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A simple household method for the removal of iron from water

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ABSTRACT: With a view to developing a simple household method for removing iron from water, a laboratory study was undertaken to assess the potential of potassium permanganate, ceramic candle filter, or a combination of the two in removing iron from iron-spiked tap water. Batch tests using potassium permanganate with 5 min slow mixing and 2.5 h settling showed an iron removal in the range of 79–99% for the water samples tested (pH 6.0–10.0; initial iron concentration 3.5–10.0 mg/L). The optimum dose of potassium permanganate varied between 1.6 and 8.0 mg/L. Removal was generally higher at higher pH. Tests with a ceramic candle filter showed that, used alone, it could not remove iron efficiently; removal ranged between 7 and 20%. However, when water mixed with potassium permanganate (for 5 min) was fed into the filter, a high iron removal (91–99%) was observed. An *Escherichia coli* challenge test showed improved bacteria removal in presence of potassium permanganate. The results of the study indicated that a combination of potassium permanganate and candle filter can be used effectively for the household removal of iron in the rural areas of developing countries.

INTRODUCTION

Elevated levels of iron are found in many natural waters. Concentrations in excess of 0.3 mg/L may produce detectable taste and odour, red-coloured water which may stain clothes, household utensils and plumbing fixtures, and the growth of iron bacteria in pipes, which can produce additional taste and odour problems [1].

The most common method for iron removal is aeration followed by sedimentation and filtration. However, for many waters, simple aeration will not provide an effective oxidation and precipitation within a reasonable time. Furthermore, organic material may interfere with removal of iron by precipitation [2].

The use of strong oxidising agents such as chlorine, ozone or potassium permanganate can serve to oxidise iron more rapidly and can also destroy the organic materials present. Permanganate will function adequately at pH > 7.5 [3] and chlorine at pH > 8.5 [4].

A survey conducted by the authors in the rural areas of North-East India showed very high levels of iron in the ground waters drawn from tube wells [5]. Although community water treatment plants, based on the aeration–filtration principle, have been set up in many areas, most of these plants were found to be nonfunctional due to either improper maintenance or to inadequate aeration. This showed the need for developing suitable household methods for iron removal in rural areas of developing countries. Such methods should be simple, easy to use, and economical.

The present study evaluated the potential of potassium permanganate, an oxidising agent and the ceramic candle filter, which is becoming popular in developing countries for household water purification, and the combination of the two in removing iron from water. Laboratory tests were conducted which employed water from different initial iron concentrations and pHs.

METHODS AND MATERIALS

Water samples with the required concentration of iron were prepared by dissolving ferrous sulphate in tap water. Typical characteristics of the tap water were: pH 8.0, hardness 23 mg $CaCO_3$/L, alkalinity 44 mg $CaCO_3$/L. Freshly prepared water samples were used in all tests. The pH of the samples was adjusted by adding 1 N NaOH or H_2SO_4. Iron concentrations were determined by the phenanthrolene method [6].

Batch tests to determine the efficiency of potassium permanganate in removing iron were undertaken by adding different doses of permanganate to 1-L glass beakers containing 1 L of the water samples. The beakers were then stirred at 20 r.p.m. for 5 min using a standard jar-test apparatus. The contents of the beakers were then allowed to settle, and the supernatants were analysed for iron and pH after 1 h and 2.5 h. The test was then repeated, employing waters with different initial iron concentrations and pH.

The domestic ceramic candle filter used in this study comprised two chambers. The top chamber houses the candle and serves as a raw water reservoir, and the bottom chamber serves as storage for the filtrate. Using a bubble test [7], the 'maximum pore diameter' of the candle was estimated as 39 μm. In order to evaluate the performance of the filter in removing iron, 10 L of water with a known iron content was stirred (without permanganate) at 20 r.p.m. for 5 min, as mentioned earlier. This water was then poured into the top chamber of the water

Table 1 Iron removal by potassium permanganate in batch tests

Initial iron conc. (mg/L)	Initial pH	Optimum dose of permanganate (mg/L)	Iron removal after stated time (%) 1-h	2.5-h	Final pH
3.5	6.0	3.0	25	79	4.8
	7.1	2.7	48	79	6.4
	8.2	2.3	59	80	7.2
	10.0	6.0	74	79	8.8
5.0	7.1	3.8	41	90	6.4
	8.5	2.3	50	90	7.2
	10.0	1.6	47	96	8.8
10.0	6.0	8.0	70	81	4.8
	7.5	4.8	72	90	6.1
	8.5	2.6	70	99	6.8

filter and allowed to pass through the candle into the bottom chamber. The filtrate was analysed for iron. In order to evaluate the removal by candle filter–permanganate combination, the tests were repeated by adding the optimum dose of permanganate (as found from the batch tests) before stirring.

RESULTS AND DISCUSSION

The results of the batch studies with potassium permanganate are presented in Table 1. The optimum dose was selected as that dose which gave maximum iron removal. Addition of excess permanganate resulted in reduced removal, as well as a pale yellow colouration of the water. Iron removal ranged between 79 and 99% for the water samples tested. The requirements of permanganate were less at higher pH; for example, at an initial iron concentration of 5 mg/L, 3.8 mg/L of the permanganate was required to achieve a maximum removal at pH 6.0, whereas only 1.6 mg/L of permanganate was needed at pH 10.0. This is in conformity with the observation of Morgan & Stumm [8], who found that the amount of potassium permanganate which was required for the oxidation of ferrous ion decreased with increasing pH. Table 1 also shows that the oxidation of ferrous iron is accompanied by a reduction in water pH. pH reductions were generally in the range of 1.0–1.5 pH units.

Results of the batch tests indicated that potassium permanganate is effective for iron removal over a wide range of pH. This shows that permanganate can be used as an oxidising agent in domestic water treatment, for the removal of iron. The observation that an addition of potassium permanganate in excess of the optimum dose resulted in a yellow colouration of water is particularly significant from the point of view of application of this method for domestic iron removal in rural areas of developing countries. This obviates the need for knowing the initial iron concentration as well as the dose of permanganate required.

Table 2 Performance of the filter without potassium permanganate

Initial iron conc. (mg/L)	Initial pH	Iron removal (%)
3.5	7.1	7
	7.5	9
	8.2	13
5.0	7.1	16
	7.5	18
	8.2	19
10.0	7.1	18
	7.5	19
	8.2	20

Table 3 Performance of the filter with potassium permanganate

Initial iron conc. (mg/L)	Initial pH	Dose of permanganate (mg/L)	Iron removal (%)
3.5	7.1	2.7	91
	7.5	2.5	91
	8.2	1.6	94
5.0	7.1	3.8	95
	7.5	3.5	96
	8.2	2.3	96
10.0	7.1	5.0	96
	7.5	4.8	96
	8.2	4.1	97

Although potassium permanganate was found to be efficient in removing iron, separating the supernatant after settling could be a problem, since disturbing the container would result in the dispersion of settled flocs. A ceramic candle filter was thought to be useful for separating the formed flocs.

The results of the study which used the candle filter are presented in Tables 2 and 3. Two sets of tests were performed with the same water sample, one without permanganate and the other with the optimum dose of permanganate found from the batch study. From Table 2 it can be seen that candle filter alone could not remove iron efficiently. The removal ranged between 7 and 20%. This low removal was presumably due to the absence of floc formation, since simple agitation for 5 min did not result in oxidation of the ferrous ion.

The combination of potassium permanganate with the ceramic candle filter gave excellent iron removal (Table 3). Removal was always higher than 90% and was more than 95% for most of the water samples tested. The filtrate iron level remained in the range of 0.2–0.4 mg/L. It should be noted that the World Health Organization recommends a guideline value of 0.3 mg/L for iron in drinking water [9].

Table 4 *Escherichia coli* challenge test

	Influent conc. (CFU/mL)	Effluent conc. (CFU/mL)	Log reduction
Filter	130 000	4500	1.46
Filter–potassium permanganate	175 000	12	4.16

Over time, a considerable reduction in filtration rate was observed. It was observed that after 3 days of continuous operation of the candle filter, the filtration rate was reduced from an initial value of 1200 mL/h to 720 mL/h for an initial iron concentration of 10 mg/L. This was due to clogging of the candle pores by the flocs that were formed. However, the filtration rate improved following scrubbing of the filter candle. This indicates the need for frequent cleaning of the candle. It should be mentioned that the filter candle manufacturer recommends daily cleaning when it is used as a microbiological water purifier.

In order to evaluate the bacterial removal efficiency of the candle filter, an *Escherichia coli* challenge test was performed, with or without potassium permanganate. For this, a pure culture of *E. coli* was introduced into 10 L of sterile tap water with an iron concentration of 5.0 mg/L at pH 7.5. This water was then poured into the top chamber of the filter and allowed to pass through the candle into the bottom chamber. Filtrate was collected from the candle outlet and enumerated for *E. coli* using the pour plate method (35 °C, 48-h, plate count agar). In order to evaluate the bacterial removal by permanganate–ceramic candle filter combination, the test was repeated by adding the optimum dose of permanganate. The results of the test are presented in Table 4. It can be seen that, while ceramic candle filter alone effected about a 1.5-log reduction of *E. coli*, its combination with permanganate increased the removal by 2.7 log units. Thus, the combination of potassium permanganate with candle filter can be efficiently used for household iron removal in the rural areas of developing countries. However, it should be noted that, in the present study, the tests used iron-spiked tap water. Further studies should be conducted using natural waters of high iron content before recommending this method for general use.

CONCLUSIONS

Batch studies indicated the potential of potassium permanganate to remove iron from water. However, a long settling time was required for the effective settling of the flocs that were formed. The candle filter alone could not remove iron efficiently. A combination of the ceramic candle filter and the potassium permanganate gave excellent iron removal, which was always more than 90%. This indicated the potential of this method for application in the rural areas of developing countries for the removal of iron from water.

BIBLIOGRAPHY

1 Benefield LD, Judkins JF, Weand BL. *Process Chemistry for Water and Wastewater Treatment*. New Jersey: Prentice-Hall Inc., 1982.

2 Cromley TJ, O'Connor JT. Effect of ozonization on the removal of iron from groundwater. *JAWWA* 1976; **68**: 315–318.

3 Curry MD, Reynold M. Using byproducts of an iron removal process to improve water treatment. *JAWWA* 1983; **75**: 246–248.

4 Wong M. Chlorination-filtration for iron and manganese removal. *JAWWA* 1984; **76**: 76–79.

5 John S, Sarmah A. Presence of iron in rural water supply sources: A case study from the North-Eastern region. *Indian J Environ Protection* 1997; **17**: 30–32.

6 APHA. *Standard Methods for the Examination of Water and Wastewater*, 16th edn. New York: American Public Health Association, 1985.

7 Bureau of Indian Standards. *IS:7402, Part II—Specifications for Ceramic Water Filters*. New Delhi: Bureau of Indian Standards, 1975.

8 Morgan JJ, Stumm W. Colloid chemical properties of manganese dioxide. *J Colloid Sci* 1964; **19**: 437–444.

9 WHO. *Guidelines for Drinking-Water Quality*, Vol. 1, Recommendations. Geneva: World Health Organization, 1984.