



# Cd extraction potential of *Thlaspi caerulescens* in extracontinental climate conditions (Zakamensk, Buryatia, Russia)

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## ARTICLE INFO

### Article history:

Received 11 October 2013

Accepted 4 January 2014

Available online 13 January 2014

### Keywords:

Cadmium

Phytoextraction

*Thlaspi caerulescens*

## ABSTRACT

*Thlaspi caerulescens* is known to be a Cd hyperaccumulator used in a number of countries for remediation of the contaminated areas. The objective of the study was to investigate Cd uptake by this plant in extracontinental climatic conditions of Buryatia. Performed experiments included a study of the following factors affecting Cd accumulation by the plant: 1) levels of Cd contamination of the soil; 2) soil Cd availability to plants; 3) time period of the plant – contaminated soil interaction. Cd contamination was simulated by addition of different Cd doses (0; 1; 5; 10; 50; 100; 200; 500 mg/kg) to native soil sample. To facilitate phytoextraction 3 mmol/kg of EDTA was used as background for similar Cd doses. After Cd and EDTA application the soil was incubated for 30 and 365 days before planting. Obtained data showed that toxic, neutral or stimulating Cd effect in *T. caerulescens* depended upon the applied Cd doses and the soil incubation period. Cd doses from 1 to 200 mg/kg resulted in a corresponding decrease of plant biomass and those ranging from 200 to 500 mg/kg terminated germination of plant seeds sown in contaminated soil after its 30 day incubation. However the increased period of incubation (365 days) prior to seeding diminished metal toxicity for plants and soil Cd doses of 1 to 10 mg/kg stimulated the biomass growth by 13% versus control. At maximum Cd dose of 500 mg/kg shoots accumulated 259 mg/kg of Cd in dry mass and the root system up to 609 mg/kg. Removal of soil Cd by plants per square unit varied from 0.13 to 12.92 mg/m<sup>2</sup> depending upon Cd dose in soil and its incubation period. In experiment with 30 day soil incubation maximum Cd removal was observed for Cd dose of 50 mg/kg, while after 365 day incubation maximum removal effect was registered for a higher Cd dose of 100 mg/kg. Application of EDTA in the dose of 3 mmol/kg as a background substance to mobilize soil Cd proved to be toxic and therefore unreasonable since no germination took place. The experiments showed that Cd extraction potential of *T. caerulescens* in arid soils of Buryatia is low as compared to published data and complete remediation of the soils containing from 1 mg/kg to 10 mg/kg of Cd requires no less than two to ten harvests.

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## 1. Introduction

Numerous techniques have been developed to remove heavy metals from soil. There are technical, physical, chemical and combined methods (Galiulin and Galiulina, 2003; Ilyin, 1991; Luo et al., 2006; Osipov and Alekseev, 1996; Popesko and Solov'yev, 1996). As a rule, many of these methods have shortcomings such as high costs and worsened soil fertility. That is why researchers have lately focused on low cost soil saving techniques, phytoextraction in particular. More often metal hyperaccumulator plants are used.

*Thlaspi caerulescens* was reported to be a Cd hyperaccumulator that is able to accumulate more than 100 mg Cd per 1 kg of its dry shoots (Baker et al., 2000). However Cd concentration in plant biomass may be influenced by many factors such as species variety, physical and chemical soil properties, Cd availability and mobility due to natural and climatic conditions.

To stimulate metal uptake by plants and to increase removal of pollutants with biomass chemical additives such as chelates are also used and both believed to increase metal uptake and to make metals less toxic for plants. Among most common chelates there are: EDTA (ethylenediaminetetraacetic acid), CDTA (1,2 cyclohexylene diamine tetraacetic acid), EDDHA (ethylene diamine dihydroxyphenylacetic acid), (Shen et al., 2002), NTA (nitrilotriacetic acid), EDDS (ethylenediaminedisuccinic acid) (Grčman et al., 2003; Kayser et al., 2000; Kos and Leštan, 2003, 2004; Kulli et al., 1999; Meers et al., 2005) etc. One of the ways to increase metal accumulation in roots is thermal impact by hot water (Jarvis et al., 1976). Therefore some researchers (Luo et al., 2006) offer to combine these techniques and apply chelates in soils in a hot aqueous solution for some time before harvesting.

Contamination makes it necessary to find effective ways of its clean up by natural extraction of pollutants, e.g. to select plants able to metal uptake under conditions of a rather severe natural and ecological conditions of Buryatia. For this purpose we studied the possibility of soil Cd extraction with the help of *T. caerulescens* which is a known Cd hyperaccumulator naturally found worldwide (the western part of the USA, in the northern parts of Finland and Sweden, the Alps, the

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Pyrenees, Massif Central (south-central France), eastern Norway, southern Germany and northern Great Britain).

## 2. Materials and methods

### 2.1. Site description

The experimental plot was located in town of Zakamensk (Buryatia, Russia, Fig. 1). Zakamensk is situated in the mountain, forest and steppe zone at the height of 1100 meters over the sea level in the flood plain of the Modonkul river flowing from Dzhidinsky ridge. The climate in the region is extreme continental with cold, little snow, windless winter and short, dry and hot summer. Frostless period lasts for 67–70 days. Average annual temperature is below zero (−1.4 to −2.8 °C). Average annual precipitation equals 360–400 mm.

The town of Zakamensk located at the Republic of Buryatia, Russian Federation is known for hosting toxical technogenic wastes produced by mining and operation of the Dzhidinsky Tungsten and Molibdenum Combine. The combine developed three minefields and created two large tailings of over 40 million tons of technogenic sands, located close to the residential area (less than 1–2 km from the town).

Sands of tailings contaminate the town soil cover and in some places thickness of the sand deposits reaches 2 m. Due to the lack of knowledge about the toxicity of tailings in the last century the contaminated sands were used in road and dam building, construction. Studies were made and recommendations given to use sands as mineral fertilizers. Besides anthropogenic dispersion the contaminated sands were intensively eroded by water and wind. Their natural transport in landscapes resulted in deposition in the Modonkul river flood plain and estuary.

According to Yakushina et al. (2005) and our data Cd concentration in covering sands varies between 9 and 170 mg/kg while in the soil cover Cd concentration is lower and ranges from 0.015 to 10.4 mg/kg

(Fig. 2, Table 1). Maximum value exceeds two orders the world means for lithosphere and soils (0.13 mg/kg in lithosphere and 0.5 mg/kg in soils) and one order the background average for soil Cd in Buryat Republic (Table 1).

### 2.2. Experimental design and techniques

Our design included a study of the following factors affecting Cd accumulation by the plant: 1) levels of Cd contamination of the soil; 2) soil Cd availability to plants; 3) time period of plant-contaminated soil interaction.

Soil samples used in the experiment were collected from the upper layer (0–20 cm) of uncontaminated garden soil of Zakamensk. Some physical and chemical soil properties and Cd content in the original samples is presented in Table 2.

The selected soils were dried at room temperature (20–22 °C), sieved through a 2 mm screen and thoroughly mixed. 10 kg of air dry soil were put into pots sized 0.22 m (length) by 0.16 m (width), 0.3 m deep. Prior to the use all the pots were treated with 5% HNO<sub>3</sub> and washed with deionized water.

Cd was added to soil in incremental doses (0, 1, 5, 10, 50, 100, 200 and 500 mg/kg) as water solution of Cd acetous salt ( $\text{Cd}(\text{C}_2\text{H}_3\text{O}_2)_2 \times 4\text{H}_2\text{O}$ ). Another set of soils was treated with the same Cd doses against background of 3 mmol/kg EDTA ( $\text{C}_{10}\text{H}_{14}\text{O}_8\text{N}_2\text{Na}_2 \times 2\text{H}_2\text{O}$ ) added to soil simultaneously. After the treatment soil containing Cd and EDTA (second set) was thoroughly mixed and incubated for 30 and 365 days according to the established scheme of experiment. The experiment was carried out in quadruplicate. Because no germination took place therefore this data is not shown or included.

Pots were placed in the open air. The polyethylene shelter put over pots at the height of about 2.5 m to escape uneven rainfall and overwetting. Pots were not affected by any shading. After incubation 20 seeds of *T. caerulea* kindly given by the Novosibirsk botanical gardens were sown in each pot.

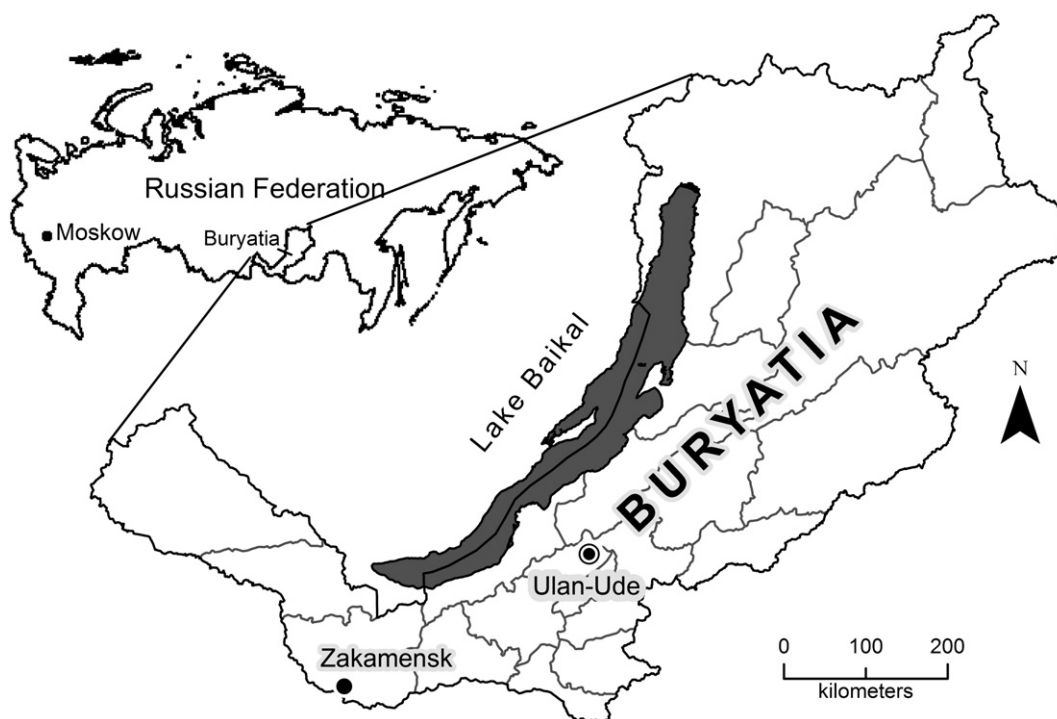


Fig. 1. Location of the Buryatia Republic and the Zakamensk test site.

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