Data Article

Phytoremediation: Data on effects of titanium dioxide nanoparticles on phytoremediation of antimony polluted soil

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ARTICLE INFO

Article history:
Received 17 May 2020
Revised 28 June 2020
Accepted 29 June 2020
Available online 3 July 2020

Keywords:
Phytoremediation
TiO2 nanoparticles
S. bicolor
Antimony
Chlorophyll content
soil

ABSTRACT

This data article presents effects of titanium dioxide nanoparticles (TiO2 NPs) on phytoremediation of antimony contaminated soil using S. Bicolor in detail. Seedlings of S. bicolor were exposed to different doses of TiO2 NPs (0,50,100,250,500 and 1000 mg/kg) in plastic pots containing Sb-contaminated soil and cultivated over a 80-day period in a greenhouse. Harvested plants were dried in an oven at 70 °C for 48 h to obtain dry weight of the biomass. The concentrations of metalloid(s) in soil as well as in plant organs were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). Chlorophyll contents of fresh leaves materials were measured by UV spectrophotometry at 645 nm and 663 nm. Data on distribution of Sb and Ti in roots and shoots of S. bicolor contaminated soil treated with different levels of TiO2 NPs are indicated in tables. Figures presented the data on plant growth behavior, Sb and Ti accumulation capacities, and physiological response of S. Bicolor in various treatments. The presented data are beneficial to gain insight into phytoremediation potential of S. bicolor in Sb-contaminated soil as well as plant behavior under the stress of both Sb and TiO2 NPs in soil. These data are useful for environmental researchers, soil and plant scientists, nanotechnology experts, stakeholders and decision-makers involved in soil decontamination challenges.

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https://doi.org/10.1016/j.dib.2020.105959
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Specifications table

| Subject                        | Environmental Engineering |
|-------------------------------|---------------------------|
| Specific subject area         | Phytoremediation, nanoparticles |
| Type of data                  | Tables, Figures           |
| How data were acquired        | Data collected from phytoremediation of Sb spiked soil mixed with different levels of TiO2 NPs in a greenhouse study. ICP-OES, UV spectrophotometry and SPSS software were used. |
| Data format                   | Raw, Analyzed             |
| Parameters for data analysis  | Different concentrations of TiO2 NPs were applied to Sb-contaminated soil and the effects of TiO2 NPs treatments on growth behavior of S. Bicolor, absorption and translocation of antimony, accumulation capacity, and photosynthetic chlorophyll content of S. bicolor in different treatments were examined to collect the required data. |
| Description of data collection| Titanium dioxide nanoparticles were synthesized in the lab. Plant seeds were sown in pots filled with Sb-contaminated soil containing different concentrations of TiO2 NPs to examine the effectiveness of TiO2 NPs-assisted phytoremediation. Germination, biomass and length of S. Bicolor in different treatments were monitored during a 80-day period. Harvested plants were analysed for metal(loids) and chlorophyll content. Obtained data were analysed using SPSS software. |
| Data source location          | School of Environment, College of Engineering, University of Tehran. Collected soil samples from southern part of Tehran Province, Iran, 35° 32’ 18” N, 51° 24’ 27” E. |
| Data accessibility            | Data are available in the article. |

Data description

Data provided in this article show the possibility of association of TiO2 nanoparticles in phytoremediation of antimony polluted soils. The results demonstrate the effect of TiO2 nanoparticles treatment on seedling emergence, plant biomass and length of S. Bicolor. Moreover, absorption, translocation and accumulation of antimony in different treatments as well as impact of TiO2 nanoparticles on photosynthetic chlorophyll content of S. Bicolor were presented in this data article. Figs. 1–2 represent germination rate and growth parameters of S. bicolor grown in Sb-contaminated soil treated with different levels of TiO2 NPs. S. bicolor showed high tolerance to the presence of different contents of TiO2 nanoparticles in Sb-polluted soil, with the lowest germination rate of 76.7 ± 2.9% in 1000 mg/kg TiO2 NPs treatment. Total plant biomass increased with the application of 50 to 250 mg/kg nanoparticles of TiO2, while declining trend was observed in amended soils with higher TiO2 NPs concentrations. Bio concentration factors (BCF) and translocation factors (TF) of Sb for S. bicolor in different treatments are shown in Fig. 3. Distributions of Sb and Ti in organs of S. bicolor cultivated in antimony contaminated soil treated with TiO2 nanoparticles after 80 days are presented in Tables 1 and 2, respectively. Concentrations of Sb in roots of S. bicolor were 43.11,57.33,73.88,44.38 and 29.45 mg/kg in treated soils with 50,100,250,500, and 1000 mg/kg TiO2 nanoparticles, respectively, compared to 31.78 mg/kg of the control. A total concentration of Sb in S. bicolor grown in presence of 250 mg/kg TiO2 NPs was 319.16 mg/kg with a significant increase of 2.23 times, compared to the control treatment. Data shows that addition of TiO2 nanoparticles to soil, particularly at lower doses, increased the absorption and translocation of Sb in comparison with control treatment. Accumulation of Sb in shoots of S. bicolor was greater than roots in all treatments. Increase in BCF values was ob-
Fig. 1. Final seedling emergence of *S. bicolor* in Sb-contaminated soil treated with TiO$_2$ NPs. Error bars represent standard deviation of three replicates. Different letters represent significant differences between the treatments (mean ± SD; n = 3; p < 0.05).

### Table 1
Distribution of Sb in the roots and shoots of *S. bicolor* in Sb-contaminated soil treated with TiO$_2$ NPs after 80 days. Standard deviations for three replicates are presented.

| TiO$_2$ NPs concentration (mg/kg) | Sb concentration (mg/kg) | Roots       | Shoots       |
|----------------------------------|---------------------------|-------------|--------------|
| 0                                | 31.78 ± 1.54              | 67.06 ± 2.95|
| 50                               | 43.11 ± 2.68              | 100.45 ± 3.61|
| 100                              | 57.33 ± 2.58              | 153.64 ± 8.78|
| 250                              | 73.88 ± 5.14              | 245.28 ± 7.82|
| 500                              | 44.38 ± 2.17              | 87.87 ± 6.75|
| 1000                             | 29.45 ± 2.86              | 48.59 ± 2.86|

### Table 2
Distribution of Ti in roots and shoots of *S. bicolor*, bioconcentration factors (BCF) and translocation factors (TF) of Ti in *S. bicolor* grown in Sb-contaminated soil treated with TiO$_2$ NPs after 80 days. Standard deviations for three replicates are presented.

| TiO$_2$ NPs concentration (mg/kg) | Ti concentration (mg/kg) | Accumulation and translocation factors of Ti |
|----------------------------------|---------------------------|---------------------------------------------|
|                                  | Roots | Shoots | BCF | TF  |                  |
| 0                                | 545.95 ± 7.78 | 283.89 ± 22.04 | 1.44 ± 0.11 | 0.52 ± 0.03 |
| 50                               | 791.11 ± 28.95 | 435.11 ± 16.41 | 1.53 ± 0.07 | 0.55 ± 0.04 |
| 100                              | 895.23 ± 30.75 | 563.99 ± 39.87 | 1.88 ± 0.06 | 0.63 ± 0.06 |
| 250                              | 1127.63 ± 16.51 | 811.89 ± 33.66 | 2.18 ± 0.04 | 0.72 ± 0.03 |
| 500                              | 1393.39 ± 49.02 | 724.56 ± 42.50 | 1.7 ± 0.09 | 0.52 ± 0.05 |
| 1000                             | 1578.43 ± 70.55 | 726.08 ± 137.23 | 1.64 ± 0.08 | 0.46 ± 0.07 |

Observed in *S. bicolor* grown in 50–250 mg/kg TiO$_2$ nanoparticles treated soil, compared with the control soil. The BCF of Sb for the *S. bicolor* grown in treated soil with 1000 mg/kg TiO$_2$ nanoparticles was 1.32, which was only 4.76% higher than that of control treatment. TF values in TiO$_2$ nanoparticles treatments ranged from 1.65 to 3.32 for Sb, with the highest TF values obtained for 250 mg/kg TiO$_2$ nanoparticles. Concentrations of Ti in roots increased with TiO$_2$ nanoparticles concentration to hit a plateau of 1578.43 mg/kg in treated soil with 1000 mg/kg TiO$_2$ nanoparticles, which was 2.89 times greater than the corresponding value in control treatment. BCF and
TF values of Ti in TiO$_2$ nanoparticles treatments ranged from 1.44 to 2.18 and 0.46 to 0.72, respectively.

The accumulation capacities in roots and shoots of *S. bicolor* treated with TiO$_2$ nanoparticles were shown in Fig. 4 and Fig. 5, respectively, for Sb and Ti. The greatest total Sb accumulation capacity in *S. bicolor* reached 4034.3 μg per pot, which was achieved in 250 mg/kg TiO$_2$ nanoparticles treatment, while the least Sb accumulation capacity was determined to be 576.8 μg per pot in 1000 mg/kg TiO$_2$ nanoparticles treatment. The greatest total Ti accumulation capacity in *S. bicolor* was found to be 18,521.33 μg per pot, which was also achieved in 250 mg/kg TiO$_2$ nanoparticles treatment. Fig. 6 illustrates changes of chlorophyll content of *S. bicolor* under the effect of different doses of TiO$_2$ nanoparticles in contaminated soil. Chl a/Chl b ratio was slightly changed at low concentrations of TiO$_2$ nanoparticles compared with the control; however, Chl a/Chl b ratio in presence of 500–1000 mg/kg TiO$_2$ nanoparticles showed profound difference with the control.
Experimental design, materials and methods

The collected soil samples were sieved through a 2-mm mesh to exclude the gravel and large debris, and then air-dried (22–25 °C) for one week. The sieved soil was thoroughly mixed by hand before adding Sb to soil. The obtained soil was placed in plastic pots. Pots were filled with 1 kg of soil and mixed with 150 ml distilled water containing K₂H₂Sb₂O₇•4H₂O, to provide desired level of Sb in soil. In the control pots 150 mL of clean DW was added [1]. The pots were kept in a dark room (20–24 °C) and stabilized for eight weeks at 70% of field capacity using tap water before planting. Chemical analysis of the soil was carried out prior to sowing the seeds. Briefly, the soil pH was measured in suspension using a 1:2.5 (w/v) ratio of soil-water ratio. Phosphorus was determined by Olsen P extracting solution (0.5 M NaHCO₃, pH 8.5), total nitrogen by the Kjeldahl measurement (VELP Scientifica, UDK 142, Italy), organic carbon (OC) content was measured according to the Walkley-Black method, in which organic carbon is oxidized using potassium dichromate [2]. Electrical conductivity (EC) was measured using a conductivity meter in a soil-water extract (1:2.5 soil: water ratio (w/v)). The soil texture was determined using a Bouyoucos densitometer which is classified as Clay-Loam (CL). The obtained data represent the mean value of three replicates. Sb and Ti contents of soils were determined as described by the USEPA-3050B method [3]; 0.5 g of soil sample was digested with a mixture of concentrated 14 mL of HNO₃, HClO₄ and HF (5:1:1, v/v/v) in a tightly closed Teflon vessel for 4 h. Then the concentrations of elements in soil were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) (Perkin Elmer Optima 5300 DV) [4]. Sb and Ti could be detected at a limit of 0.002 mg/L. All the analytical determinations were carried out three times and the average values were reported.

In order to prepare TiO₂ NPs, 50 ml TiCl₄ was slowly added to 200 mL distilled water (DW) in an ice bath and stirred for 30 min using a magnetic stirrer to gain a homogeneous solution. Then, the bath temperature was increased to boiling point till the process of formation of nanoparticles completed. 150 mL of urea solution (104 mg/mL) was added under constant stirring rate till the solution turned into a white colloid without any precipitation. The obtained solution was then allowed to settle overnight and the precipitate was washed with DW for 5 times [5]. When TiCl₄ hydrolyses, TiO₂ particles in accompany with H⁺ and Cl⁻ ions were produced, which can be described by the following reaction:

$$TiCl_4 + 2H_2O \rightarrow TiO_2 \downarrow + 4H^+ + 4Cl^-$$  (1)
Fig. 4. The Sb accumulation capacity in roots (a) and shoots (b) of S. bicolor treated with TiO$_2$ NPs after 80 days. Error bars represent standard deviation of three replicates. Different letters represent significant differences in roots and shoots, respectively, between the treatments (mean ± SD; n = 3; p < 0.05).

Then, the volume of the suspension was made up to 100 mL with deionized water, containing the desired concentration of the TiO$_2$ NPs per 100 mL deionized water. The size of TiO$_2$ NPs were determined using transmission electron microscopy (TEM), manufactured by PHILIPS (EM208 S), with an acceleration voltage of 100 kV. The size of the TiO$_2$ NPs particles covers a range between 15 and 40 nm. Selection of TiO$_2$ NPs concentration range was based on the preliminary experiments, which showed that TiO$_2$ NPs concentration of lower than 50 mg kg$^{-1}$ had negligible influence on plant growth and Sb uptake. Applying higher than 1000 mg kg$^{-1}$ TiO$_2$ NPs to soil exhibited severe inhibitory effects on plant growth. Therefore, the TiO$_2$ NPs concentration range was selected as 50–1000 mg kg$^{-1}$ to assess the impacts of TiO$_2$ NPs on phytoremediation of Sb-contaminated soil. Synthesized TiO$_2$ NPs were applied to the soil at desired levels of TiO$_2$ NPs per kilogram of soil by suspending 50–1000 mg of the TiO$_2$ NPs in 300 mL of deionized water separately, sonicated in water bath for 30 min at 30°C with occasional stirring.

Plant seeds were obtained from the National Plant Gene Bank of Iran (NPGB) and sown in plastic pots containing different concentrations of TiO$_2$ NPs. Nanoparticles of TiO$_2$ at doses
of 0, 50, 100, 250, 500 and 1000 mg/kg were added to the prepared plastic pots containing Sb-contaminated soil and thoroughly mixed. *S. bicolor* was cultivated over an 80-day period in a greenhouse. The seeds were planted in the 1.5–2.0 cm depth of the surface soil in each pot. Pots were kept in a greenhouse under natural sunlight (20–25 °C, 10–12 h light) to imitate real-world conditions. Pot experiments were carried out in three replicates. Pots were monitored to assess seedling emergence rate in different treatments and grown plants were harvested after 80 days, and the biomass and length of roots and shoots were measured. Plants were dried in an oven at 70 °C for 48 h to obtain dry weight of the biomass.

After harvesting, roots and shoots of the plants were thoroughly rinsed with distilled water, dried at room temperature (22–25 °C), and then oven-dried at 60 °C for 12 h. The obtained sam-
ples were passed through a 200 mesh. The amount of 0.2 g ground sample was digested in a digestion tube. 15 mL of 70% HNO₃ was added and heated at 120°C for 90 min. After cooling down, 3 mL 30% H₂O₂ was added to the digestion block, then heated again to 120°C for 90 min. The obtained solution then let to be cooled down and filled up with Milli-Q water to 50 mL, and then analyzed for the Ti and Sb concentrations by inductively coupled plasma optical emission spectrometry (ICP-OES) (Perkin Elmer Optima 5300 DV) [6]. Bio concentration factor (BCF) and translocation factor (TF) values were calculated using the following equations [7]:

\[
BCF = \frac{\text{Concentration of metal in roots}}{\text{Concentration of metal in test soil}}
\]

\[
TF = \frac{\text{Concentration of metal in shoots}}{\text{Concentration of metal in roots}}
\]

Fresh leaves were analyzed in dark condition in order to determine chlorophyll content. Accurately weighted amount (0.5 g) of intact leaves were grinded thoroughly, 20 ml of 80% acetone was added. Milled mixture was then incubated at 4°C for 3 h, and centrifuged for 5 min at 2500 rpm to remove particulate matter. The supernatant was filtered and transferred into a 50 ml volumetric flask and the volume was made up to 50 ml by addition of 80% acetone. Chlorophyll content was measured by UV spectrophotometry at 645 nm and 663 nm [8]. The chlorophyll \( a \) (Chl \( a \)), chlorophyll \( b \) (Chl \( b \)), and chlorophyll \( a+b \) (total chlorophyll) contents were calculated using the following equations [9]:

\[
\text{Chl} \ a = 12.7 \times A663 - 2.69 \times A645
\]

\[
\text{Chl} \ b = 22.9 \times A645 - 4.68 \times A663
\]

\[
\text{Chl} \ (\text{total}) = 8.02 \times A663 - 20.21 \times A645
\]

All statistical analyses were performed using IBM SPSS Statistics 24. All the results in this paper are presented as the mean with standard errors (\( n = 3 \)). Significance of differences was determined using one-way analysis of variance (ANOVA), followed by least significant difference (LSD) test. Significance level was considered at \( P = 0.05 \).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Acknowledgments

The authors would like to thank the University of Tehran for the financial support for this research.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.105959.

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