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Lead, Cadmium, and Arsenic in Commercial Algae of the Sea of Japan

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Abstract—The concentrations of toxic elements (arsenic, cadmium, lead) in commercial algae *Saccharina japonica* and *Ahnfeltia tobuchiensis* from different habitats of the Sea of Japan have been determined. Bioaccumulation of heavy metals has been analyzed with respect to the habitat and growth conditions. The lead content of *Sascharina japonica* from all habitats and arsenic content of the same alga species from the Ol'ga Bay, Kievka Bay, and Tatar Strait have been found to exceed maximum permissible levels. Increased lead concentrations have been detected in *Ahnfeltia tobuchiensis*. Samples of *Ahnfeltia tobuchiensis* collected from the bottom layer contain more toxic elements than those from the upper layer.

Keywords: lead, cadmium, arsenic, brown algae, red algae, *Saccharina japonica*, *Ahnfeltia tobuchiensis*

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INTRODUCTION

Primorski Krai possesses a highly developed infrastructure and a large number of fish processing enterprises and is an important fishing ground of the Russian Far East. Coastal waters of Primorski Krai (the Sea of Japan) are traditional areas where *Saccharina japonica* and *Ahnfeltia tobuchiensis* are harvested [1, 2]. However, at present water basins of Primorski Krai suffer from considerable anthropogenic load related to industrial and domestic activities of enterprises in Vladivostok, Nakhodka, Bol'shoi Kamen', and settlements on the Sea of Japan coast [3, 4]. Coastal waters of Primorski Krai where most industrial facilities are located represent the most polluted region of the Far East [5, 6].

Taking into account the above stated, estimation of safety of commercial algae with respect to their habitat constitutes an important problem. The goal of the present work was to study accumulation of lead, cadmium, and arsenic in commercial brown and red algae of the Sea of Japan.

EXPERIMENTAL

As subjects for the study we used commercial brown and red algae *Saccharina japonica* and *Ahnfeltia tobuchiensis*. The brown algae *Saccharina japonica* were harvested during the 2013 fishing season from the coastal waters of the southern and northern areas of the Sea of Japan, Kievka Bay (May), Ovsyankin Cape (June), Ol'ga Bay, Anna Bay, northwest part of the Tatar Strait (water area from Syurkum Cape to Chikhachev Bay) (July), and Sokolovskaya Bay (August) (Fig. 1). The red algae *Ahnfeltia tobuchiensis* were harvested in June 2013 from different parts (upper, middle, and bottom layers) of the seaweed fields in the Stark Strait and Perevoznaya Bay (Peter the Great Gulf, the Sea of Japan; Fig. 2).

The concentration of lead was determined by atomic absorption spectroscopy using a Shimadzu AA-6800 instrument (single-slit acetylene–air flame atomizer). The concentrations of arsenic and cadmium were determined using the same instrument with a graphite tube atomizer. Background correction was performed with a deuterium lamp. Samples were prepared according to [7]. The algae were tested for safety according to SanPiN 2.3.2.1078-01 [8].

RESULTS AND DISCUSSION

The concentration of heavy metals in *Saccharina japonica* depended on its habitat. The concentrations of different elements in samples from the same area

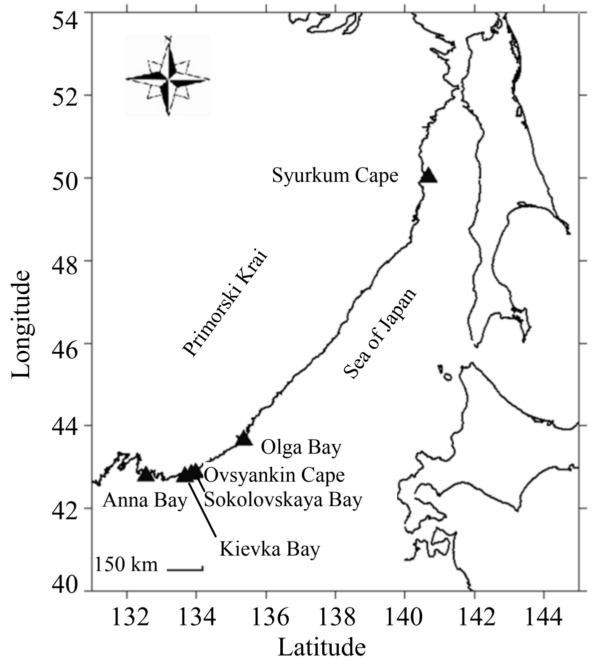

Fig. 1. Map of *Saccharina japonica* harvesting areas in the Sea of Japan.

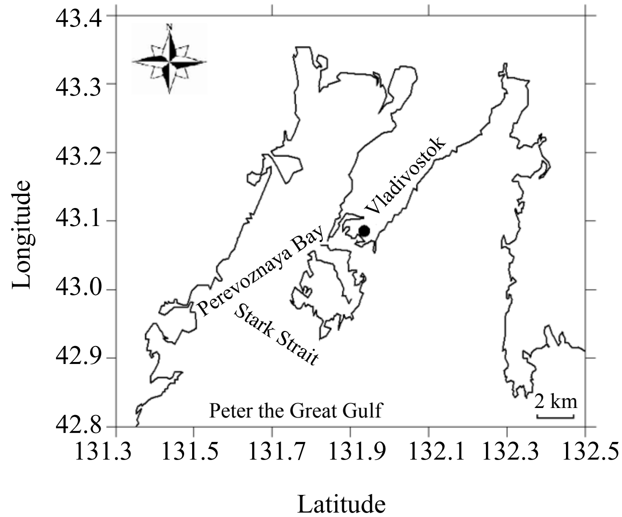

Fig. 2. Map of *Ahnfeltia tobuchiensis* harvesting areas in the Sea of Japan.

were also different. The highest concentration of arsenic was found in the algae from the Olga Bay and Kievka Bay, the algae from the Ovsyankin Cape water area contained the highest concentration of lead, and cadmium was the most abundant in the algae from the Kievka Bay (Fig. 3).

The lead content of the algal samples from all areas exceeded the maximum permissible level (MPL 0.5 mg per kilogram of wet algae) by a factor of 2.8 to 7.4. The lowest lead concentration (1.42 mg/kg) was found in *Saccharina japonica* from the Ol'ga Bay and Anna Bay (Fig. 3). The arsenic content of the algae from the Ol'ga Bay, Kievka Bay, and Tatar Strait was higher than the specified value (5.0 mg/kg). The algae growing in the Sokolovskaya Bay and Anna Bay revealed the lowest concentration of arsenic (4.05 and 4.6 mg/kg, respectively).

The lowest concentrations of cadmium were detected in the algae from the Sokolovskaya Bay (0.12 mg/kg) and Kievka Bay (0.23 mg/kg); these values are considerably lower than the MPL (1.0 mg/kg) (Fig. 3).

Ahnfeltia tobuchiensis is an agar-containing alga species which grows mainly in the Stark Strait. Here, the algal layer reaches a thickness of 90 cm. The concentrations of toxic elements in different parts of the algal layer were different. The concentrations of lead in the algae from the upper, middle, and bottom parts of the layer exceeded the MPL by factors of 6.4, 7.0, and 10.8, respectively (Fig. 4). The lead content of

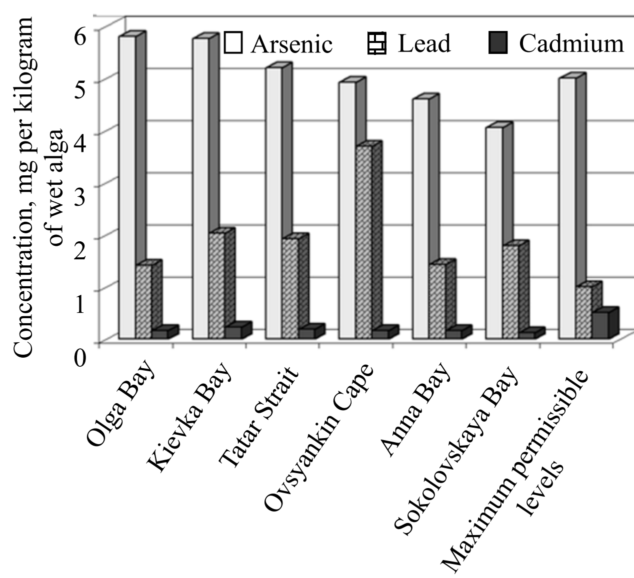

Fig. 3. Concentrations of arsenic, lead, and cadmium in *Saccharina japonica* samples from different habitats (Sea of Japan).

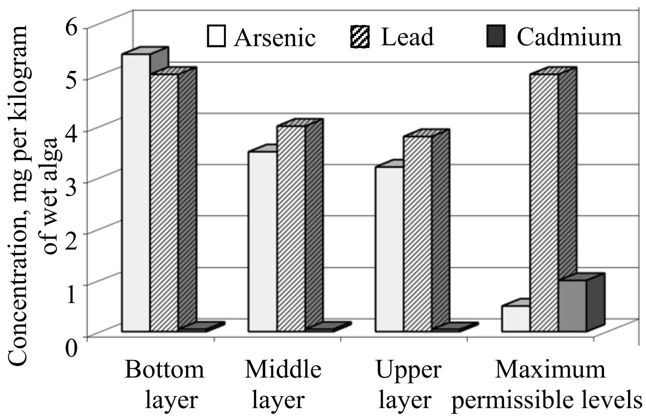

Fig. 4. Concentrations of arsenic, lead, and cadmium in *Ahnfeltia tobuchiensis* from the Stark Strait.

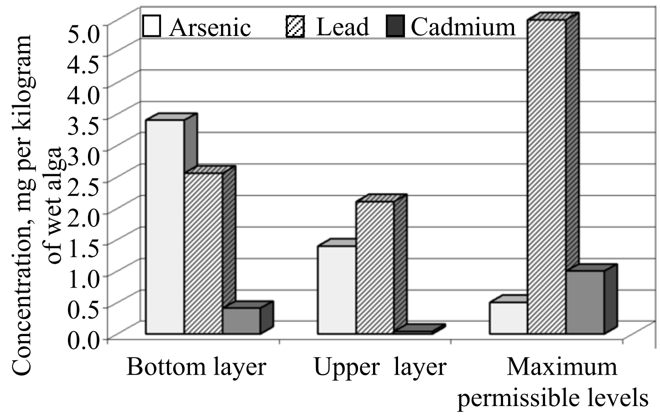

Fig. 5. Concentrations of arsenic, lead, and cadmium in *Ahnfeltia tobuchiensis* from the Perevoznaya Bay.

the bottom layer was 1.7 times higher than that of the upper layer, and the arsenic and cadmium contents of the bottom layer were 1.3 times higher. The concentrations of cadmium and arsenic were within the allowable range (Fig. 4).

The second (in magnitude) *Ahnfeltia tobuchiensis* field in the Sea of Japan is located in the Perevoznaya Bay. Its thickness amounts on the average to 40 cm. The distribution pattern of toxic elements from top to bottom of the layer was similar to that observed for the samples from the Stark Strait. The bottom layer was enriched in cadmium, lead, and arsenic by factors of 10, 2.4, and 1.2, respectively, compared to the upper layer. The lead content of the upper and bottom layers exceeded the MPL by factors of 2.8 and 6.8, respectively. The concentrations of cadmium and arsenic were within normal limits (Fig. 5).

CONCLUSIONS

Thus, the concentrations of toxic elements (arsenic, lead, and cadmium) in *Saccharina japonica* depend on its habitat. The lead content of the algal samples from all the examined areas exceeds the maximum permissible level. The algae from the Ol'ga Bay, Kievka Bay, and Tatar Strait are characterized by increased concentration of arsenic, while the concentration of cadmium falls within the normal range.

Accumulation of toxic elements by *Ahnfeltia tobuchiensis* is determined by the location of the algae field and position in the latter. The concentrations of arsenic and cadmium in all samples do not exceed the MPLs. The lead content of the algae from the Stark Strait is higher than that of the algae from the Perevoznaya Bay. The concentration of lead in all samples of *Ahnfeltia tobuchiensis* exceeds the MPL. The bottom layer of the algae field contains more lead than the upper layer.

On the basis of the obtained data, it is recommended to use *Saccharina japonica* growing in coastal waters in the south of Primorski Krai (Kievka Bay, Anna Bay, Sokolovskaya Bay, Ol'ga Bay, Ovsyankin Cape, Tatar Strait) only in the manufacture of alginic acid and its salts. *Ahnfeltia tobuchiensis* from the Perevoznaya Bay and Stark Strait may be used for the manufacture of agar.

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