Asian J. Exp. Sci., Vol. 23, No. 1, 2009; 61-66

Studies on Water Treatment for Removal of Nitrate

Kavita Batheja*[1], A.K. Sinha[1] and Gita Seth[2]
[1] Department of Geology, University of Rajasthan, Jaipur-302004 (Raj.); India.
[2] Department of Chemistry, University of Rajasthan, Jaipur-302004 (Raj.); India.

Abstract : Groundwater studies in arid zones of Churu block and adjacent villages exhibit high nitrate concentrations which make the groundwater unsuitable for drinking. Though there are many nitrate remediation methods/products in market, these may not be feasible for use at rural level. This paper describes a preliminary investigation on nitrate remediation abilities of active neutral alumina, activated charcoal, agar, yellow mustard and bentonite in singular or combined form. With some limitations these remedial measures can prove to be helpful in reduction of nitrate concentration in groundwater of the study area to appreciable extents.

Key words : Nitrate removal, Churu, Groundwater

Introduction

According to water quality standards set by World Health Organisation (WHO), the guideline value for nitrate is 10 ppm. The Indian Council of Medical Research (ICMR) has recommended a highest desirable level of 20 ppm of nitrate in drinking water while maximum permissible level recommended is 50 ppm (Goel and Sharma, 1996). High nitrate may cause methaemoglobinemia, gastric cancer and birth defects (Mirvish, 1985). Fassett (1973) reported a rapidly occurring severe gastroenteritis with abdominal pain, blood in the urine and faeces as symptoms of acute nitrate intoxication. Methaemoglobinemia was found prevalent in all age groups in areas of Rajasthan with high nitrate concentrations in drinking water (Gupta *et al.*, 1999). Recurrent acute respiratory tract infections in some areas of Rajasthan have been attributed to high nitrate concentrations in drinking water (Gupta *et al.*, 2000). High nitrate concentrations may be found in natural waters due to excessive use of fertilizers, disposal of industrial wastes, disposal of human sewage or plantation of leguminosae crops which fix atmospheric nitrogen in form of nitrate. The groundwater studies conducted by the authors in parts of Churu district, Rajasthan exhibited high nitrate concentrations caused by leguminosae crops grown in the area. There are a number of treatment technologies available in the market for efficient reduction of nitrate in drinking water e.g. electrodialysis, reverse osmosis, ion exchange, catalytic reduction, biological treatment. But these techniques require high cost and skilled maintenance which may not be available in rural areas and therefore it becomes imperative to find out cost effective remedial measures for nitrate in groundwater. In the present study denitrification by bioremediation, chemical remediation and mineral remediation was investigated at room temperature and the results are being reported here. The studies were extended to investigate effects of these remedial measures on other parameters of water.

* **Corresponding author :** Kavita Batheja, Department of Geology, University of Rajasthan, Jaipur-302004 (Raj.); India.; E-mail : *kavita.batheja@gmail.com*

Materials and Methodology

Standard solutions of nitrate of varying concentrations

All the apparatus to be used were thoroughly cleaned. Standard nitrate solution of 1000 ppm concentration was prepared. From this 1000 ppm solution different standard solutions of 200 ppm, 400 ppm and 800 ppm were made. 50 ml. of each of these solutions was used in every experiment.

Substances used as remedial measures

Active neutral alumina, activated charcoal, yellow mustard (powdered), agar, and bentonite. Alumina adsorbs organic acids, alcohols, gases, metals etc. and has been used in chromatography for its adsorbing properties.

One gram of activated carbon can have a surface area in excess of 500 m^2, with 1500 m^2 being readily achievable. There are micropores which provide superb conditions for adsorption to occur since adsorbate material can interact with many surfaces simultaneously.

Mustard has some tolerance to salinity and is similar to barley in its productivity on saline soils. Ground yellow mustard can absorb excess fat and fluid (approximately 4.5 times its own weight).

Gels made from purified agar have large pore sizes, making them useful for size-separation of large molecules, such as proteins or protein complexes or DNA fragments.

Bentonite is used in a number of industrial cleansing applications and waste water purification due to its excellent absorption and adsorption properties.

Four experiments were conducted at room temperature. Every experiment consisted of six sets of remedial treatments

(i) alumina+bentonite*

(ii) mustard

(iii) agar

(iv) activated charcoal

(v) activated charcoal+agar*

(vi) bentonite

* *equal quantities by weight*

Experiment 1: 200 ppm nitrate solution treated with 2 gm of each of i) - vi) above for 2 hours.

Experiment 2: 400 ppm nitrate solution treated with 4 gm of each of i) - vi) above for 4 hours.

Experiment 3: 800 ppm nitrate solution treated with 8 gm of each of i) - vi) above for 8 hours.

Experiment 4: 800 ppm nitrate solution treated with 8 gm of each of i) - vi) above for 24 hours.

Along with the above series of experiments different quantities of alumina with bentonite (1 gm alumina + 7 gm bentonite, 2 gm alumina + 6 gm bentonite, 3 gm alumina + 5 gm bentonite, 5 gm alumina + 3 gm bentonite, 6 gm alumina + 2 gm bentonite, 7 gm alumina + 1 gm bentonite) and activated charcoal with agar (1 gm activated charcoal + 7 gm agar, 2 gm activated charcoal + 6 gm agar, 3 gm activated charcoal + 5 gm agar, 5 gm activated charcoal + 3 gm agar, 6 gm activated charcoal + 2 gm agar, 7 gm activated charcoal + 1 gm agar) were tested on 800 ppm nitrate solution for 24 hours.

Nitrate was measured colorimetrically using Brucine method (http://www.epa.gov/waterscience/methods/method/files/352_1.pdf).

It was planned to extend the study of most efficient nitrate removal method for removal of other parameters: pH, electrical conductivity (EC), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total hardness (TH), chloride (Cl^-), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), fluoride (F^-) also.

Results

Results of these experiments are shown in Tables 1-4 and Figure 1.

The water treated with yellow mustard showed a light yellow tinge. Yellow mustard, agar and bentonite adsorbed water and floated up. Activated charcoal is quite efficient in reducing nitrate concentration in the solution even at higher concentration of nitrate with a removal capacity of around 81% in 800 ppm nitrate solution. Nitrate removal capacity increased with the time of contact and amount of activated charcoal. Though agar alone did not produce encouraging results, it was more effective when combined with activated charcoal at higher concentration of nitrate. Yellow mustard was effective at low concentrations of nitrate with reducing 200 ppm nitrate to 45.76 ppm in 2 hours time. Different remedial measures were at their best in different conditions.

Table 1 : 200 ppm Nitrate Treated with 2 gm of Remedial Measure for 2 Hours

	Alumina + Bentonite	Mustard	Agar	Activated Charcoal	Activated Charcoal+ Agar	Bentonite
Nitrate left (ppm)	155.59	45.76	160.42	110.91	120	156
% nitrate left	77.79	22.28	80.21	55.45	60	78
% nitrate removal	22.21	77.72	19.79	44.55	40	22

Table 2 : 400 ppm Nitrate Treated with 4 gm of Remedial Measure for 4 Hours

	Alumina + Bentonite	Mustard	Agar	Activated Charcoal	Activated Charcoal+ Agar	Bentonite
Nitrate left (ppm)	145.93	155.59	169.84	120.08	141	240.36
% nitrate left	36.48	38.89	42.46	30.02	35.25	60.09
% nitrate removal	63.52	61.11	57.54	69.98	64.75	39.91

Table 3 : 800 ppm Nitrate Treated with 8 gm of Remedial Measure for 8 Hours

	Alumina + Bentonite	Mustard	Agar	Activated Charcoal	Activated Charcoal+ Agar	Bentonite
Nitrate left (ppm)	354.57	394.71	414.44	149.07	162.6	350.03
% nitrate left	44.32	49.33	51.8	18.63	40.65	43.75
% nitrate removal	55.58	50.67	48.2	81.37	59.35	56.25

Table 4 : 800 ppm Nitrate Treated with 8 gm of Remedial Measure for 24 Hours

	Alumina + Bentonite	**Mustard**	**Agar**	**Activated Charcoal**	**Activated Charcoal+ Agar**	**Bentonite**
Nitrate left (ppm)	304.96	423.17	406.76	149.59	320.4	317.76
% nitrate left	40.42	52.89	50.84	18.69	40.05	39.72
% nitrate removal	59.58	47.11	49.16	81.31	59.95	60.28

Table 5 : Results of Water Treatment: 2 gm Alumina and 6 gm Bentonite Used for 24 Hours

	pH	EC	Na^+	Ca^{2+}	Mg^{2+}	TH	K^+	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-	CO_3^{2-}	F^-
Before Treatment	7.5	6750	1610	44	36	260	21	1598	171	854	625	0	1.2
After Treatment	7.25	4550	925	65	78	490	14	924	250	659	502	0	2
% Decrease	3%	33%	43%	-48%	-117%	-88%	33%	42%	-32%	23%	20%	0%	-40%

In another series of experiments it was discovered that a combination of 2 gm alumina and 6 gm bentonite on 800 ppm nitrate solution for 24 hours at room temperature produced a 92.57% reduction in nitrate concentration. Only 59.362 ppm of nitrate remained in the solution. Thus, these remedial measures singularly or in combined forms can be helpful in reduction of nitrate concentration in groundwater of the study area to appreciable extents. The experiment of 2 gm alumina and 6gm bentonite was extended to treat other parameters of groundwater also and the results are being produced here in tabular as well as graphical form (Table 5 and Figure 2) [All parameters are measured in ppm except pH and EC (Electrical conductivity). EC is measured in microsiemens/cm].

It was observed that electrical conductivity (EC), sodium (Na^+), chloride (Cl^-), nitrate (NO_3^-), potassium (K^+) and sulphate (SO_4^{2-}) were decreased by 33%, 43%, 42%, 20%, 33% and 23% respectively, while there were increments in the concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), total hardness (TH), bicarbonate (HCO_3^-) and fluoride (F^-) by 48%, 117%, 88%, 32% and 40% (Figure 3). Though at first instance it seems that there was greater increase in the concentration of Ca^{2+}, Mg^{2+}, TH and F^- than the decrease in the values of EC, Na^+, Cl^-, NO_3^-, K^+, SO_4^{2-}, HCO_3^-, yet the increase does not take the concentration into non potable levels and therefore is not harmful. On the other hand the decrease in some of the parameters such as chloride brings down the non potable concentrations into potable level.

Discussions

Remedial measures singularly or in combined forms can be helpful in reduction of nitrate concentration in groundwater of the study area to appreciable extents. Agar alone was not efficient for removal of nitrate yet when combined with activated charcoal it gave encouraging results. Yellow mustard was effective for removal of low nitrate concentration but at higher concentration of nitrate it became ineffective. There are some limitations also like production of large amount of waste, appearance of yellow tinge in the

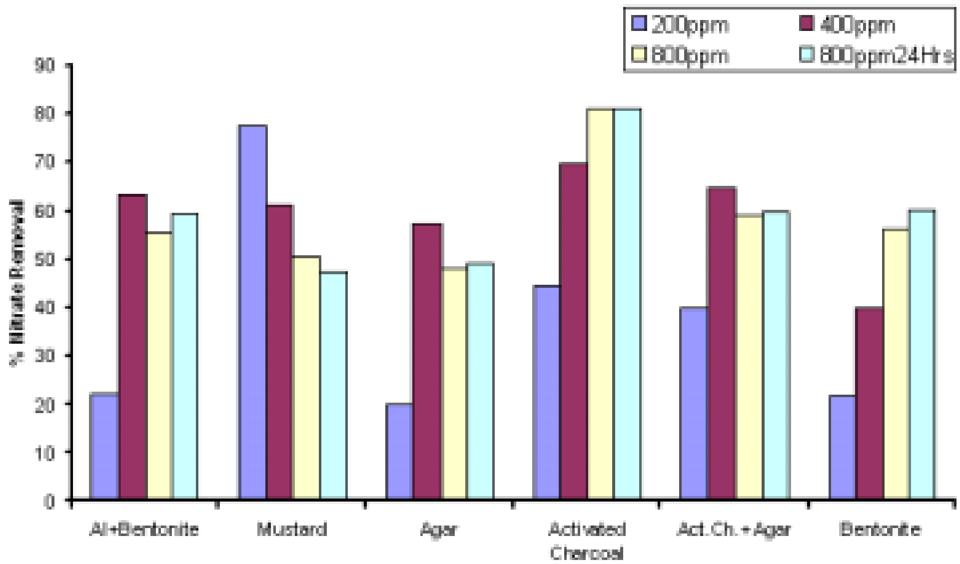
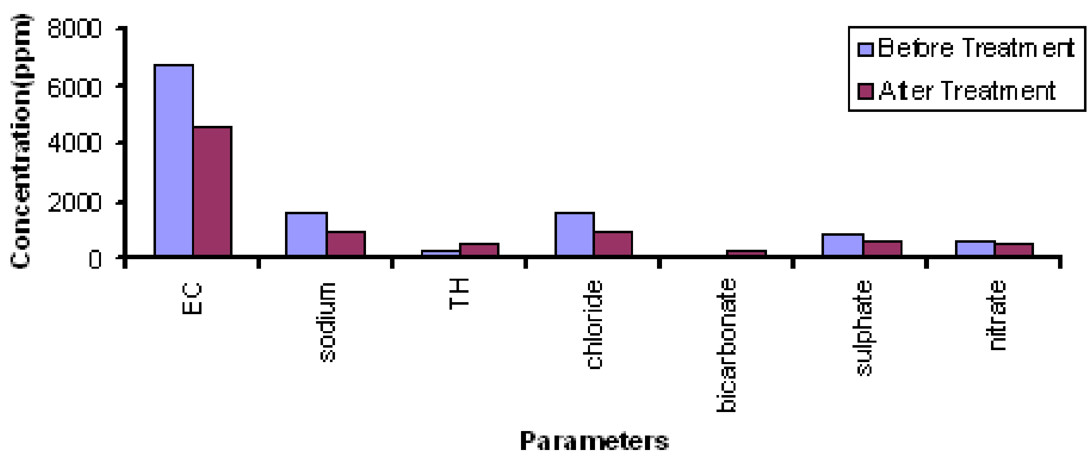


Fig. 1 : Comparative Nitrate Removal Efficiency (in Percentage)



Note: *Concentration values for calcium, magnesium, potassium, carbonate, fluoride are being omitted in the graph since these have too small values.*

Fig. 2 : Results of Water Treatment: 2 gm Alumina and 6 gm Bentonite Used for 24 Hours

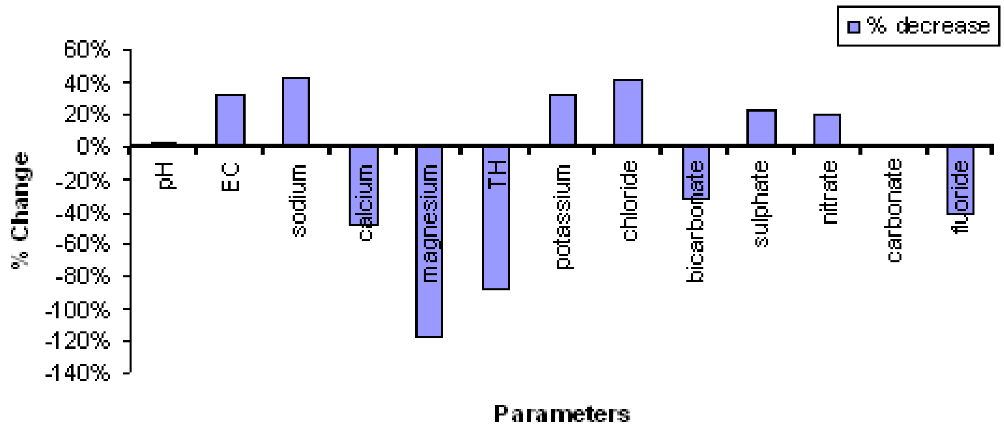


Fig. 3 : Percent Decrease in Different Parameters: 2 gm Alumina and 6gm Bentonite Used for 24 Hours

water treated with yellow mustard. Research on waste management is being carried out. Yet these experiments suggest that there is further need and scope for development of these kinds of remedial measures which may be helpful to mitigate woes of inhabitants of the study area.

References

Fassett D.W. (1973): Nitrates and nitrites: toxicants occurring naturally in foods. Communication in Food Protection (Washington D.C.: National Academy of Science) pp.7-25

Goel P.K. and Sharma K.P. (1996): Drinking water standard. Environmental guidelines and standards in India.(India: Technoscience Publications) pp.15-24.

Gupta S.K., Gupta R.C., Seth A.K., Bassin J.R., Gupta D.K. and Sharma S. (1999): Epidemiological evaluation of recurrent stomatitis, nitrates in drinking water and cytochrome B_5 reductase activity. *American Journal of Gastroenterology*, **94**, 1808–1812

Gupta S.K., Gupta R.C., Seth A.K., Bassin J.R., Gupta D.K. and Sharma S. (2000): Recurrent acute respiratory infections in areas with high nitrate concentrations in drinking water. *Environmental health prospective*, **108**, 363–366

Mirvish S.S. (1985): Gastric cancer and salivary nitrate and nitrite. *Nature*, **315**, 461-462.