Significance of arsenic resistant prokaryotes in climate change perspective

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ABSTRACT: The purpose of this study was to observe symbiotic prokaryotes under the optical and scanning electron microscope for their morphology and multiple roles including arsenic immobilization in the natural environment. Microbial mats proliferating near to the arsenic contaminated (141 to 997 $\mu\text{g L}^{-1}$) tube-wells were collected for this study. The results of microscopic observation showed that the symbiotic prokaryotes in microbial mats were mainly consisting of *Coccus*, *Bacillus*, and *Filamentous* microbes associated with photo-synthetic *Cyanobacteria*; enabling to accumulate high concentrations of As (550 mg kg^{-1}). ED-XRF analysis also confirmed the presence of As in microbial mats associated with Na, Mg, Al, Si, P, S, K, Ca, Ti, Mn, Fe, Zn and Sr. Henceforth, it can be concluded that the symbiotic prokaryotes can play a significant role in enabling to uptake arsenic from tube-well water, and release O_2 in the ambient air simultaneously. Our findings are very encouraging for further research to promote a sustainable mitigation effort for provision of As safe drinking water and a CO_2 reduced safer environment.

1 INTRODUCTION

Arsenic (As) toxicity is a global health problem affecting millions of people through drinking water. Besides global warming is an important factor for climate change due to increasing CO_2 in the atmosphere. Therefore As contamination of ground water and climate change are receiving attentions from global community as important issues of contemporary research for the sake of public health and environmental disaster. Arsenic, the metalloid poses serious health threats for human when it exceeds the WHO guideline value $10 \mu\text{g L}^{-1}$ in drinking water. However, some symbiotic prokaryotes are enabling to obtain energy even in an extreme or toxic environment and are intimately involved with the biogeochemical cycling of metals or metalloids for their own niche (Oremland & Stolz, 2003). It is well known that certain prokaryotes such as *Cyanobacteria* are famous for their oxygenic photosynthesis (Badqer & Price, 2003). Besides this microbial mats consisting of microbes are capable of accumulate As and produce biominerals in geo-aquaeco system (Tazaki et al., 2003; Islam et al., 2014). The aim of this study was to observe symbiotic prokaryotes under the optical and scanning electron microscope for their multiple roles; such as controls on arsenic immobilization and photo synthetic activities.

2 METHODS AND MATERIALS

2.1 Materials

Various colored microbial mats proliferating near to the arsenic contaminated tube-wells were collected from Hazigonj Upazila, a highly As contaminated areas in Bangladesh (BGS/DPHE, 2001). Tube-well waters were circum pH with a high concentration of As (141 to 997 $\mu\text{g L}^{-1}$), much higher than that of WHO standard. A part of sample was fixed with 1% gluteraldehyde and carried to the Kanazawa University laboratory for further analysis and observations.

2.2 Observations and analyses

Optical microscopic observations were carried out by an epifluorescence microscope (Nikon EFD3, equipped with Digital camera: COOLPIX995). Epis-copic and DAPI stained samples were observed in this study. Scanning electron microscopic (JEOL JSM-5200LV) technique was applied for micro morphology of symbiotic prokaryotes. Besides this, to determine the elemental concentrations; dried microbial mats were analyzed by ED-XRF (JEOL JSX 3201). Especially, Neutron activation analytical technique was applied for determining the arsenic concentration in microbial mats.

Figure 1. Micrographs show the presence of Coccus, Bacillus, Filamentous and Cyanobacteria in As rich microbial mats.

3 RESULTS AND DISCUSSION

3.1 Microscopic observations

The results of microscopic observation are shown in Figure 1. Optical micrograph indicated the colony of symbiotic prokaryotes in microbial mats, mainly consisting of autotrophs and heterotrophs, such as *Coccus*, *Bacillus*, and *Filamentous* microbes associated with *Cyanobacteria* (A). DAPI stained epifluorescence micrograph showed the fluorescent blue and red part indicating DNA in prokaryotic cells, photosynthetic pigments in chromatophores of photo-autophytes including *Cyanobacteria* (B). SEM micrograph confirmed the presence of As resisting *Coccus* and *Bacillus* types of prokaryotes associated with diatom in a fixed sample (C and D). In this study, we found vigorous proliferations of As resistant *Cyanobacteria* in microbial mats, those can reduce CO₂ in the environment as they are only photosynthetic prokaryotes able to produce Oxygen (Badqer & Price, 2003). Furthermore it is reported that *Cyanobacteria* are responsible for roughly 10 % of global photosynthetic activities (Mangan *et al.*, (2016).

3.2 As accumulation in microbial mats

The profile of microbial metal accumulation is presented in Table 1. The semi quantitative analytical data showed the presence of As associated with Na, Mg, Al, Si, P, S, K, Ca, Ti, Mn, Fe, Zn and Sr in all microbial mats. Intimate involvement of microbe metal interactions might play the key role in immobilizing the corresponding metals or metalloids from the As contaminated tube-well water sources (Tazaki *et al.*, 2003). However, Neutron activation analysis (NAA) data showed a high concentration of As (550 mg kg⁻¹) in microbial mats, which is several thousand times higher than that of corresponding tube well water (Islam *et al.*, 2014).

Table 1. Elemental concentrations in different microbial mats.

El	D-Gy	LG	DG	LB 1	LB 2	LB 3	Gy
Na	nd	nd	0.56	nd	nd	nd	nd
Mg	1.65	4.72	1.76	1.41	1.29	2.15	1.19
Al	5.55	3.18	8.38	3.00	3.3	6.24	4.3
Si	40.2	32.86	51.20	19.34	28.22	46.08	28.34
P	2.63	3.00	2.84	4.47	4.35	3.32	5.63
S	1.47	2.40	1.08	1.78	3.62	1.40	2.64
K	7.56	3.64	7.99	4.99	9.17	7.63	6.86
Ca	13.83	10.98	7.42	17.28	17.03	7.77	12.45
Ti	2.71	2.88	2.47	1.46	2.95	3.33	3.37
Mn	0.93	4.00	0.32	0.86	1.30	1.11	2.66
Fe	22.89	30.05	15.95	44.43	28.22	20.35	31.23
Zn	0.33	1.89	nd	0.36	0.18	0.16	0.68
As	0.16	0.26	0.02	0.46	0.21	0.18	0.50
Sr	0.1	0.17	nd	0.15	0.12	0.08	0.15
	100	100.03	99.99	99.99	99.96	99.89	100 wt%

El; Elements, D-Gy; Dim Grey, LG; Light Green, DG; Deep Green, LB 1; Light Brown 1, LB 2; Light Brown 2, LB 3; Light Brown 3, Gy; Grey, nd; not detected.

4 CONCLUSIONS

Symbiotic prokaryotes can play a significant role in enabling to uptake arsenic from well water, and release of O₂ in the atmosphere. Further research are needed to develop a sustainable mitigation effort for provision of As free safe drinking water and a CO₂ reduced safer environment.

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