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FTIR and XRPD Studies for the Mineralogical Composition of Jharkhand Bentonite

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ABSTRACT

Twenty three samples of bentonite were surveyed and collected from the different parts of Jharkhand hills particularly Sahibganj, Dumka, Godda, Deoghar, Lohardagga and Daltaganj for their studies to trace out good quality bentonite having commercial values. For the first time, Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Powder Diffraction (XRPD) analysis of bentonite samples from hills of Jharkhand were undertaken to obtain their mineralogical composition. The FTIR and XRPD analysis indicates that all the samples contain high quantity of Montmorillonite and hence are good quality bentonite, except for two samples, one from Daltaganj and another from Dumka. Most of these samples have been found to contain Kaolinite and traces of Quartz along with Montmorillonite.

Keywords: Bentonite, Jharkhand, FTIR, XRPD, Mineral Composition, Montmorillonite

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INTRODUCTION

Bentonites are important for numerous industrial applications like chemical and oil industry and environmental protection [1]. According to their origin and genesis different bentonites are distinguished depending on the way of geological formation, the chemical and mineralogical composition, especially Montmorillonite content, particle size distribution, specific surface area, cation exchange capacity, acid–base properties of the edge sites, swelling, and adsorption and migration rate of different substances. Thus knowledge of these properties is important with respect to their application and price. The present study deals with the investigation of mineralogical composition of bentonite samples collected from the different parts of Jharkhand hills.

Scanty literature [2-8] is available regarding the quality of vast deposits of bentonite in the hills of Jharkhand. Arushi Gupta *et. al*. have shown that the bentonite from Rajmhal hill are good quality bentonite [9-11] and can be used commercially, as a suitable alternative for low cost methods of removal of fluoride from water, particularly, potash alum used in the well-established Nalgonda method. Comprehensive study has been undertaken to determine the quality of bentonite from hills of Jharkhand so that it can be used to provide potable water to rural population of the region. It involved extensive survey, sample collection and analysis of bentonite from different parts of Jharkhand hills particularly to Sahibganj, Dumka, Godda, Deoghar, Lohardagga and Daltaganj.

EXPERIMENTAL

Twenty three samples were collected after thorough survey in the hills of Jharkhand under the team leader Dr. Shashi Shekhar Singh (Geology Department, M.S. College, Bhagalpur) along with team members Dr. Vats Amitabh (Rajoun, Banka) and Dr. Babita Kumari (Mahila College, Godda). The samples were prepared and packed as per the methods reported in literature earlier [12]. The samples were marked AB (Arushi Bentonite) and were analysed using Fourier Transform Infra Red (FTIR) spectroscopy and X-Ray Powder Diffraction (XRPD).

Perkin Elmer Spectrometer Spectrum One instrument in Sophisticated Analytical Instrument Facility (SAIF) at IIT Chennai was used for undertaking FTIR analysis. The technique involved drying the samples and mixing the solid residue with potassium bromide (KBr) to form a homogeneous powder, which was then compressed into a solid pellet. The pellet was placed in a sample holder where it was scanned by Infrared Radiation (IR) to yield a pattern of the beam transmitted through the sample from 400 to 4000 cm^{-1} at resolution of 4 cm^{-1}. Table 1 gives the details of observed peaks on Bentonite and their significance from literature [13]. Table 2 lists out the peaks observed in different samples. The FTIR spectrum of few samples is given in Figure 1.

The mineral composition was analysed using XRPD. XRPD patterns were taken at ambient temperatures by the use of a Phillips XPRT Pro Powder X Ray Diffractometer at

Sophisticated Analytical Instrument Facility (SAIF) at Gauhati University. It is equipped with Cu anode ($K_{\alpha1}$ λ = 1.54056 Å, $K_{\alpha2}$ λ = 1.54439 Å, $K_{\alpha1}$ / $K_{\alpha2}$ = 0.5; 40 KV and 30 mA). The scanning rate was 2° (2θ) min^{-1} ranging from 4° to 90°. The mineral composition is calculated on the basis of the relative intensity rates of the reflection characteristic to the minerals, applying the literature or experimental corundum factors on minerals. The XRPD pattern of few samples are given in Fig. 2.

Table 1 Characteristic Wave number of peaks in FTIR spectrum of Bentonite

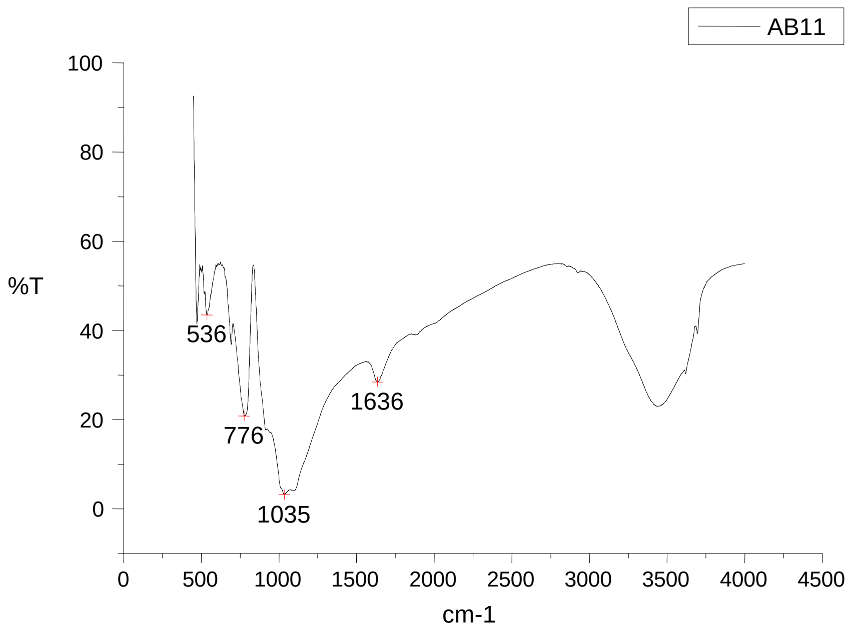
S No	Wave Number	Type of Curve	Type of Bond
1.	3600- 3700 cm^{-1}	Strong band	Structural OH group (multiple bands) Al-OH-Al
2.	3622 -3632 cm^{-1}	Single sharp band	O-H stretching, (Mg, Al)-OH
3.	3446-3448 cm^{-1}	Broad band	OH stretching of structural hydroxyl groups and water
4.	1640 cm^{-1}	Peak	OH deformation mode of water
5.	1024-1043 cm^{-1}	Strong band	Si–O stretching (in-plane) vibration
6.	916 - 918 cm^{-1}	Peak	Deformation of OH linked to $2Al^{3+}$
7.	875-885 cm^{-1}	Peak	Deformation of OH linked to Fe^{+3} and Al^{3+}
8.	839 – 850 cm^{-1}	Peak	Deformation of OH linked to Al^{3+} and Mg^{2+}
9.	778 - 791cm^{-1}	Band	quartz
10.	620cm^{-1}	Band	Al-O and Si-O (out of plane) coupled bond
11.	524cm^{-1}	Band	Al-O-Si group deformation mode
12.	466 - 470cm^{-1}	Peak	Si-O-Si deformation

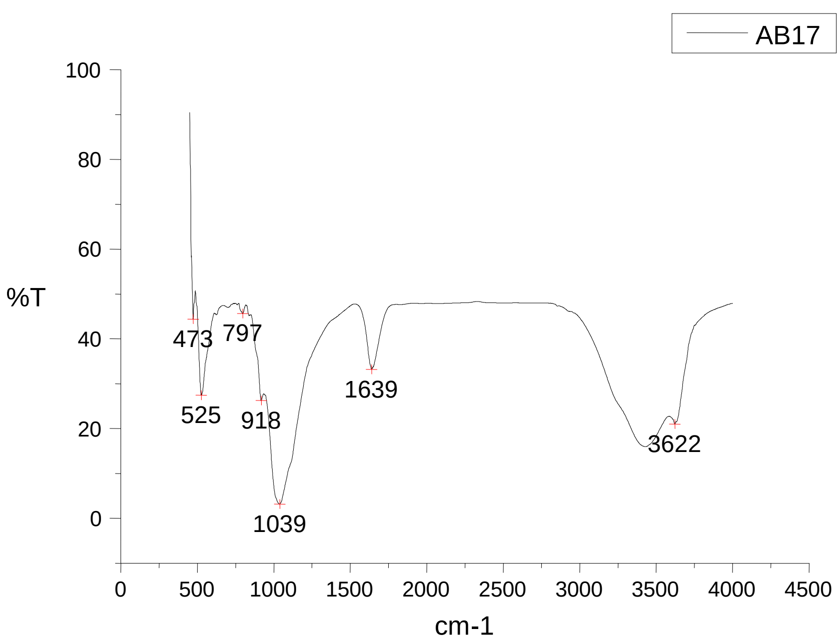
Table 2 Observed wave numbers in FTIR spectrum of Bentonite from Jharkhand Hills

S No	Wave Number (Literature Values) (cm^{-1}) →		466	524	620	793, 778, 692	791	850	885	913	1050	1640	3446	3632	3695
	Sample Code	Place													
1.	AB 1	Bakudih	√	√		√	√			√	√	√	√		
2.	AB 2	Sahibganj	√	√	√	√	√			√	√	√	√	√	√
3.	AB 3	Bakudih	√	√	√	√	√	√	√	√	√	√	√	√	
4.	AB 4	Bakudih	√	√		√				√	√	√	√	√	√
5.	AB 5	Deoghar	√	√		√	√			√	√	√	√	√	√
6.	AB 6	Chitra	√	√			√			√	√	√	√	√	√
7.	AB 7	Jasidih	√	√	√	√	√			√	√	√	√	√	√
8.	AB 8	Dumka	√	√	√	√	√			√	√	√	√	√	√
9.	AB 9	Goddha	√	√	√	√	√			√	√	√	√	√	
10.	AB 10	Sahibganj	√	√		√	√			√	√	√	√	√	√
11.	AB 11	Sahibganj	√	√	√	√				√	√	√	√	√	√
12.	AB 12	Godda	√	√	√	√	√	√		√	√	√	√	√	
13.	AB 13	Daltaganj	√	√		√	√			√	√	√	√	√	√
14.	AB 14	Daltaganj	√	√		√	√			√	√	√	√	√	√
15.	AB 15	Goddha	√	√	√	√				√	√	√	√	√	
16.	AB 16	Goddha	√	√		√	√			√	√	√	√	√	√
17.	AB 17	Dumka	√	√		√	√			√	√	√	√	√	

18.	AB 18	Dumka	√	√		√	√			√	√	√	√	√	√
19.	AB 19	Dumka	√	√		√	√			√	√	√	√	√	√
20.	AB 20	Goddha	√	√	√	√	√			√	√	√	√	√	
21.	AB 21	Daltaganj	√	√		√	√	√		√	√	√	√	√	√
22.	AB 22	Lohardaga	√	√		√	√	√		√	√	√	√	√	√
23.	AB 23	Dumka	√	√		√	√			√	√	√	√	√	√

Fig 1. FTIR Plot AB11, AB17, AB20, AB23





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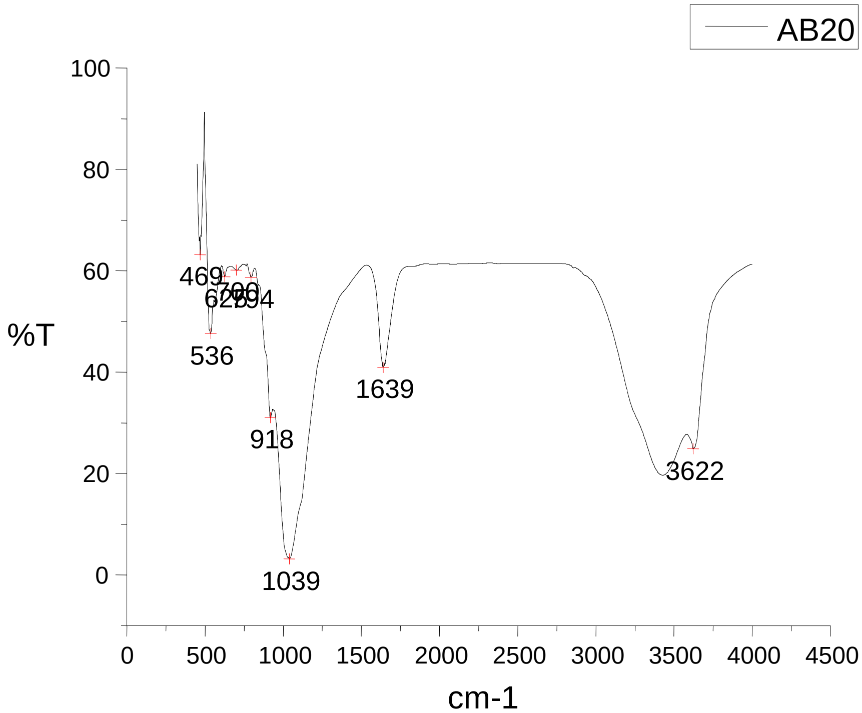

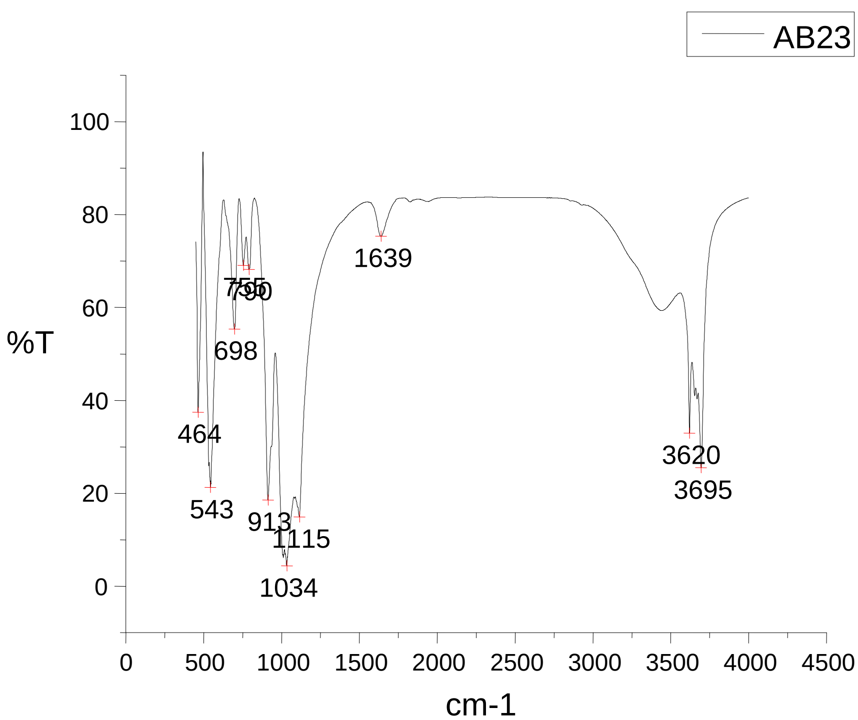

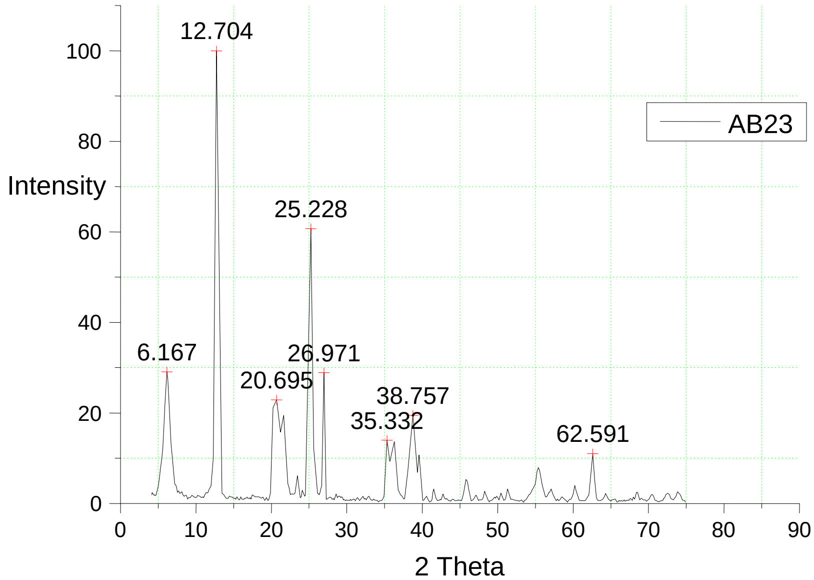
AB23
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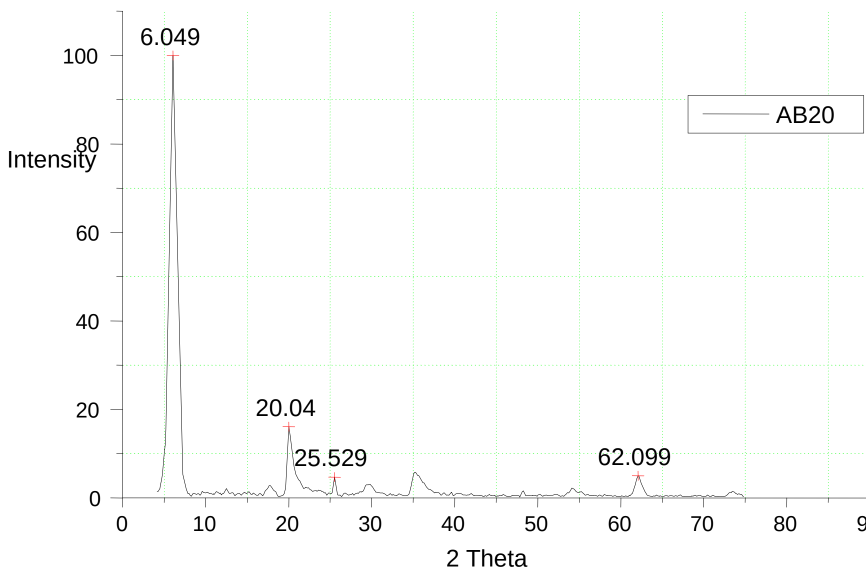
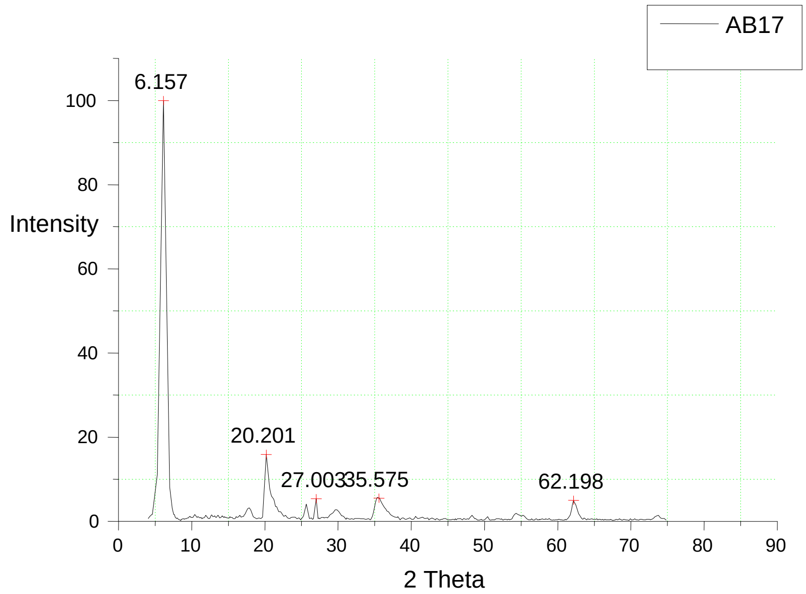
2 Theta
12.704
25.228
6.167
26.971
20.695
38.757
35.332
62.591


AB20
Intensity
2 Theta
6.049
20.04
25.529
62.099



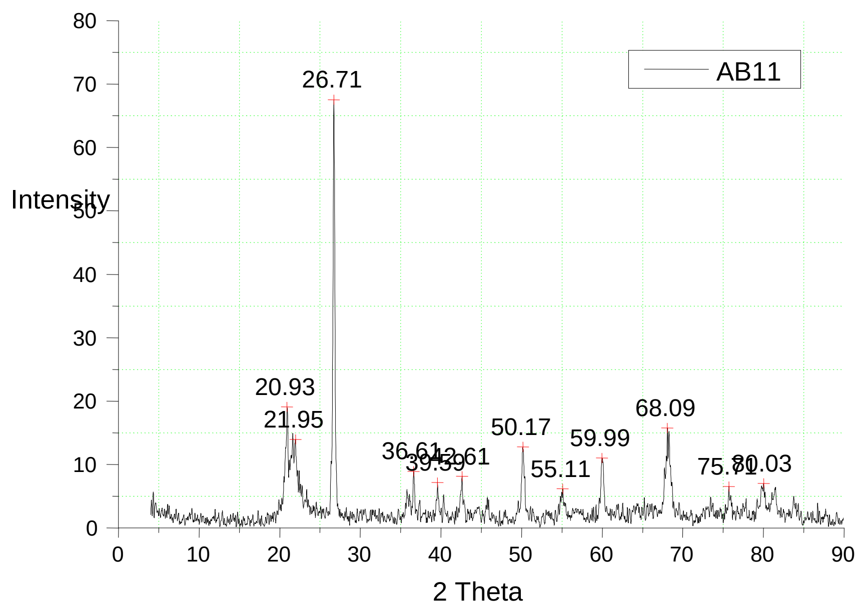


Fig 2. XRD Plot AB11, AB17, AB20, AB23

RESULTS AND DISCUSSION

Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectrum of all the 23 samples showed characteristic of Montmorillonite mineral with a single sharp band at 3632 cm^{-1}, followed by a broad band at 3446 cm^{-1} for OH stretching of structural hydroxyl groups and water, respectively. Each sample showed absorption peaks in region 3400 cm^{-1} and 1640 cm^{-1} attributed to the OH deformation mode of water. The strong vibration band between 3600 cm^{-1} and 3700 cm^{-1} is correlated to structural OH groups. However, this band is absent in AB12, AB15, AB17, AB20. The absorption range 3700cm^{-1} is due to hydroxyl group in dioctahederal mineral each pair of Al^{3+} ions has two hydroxyl groups which are related by centre of symmetry between Al^{3+} ions. Farmer and Russel [14] stated that coupling between the vibrations of the two hydroxyl groups can give two frequencies of vibrations in which the two OH groups are out of phase (IR center) and in phase vibrations (IR inactive).

In the lower frequency region, all samples showed a strong band at 1024-1050 cm^{-1} for Si-O stretching (in-plane) vibration of layered silicates, characteristic of Montmorillonite. IR peaks between 916-918 cm^{-1} is attributed to deformation of OH linked to $2Al^{3+}$ (Al-OH-Al or Al-Al-OH) was observed in all samples. AB3, AB12, AB17, AB18, AB19, AB20, AB21, AB22 showed IR peaks between 839-850 cm^{-1} attributed to deformation of OH linked to Al^{3+} and Mg^{2+} (Al-OH-Mg). All samples showed the 467-469 cm^{-1} band indicating Si-O-Si deformation, and the band at 524 cm^{-1} corresponds to the deformation mode of Al-O-Si group. The 620 cm^{-1} band is a coupled Al-O and Si-O (out-of-plane) bond which was present in samples AB7, AB8, AB9, AB11, AB12, AB15, and AB20. Presence of small quantity of quartz in all samples indicated by the bands at 778 cm^{-1} and 791 cm^{-1}[15].

X-Ray Powder Diffraction (XRPD)

The results of XRPD of 23 samples have been compared with the reported values in the literature and are summarized in Table 3. All the samples except AB7 and AB11 show presence of Montmorillonite as major constituent. AB1, AB3, AB14 and AB16 contain Montmorillonite along with Quartz and Kaolinite which is indicated by d spacing peaks of 100% intensity at 5.83, 26.66 and 12.34 respectively. AB2, AB4, AB10, AB15, AB18, AB19, AB20, AB21, AB22 and AB23 showed a strong peak at d spacing 5.8, 19.72 and 29.57. On comparing the intensities of these peaks with other peaks in the graph it was confirmed that Montmorillonite is the dominant mineral in these samples. AB5 and AB13 showed high intensity peak at d spacing 12.34, 24.86 and 26.66 indicating Kaolinite and Quartz respectively as chief minerals. A low intensity peak at d spacing 54.95 confirmed the presence of Montmorillonite in traces. AB6, AB12 and AB17 contain Montmorillonite and Quartz in dominant amount as compared to Kaolinite which is very less (low intensity peak at d spacing 20.20 in AB6 and AB20). AB12 does not contain Kaolinite as no peak was observed in this region. The d-spacing at 5.8 and 12.34 indicates the presence of Montmorillonite and Kaolinite.

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Table 3: Observed minerals in Bentonite from Jharkhand Hills

Literature Value		M	K	M	M	K	Q	K	M	K	Q	M	Q	Q	Q	M	K	K	K	Q	M	M	Q
Code	**Place**	**5.89**	**12.34**	**17.69**	**19.72**	**20.31**	**20.86**	**21.19**	**23.59**	**24.86**	**26.66**	**29.57**	**36.56**	**39.47**	**50.16**	**53.91**	**56.81**	**57.98**	**57.98**	**59.97**	**61.83**	**62.29**	**68.36**
AB 1	Bakudih	5.53	12.30					21.23	23.53	25.73	27.39	29.77	34.75	41.63	50.85						61.81		
AB 2	Sahibganj	6.09	13.75		19.93			22.93	23.79		27.55	30.07	35.25	41.75	50.91						62.05		
AB 3	Bakudih	6.05	12.39			20.29				24.85	26.65	28.41	35.19	39.57			55.39				61.85		
AB 4	Bakudih	5.85					19.79					29.35	35.61			54.33						62.11	
AB 5	Deoghar		12.31				20.83			24.91	26.63			38.39	50.07	54.95				59.91			68.33
AB 6	Chitra	5.55				20.01		21.39			26.69	28.05	35.29	38.51		54.29					61.97		
AB 7	Jasidih						20.83				26.63		36.51	42.43	50.13					59.95			68.17
AB 8	Dumka	6.01	12.27			20.05				24.87			36.07			54.11					61.39		
AB 10	Sahibganj	5.85	12.30		19.71			21.31		24.97	26.67	28.71		38.29		54.89						62.13	
AB 11	Sahibganj						20.93	21.95			26.71		36.61	39.59	50.17					59.99			68.09
AB 12	Godda	5.87			19.99						26.73	29.19	36.41			53.99						62.17	
AB 13	Daltaganj		12.35			20.41		21.37		24.89	26.67		35.09	38.39		54.93						62.25	
AB 14	Daltaganj	6.37			19.75	20.67				24.93	26.47	28.69	35.87	39.15		54.07						62.07	
AB 15	Goddha	5.96				20.03																	
AB 16	Goddha	6.19	12.59			20.57				25.12	26.89		36.16	38.65									
AB 17	Dumka	6.15				20.20					27.00		35.57									62.19	
AB 18	Dumka	6.45			19.83			22.97			26.20		35.61			53.95					61.71		
AB 19	Dumka	6.03			19.89					24.97		29.07	36.45			54.59					61.97		
AB 20	Goddha	6.04				20.04				25.52											62.09		
AB 21	Daltaganj	6.12	12.62			20.12				25.13	26.83			38.71						60.16		62.44	
AB 22	Lohardaga	6.08	12.63			20.10				25.16	26.31											62.17	
AB 23	Dumka	6.16	12.70			20.69				25.22	26.97		35.33	38.75								62.59	

Legend: M- Montmoillonite, K Kaolinite, Q- Quartz

AB7 and AB11 have a strong peak exclusively at d spacing 26.66 and 36.51 indicating the presence of Quartz. In these samples, it may be concluded from the comparison of the intensities of the peaks of Montmorillonite and Quartz that the main component of bentonite is Quartz, whereas Montmorillonite is present in negligible fractions. Presence of Quartz in these samples is further substantiated by the absorption characteristic obtained in FTIR spectroscopy which gave the characteristic absorption peak at 778 cm^{-1} and another band around 692 cm^{-1} (indicative of Quartz). On comparing the intensities of the peaks it was confirmed that the major constituent of most of Jharkhand hills bentonite are Montmorillonite and Kaolinite while Quartz is negligible.

CONCLUSION

Twenty three samples of bentonite were collected from the different parts of Jharkhand hills after thorough survey, particularly for examining their properties to trace out good quality bentonite having commercial values. The FTIR and XRD analysis indicates that all the samples, except one each from Daltaganj and Dumka contain high amount of Montmorillonite and hence are good quality bentonite. Most of samples have been found to contain Kaolinite and traces of Quartz along with Montmorillonite. Presence of high concentration of Montmorillonite makes bentonite from hills of Jharkhand a suitable contender for applications such as removal of fluoride from water.

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REFERENCES

[1] Nagy NM, Konya J. Applied Clay Science 2005; 28: 257– 267.
[2] Siddique HN, Bahl DP. Memoirs of the Geological Survey of India 1965; 96.
[3] Satyabrat, Balu K, Thomas KT. Transformation of naturally occurring interstratified Radioactive Waste BARC 1971.
[4] Raja Rao. Rec Geol Surv Ind 1953; 87(1): 72.
[5] Chaliha B. Sci Cult 1955; 21: 161.
[6] Guha SK, Sen Sudhir. Trans Ind Chem Soc 1961; 20: 73-87.
[7] Bishnui BM, Prasad R. Bull Cent Glass Ceram Res Inst 1960; 7: 11-28.
[8] Bhola KL. Quart Jour Geo Min Met Soc Ind 1947; 19: 55-77.
[9] Gupta A, Kumar M, Jha AK, Mishra BK, Choudhary J, Mishra B. Asian Journal of Chemistry 2011; 23(12): 5491-5494.
[10] Gupta A, Kumar M, Choudhary J, Mishra B. Communicated to Indian Chemical Society 2013.
[11] Gupta A, Amitabh V, Kumari B, Mishra B. IOSR Journal of Applied Chemistry 2013; 4(4): 42-46
[12] Choudhary J. PhD Thesis T.M Bhag. Univ. 1985.
[13] Madejova J, Komadel P. Clays and Clay Minerals 2001; 49(5): 410–432.
[14] Famer VC, Russel JD. Spectro chim Acta 1964; 20: 1149-1173.
[15] Marel HWVD, Beutelspacher H. Atlas of infrared spectroscopy of clay minerals and their admixtures, Elsevier Scientific Publishing, Amsterdam, 1976.