Reduction of Microbial Contamination in Drinking Water using Flocculant Settling

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Abstract: Pakistan is subjected to rapid water shortage due to different social and environmental problems. Moreover, the drinking water is being contaminated at an alarming rate that is mostly due to the discharge of untreated domestic and industrial effluent and agricultural run-off. Therefore, this study was designed to evaluate the water quality problems of the subject area and to determine a cost effective treatment technique. The main objective was to determine the removal efficiency of microbial contamination using flocculant settling. The main pollutants identified by conducting water quality tests are arsenic, fluoride, nitrates and microbial contamination. The maximum concentration of arsenic, fluoride, nitrates and microbial contamination were observed as 12ppb, 2.2mg/L, 26mg/L and 84 colonies/100mL, respectively. During discrete settling tests performed in a 12cft column, it was noticed that the removal of microbial contamination corresponding to a detention time of 225min is 26.7% only. While working on different coagulants, it was observed that the optimum alum, lime and magnesium dosage for the removal of microbial contamination is 31.5mg/L, 10.5mg/L and 27mg/L respectively. The final re-sults of the study suggest that the use of lime as a coagulant to improve the quality of water in terms of microbial contamination is an effective and reliable technique, both in terms of its treat-ability performance and cost-effectiveness, which was noticed to be 77.7%.

Key words: Water quality, contamination, pollutants, coagulation, coliform, alum, Pakistan

Introduction

Pakistan's current population of 141 million is expected to grow to about 221 million by the year 2025. This increase in population will have direct impact on the water sector for meeting the domestic, industrial and agricultural needs. Pakistan has now essentially exhausted its available water resources and is on the verge of becoming a water deficit country (WHO and UNICEF n.d.). The per capita water availability has dropped from 5,600m3 to 1,000m3. The quality of groundwater and surface-water is low and is further deteriorating because of unchecked disposal of untreated munici-pal and industrial waste water and excessive use of fertilizers and insecticides (WHO and UNICEF 2006).

Results from various investigations and surveys indicate that water pollution has increased in Pakistan. The water quality deterioration problems are caused by the discharge of hazardous industrial wastes including persistent toxic synthetic organic chemicals, heavy metals, pesticide products and municipal wastes, untreated sewage water to natural water bodies. In several areas, increased arsenic, nitrate and fluoride contamination was detected in drinking water in addition to microbial contamination (West 2006, Pak-EPA 1999).

Water pollution is a major problem in the global context. It has been suggested that it is the leading worldwide cause of death and diseases and that it accounts for the deaths of more than 14,000 people daily (Nwachcuku and Gerba 2004).

The major water quality problems being faced by Pakistan are microbial contamination, arsenic, nitrates and fluoride contamination. Therefore, this study was designed to evaluate the water quality of the local (subject) zone, and to determine an optimum treatability option for the removing of desirable contaminents. The main objective was to determine the removal efficiency of microbial contamination using sedimentation process.

Material and Methodology

Various samples from different locations were collected in clean and sterilized bottles, which were then analyzed for major water quality parameters using standards methods (APHA, AWWA & WEF, 1995). Attempts of reducing the microbial contamination were also conducted by using a laboratory scale plain sedimentation tank within effective volume of 12cft. For the intensification of settling process the most common and cheapest coagulants like lime, alum and magnesium sulfate were used in the study, using "Jar Test Apparatus" (Masters 1998, Lindsten 1984, Holleman and Wiberg 2001).

Results and Discussion

The results obtained from the physical, chemical and biological analysis of water samples obtained from various sources are tabulated below. The results obtained from the tests indicate that the water quality in most parts of the subject area is polluted in one way or the other. The main pollution identified in terms of microbial, arsenic, nitrates and fluoride. To determine the optimum and feasible treatability solution for the

water treatment, synthetic samples were made containing the subject pollutants, namely, arsenic, nitrates, fluoride and maximum turbidity for the microbial pollution were added. These samples were then tested first by making trials on plain sedimentation and then by adding various types of coagulants like during the Jar Test to find an optimum treatability solution for them. Namely the coagulants used were alum, lime and magnesium sulfate.

S. No.	Parameter	Unit	Result	WHO	Remarks
1	pH	-	7.4	6.5-8.5	Within the limits
2	Temperature	oC	20	--	--
3	Turbidity	NTU	3.5	5	Within the limits
4	Arsenic	ppb	12	10	Beyond the limits
5	Fluoride	mg/L	2.2	1.5	Beyond the limits
6	Nitrates	mg/L	14	10	Beyond the limits
7	Total Coilform	No/100mL	16	Nil	Beyond the limits

Table 1: Water Quality Analysis of the Ground Source

S. No.	Parameter	Unit	Result	WHO	Remarks
1	pH	-	10.4	6.5-8.5	Beyond the limits
2	Temperature	oC	22	--	--
3	Turbidity	NTU	9.5	5	Beyond the limits
4	Arsenic	ppb	7.0	10	Within the limits
5	Fluoride	mg/L	2.0	1.5	Beyond the limits
6	Nitrates	mg/L	26	10	Beyond the limits
7	Total Coilform	No/100mL	84	Nil	Beyond the limits

Table 2: Water Quality Analysis of the Surface Source

S. No.	Parameter	Unit	Result	WHO	Remarks
1	pH	-	8.1	6.5-8.5	Beyond the limits
2	Temperature	oC	20	--	--
3	Turbidity	NTU	4.8	5	Within the limits
4	Arsenic	ppb	11	10	Beyond the limits
5	Fluoride	mg/L	1.8	1.5	Beyond the limits
6	Nitrates	mg/L	13	10	Beyond the limits
7	Total Coilform	No/100mL	27	Nil	Beyond the limits

Table 3: Water Quality Analysis of the Tap Source

Detention Time	Percentage Removal			
(min)	Arsenic	Fluoride	Nitrates	Total Coliform
25	0.9	0.7	2.2	17.6
50	0.71	1.4	1.4	19.7
75	1.1	1.7	0.7	21.1
100	0.84	0.8	2.1	23.4
125	1	1.2	2.1	24.4
150	0.65	1.4	1.9	25.1
175	0.8	1.6	2	26
200	1.3	1.1	1.8	26.8
225	1.2	0.6	2.4	26.7
250	1.2	0.5	2.3	28.2
275	1.4	1	1.6	28.1
300	1.5	1.3	1.8	29

Table 4: Result Obtained from the Sedimentation Test

Treatability performance of discrete settling

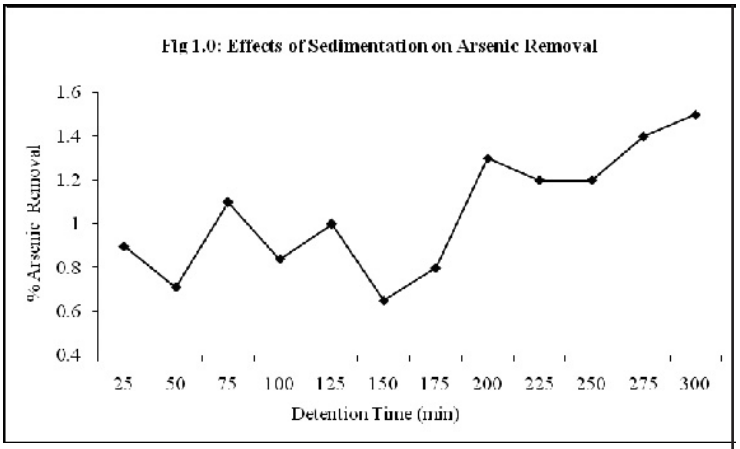
Since, the water samples from various locations were highly polluted and did not meet the criteria of the WHO drinking water parameters standards, therefore, in the first attempt, the synthetic water sample was tried in a model sedimentation tank of about 12cft. At regular interval of time 25min, 50min, 75min, up to 300min, the percentage removal of arsenic, fluoride, nitrates and microbial contamination were observed and the data obtained is shown in the Table 4.

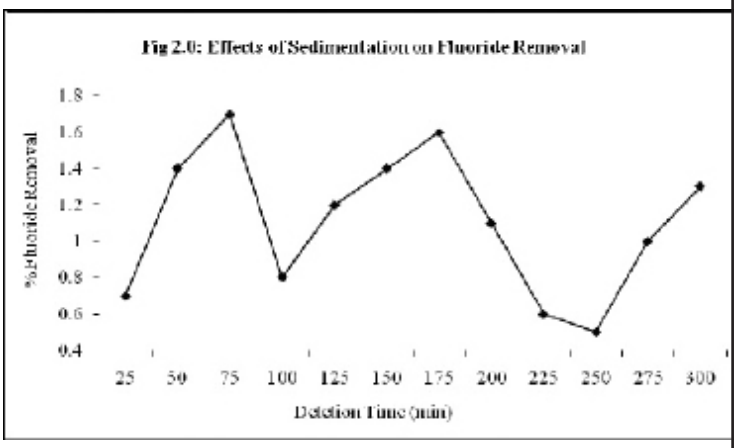
The minimum arsenic removal efficiency of 0.65%, fluoride removal efficiency of 0.5%, nitrates removal efficiency of 0.7% and microbial removal efficiency of 17.6% were observed at detention time of 150min, 250min, 75min and 25min, respectively. Whereas, the maximum arsenic removal efficiency of 1.5%, fluoride removal effi-ciency of 1.7%, nitrates removal efficiency of 2.4% and microbial removal efficiency of 29% were observed at detention time of 300min, 75min, 225min and 300min re-spectively. However, the maximum and minimum percentage removal of arsenic, fluoride, nitrates and microbial contamination during the plain sedimentation tests trial does not meet the requirements of WHO drinking water quality standards. Thus it requires advanced or conventional treatment to bring down these various pollut-ants to the desired standard. The optimum removal of arsenic, fluoride, nitrates and microbial contamination at a detention time of 225min in a plain sedimentation tank was observed as 1.2%, 0.6%, 2.4% and 26.7% respectively. The percentage removal of arsenic, fluoride, nitrates and microbial contamination is presented in Figures 1-4.

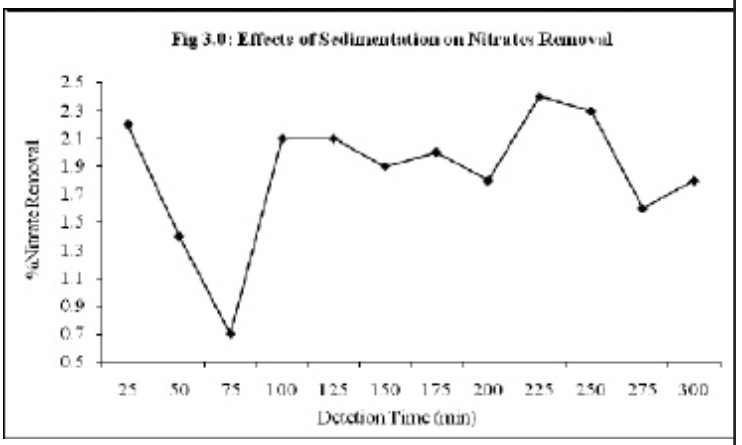
Treatability performance of coagulants dosage

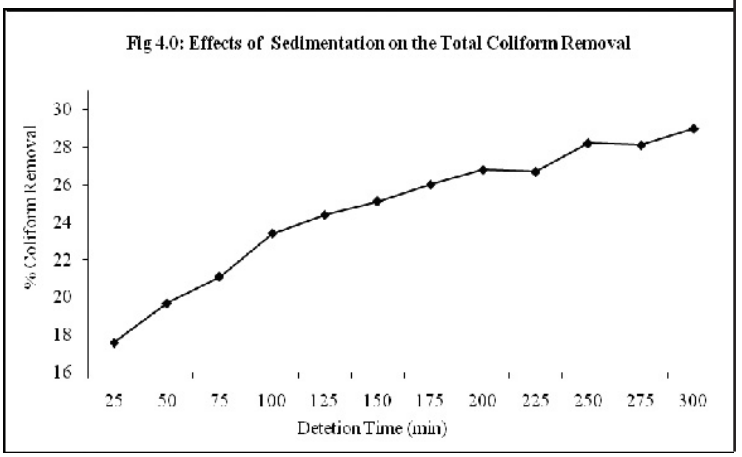
In order to determine the optimum dosage of alum, lime and magnesium sulfate, they were used as coagulants varying in concentration from 4.5mg/L to 54mg/L, 1.5mg/L to 18mg/L and 3.0mg/L to 36mg/L respectively. Figures 5-7 illustrate the effects of different coagulants of the removal of microbial contamination from drinking water.

The minimum microbial contamination removal by using alum, lime and magne-sium sulfates were observed as 22.1%, 61.2%, and 18% respectively. Whereas, the maximum microbial contamination removal by using alum, lime and magnesium sul-fates were observed as 54%, 77.7% and 28.8%, respectively. The optimum dosage of alum, lime and magnesium sulfates for the removal of microbial contamination was observed as 31.5mg/L, 10.5mg/L and 27mg/L respectively.









Selection of coagulant

Selection of coagulant on the basis of cost comparison was carried out. Since, the optimum dosage determine by the Jar Test for alum, lime and magnesium is 31.5mg/L, 10.5mg/L and 27mg/L respectively. To select the cost effective coagulant the following analysis was carried out for the water flowing at the rate of 100L/min (assumption). The detail cost analyses are given in Table 5.

Coagulant	Dosage (mg/L)	Unit Price ($/kg)	Daily Cost ($)
Alum	31.5	0.14	6.64
Lime	10.5	0.12	1.85
Magnesium Sulfates	27	0.18	7.10

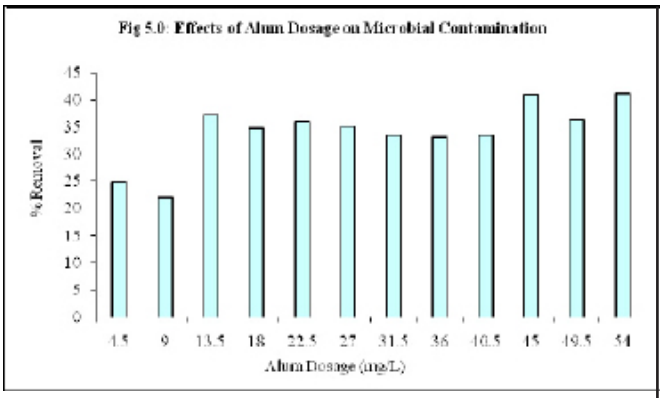
Table 5: Selection of Optimum Coagulant Dosage

From the cost and treatability analysis, lime is determined as the most effective coagulant for the treatability performance of polluted water containing arsenic, fluo-ride, nitrates and total coliforms. The total cost required per day for the optimum treatability of water quality is determined as 1.85 US dollars.

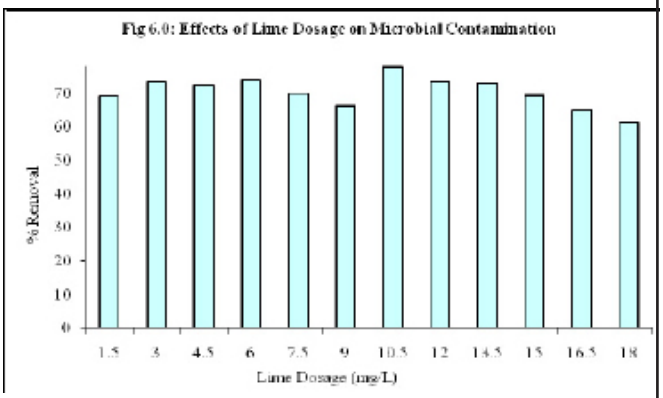
Conclusion and Recommendations

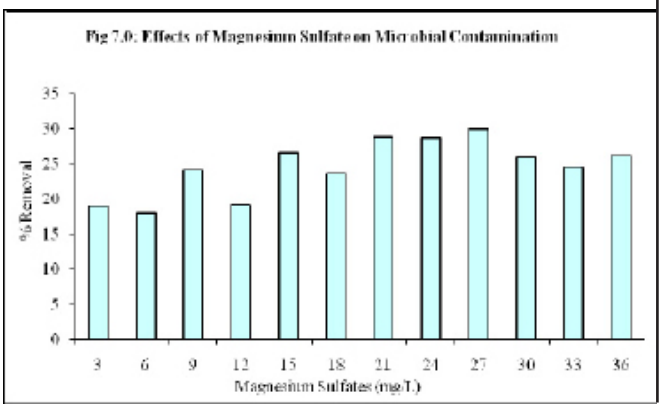
The following conclusions have been derived from working on the water quality sam-ples analysis and using various coagulants;

- The water quality in most parts of the subject area is polluted in one way or the other, but the main pollutants are arsenic, fluoride, nitrates and microbial contamination.
- The maximum pollutants concentration observed in the subject area in terms of arsenic, fluoride, nitrates and microbial contamination is 12ppb, 2.2mg/L, 26mg/L and 84 colonies/100mL respectively.
- During discrete (plain) settling, the optimum removal of microbial contamination corresponding to a detention time of 225min is 26.7% only.
- The optimum alum, lime and magnesium dosage for the removal of microbial contamination is 31.5mg/L, 10.5mg/L and 27mg/L respectively.
- The removal of microbial contamination by using alum, lime and magnesium corresponding to their optimum dosage is 54%, 77.7% and 28.8%, respectively.
- The total cost of lime required per day for the water treatment flowing at the rate of 100L/min is 1.85 US dollars.



A long-term study is required to carry out the complete





water quality analysis for at least twelve months to study the characteristics changes subjected to seasonal variations and flow rates. Different types of coagulants and filter media should be used to evaluate a better treatability performance.

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