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Chemical Composition and Molecular Formula of Rajmahal Bentonite (Jharkhand)

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Twenty six samples of bentonite of Rajmahal hills (Jharkhand) were studied for their percentage composition of constituents such as SiO_2, Al_2O_3, Fe_2O_3, TiO_2, P_2O_5, Na_2O, MgO, CaO and K_2O. These samples were collected from different places and available in different colours from Rajmahal hills. These samples contain high percentage of silica with lower limit of 34.64 % and higher limit of 56.24 % was comparable well with the literature values. Theoretical molecular formula was calculated and presented as $(Si_aAl_b)(Al_cFe_dMg_e)Ca_fNa_gK_hO_{10}(OH)_2$ where a = 2.57-3.57, b = 0.42-1.43, c = 1.14-1.67, d = 0.10-0.56, e = 0.01-0.53, f = 0.03-0.48, g = 0.12-1.23 and h = 0.03-0.53. The theoretical formula of bentonite minerals of Rajmahal hills are reported for first time in literature.

Key Words: Bentonite, Rajmahal bentonite, Analysis, Theoretical formula.

INTRODUCTION

From the survey of the literature, it appears that little attention has been paid for the bentonite minerals of Rajmahal hills in Jharkhand. Siddique and Bahl[1], Balu and Thomas[2] gave some information regarding the deposits of bentonite in Jharkahand erstwhile in Bihar but not gave detail. Raja Rao[3] pointed out about the occurrence of bentonite near Rajmahal. Chaliha[4] discussed the suitability of Bihar bentonite as bleaching clay. Guha and Sen[5] and Bishui and Prasad[6] have discussed the mineralogical and chemical aspects of these bentonite but only to some extent. Rajmahal hills in old Santhal Parganas distt. in Jharkhand have got vast deposits of bentonite minerals[7] which have not received adequate attention from the point of the view of their chemical compositions and theoretical molecular formulae. There are limits of indications in literature[1] about a few of these bentonite but for the reasons not known these bentonite have not been studied thoroughly. It is worthwhile to mention here that in past geological surveys of India collected few samples from mines available near the Railway stations such as Bakudih, Taljahri, Tinpahar on the Sahibganj loop line of eastern railway. But the different grades and different coloured samples from the remote part of the hills were not taken for the studies.

In view of the growing importance and industrial utility of the bentonite minerals, it was proposed to analyze the large number of bentonite samples of Rajmahal belt in order to get the chemical composition of these samples for determination of theoretical molecular formulae.

EXPERIMENTAL

Twenty six samples of Rajmahal bentonite were collected and coded SRHB meaning Santhal Pargana Rajmahal Hill bentonite. The percentage of constituents was determined by following standard methods followed by Ambi *et al.*[9-15]. The correctness of the readings was substantiated by each other. The data of the percentage analysis of the constituents are presented in Table-1. These percentage data of the constituents of bentonite were used for the calculation of theoretical molecular formula of the sample.

RESULTS AND DISCUSSION

On examining the data presented in Table-1, it may be noted that the Rajmahal bentonite contains high percentage of silica and the variation of the percentage maintaining the lower limit of 34.64 % and higher limit of 56.24 %. These data are comparable with some known data for the bentonite in USA, Canada and some states of India (Table-2). Certain samples such as

TABLE-1
CHEMICAL COMPOSITION IN PERCENTAGE OF BENTONITE MINERALS OF RAJMAHAL HILLS

S. No.	Name of place	Code number	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_3	MnO_2	Na_2O	MgO	CaO	K_2O
1	Bakudih	SRHB -1	54.85	26.82	2.07	1	Tr	–	1.36	2.86	3.9	0.46
2	Bakudih	SRHB -2	52.75	24.64	3.02	1.6	Tr	0.4	1.02	3.56	2.86	0.84
3	Mandali Mirjachaunki	SRHB -3	35.67	33.06	4.32	1.3	Tr	0.2	1.32	2.75	6.3	0.42
4	Baldhatri Mirjachaunki	SRHB -4	44.19	22.75	8.02	2.4	Tr	0.25	5.84	1.02	1.6	4.32
5	Bakudih	SRHB -5	45.62	24.62	7.62	1.9	Tr	0.43	4.02	0.32	3.02	4.42
6	Bakudih	SRHB -6	40.32	32.52	8.59	1.62	–	0.52	5.12	0.48	1.56	3.92
7	Motijharna Bangla Maharajpur	SRHB -7	42.53	26.98	4.35	1.52	–	0.45	3.56	1.26	1.23	5.58
8	Simaljuril (Bangla Taljhari)	SRHB -8	40.23	28.76	7.49	–	0.01	0.1	7.2	0.9	1.94	0.46
9	Bakudih	SRHB -9	46.48	26.52	6.8	2.4	–	0.14	4.6	0.16	0.48	1.96
10	Bhut bangla East of Mirjachaunki	SRHB -10	34.64	28.94	7.01	2.36	–	0.16	0.85	4.62	5.62	1.23
11	Madhyo bari pahar west to banjhi	SRHB -11	56.24	18.98	3.65	1.07	–	0.52	5.55	0.64	6.53	0.38
12	Kusma phatak (Kotal pokhar)	SRHB -12	–	23.04	6.49	1.5	–	0.2	6.62	3.02	3.06	0.56
13	Madhyo bari pahar west to banjhi	SRHB -13	–	19.18	–	1.4	–	0.1	1.33	3.52	3	0.25
14	Balbhadri	SRHB -14	43.52	31.62	7.66	1	–	0.5	2.48	4.23	3.15	0.46
15	Garara pahar west to Mirjachaunki	SRHB -15	42.37	22.93	7.84	1.2	–	0.22	6.26	1.86	1.68	0.48
16	Ranidih west to Mirjachaunki	SRHB -16	42.58	30.64	6.52	1.35	0.05	0.25	3.59	1.46	0.68	3.68
17	Pakur	SRHB -17	44.35	31.52	6.56	1	–	0.2	4.23	0.52	0.54	4.56
18	Brindavan Behra	SRHB -18	38.46	33.83	5.04	0.95	–	0.11	7.6	0.54	1.3	2.68
19	Brindavan-1	SRHB -19	37.32	30.02	10.06	2.5	–	0.15	8.96	2.46	2.3	1.02
20	Brindavan-2	SRHB -20	38.12	29.05	7.02	0.86	–	0.3	7.46	2.52	1.82	2.03
21	Brindavan-3	SRHB -21	48.76	24.56	3.62	1.52	–	0.42	6.89	1.8	2.62	3.05
22	Sihli mines 2	SRHB –22	–	–	4.33	2.4	–	0.25	2.36	2.35	6.46	0.36
23	Kani-2	SRHB -23	50.82	21.5	8.05	1.05	0.07	0.15	7.25	1.2	2.45	1.38
24	Kirtania Mirjachaunki	SRHB -24	43.27	25.62	4.25	1.08	0.05	0.36	9.11	0.28	9.56	2.93
25	Banjhi-1	SRHB -25	52.37	20.41	4.79	2.25	–	Tr	9.44	0.94	0.9	1.05
26	Banjhi-2	SRHB –26	47.76	27.3	2.4	2.6	–	Tr	1.56	2.54	2.78	0.36

SRHB-3, 10, 18, 19 and 20 contain silica less than 40 %. These data (Table-2), comparable with the data (Table-1) proved authenticity in establishing the nature of bentonite from different places.

The percentage of alumina in Rajmahal bentonite samples varied from 18.98 % to 33.06 %. Some of the samples such as SRHB-3, 6, 14, 16, 18 and 19 contain alumina more than 30 %. The percentage of alumina in yellow stone of USA, California samples, Rosalind Alberta sample, Akli (Barmer) sample, Bhimbar sample and Kutch sample are 19.78, 12.76, 15.44, 19.40, 17.00, 18.78 %, respectively whereas the percentage of alumina content in Gujarat and Bihar is 29.39 and 28.08 %, respectively. It is clear that some of the samples of Rajmahal hills are richer in alumina content as compared to other known samples of the world. These bentonite are considered as low grade aluminum minerals. It is supported by the analytical data of bauxite mineral in Rajmahal hill (Durgatola to Singharsi) in Table-3 meaning Rajmahal hills contain bauxite associated with low grade clay mineral of aluminum.

The silicon dioxide and aluminum oxide ratio varies from 1.07 to nearly 2.0 except in the case of SRHB-11 and 25 where this ratio is slightly higher as 2.96 and 2.56, respectively, for yellow stone of USA is 3.03, for California USA is 4.60, for Barmer sample is nearly 2.90, Bhimbar sample is 3.0, for Gujarat sample is 1.90, for Kutch sample is 2.90 and Bihar sample is 1.70. The ratio of Al_2O_3 to Fe_2O_3 varies from 2.67 to 6.78. This ratio maintains the high values of 12.95 in the case of SRHB-1 and in the case of SRHB-2 it is 8.15 and in case of SRHB-26 it is 11.37.

TABLE-2
PERCENTAGE COMPOSITION OF BENTONITE FROM LITERATURE[1,2]

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O
Harwecha	47.82	15.88	9.8	1.34	2.4	2.23	0.8	2.29
Hati Singh Ki dhani	50.86	20.99	7.2	1.32	Tr	3.04	0.56	1.13
Akli Giral	47.25	18.27	9.54	1.24	1.07	1.41	0.96	1.75
Akli Thumbli Giral	57.35	16.98	7.34	1.28	1.54	1.54	1.55	1.2
Thumbli Akli	49.99	20.11	6.79	1.34	0.68	1.23	0.82	3.24
Bisala	46.38	25.15	8.4	1.7	tr	Tr	0.56	1.46
Bhadres	45.77	19.06	12.6	2.19	Tr	3.11	0.81	1.23
Mahwar	41.12	19.58	12.6	1.74	1.16	2.46	0.8	1.16
USA	59.92	19.78	2.96	2.96	0.64	1.33	0.57	2.06
Canada	53.96	15.44	1.31	1.31	0.8	6.99	0.54	–
Akli	54.9	19.4	6.8	6.8	0.2	–	0.9	2.1
Jammu and Kashmir	52.4	17	1.8	1.8	1.9	1.3	–	2.51
Kutch	51.56	18.75	14.34	14.34	3.76	2.47	–	–
Gujrat	50.42	29.39	6.06	6.06	1.95	1.32	–	–
Bihar	51.18	28.08	5.32	5.32	2.26	1.54	9.42	1.3
California	58.83	12.76	5.9	5.9	1.21	3.39	1.65	0.91

TABLE-3
ANALYSIS OF DATA OF BAUXITE MINERAL IN RAJMAHAL HILLS

Place	Al_2O_3 (%)	SiO_2 (%)	TiO_2 (%)	Fe_2O_3 (%)	Loss on ignition (%)
Singarsi	49.55	1.53-187	3.5	7.182-18.75	25.3
Mitojharna	52.15*	1.55	1.65	18.5	26
Durgatola	46.63	2.78	3.87	20.4	25.59

*This has confirmed the earlier findings of Dr. Bivekanand Mishra.

The silicon dioxide and ferric oxide ratio ranges from 3.52 to nearly 11.0 except for SRHB-1, 2, 11, 21, 26. The values are, respectively 26.49, 17.46, 15.40, 13.40 and 19.88, high value. In the case of samples SRHB-1,2 and 26 the ratio of Al_2O_3 to Fe_2O_3 is also very high. These samples contain titanium dioxide from 1.00-2.40 %. The reported values of titanium dioxide content in Bihar bentonite are 1.59, 2.04 and 2.65 %[5,6]. Small range of variation is present in almost all the samples of bentonite from different parts of the world[16-20]. These bentonite samples under study do not contain titanium dioxide in the abnormal range as compared to other bentonite whether Indian or bentonite from other parts of the world.

The percentages of sodium oxide, potassium oxide, calcium oxide and magnesium oxide have also been reported and may be compared with the literature values in Table-2. On the basis of the amount of alkali and alkaline earth metal oxides present in bentonite samples, Rajmahal bentonite may be classified into (a) alkali based bentonite-they are SRHB-4, 5, 6, 7, 8, 9, 11, 15-21, 23-25. (b) Alkaline earth based bentonite-they are SRHB-1, 2, 3, 10, 12, 13, 14, 22, 26. In very small amounts phosphorous was found to be present in SRHB-8,15, 23, 24. Very faint test for phosphorous was given by SRHB-1 to 5. These bentonite are non phosphatic in nature.

Theoretical molecular formula of Rajmahal bentonite: Caillere and Henin[21] calculated the formula from percentage composition of the constituents of the mineral by dividing the percentage of oxide by molecular weight from which the number of oxygen atoms as obtained and is shown in Table-4. The value of n is equal to 11 for idealized bentonite mineral referred to montmorillonite[22]. The molecular formula of these are

TABLE-4
THEORETICAL MOLECULAR FORMULA OF SRHB-1

Chemical analysis	No. of molecules (k)	No. of oxygen atoms (l)	No. of cations (m)	No. of ions in half lattice structure (p = m × n/N)
SiO_2	54.85/60 = 0.9141	1.8283	0.9141	3.5595
Al_2O_3	26.82/102 = 0.2629	0.7888	0.5258	2.0476
Fe_2O_3	2.07/160 = 0.0129	0.0388	0.0258	0.1007
MgO	2.85/40 = 0.0715	0.0715	0.0715	0.2784
CaO	3.96/56 = 0.0707	0.0707	0.0707	0.2752
Na_2O	1.36/62 = 0.0219	0.0219	0.0438	0.1708
K_2O	0.46/94 = 0.0048	0.0048	0.0097	0.0381

N = 2.8250122, n = 11 (No. of oxygen in half lattice structure of the dihydrated mineral n/N = 11/2.8250 = 3.8937. Formula $(Si_aAl_b)(Al_cFe_dMg_e)Ca_fNa_gK_hO_{10}(OH)_2$.

TABLE-5
THEORETICAL MOLECULAR FORMULA OF BENTONITE MINERALS OF RAJMAHAL HILLS

Code No.	a	b	c	d	e	f	g	h
SRHB-1	3.55	0.45	1.59	0.10	0.27	0.27	0.17	0.038
SRHB-2	3.57	0.43	1.53	0.18	0.36	0.20	0.15	0.077
SRHB-3	3.57	1.43	1.57	0.5	0.29	0.48	0.18	0.038
SRHB-4	3.25	0.75	1.22	0.44	0.11	0.12	0.05	0.400
SRHB-5	3.26	0.74	1.33	0.40	0.03	0.23	0.55	0.400
SRHB-6	2.85	1.15	1.56	0.35	0.05	0.11	0.70	0.550
SRHB-7	3.16	0.64	1.52	0.24	0.14	0.09	0.51	0.530
SRHB-8	2.92	1.08	1.37	0.40	0.10	0.15	0.15	0.042
SRHB-9	3.32	0.68	1.15	0.36	0.01	0.03	0.63	0.180
SRHB-10	2.66	1.34	1.28	0.40	0.53	0.46	0.12	0.120
SRHB-11	3.88	0.12	1.42	0.18	0.60	0.18	0.74	0.033
SRHB-14	2.28	1.12	1.35	0.33	0.42	0.22	0.77	0.290
SRHB-15	3.18	0.82	1.20	0.44	0.20	0.12	0.91	0.230
SRHB-16	3.01	0.99	1.56	0.34	0.15	0.06	0.49	0.530
SRHB-17	3.05	0.95	1.44	0.53	0.05	0.76	0.56	0.400
SRHB-18	2.78	1.22	1.57	0.27	0.06	0.10	1.07	0.190
SRHB-19	2.64	1.36	1.14	0.56	0.26	0.17	1.23	0.092
SRHB-20	2.80	1.20	1.31	0.38	0.27	0.14	1.06	0.190
SRHB-21	3.57	0.63	1.36	0.18	0.18	0.90	0.92	0.260
SRHB-23	3.65	0.35	1.22	0.37	0.11	0.16	0.37	0.100
SRHB-24	3.12	0.88	1.29	0.22	0.03	0.35	1.27	0.269
SRHB-25	3.63	0.37	1.29	0.24	010	0.66	1.26	0.093
SRHB-26	3.39	0.61	1.67	0.12	0.24	0.21	0.21	0.320

recorded in Table-4. The general theoretical structural formula of half unit cell structure of bentonite minerals of Rajmahal hills may be written like $(Si_aAl_b)(Al_cFe_dMg_e)Ca_fNa_gK_hO_{10}(OH)_2$ where a = 2.57-3.57, b = 0.42-1.43, c = 1.14-1.67, d = 0.10-0.56, e = 0.01-0.53, f = 0.03-0.46, g = 0.12-1.23 and h = 0.03-0.53. While calculating the theoretical molecular formula of bentonite, the percentage of titanium oxide was not taken into consideration because the main constituent of bentonite is montmorillonite of which titanium dioxide is not the constituent part[12,13]. The structural formula of tinpahar clay has been given as $(Si_aAl_b)^{IV}(Al_cFe_dMg_e)^{II}O_{20}(OH)_4$. a = 6.31, b = 1.69, c = 4.05, d = 0.18, e = 0.22.

Tinpahar is a Railway station of Sahibganj loop line of Eastern Railway going to Howrah from where a branch Railway line runs to Rajmahal situated on the bank of Ganga river. There is a place near this station which is known as Brindavan. The samples collected from Brindavan have been coded as SRHB-18-21. The maximum value of 'a' for silicon atom in the theoretical molecular formula of half unit cell is 3.37 which is nearly half of a = 6.31 as reported in the above formula of the bentonite clay. The combined value for 'b' and 'c' for Brindavan sample is not more than 3.0 whereas the reported value in the case of tinpahar sample is nearly 6.0. This is double of the value reported by us for half unit cell.

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REFERENCES

1. H.N. Siddique and D.P. Bahl, Memoirs of the Geological Survey of India, p. 96 (1965).
2. B.K. Satyabrat and K.T. Thomas, Transformation of Naturally occurring Intersterified Radioactive Waste", BARC (1971).
3. Raja and C.E. Rao, *Rec Geol. Surv. Ind*., **87**, 72 (1953).
4. B. Chaliha, *Sci. Cult*., **21**, 161 (1955).
5. S.K. Guha and S. Sen, *Trans. Ind. Chem. Soc*., **20**, 73 (1961).
6. B.M. Bishnui and R. Prasad, *Bull. Cent. Glass Ceram. Res Inst*., **7**, 11 (1960).
7. K.L. Bhola, *Quart J. Geol. Min. Met. Soc. (India)*, **19**, 55 (1947).
8. A.I. Vogel, Textbook of Quantitative Inorganic Analysis, edn. 3.
9. S. Ambi, M.Tech. Dissertation, Indian Institute of Technology, Delhi , India(1977).
10. S. Ambi, N.K. Jha, M.M. Prasad and B. Mishra, *J. Indian Chem. Soc.,* **54**, 1077 (1978).
11. N.K. Jha, B. Mishra and M.M. Prasad, *Ind. Courier*, **8**, 1 (1976).
12. J. Choudhary, Ph.D. Thesis, T.M. Bhagalpur University, India (1985).
13. B.K. Mishra, Ph.D. Thesis, T.M. Bhagalpur University, India (2001).
14. S.S. Mishra, Ph.D. Thesis, S.K.M. University, India (2008).
15. A.K. Jha, Ph.D. Thesis, S.K.M. University, India (2011).
16. C.W. Davis and H.C. Vacher, US Bur. Mines, Tech. Paper No. 609, 88 (1940).
17. S. Krishnaswamy, Indian Mineral Resources, Oxford and B.H. Publications Co., New Delhi, edn. 2 (1979).
18. B.C. Ray, *Mem. Geo. Surv. Ind*., **86**, 55 (1957).
19. K.L. Bhola, *Quart. Jour. Min Met. Soc. India*, **19**, 55 (1947).
20. P.K. Ghos, *Bull. Nat. Inst. Sci. Indian*, 101 (1952).
21. S. Caillere and S. Henin, Mineralogic Des. Agrles Masson et. Cis. Pana., p. 151 (1963).
22. N.K. Jha, Private Communication, August, Chemistry Department, IIT Delhi (1982).