologically safe. However, groundwater frequently contains excessive amounts and an unacceptably high level of inorganic ions making the water quite salty. Besides, specific ions require removal before the water is suitable for water supply. This includes iron, the presence of which makes it objectionable for aesthetic reasons. Iron in groundwater in reduced form of ferrous (Fe^{2+}) is relatively soluble. An increase in the oxidation-reduction potential of water readily converts ferrous ions to ferric (Fe^{3+}) and subsequently allows ferric iron to hydrolyse and precipitate as hydrated ferric oxide. It is this oxide that makes iron-laden waters objectionable and imparts yellow-orange coloration with associated tastes and odour (Bartram, 1996). According to Twort (1974), the two most common effects of excess iron can make a water unpalatable, thus, imparting a bitter taste and upon exposing the iron contaminated water to air, the iron is likely to precipitate and the deposits cause brown stains.

One of the series of steps for iron removal, which exceed a permissible National guideline for Drinking Water Quality as well as World Health Organization (WHO) guideline of 0.3 mg/L, is the coagulation flocculation process which is going to promote an agglomeration of impurities whereby the precipitates can be settled or floated in the sedimentation tank. Coagulation is an essential part in water treatment to reduce the undesirable impurities in water and the most commonly used coagulant is the aluminium salt, i.e alum.

For many years alum has been the most popular coagulant for water treatment, although there are some concerns about possible health hazards for aluminium residuals following its use (Tebut, 1992). However, one of the alternative coagulants proposed by the National Hydraulics Research Institute, Malaysia (NAHRIM) is the used of PAC as coagulant for impurities removal (NAHRIM, 2000). According to Gucharan (1999), due to its significant porosity, the activated carbon has the property of removing tastes and odours by absorbing gases, iron and manganese.

Its principle is absorption where the contaminant is attracted to and held on the surface of the carbon particles and due to its small pores and a large surface area will eventually lead to a better effectiveness in removing taste and particularly odour. It has been reported that a single gram of activated carbon can have a total surface area of more than 1000 sq.ft (Joseph, 2005).

Methodology

Research work was carried out at the Water & Hydrology Laboratory, Faculty of Civil Engineering, UiTM Pahang. The flocculation process was carried out using a jar test procedure in 1-litre beakers. All the jar tests were carried out at room temperature. 1000 mL of the test water was added to each 1-litre beakers. The water samples were taken from an existing tube-well located in UiTM Pahang. The solutions were then stirred rapidly, followed by slow stirring and quiescent settling for 30 minutes. Following settling, a supernatant sample was withdrawn and filtered through 0.45 μm filter paper before being analysed for residual iron.

During the experiments, the pH of the water was adjusted to a given value with 1M NaOH or 1M HCl solutions and was measured using pH-meter. Residual iron was measured using a DRH 890 Hach Colorimeter. Distilled water was used in all the experiments. PAC was diluted with distilled water to a concentration of 10 mg/L as PAC before used. All the stock solutions were prepared on daily basis to prevent degradation over time.

Basic sample parameters are 79 NTU for turbidity, pH of 7.63 and ferrous contents of 0.4 mg/L. The water had an excess iron for drinking water standard limit but did not exceed the raw water standard permissible limit of 1.0 mg/L. As such, the iron concentration in the raw water was increased to about (0.8 – 1.1 mg/L) range by the addition of ferrous sulphate solution. The first set of jar tests was conducted to select the coagulant dosage (optimum dosage) on the above dosage. The second set test was then carried out for selecting the optimum pH based on the coagulant dosage in the first set.

Results and Discussion

The effect of the dosages of coagulants on their coagulation performance was carried out at pH 7.60 and the result is shown in Table 1. The PAC coagulants produced the general trend of increased removal rate for both under and over dosing leaving a residual content of 0.11 mg/L at 87.8% removal. Figure 1 seems to provide clear evidence that PAC is going to offer a better iron removal rate.

Table 1: Summary of Results at Different PAC Dosage

Jar no.	Turbidity (NTU)	Iron (Fe) content (mg/L)	PAC dose (mg/L)	Residual Iron (mg/L)	Floc size	Flocs settling	% of iron Removal (FS)	
				NFS	FS			
1	71.80	0.90	25	0.18	0.11	Large	Fast	87.8
2	72.00	0.80	35	0.17	0.13	Large	Fast	84.0
3	74.10	0.97	45	0.20	0.16	Medium	Slow	83.4
4	77.50	0.83	50	0.18	0.14	Medium	Slow	83.1
5	72.50	0.94	55	0.20	0.12	Medium	Slow	87.2
6	75.20	0.90	60	0.20	0.11	Medium	Slow	87.7

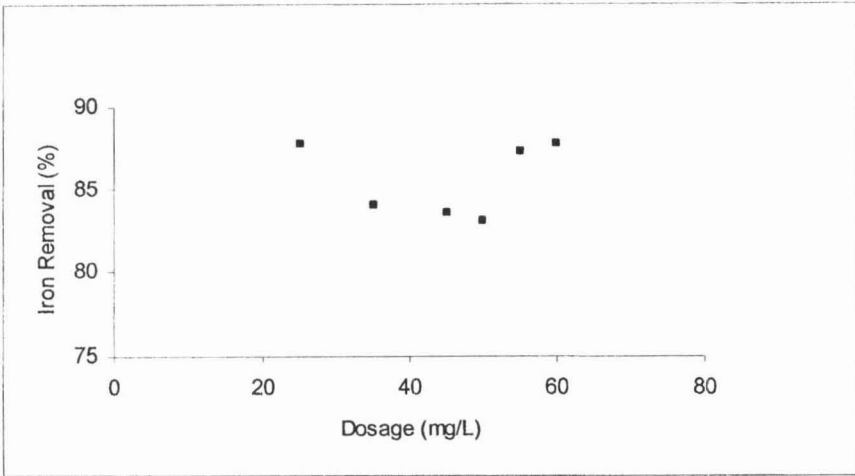*NFS – Non filtered supernatant
FS – Filtered Supernatant

Figure 1: Effect of PAC coagulant dosages on iron removal

The effect of pH on the removal of 25 mg/L for PAC is shown in Table 2 and Figure 2 with the removal rate for iron was around 87%. It can be seen that iron removal is not much of pH dependent within the narrowly tested range. The fact is that the solubility of $Al(OH)_3$ is pH dependent and is low between pH 5 – 7.5; outside this range coagulation with aluminium salts is not successful.(Tebut, 1992). Residual iron in the water following coagulation PAC should be minimised because any hydrated ferric oxide makes the iron-laden waters objectionable and its colloidal suspensions can give the water a uniformly yellow-orange, murky cast. It is this coloration together with associated tastes and odour can make the water undesirable for domestic use once the level exceed 0.3 mg/L.

Table 2: Summary of Results for an Optimum Dosage of PAC with Different pH

Jar no.	Turbidity (NTU)	Iron (Fe) content (mg/L)	pH	Residual Iron (mg/L)	Floc size	Flocs settling	% of iron Removal (FS)	
				NFS	FS			
1	82.9	0.95	5.21	0.15	0.13	Large	Fast	86.3
2	83.9	0.96	6.34	0.15	0.12	Large	Fast	87.5
3	84.1	0.92	6.63	0.17	0.13	Medium	Slow	85.8
4	84.4	0.98	7.21	0.18	0.14	Medium	Slow	85.7
5	83.9	0.97	7.71	0.17	0.14	Medium	Slow	85.5
6	82.2	0.91	8.43	0.16	0.13	Medium	Slow	85.7

*NFS – Non filtered supernatant
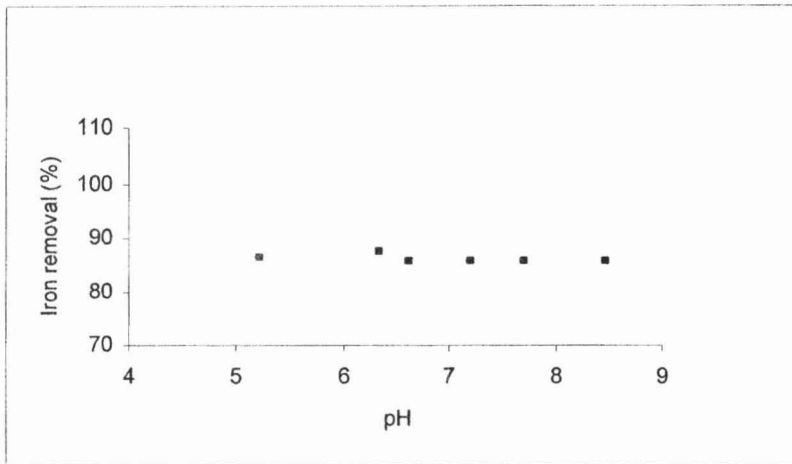FS – Filtered Supernatant

Figure 2: Effect of pH on Iron Removal at Optimum Dosage

As can be seen from both Table 1 and Figure 2, PAC shows a better performance with under and over dosing of coagulants. That trend seems to indicate that under and over dosing will result in deterioration in iron content. The trend for the effect of pH range on residual iron shown in Figure 3 needs to be further elaborated. PAC offered a slightly wider range performance on the final residual iron and the optimum iron removal were achieved basically in the range of 5.0 – 8.4. This is also consistent with findings of other researchers (Bao-Yu, 2005). The possible explanation would be; as the pH is increased, say higher than optimum pH value, the increase of pH favoured the hydrolysis of metal-ions and decreased the formation of positively charged ions. Hence, the ability for coagulants to neutralise the negative charge on colloids became small and thus colloidal matter could not be removed effectively.
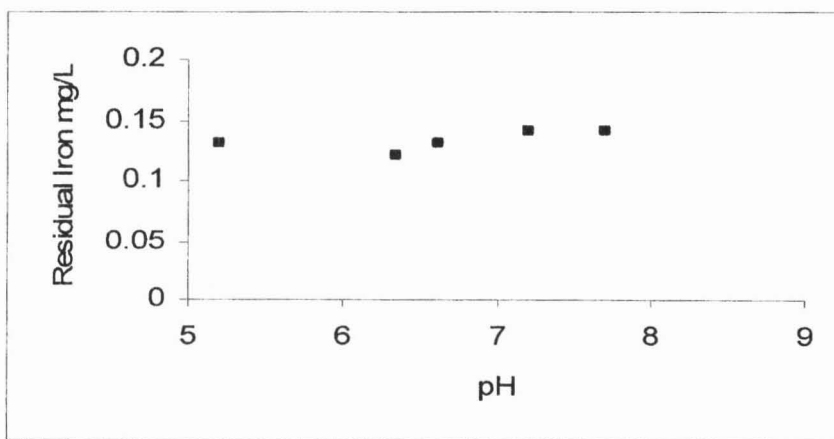

Figure 3: Effect of pH on Residual Iron

Conclusion

The performance of PAC coagulant for removing iron from ferruginous water was found to be highly successful and it was also found to be optimum at under and over dosing. The optimum iron removals were achieved at pH 5.2 – 8.4 with the optimum pH of 6.34. These reported results seem to prove the possibility of PAC to offer a better performance with a slightly better pH range to be achieved over 85% removal rate. It was also found that the floc formed with PAC coagulant

is heavier and larger in size at its optimum dosage. The concentration of residual iron in treated water by the selected PAC was 0.12 mg/L which completely comply with the regulated limit of 0.30 mg/L.

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