THE ROLE OF TEMPERATURE IN THE BIOACCUMULATION PROCESSES OF MANGAN FROM SURFACE WATER, IN SPECIES *SALVINIA NATANS* (L.) ALL.

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Abstract

In this article we wanted to demonstrate the influence that temperature has on the processes of manganese accumulation in the species *Salvinia natans* (L.) All. In order to reach the proposed objective, different concentrations of manganese present in the water were tested at different temperature levels (15°, 25° and 35° C) and the samples of plant material were analyzed at different time intervals (0h, 24h, 72h and 120h).

Introduction

Water supply is the key to civilization and offers development opportunities in a certain geographical area. Assessing the water supply for domestic and industrial use requires a broad approach to define and determine the socio-cultural, demographic and economic benefits of water. A number of studies highlight the important role of water availability in maintaining and advancing living standards [1,2]. Water resources are open to pollution due to population growth, technological development and growth of industrial activity. In many regions of the world, in urban areas, the metal load in drinking water resources is at an alarming level, due to the elimination of untreated or partially treated industrial wastewater [3,4]. Because heavy metals are difficult to neutralize under natural conditions, they are usually ingested by aquatic animals and plants, as well as by terrestrial crops and then enter the human body through the food chain after a high enrichment in the propagation bodies [5].

Salvinia natans (L.) All. is a fast-growing aquatic pteridophyte of the Salviniaceae family, native to large regions of Asia, Europe and Africa and introduced to North America. The species produces creeping roots up to 20 cm long, with up to 12 axillary branches, and two types of leaves, floating and submerged. The floating leaves are 0.8–1.4 cm long and 0.5–0.8 cm wide. The submerged leaves are dissected into linear segments, covered with hair and can act as roots. The typical habitats of *S. natans* are ponds and ditches with slow and shallow eutrophic water [6]. *Salvinia* sp. it can double its biomass in less than 2 days. Moreover, the plant can have a high productivity around 5.8-11.4 g in dry weight/m^2/day when grown in a chemically defined Hoagland environment and around 20-120 kg/ha/day under natural conditions [7], these things are especially important in order to be able to ensure the vegetal material and to make efficient the purification systems based on this species. In addition to its high growth, the species accumulates trace elements and has been used to remove both nutrients and metals from polluted waters [6]. Dhir and Srivastava (2011) demonstrated a gradual decrease in metal content in wastewater samples with an initial metal content of 15 mg Me/L by renewing plant biomass at well-defined time intervals. The elimination of Zn, Cu, Ni and Cr in the proportion of 84.8%, 73.8%, 56.8% and 41.4%, respectively, was noticed after four such plant renewals. According to the same authors, the accumulation of Cr, Fe, Ni, Cu, Pb and Cd was between 6 and 9 mg/g dry matter, while the accumulation of Co, Zn and Mn was around 4 mg/g dry matter [8]. Based on these considerations, this article aims to streamline the treatment of surface water loaded with manganese in specific laboratory conditions and at different temperature levels, using the species *Salvinia natans* (L.) All.

Experimental

Plant material

The experiments were performed on plant material (*Salvinia natans* (L.) All.) harvested from the natural environment and acclimatized in laboratory conditions for seven days. The test solutions in which the plants were introduced were manganese-enriched surface waters (surface waters had an imperceptible load of heavy metals) to reach the desired concentrations. The water needed for the experiments was taken from the river Bega, shortly before the start of the study. The reagents used for water enrichment were stock, monometallic solutions with a concentration of 1000 mg Me/L purchased from specialized companies in the field.

Experimental conditions

Approximately 10 grams of plant material, representing 6 individuals with 5-6 nodules each, were placed in transparent plastic containers with a diameter of 8 cm containing 300 mL of surface water enriched up to concentrations of 1, 2 and 4 mg Mn/L. The amount of metal was determined both initially (0h) and after 24h, 72h and 120h experimentally during which the plants stayed in the incubator at different temperature ranges (15° C, 25° C, 35° C ± 0.5° C) having a day/night cycle of 16/8. The choice of metal concentrations was consistent with the 5th grade of quality from the Romanian Order nr. 161/2006 [9], which reports values for Manganese >1000 μg/L, and by doubling them twice consecutively, the above concentrations were reached.

Methods of analysis

After various drying, calcination and digestion processes, the plant material was brought to liquid state, and the determination of the metals in the samples was performed with an Avanta GBC AAS spectrophotometer (GBC Scientific Equipment Pty Ltd, Australia) in accordance with existing standards.

Bioaccumulation factor (BCF)

The accumulation of a chemical by aquatic organisms is generally expressed as a bioaccumulation factor (BCF). This factor is expressed as the ratio between the final concentration of metal ions in the plant and the initial concentration of metal in water. It is an indicator of the accumulation capacity of metals by plants at the metal concentration in the environment [10].

$$BCF = \frac{Cme-plants}{Cme-water}$$

where,

$C_{me\text{-}plants}$= final metal concentration in the plant, expressed in mg Me/kg

$C_{me\text{-}apa}$= initial concentration of metal in water, expressed in mg Me/L

Results and discussion

The table below shows the amount of manganese accumulated in the tissues, at each temperature level and after each time interval.

Table 1. The amount of manganese accumulated by *Salvinia natans* under different temperature conditions and after certain periods of time

Stress factor	The amount of Mn accumulated in *Salvinia natans*, mg Mn/kg s.u.											
	15°C				25°C				35°C			
	0h	24h	72h	120h	0h	24h	72h	120h	0h	24h	72h	120h
1 mg Mn/L	82.0	175	386	504	82.0	113	315	262	82.0	87.0	530	614
2 mg Mn/L	82.0	553	1039	805	82.0	361	490	798	82.0	256	495	591
4 mg Mn/L	82.0	540	1024	993	82.0	125	664	337	82.0	90.0	97.0	144

The results obtained demonstrate the ability of this species to accumulate manganese, specific for each temperature range and for the initial concentration of metal in the environment. The data obtained by us are in accordance with those in the literature, where Dhir and Srivastava (2011), report values of manganese in the plant located around 4000 mg/kg s.u., at an initial metal concentration of 15 mg Mn/L [8]. Therefore, the present species is very suitable for bioremediation of manganese-laden surface waters, and to determine the ability of the species to accumulate metals compared to the amount of pollutant found in the environment, the values calculated for the bioaccumulation factor are presented below.

Bioaccumulation factor (BCF) of Mn in Salvinia natans (L.) All.

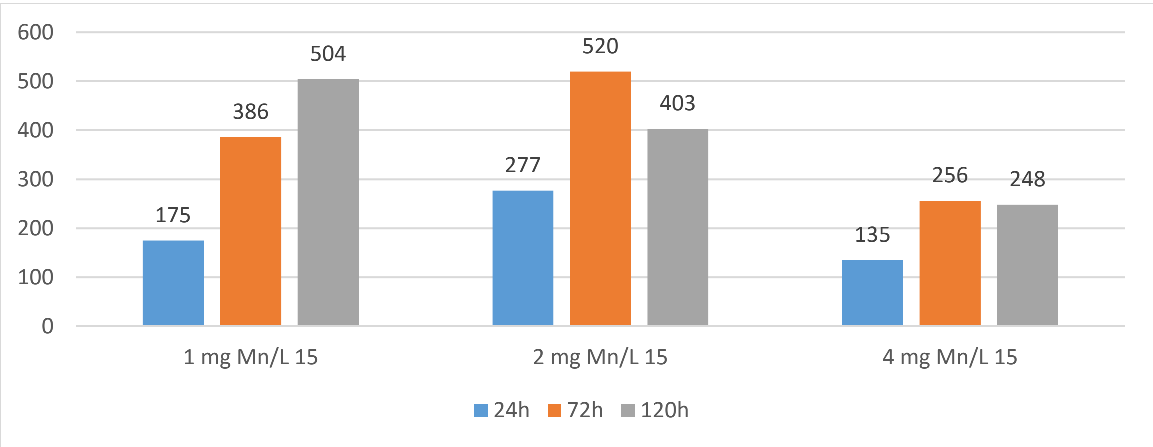

Figure 1. Mn bioaccumulation factor for *Salvinia natans* at 15° C

At a temperature of 15°C, we observe an affinity of the plant for the bioaccumulation of manganese at low concentrations. Here we observe the highest values of BCF in the case of concentrations of 1 and 2 mg Mn/L. The hypothesis is also supported by the fact that we find the highest value (520) of the bioaccumulation factor in the case of the experimental variant with 2 mg Mn/L, after the first 72 hours.

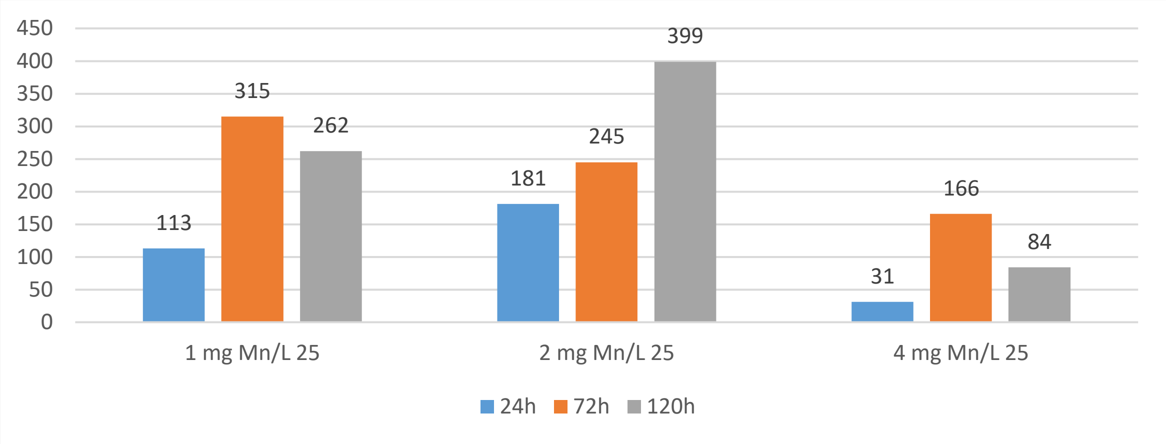

Figure 2. Mn bioaccumulation factor for *Salvinia natans* at 25^{o} C

At a temperature of 25 ° C, the bioaccumulation processes in *Salvinia natans* gradually increase in the first 72 hours for the initial metal concentrations of 1 and 4 mg Mn/L, after which it decreases in the next 120 hours. In the case of the experimental variant with 2 mg Mn/L, the increase of the bioaccumulation factor is directly proportional to the contact time, so that a maximum of 399 is reached after 120h. As at the previous temperature, the ability of the species to accumulate metals depends on their concentration in the environment, so the most satisfactory results are obtained at a concentration of 1 and 2 mg Mn/L in the environment.

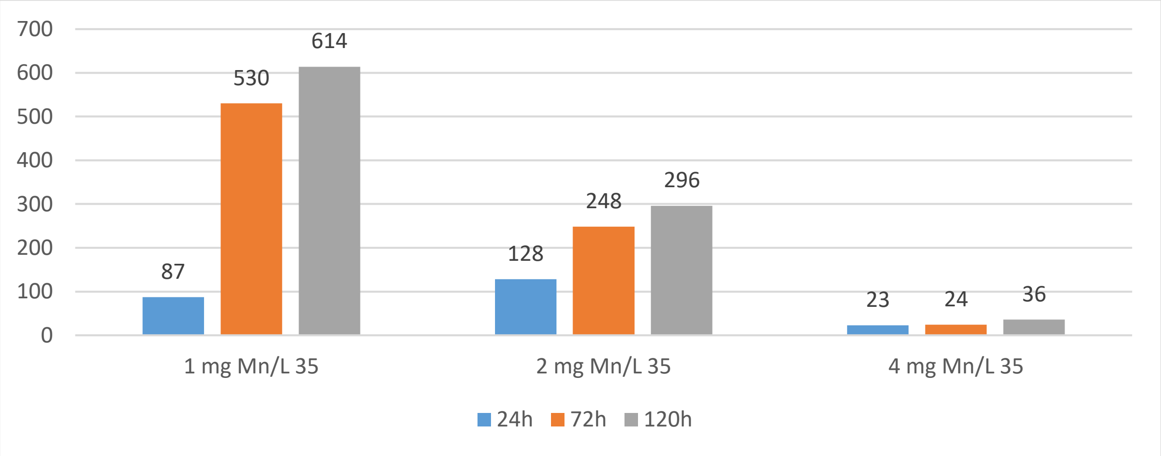

Figure 3. Mn bioaccumulation factor for *Salvinia natans* at 35^{o} C

At a temperature of 35^{o} C, the highest bioaccumulation factor of 614, is obtained after 120h in the case of the 1 mg Mn/L variant. There is a gradual decrease of the bioaccumulation factor from a maximum of 614 in the case of a concentration of 1 mg Mn/L, to 296 in the case of a concentration of 2 mg Mn/L, to a minimum of 36 in the case of a concentration of 4 mg Mn/L. In an overview of the situation, we observe a drastic decrease of the bioaccumulation processes with the increase of the manganese dosage from the environment, similar to what was obtained at the other two temperature levels.

Conclusions

The present study demonstrated the vital role played by ambient temperature in the processes of bioaccumulation of manganese from surface waters by *Salvinia natans*, so that they are inversely proportional to the gradual increase in temperature (15^{o} C > 25^{o} C > 35^{o} C). Regarding the concentration of metal in the environment, it is not recommended to use the plant at concentrations exceeding 2 mg Mn/L. The ideal exposure time is between 72h and 120h experimental, after which, if necessary, the plants can be renewed. Characteristics such as the high rate of manganese accumulation and the short exposure time, make the species *Salvinia natans* suitable in phytoremediation studies.

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