JOURNAL OF ENVIRONMENTAL SCIENCES XX (2017) XXX–XXX

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JES JOURNAL OF ENVIRONMENTAL SCIENCES

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Development of a novel myconanomining approach for the recovery of agriculturally important elements from jarosite waste

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A R T I C L E I N F O

Article history:
Received 21 March 2017
Revised 15 September 2017
Accepted 30 September 2017
Available online xxxx

Keywords:
Bioleaching
Fourier transform infrared spectroscopy (FTIR)
Transmission electron microscopy (TEM)
Jarosite
Nanoparticles
Seed-emergence activity

A B S T R A C T

In this study, an ecofriendly and economically viable waste management approach have been attempted towards the biosynthesis of agriculturally important nanoparticles from jarosite waste. *Aspergillus terreus* strain J4 isolated from jarosite (waste from Debari Zinc Smelter, Udaipur, India), showed good leaching efficiency along with nanoparticles (NPs) formation under ambient conditions. Fourier-transform infrared spectroscopy (FT-IR) and transmission electron microscopy (TEM) confirmed the formation of NPs. Energy dispersive X-ray spectroscopy (EDX analysis) showed strong signals for zinc, iron, calcium and magnesium, with these materials being leached out. TEM analysis and high resolution transmission electron microscopy (HRTEM) showed semi-quasi spherical particles having average size of 10–50 nm. Thus, a novel biomethodology was developed using fungal cell-free extract for bioleaching and subsequently nanoconversion of the waste materials into nanostructured form. These biosynthesized nanoparticles were tested for their efficacy on seed emergence activity of wheat (*Triticum aestivum*) seeds and showed enhanced growth at concentration of 20 ppm. These nanomaterials are expected to enhance plant growth properties and being targeted as additives in soil fertility and crop productivity enhancement.

Introduction

Presently, an annual production of approximately 960 million tonnes (MT) of solid waste as by-products of processes like industrial, mining, agricultural and municipal has been reported in India. Out of this, around 4.5 MT are considered to be hazardous in nature (Er. Nitisha Rathore and Er. Devendra, 2014). Jarosite is one such important solid waste material, which is generated during the hydrometallurgical metallic zinc extraction process of zinc industries. Currently, substantial quantity of jarosite waste is being generated universally and China, Canada, USA, Japan, Australia, Spain, Holland, France, Yugoslavia, Korea, Brazil, Mexico, Norway, Germany, Argentina, Belgium and India are top producers (Pappu et al., 2011). Approximately 2.5 MT of such zinc residues are being disposed of *per annum* globally (Asokan,

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https://doi.org/10.1016/j.jes.2017.09.017
1001-0742/© 2017 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

2007; Asokan et al., 2006). About 0.25 MT of jarosite is released in India *per annum* (Er. Nitisha Rathore and Er. Devendra, 2014).

The generated jarosite waste is hazardous in nature due to the presence of toxic heavy metals (Al, Cu, Cd, Cr, Pb *etc*.) and is posing severe hazards to the exposed abiotic and biotic components of the ecosystem. In order to avoid environmental problems caused by the leaching of heavy metals from jarosite waste, researchers are developing methods/technologies for its management (Katsioti et al., 2006; Vyas, 2011). In the last two decades, various jarosite waste management strategies have been developed by researchers for their safe disposal and application like the development of landfill, construction and ceramic materials. Each management strategy has its own advantages and disadvantages, and these are non-renewable in nature and require large scale set up (Acharya et al., 1992; Katsioti et al., 2006). The reported method in this paper is an alternative ecofriendly biological approach to the existing physico-chemical methods of jarosite waste management.

The biological approach based on interactions between fungi and metallic elements/compounds has been well established, and the inherent ability of fungi to extract and/or bioaccumulate metallic elements/compounds is already applied in biotechnological processes such as bioleaching and bioremediation. As an outcome of research in the nanoparticles biosynthesis field, it has been reported that fungi possess inherent capability to synthesize metallic nanostructured materials by the intra- or extra-cellular reduction of metallic elements/compounds (Mishra and Rhee, 2010; Ren et al., 2009; Santhiya and Ting, 2005). As a novel method, myconanomining (Fungi mediated bioleaching and conversion of bulk metallic elements/compounds into nano-structures) is considered safe and ecologically benign for the conversion of bulk inorganic (metal based) materials into nanostructured forms.

In this myconanomining approach, the use of fungal biomass aqueous extract containing secretome for bioleaching from collected jarosite waste materials and subsequent biosynthesis of nanoparticles (plant nutrients Fe and Zn) is a possibility that has not been applied extensively. The use of myconanomining for bioleaching and biosynthesis of metal nanoparticles from jarosite waste can offer several advantages over other environmental biological process, such as: (i) more biomass production, (ii) fungal secretome contains large amounts of extracellular proteins with diverse functions, (iii) more biosorption of metallic elements/compounds at low pH and (iv) high metal reducing activity of secretome.

Therefore, considering the importance and future scope of myconanomining approaches, the following objectives have been formulated for this study (i) Total metal analysis of jarosite waste using Atomic Absorption Spectroscopy technique; (ii) Isolation and characterization of promising fungal strain for myconanomining from jarosite waste using culture enrichment technique; (iii) Bioleaching and biosynthesis of plant nanonutrients *via* myconanomining approach using *Aspergillus terreus* strain J4 and (iv) *in-vitro* assessment as a nutrient use efficacy of biosynthesized metal nanoparticles on wheat using seed emergence promoting activity.

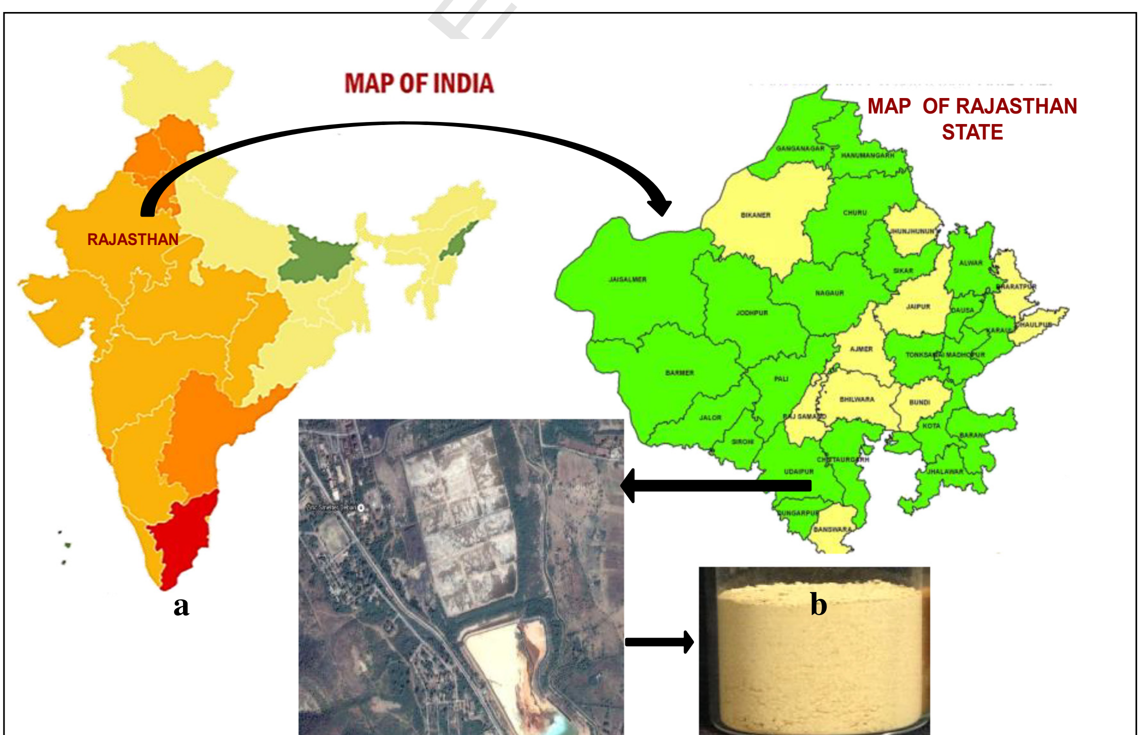

Fig. 1 – (a) Jarosite sample collection site (24°35′58″N 73°49′8″E) (http://wikimapia.org/171241/HZL-Debari (03/12/2015)); (b) jarosite as-collected.

Please cite this article as: Bedi, A., et al., Development of a novel myconanomining approach for the recovery of agriculturally important elements from jarosite waste, J. Environ. Sci. (2017), https://doi.org/10.1016/j.jes.2017.09.017