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Short Note

Softening of Hard Water by Bentonite Mineral

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Abstract: The paper reports and discusses the results of removal of hardness by Bentonite minerals. Hybridised IX-fibres that contain dispersed hydrated ferric oxide (HFO) nano particles have also been reported for removal of hardness. Locally available bentonite minerals generally consist of montmorillonite. Besides useful adsorbent of ions in solution, bentonite is known for ion exchange. Bentonite is mixed well with water sample and time is allowed for ion exchange to take place. As a result calcium ion is exchanged. This ion exchange process here has been recognized for softening of water or benign removal of hardness. The particle size is of 0.3 m prepared in the laboratory. The main constituents of bentonite minerals are alumina, silica, iron oxide and oxides of sodium, potassium, calcium and magnesium. The bentonites have been found to be a natural exchanger. The cation exchange capacity of bentonite minerals may be attributed to the lattice structure as the clay minerals contain anions and cations in the exchangeable state. The bentonite minerals of 0.3 m size has been studied with different doses up to a certain interval of time and with fixed dose to different interval of time. The experiments were done by simple titration with N/50 HCl using methyl orange as an indicator.

Key words: Bentonite minerals, ion exchange, hardness.

Introduction

Bentonite minerals of different parts of the country have been reported for ion exchange capacity. Calcium bentonite may be converted to sodium bentonite by a process known as ion exchange (Hofmann and Endell, 1938). Sodium carbonate is added to wet bentonite and allowed for ion exchange to take place (Lagaly 1995, Inchurchman, 10th International Conference, Australia; and Brady, 2002). The environment friendly removal of hardness has been reported by using hybridized IX-fibres that contain dispersed hydrated ferric oxide (HFO) nanoparticles (Greenleaf et al., 2006). But the naturally available Rajmahal bentonites may prove a better option. The bentonite samples collected from different places have also been studied for swelling, bulk density and loss on ignition (Jha et al., 2010).

Total hardness (as $CaCO_3$ in mg/L) should not exceed 200 prescribed by WHO (1997); and Bureau of Indian Standards (BIS, 1991).

Zeolites are also used as ion exchange beds in domestic and commercial water purification, softening and other applications (Flavio, 2008). Composition of Zeolites are as follows.

SiO_2	70.19–75.90%
Al_2O_3	9.90–11.81%
Fe_2O_3	1.55–4.90%
CaO	3.35–3.30%
K_2O	0.10–3.10%
Na_2O	2.00–2.60%
pH(H_2O)	7.5–7.6

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The percentage composition of some samples of bentonites are as follows.

SiO_2	35–47%
K_2O	0.38–5.45%
Al_2O_3	26.9–32.94%
Fe_2O_3	2.20–6.80%
TiO_2	0.92–2.35%
MnO_2	0.19–0.44%
Na_2O	0.78–6.58%
MgO	1.26–4.71%
CaO	1.22–6.32%

These bentonites have been used as ion exchangers. The samples collected are from Bakudih Railway Station, Mandali Mirjachowki, Motijharna, Bhut Bangla, Amdapada and Madro Fossil Park of Sahibganj district of Jharkhand. The colour of the samples were grey, light pink and brown. Cation exchange is a reversible interchange of ions between a solid and liquid phase without permanent change in the structure of the phase. The ion exchange in agriculture was recognized as a physico-chemical process (Jamrack, 1963; Kunel, 1964). They examined the exchange of Ca^2+and NH_4+ ions in soils and traced it to alumino silicates present in the soil. Substances of both natural and manmade are found to have ion exchange capacity.

Cation exchange capacity may be represented as

BH + M+ = BM +H+

M+ – cation

H+ – cation

M+ exchanges H+ cation and BH is an exchanger.

According to law of mass action

$$K = [BM][H+] / [BH][M+]$$

K is thermodynamic equilibrium constant. The distribution co-efficient of an exchange for two metals in low concentration can be represented as.

$$DM_1 = [BM_1] / [M_1+],$$

$$DM_2 = [BM_2] / [M_2+]$$

Separation factor = DM_1/DM_2

D is taken as the distribution co-efficient which measures the affinity of exchange for a metal ion.

Thus the exchange property of Rajmahal bentonites has been exploited for the novel application in softening of hard water.

Experimental

The water samples were collected from Kolakhurd village of Jagdishpur Anchal of Bhagalpur district of Bihar. The bentonite minerals were collected from the Rajmahal Hills. They were tested for montmorillonite by benzidine solution. The samples gave blue colour with concentrated solution of benzidine indicating the presence of montmorillonite. Now the bentonite is powdered and sieved to 0.3 m by the mesh sieve available in the laboratory and dried. 1g dried sample is added to 0.1 L water sample and stirred by mechanical shaker for different contact time. The solution is filtered by a buchner funnel and the filtrate is collected. Different doses of bentonite is also added to 0.1 L water sample in a conical flask for a contact time of 60 min. After shaking it is filtered.

This experiment has been repeated for different samples of bentonites. The hardness is measured by titrating the filtrate by N/50 HCl using methyl orange as an indicator. The filtrate is also analysed for sodium estimation by flame photometer model no. CL378.

Results and Discussion

Water samples S_2 and S_3 collected from the Kolakhurd village has the hardness of 89 g and 53 g per 100 litres, respectively. S_2 water sample is treated with 1g sieved bentonite for a contact time of 60 min, 75 min and 120 min. The hardness decreased from 89 g per 100 litre to 48 g $CaCO_3$ in 120 min as depicted in Table 1 and Figures 1 and 2.

Table 1: Hardness of (S_2 and S_3) water sample treated with 1 g bentonite sample RB_3 for different intervals of time

Sample No.	*Time*			
RB_3	*Initial*	*60 min*	*75 min*	*120 min*
RB_3 (1g) + 0.1L S_2 water sample	89 g $CaCO_3$	86 g	81 g	48g
RB_3 (1 g) + S_3 water sample	53 g $CaCO_3$	52 g	44 g	40 g

S_3 sample is treated with 1 g RB_3 and RB_6 for a contact time ranging from 60 min to 120 min. It is observed that the hardness of S_3 water sample decreased from 53 g/100 litre to 40 g/100 litre in 120 min with RB_3 bentonite sample of Tarapahar, Mandro of Rajmahal Hills. The hardness of S_3 water sample decreased from 53 g/100 litre to 43 g/100 litre on using 1 g of RB_6 bentonite sample of Amdapada, Rajmahal Hills during 120 min shown in Table 2 and Figure 3.

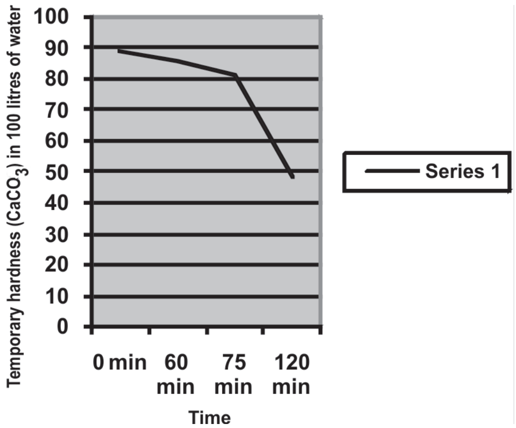

Figure 1: Hardness of S_2 water samples treated with 1 g bentonite sample RB_3 for different intervals of time.

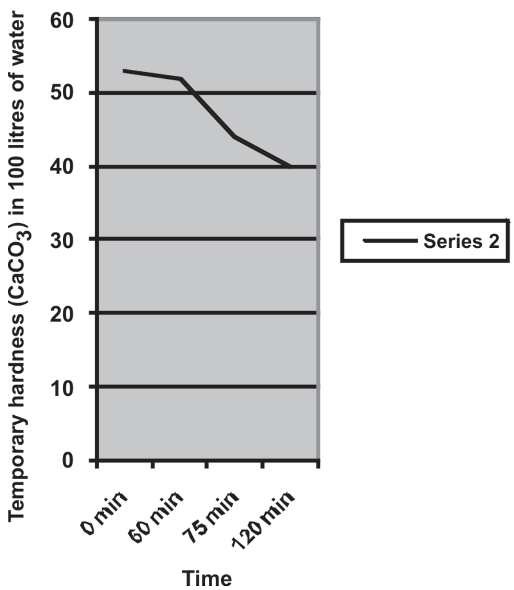

Figure 2: Hardness of S_3 water sample treated with 1 g bentonite sample RB_3 for different intervals of time.

Table 2: Hardness of S_3 water sample treated with 1 g bentonite sample RB_6 for different intervals of time

Sample No.	*Time initial*	*60 min*	*75 min*	*120 min*
RB_6 (1g) +0.1L water sample S_3	53 g	52 g	50 g	43 g

Table 3 and Figure 4 show the hardness of water sample S_3 after treatment with 1 g, 2 g and 3 g of bentonite. With a dose of 1 g bentonite RB_6 upto 60 min, the hardness is 53 g/100 litre and it decreases to 38 g/100 litre with 3g of bentonite.

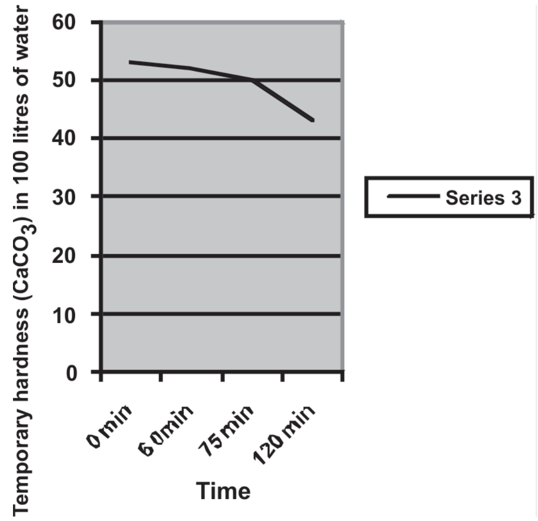

Figure 3: Hardness of S_3 water sample treated with 1 g bentonite sample RB_6 for different intervals of time.

Table 3: Hardness of water sample S_3 after treatment of different dose of bentonite sample RB_6 upto 60 min

Sample No. RB_6+S_3	*1 g*	*2 g*	*3 g*
	53 g	40 g	38 g

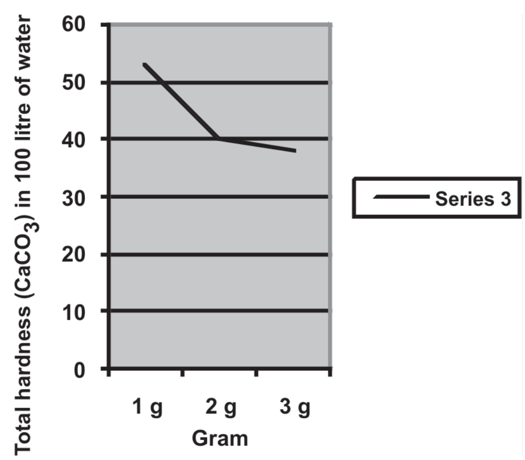

Figure 4: Hardness of water sample S_3 after treatment of different dose of bentonite sample RB_6 upto 60 min.

Table 4 and Figure 5 give the values of Na after treating 0.1 L of water S_3 with 1 g bentonite samples of RB_3 and RB_6 for a time period of 60 min to 120 min. Before treatment with bentonites samples the Na estimation of water sample was 93 ppm. After treatment with 1 g bentonite mineral of RB_3 up to 60 min, Na is 105.6 ppm and with 1 g bentonite mineral RB_6 up to 60 min, Na is 142.1 ppm.

Table 4: Na estimation after different time intervals of bentonite treated sample of water

RB_3 (1g)+S_3	Intial 93 ppm Na	60 min 105.6 ppm Na	75 min 96 ppm Na	120 min 94.6 ppm Na
RB_6 (1g) +S_3	93 ppm Na	142.1 ppm Na	108.9 ppm Na	100.7 ppm Na

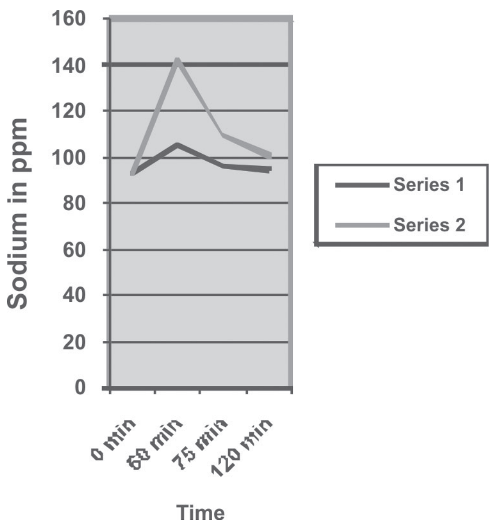

Figure 5: Na estimation after different time intervals of Bentonite treated sample of water.

Bentonites contain a higher proportion of exchangeable cations of sodium and magnesium. In Rajmahal bentonites the exchangeable cations are Na+, K+, Mg^2+ and Ca^2+. Most of the samples of bentonite contain bivalent exchangeable ions. The increased amount of Na in the bentonite treated sample clearly indicates that it has exchanged with the calcium ion of water sample. The exchange of calcium ion of hard water with bentonite is maximum in 120 min. When the dose of bentonite mineral is increased to 3 g per 0.1 L of water sample S_3 upto 60 min, the hardness drops from 53 g/100 litre to 38 g/100 litre due to exchange of calcium ion.

Na estimation after a dose of 1 g RB_3 bentonite in 120 min is 94.6 ppm and with a dose of 1 g RB_6 bentonite, Na is 100.7 ppm. This is clearly greater than 93 ppm Na of water sample S_3. This shows that the exchange of calcium of water has taken place with Na. This exchange may be with potassium also.

Conclusion

The clay minerals have been found to contain anions and cations in the exchangeable state. The exchange reaction does not affect the silica alumina sheet because exchangeable ions are held outside the silica alumina clay mineral structural unit.

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