An Artificial Channel Purification Experiment for Arsenic-rich Drainage Water from the Abandoned Mine by using *Eleocharis acicularis*

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An Artificial Channel Purification Experiment for Arsenic-rich Drainage Water from the Abandoned Mine by using *Eleocharis acicularis*

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Abstract. An artificial channel purification experiment for arsenic-rich drainage water was conducted to investigate the feasibility of phytoremediation by using *Eleocharis acicularis*. In the experiment, 15 m^2 of *Eleocharis acicularis* mats were laid in an artificial channel in two days. Two sessions of artificial flow were implemented by leading 100 L of mine drainage water containing 7.45 mg/L of arsenic into the channel each time. The arsenic concentration in the *Eleocharis acicularis* was measured using samples collected at 0 m, 25 m, and 50 m along the channel. As a result of experiments, the arsenic concentrations of the outflow for the two sessions were 1.62 mg/L and 3.12 mg/L. This shows that the arsenic concentration decreased during two sessions, whose flow totalled 200 L. The initial concentration of arsenic in *Eleocharis acicularis* was 0.18 mg/kg at 0 m point, 0.06 mg/kg at 25 m point and 0.11 mg/kg at 50 m point. After two inflows, the arsenic concentration of *Eleocharis acicularis* increased from 88.5 mg/kg to 105.0 mg/kg at 0 m, from 29.6 mg/kg to 52.8 mg/kg at 25 m, from 7.2 mg/kg to 37.8 mg/kg at 50 m, respectively, indicating that *Eleocharis acicularis* absorbs arsenic. This paper describes the results of an artificial channel experiment in which water containing arsenic was purified by using *Eleocharis acicularis*.

Keywords: Arsenic; Artificial Channel; Eleocharis acicularis; Purifying Drainage Water.

1. Introduction

When excavated soil and rock are temporarily stored at civil engineering construction sites, rainwater or snowmelt that seeps from such soil and rock may be contaminated by heavy metals. Concentrations of heavy metals such as arsenic, selenium, lead and zinc that leach from soil and rock excavated at road construction sites occasionally exceed the criteria values prescribed for each such metal. Phytoremediation, a technique for cleaning up contaminated environments, has been used for purifying mine effluent. We conducted experiments to evaluate the applicability of phytoremediation to civil engineering work. This technique is more dependent on weather conditions for cleaning up environmental contaminants. Additionally, contaminants were removed only in the rhizosphere, and it takes time to grow plants large enough to be useful for phytoremediation. However, this technique is applicable at a relatively low cost, consumes no energy, and is environmentally sound. This study used

Eleocharis acicularis (hereinafter: *E. acicularis*), a plant in the Cyperaceous family that absorbs and accumulates heavy metals, because this plant has been proven to be effective in mine effluent treatment [1-3]. *E. acicularis* is tolerant of a wide variety of heavy metals, and it absorbs these metals. The plant is a perennial that grows in clumps at ponds, marshes, reservoirs, and paddy fields, and it is distributed throughout Japan. *E. acicularis* propagates with runners that branch off from the root area. The feasibility of using this plant species for phytoremediation of river water containing low As concentration was assessed and confirmed [4]. In this experiment, *E. acicularis* was used for purifying arsenic-rich drainage water from the abandoned mine that contained arsenic and flowed in an artificial channel.

2. Details of the artificial channel

Experiments were conducted by using an artificial channel. The 50-m-long channel is made of poly vinyl chloride and consists of 5 sections. Each section is 30 cm wide and 10 m long. Short pipes were used for assembling the channel with a hydraulic gradient of 0.5 permillage (‰). In the channel, 15 m^2 of *E. acicularis* mats with a wet weight of 49.3 kg were placed (Figure 1). The *E. acicularis* used in the experiments was hydroponically cultured, and the roots of adjacent plants were intertwined. The plants were shaped to form mats (Figure 1). Water taken from the abandoned mine in the Sobetsu town [5] was used for the experiments.

Figure 1. Outline of the artificial channel and *Eleocharis acicularis* on the artificial channel

3. Experimental method

After pouring mine drainage into the artificial channel in which *E. acicularis* mats were put, *E. acicularis* and outflow were sampled to measure the arsenic content of *E. acicularis* and concentration of outflow. A total of 200.0 L of mine drainage was used, and 100.0 L of river water was poured into the channel two times over 2 days. The inflow rate was 0.5 L/min. At the onset of the experiment and each time 100.0 L of mine drainage was poured into the channel, 50 ml of outflow was sampled at the outflow end, 50 m from the inflow end. Values of air temperature, river water temperature, pH and electrical conductivity (EC) were measured when the experiment was started and every time the outflow was sampled. At three points (0 m, 25 m and 50 m from the inflow end) in the channel, 50 g of *E. acicularis* was sampled at the onset of the experiment and each time 100.0 L of mine drainage was poured into the channel. Specimens were weighed after excess moisture was wiped off. The wet weight of all specimens was 49.3 kg. After drying, the weight of these specimens was 9.4 kg, 19 % of the wet weight.

4. Analysis method

The outflow used for measuring arsenic content of *E. acicularis* and concentration of outflow was sampled, filtered, mixed with nitric acid to yield a 1wt. % nitric acid solution, and preserved. The preserved mine drainage was analyzed for arsenic concentration by using an Inductively Coupled Plasma Mass Spectrometry; Agilent 7500cx, Agilent Technologies, (hereinafter: ICP-MS). For the purpose of measuring the arsenic content of the *E. acicularis*, sampled *E. acicularis* was rinsed thoroughly with ultrapure water, dried at 80 ℃ in a dryer for 2 days, and pulverized. The fine powder from pulverization was mixed with 30wt. % hydrogen peroxide, 61wt. % nitric acid and 38wt. % hydrofluoric acid, and the mixture was evaporated at 98 °C until dry. Then, 61wt. % nitric acid was added, and the mixture was re-evaporated at 98 °C until dry. The nitric acid solution was prepared by adding 30wt. % nitric acid to the *E. acicularis* specimen and analyzing for arsenic content by using an ICP-MS.

5. Results and discussion

5.1. Changes in the arsenic concentration of the outflow

The initial concentration of arsenic in mine drainage was 7.45 mg/L. After the first and second inputs of mine drainage into the channel, the arsenic concentration in outflow was 1.62 mg/L and 3.12 mg/L, respectively (Table 1). That is, after the second input, the concentration of the mine drainage was reduced by about 42% of the initial value. This suggests that *E. acicularis* has a limited arsenic absorption capacity under the experiment conditions, but the reductions in the arsenic concentration indicate that *E. acicularis* helped lower the arsenic concentration in the mine drainage. As the pH value of the mine drainage was 2.0 - 2.1 before it was poured into the channel and was 2.8 - 3.8 when the mine drainage seeped out, the pH remained neutral during the experiment. Regarding the EC of the mine drainage, the value was 3.7 - 4.8 mS/m before the mine drainage was poured into the channel, and was 4.2 - 5.0 mS/m when the mine drainage seeped out. These results show that there was no significant change in water quality. This treatment system also serves to raise the pH. That is, the treatment system works relatively well by somewhat reducing the amount of As and raising the pH. However, in order to further improve the absorption capacity, it is necessary to devise measures to make the drainage stagnate for a longer period of time for *E. acicularis* to absorb As.

Table 1. Results of experiments for mine drainege

Mesurement item / Number of inflow		Temperature (℃)	Humidity (%)	Water Temperature (℃)	pH	EC (mS/m)	Arsenic Leachate (mg/L)
Initial		—					7.45
1	inflow	28.3	57.8	29.00	2.1	3.7	1.62
	outflow	30.3	-	32.00	3.8	4.2	
2	inflow	28.9	51.1	28.50	2.0	4.8	3.12
	outflow	27.9	-	37.00	2.8	5.0	

- : Unmeasured

Table 2. Results of arsenic concentration of the *Eleocharis acicularis*

Mesurement item / Number of inflow	Arsenic concentration (mg/kg)		
	0m point	25m point	50m point
Initial	0.18	0.06	0.11
1	88.5	29.6	7.2
2	105.0	52.8	37.8

5.2. Changes in the arsenic content of the E. acicularis
At the 0m point, the initial concentrations of As in *E. acicularis* was 0.18 mg/kg-DW which increased to 88.5 and 105 mg/kg-DW after the first and second inputs of water, respectively (Table 2). The arsenic content in the *E. acicularis* was the highest at the point 0 m from the inflow end and the lowest at the point 50 m from the inflow end. This suggests that the *E. acicularis* at the points 25 m and 50 m from the inflow end had the capacity to absorb more arsenic at the end of the experiment. The experiment results show that *E. acicularis* has the capacity to absorb and accumulate arsenic. However, because this capacity varies depending on the arsenic concentration in water and the inflow rate of water, it is necessary to examine conditions under which *E. acicularis* absorbs arsenic more efficiently.

5.3. Total content of arsenic in outflow
The total content of arsenic in the mine drainage was defined as the product of the volume of mine drainage and its initial arsenic concentration. On the other hand, arsenic concentration of *E. acicularis* was estimated by the arsenic concentration measured after the second water input. 65.1 mg/L was value for average value at 0, 25 and 50 m points.

The total content of arsenic in the mine drainage was calculated as follows:

Total content of arsenic in the mine drainage
= 7.45 mg/L (initial arsenic concentration) ×200.0 L (total volume of mine drainage)
= 1,490 mg

The total concentration of arsenic in *E. acicularis* was calculated as follows:

Total concentration of arsenic in *E. acicularis*
= 65.1 mg/kg × 9.4 kg (dry weight of *E. acicularis*)
= 612 mg

Because the arsenic content for the total amount of the outflow before it seeped out of the *E. acicularis* is 1,490 mg and because the total concentration of arsenic in *E. acicularis* is 612 mg. This total concentration of arsenic in *E. acicularis* is equivalent to 41 % absorption of the total content of arsenic in the mine drainage used for the experiment. The remaining arsenic was thought to be existed in the outflow, on the artificial channel or on the surface of *E. acicularis*.

6. Conclusions

The findings of this experiment explained above are as follows:

1. The results of the experiment conducted on using *E. acicularis* to remove arsenic in an artificial channel show that *E. acicularis* helps lower the arsenic concentration in outflow and that the capacity of *E. acicularis* to absorb arsenic depends on the volume of water.
2. The arsenic content in the *E. acicularis* increased with increase in the number of water inputs, and the arsenic content in the *E. acicularis* was higher at the upper reach of the channel and lower at the lower reach.
3. The total concentration of arsenic in *E. acicularis* is equivalent to 41 % absorption of the total content of arsenic in the mine drainage used for the experiment.

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