Bioremediation of As Polluted Groundwater in Bangladesh ; Part 3 -Ferrisymplesite (Fe3(AsO4)2・6H2o) Formation in Biomates

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Bioremediation of As Polluted Groundwater in Bangladesh; Part 3

-Ferrisymplesite ($Fe_3 (AsO_4)_2{\cdot}6H_2O$) Formtion in Biomats-

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Abstract- Ferrisymplesite ($Fe_3(AsO_4)_2{\cdot}6H_2O$) has been identified in biomats by XRD analysis at around the As polluted tube-well in Hazigonj, Chandpur, Bangladesh. Microorganisms in biomats mainly bacillus, coccus and filamentous types of bacteria play significant role in the transformation of As from water to biomats. Mineralization or immobilization of As is one of the biotransformation processes, that can be used in the detoxification or bioremediation of As - contaminated ground or surface water. The As ion can be fixed in minerals such as ferrisymplesite.

I. Introduction

The synonymous of poison 'Arsenic' is famous for it's carcinogenic, mutagenic and teratogenic characters or some of cardiovascular and neurological effects in human beings [1, 2]. Most of these kinds of disease can eventually be developed in those people, who drink As polluted water [3]. Recently, the evidence of arsenical chronic poisoning has been reported in Bangladesh and has become a serious public health problem [4]. Naturally, the tube-wells are used in Bangladesh for drinking groundwater, which contain a higher concentration of As above the WHO guideline value of 0.01 ppm even the Bangladesh standard 0.05 ppm [5]. Remediation of As in drinking water is still rather limited. Hence, bioremediation processes could be considered for its sustainability in Bangladesh [6]. Since microorganisms can grow and survive in some of the most extreme and adverse environments including high pollution or As rich conditions [7, 8]. Usually microorganisms in biomats could accumulate heavy metals and toxic elements (e.g. Fe, Mn, Cu, Zn, Cd and Pb) in the geo-aquatic environment [9, 10]. Also, it is reported that microorganisms could attenuate As concentration from the groundwater [11], resulting the formation of biominerals [12. 8]. It is one of the processes of detoxification of As in the natural environment [13].

In this study, 'ferrisymplesite' has been identified in biomats, which are produced in front of tube-well.

II. Materials and Methods

Biomats of varieties in color and groundwater samples were collected from 4 main locations ①, ②, ③ and ④ of Hazigonj (23° 15′ N and 90° 50′ E) in Chandpur, Bangladesh on the 2nd Feb, 2001 (Fig. 1). Greasy brown biomats were predominated in front of the tube well at location ① (indicated by an arrow) (Fig. 2).

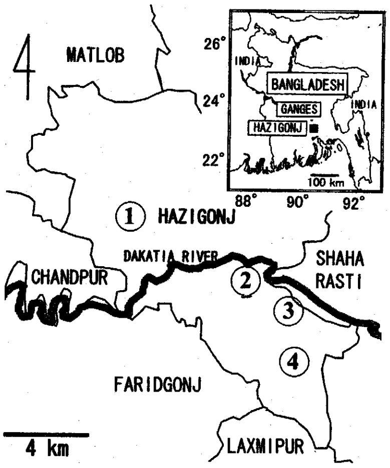

Fig. 1. Locality map of the study area showing sampling points at Hazigonj in Chandpur Bangladesh.

Fig. 2. Greasy brown biomats predominated (arrow) in front of the As - contaminated tube-well at location ① in the sampling locality.

Both of the samples (groundwater and biomats) were analyzed in the laboratory with ED-XRF for the chemical constituent. Although ground waters were tested in the field with Pack test kits by molybdenum blue method for the preliminary determination of As concentration. Besides this, for As concentration in biomats the epithermal Neutron Activation Analysis were also carried out [14]. Additionally, the existence of microorganisms in biomats was confirmed by Optical and Electron microscopic observations with fresh and air-dried powdered samples. SEM-EDX analysis was done for the reconfirmation of elemental concentrations in biomats after coated with carbon. Finally and specially XRD analysis were carried out for the mineralogical identification of biomats, those are predominating in front of the tube - wells at the sampling locality.

III. Results

A high concentration of As has been detected in the groundwater, collected from the 4 selected sampling locations. Those are ranged between 2~3.5 ppm (measured in the field by pack-test) and 0.7~3.5 ppm (in the laboratory by pack-test, after separating phosphate) with the normal and a little elevated pH value (7~7. 4). ED-XRF analysis showed the concentrations of As only in the brown biomat is about 460 times higher than that of groundwater (when water contained 0.01 wt% of As then biomats showed the concentration of 0. 46 wt %). The micro analytical data of Neutron activation analysis confirmed that biomats contain 390 ~ 552 (±1) ppm of As, which is several hundred times higher than that of water contained.

Optical and fluorescent microscopic observation of green brown and gray colored biomtas collected from location ②, ③ and ④ showed the presence of bacillus, coccus and filamentous types of bacteria associated with algal filaments of different sizes (not shown). Furthermore greasy brown biomats of location ① revealed the presence of abundant coccoidal bacteria sized about 2 ~ 4 μm (Fig. 3). DAPI (4', 6-diamidino-2-phenylindole) stained epifluorescent microscopy of greasy brown biomats established the presence of autotrophic and heterotrophic bacteria. The fluorescent blue and red parts indicated that the presence of DNA in coccoidal bacteria, and photosynthetic pigments in photoautophytic bacteria (not shown).

SEM observation showed that the crystalline structures on the surface of greasy brown biomats. EDX analysis (in the selected area) established that the crystalline materials are composed mainly of Fe, P, K and Ca with the traces of Al, Si, S, Ti, Mn, and As, which might be derived from groundwater through the tube-well (Fig. 4).

X-ray diffraction analysis (XRD) of the brown, green and gray biomats from locations ①, ②, ③ and ④ exhibited the diffraction peaks of ferrisymplesite (around 6.69, 3.99 and 3.18 Å) with quartz (3.34, 2.45 and 1.186Å), feldspars (3.17Å) and illite (9.9Å)(Fig. 5).

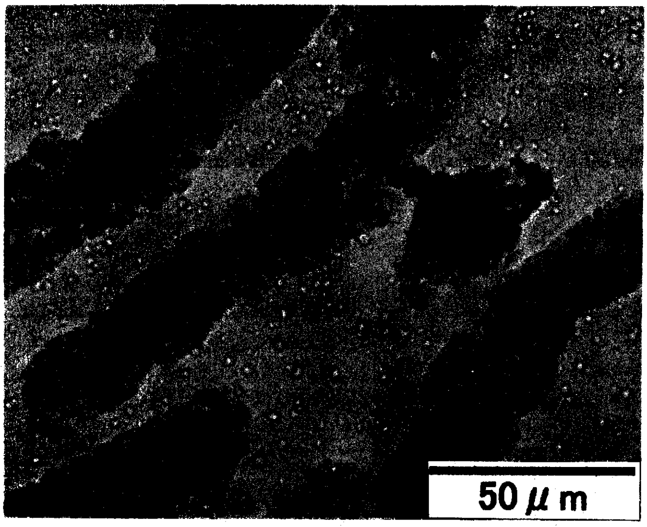

Fig. 3. Optical micrograph of greasy brown biomats collected from location ①, showing the coccoidal colony associated with dense brown materials.

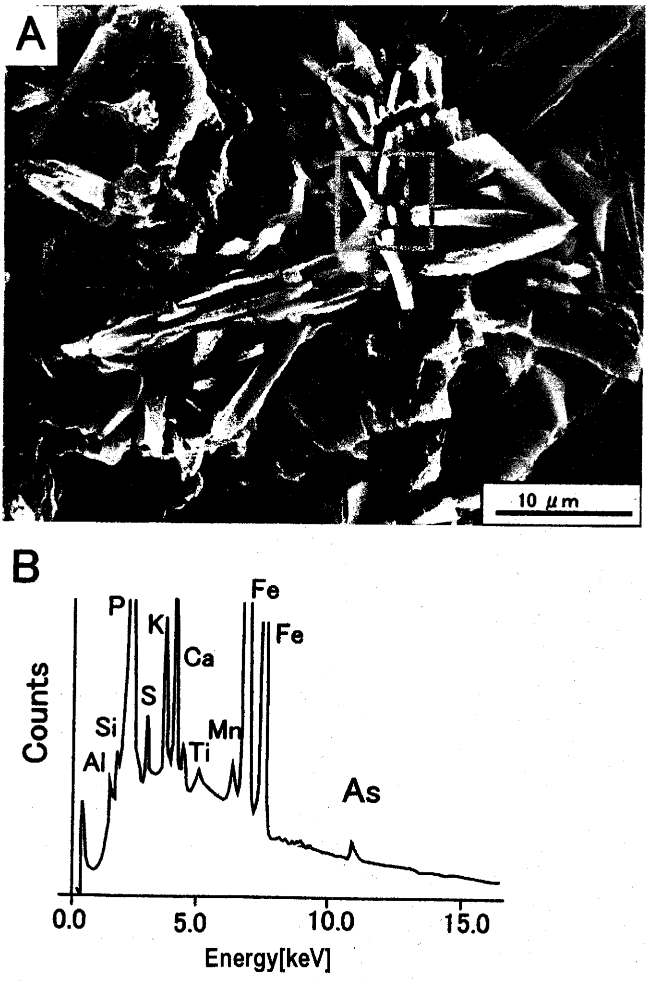

Fig. 4. SEM micrograph of greasy brown biomats collected from location ①, showing the crystalline structures on the surface of biomats (A); EDX spectrum (analytical area) indicates major chemical components of Fe, P, K and Ca with the traces of Al, Si, S, Ti, Mn and As (B).

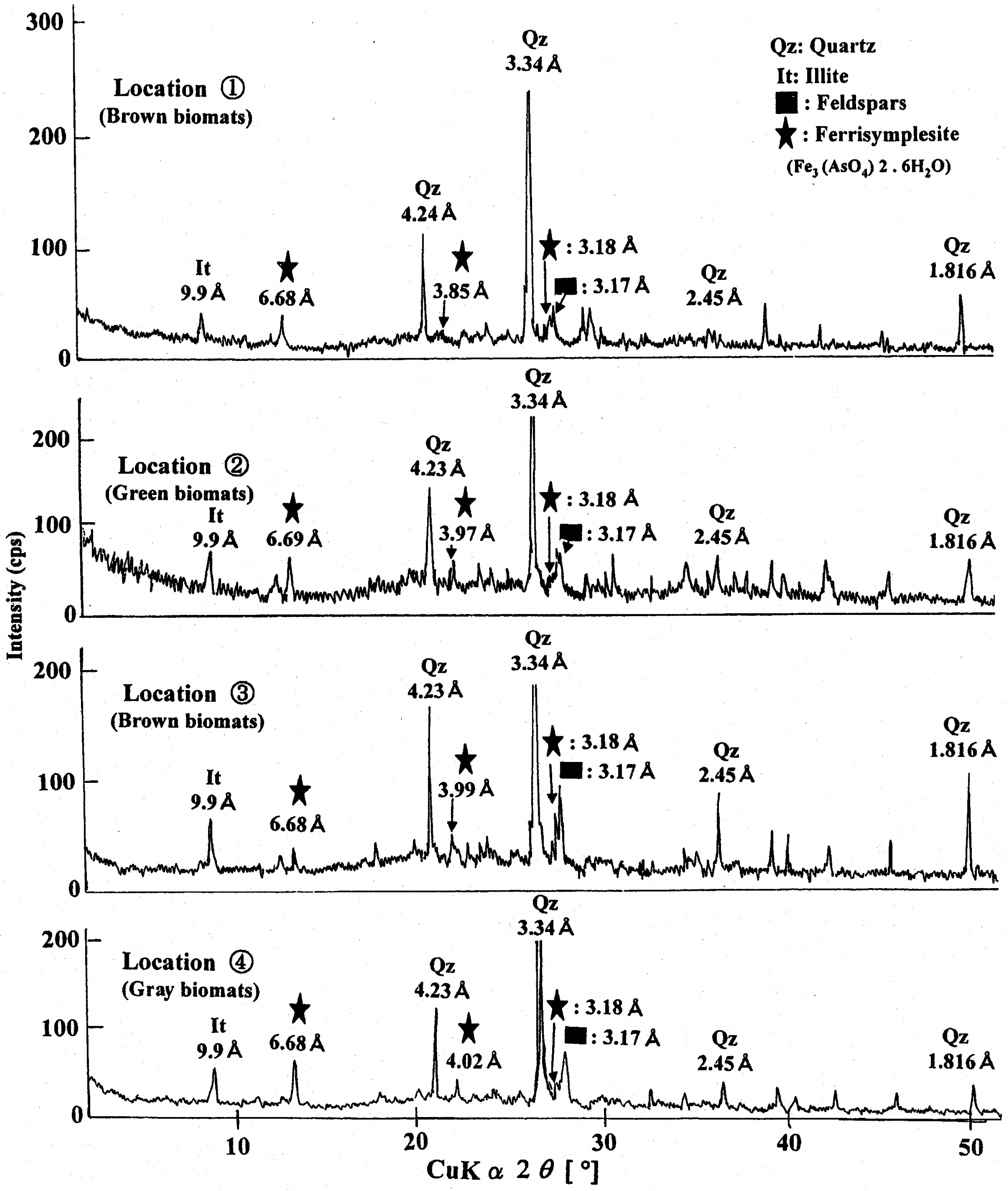

Fig. 5. X-ray powder diffraction patterns of different colored (brown, green, brown and gray) biomats collected from Hazigonj, Chandpur, Bangladesh, showing the peaks of ferrisymplesite around (6.68~6.69), (3.85~4.02) and 3.18Å) with quartz, feldspars and illite.

IV. Discussion

Basing on the results of optical microscopic and SEM observations it revealed that biomats are consisting of autotrophic and heterotrophic bacteria (bacillus, coccus, and filamentous typed) associated with photosynthetic algae those are metabolically active in an As polluted water system and enable to immobilize As. In addition ED-XRF, NAA and XRD analyses confirmed that the As ion could be accumulated in biomats from groundwater and can form biomenerals like ferrisymplesite (Fig. 5). It is ambiguously identified that a group of coexisting microbes are found enable to transport As ions into their cell surface with Fe ions forming biominerals and make them immobilize. The data are in agreement with some work of Nagai et al., who suggested that bacteria in reddish brown biomats could produce lollingite ($FeAs_2$), an arsenic mineral on their cell and intercellular surface [9]. More over, the cell wall of microbes contains more or less proteins, polysaccharides, amines, or polyamines on the microbial surface can interact with metals and metalloids and has been emphasized for binding them [15, 16, 17]

Consequently, it might be considered that microorganisms in biomats could cleanup and rehabilitate the heavy metallic pollution in the geo-aquatic environment [18].

V. Conclusions

Microbes in biomats play an important role for cleaning the As polluted geo-aquatic environment, as having their endurance ability in any toxic or polluted environment. They produce biominerals like ferrisymplesite with As contaminated groundwater and can contribute in the process of detoxification of As, which can be used in any natural aquatic - environment for bioremediation

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References

[1] H. K. Das, *Arsenic in Bangladesh: Severity and probable solution*, Bangla Academy, Dhaka. pp. 296, 2000.

[2] X. C. Le, "Arsenic Speciation in the Environment and Humans," In: Frankenberger, W.T. Jr. (Eds.), *Environmental Chemistry of Arsenic*. Marcel Dekker, New York. pp. 95-116, 2002.

[3] J. Kaiser, "Net watch," *Science*, Vol. 288, p. 1699, 2000.

[4] AAN (Asia Arsenic Network), RGAG (Research Group for Applied Geology), DOEH (Department of Occupational and Environmental Health), NIPSM (National Institute of Preventive & Social Medicine), Bangladesh, *Arsenic Contamination of Groundwater in Bangladesh. Interim Report of the Research at Samta Village*, pp. 90, 1999.

[5] BGS, DPHE, "Arsenic contamination of groundwater in Bangladesh". In: Kinniburgh, D.G., Smedley, P.L. (Eds.), *British Geological Survey (Technical Report, WC/00/19. 4 Volumes)*. British Geological Survey, Keyworth. 2001.

[6] ABM. R. Islam, K. Tazaki, "The Actual condition of arsenic pollution in Bangladesh". *Proceedings of the 108th Annual meeting of the Geol. Soc. of Japan*. p. 39. 2001.

[7] W. S. Fyfe, "The earth science and Society: The needs for the 21st century," *Proc. 30th Int'l. Geol. Congr, 2 & 3*. pp. 147-162, 1997.

[8] K. Tazaki, "Bacterial mineralization in the As-rich environment," *Abstracts of the 18th General meeting of the International Mineralogical Association*, Edinburg, Scotland, p.173, 2002.

[9] K. Nagai, ABM. R. Islam, K. Tazaki, "Bacterial Fe-As mineralization," *The Science Report of Kanazawa University*, Vol. 46, pp. 49-66, 2001.

[10] ABM. R. Islam, K. Tazaki, "Arsenic accumulation in microbial mats from underground water in Bangladesh," *The Science Report of Kanazawa University*, Vol. 45, pp. 1-12, 2000.

[11] ABM. R. Islam, K. Tazaki, R. Asada, "Arsenical pollutants in microbial mats and their contributions on the discharged underground water in Bangladesh," *Proc. of the Joint meeting of the Earth and Planetary Science*. Tokyo, Japan, B006-001, 2002.

[12] K. Tazaki, ABM. R. Islam, K. Nagai, T. Kurihara, "$FeAs_2$ biomineralization on encrusted bacteria in hot springs: An ecological role of symbiotic bacteria," *Canadian Journal of Earth Sciences (inpress)*. 2002.

[13] Jr. W. T. Frankenberger, M. Arshad, "Volatalization of Arsenic" In: Frankenberger, W.T. Jr. (Eds.), *EnvironmentalChemistry of Arsenic*. Marcel Dekker, Inc. New York, pp. 363-378, 2002.

[14] ABM. R. Islam, K. Tazaki, "Bioremediation of As polluted ground water in Bangladesh, Chemical geology (unpublished)

[15] T. Beveridge and R. Murry, "Sites of metal deposition in the cell wall of bacillus subtilis," *J. Bacteriol*. Vol. 141, PP. 876-887, 1980.

[16] T. Beveridge, "Ultrastructure, chemistry, and function of the bacterial wall," *Int. Rev. Cytol*. Vol. 72, pp. 229-317, 1981.

[17] T. Beveridge, "Interactions of metal ions with components of bacterial cell walls and their biomineralization," In poole, R., Gadd, G (Eds.), Metal microbe interactions: Spec. Publ. Soc. *Gen Microbiol*, pp. 65-83, 1989.

[18] K. Tazaki, "Architecture of biomats reveals history of geo- qua-, and bio-systems" *Episodes*, Vol. 22, pp. 21-25, 1999.