Cadmium Bioremediation by Brevibacillus spp: A Minireview

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***Abstract*—The field of bioremediation technique has experienced a substantial method in the last years but still, the choice of biocandidate is an elusive problem. In addition, the growing number of metal sources is accompanied by an increasing need for efficient bioremediate tools. In the last period, changes in bacterial taxonomy based on 16S rDNA gene sequence analysis have been reflected in the classification scheme of genus *Brevibacillus*. This review covers the different microorganisms that have been used in cadmium bioremediation and some *Brevibacillus* spp. which have been isolated and their recent application for environmental biotechnology. To our knowledge, recently, *B. agri* has been identified for cadmium resistance; therefore, *B.agri* can be a useful bacterium for cadmium bioremediation labouring new resistant genes and informatics mechanisms in bioremediation.**

***Index Terms*—Adsorption; Bioaccumulation; Bioremediation; *Brevibacillus agri*; Cadmium.**

I. Introduction

A variety of combine physiochemical or chemical techniques is available for immobilization of cadmium contaminant from water, including those that use chemical oxidation, chemical precipitation, ion exchange, and surfactant-enhanced adsorption. Although the most removal cadmium (II) technique is using precipitation there are certain disadvantages of the chemical precipitation techniques. The chemical precipitation technology is not cost-effective for the removal of cadmium (II) at a low concentration from contaminated environments (Wuana and Okieimen, 2011). Surfactant-enhanced adsorption technology has applied widely to cadmium adsorption using a variety of surfactants such as agricultural wastes, granular activated carbon, industrial wastewater (Kazemipour *et al*., 2008). Table 1 shows the capacities of some surfactant that used for cadmium adsorption.

Biological methods; however, have been sought as an alternative strategy. Hence, there is a demand for safe, and effective ways to remove cadmium (II) contaminant from the environment, considering alternative treatment of cadmium contaminated groundwater is extremely important for public health. Biological treatment techniques are considered one of the remediation techniques that increasingly gaining attention as an alternative technology because of their potential uses for providing simplicity, efficiency, and cost-effective technology for cadmium remediation especially at a dilute concentration (Tausz and Donath, 1930). These technologies exploit biological process by certain plant, alga, fungi, yeast, and *Bacteria* to bioremediate cadmium. The biological mechanisms for the removal of cadmium from water by living microorganism are via biosorption, extracellular or intercellular uptake, accumulation, complexation, oxidation, and precipitation (Means, 1994). Reviews of Jebril (2020) ; Jebril *et al*., (2022), (2022) and (2023) included the capacities of some of bacteria and plant, alga, fungi, and yeast species that used previously for cadmium removal. Bioremediation techniques are more sustainable, and economical technologies even some bioremediation techniques that required the addition of nutrients, expensive but they are still efficient environmental clean-up techniques in compared to physical, and physiochemical techniques (Tyagi *et al*., 2011). The first practice of bacteria for Cd bioremediation was explored in species of *Citrobacter* (Macaskie and Dean, 1984a; Macaskie and Dean, 1984c). Subsequent these expectations, this *Citrobacter* was too considered for this purpose in different conditions (Macaskie and Dean, 1984b; Macaskie *et al*., 1987). And later, more amendment method was applied for using *Citrobacter* sp. in Cd bioremediation such as in solutions supplemented with phosphatase substrate (Michel *et al*., 1986; Macaskie *et al*., 1994). Also, *Citrobacter* MCM B-181 was used for Cd bioremediation (Puranik and Paknikar, 1999).

Cadmium (II) Bioremediation

Bacteria have bioremediation mechanisms by which cadmium (II) can be taken up, and remove cadmium (II) from the solution. An understanding of these mechanisms is important to utilise the selectivity, and efficiency of the optimisation of the bioremediation process (Beveridge and Murray, 1980; Tsezos and Volesky, 1982; Lovley and Phillips, 1992). A review of Jebril (2020) described the catabolic landscape and physiochemical mechanisms.

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Review Bacterium Brevibacillus

The *Brevibacillus* spp. are forming a group thermophilic, psychrophilic, acidophilic, alkalophilic or halophilic, Gram positive, negative or variable, and rod-shaped *Bacteria*. The members of the genus are either strictly aerobic or facultative anaerobic, and optimally grow within the range of temperature 30°C to 45°C (Vos *et al*., 2011a). Changes in bacterial taxonomy have been reflected in the classification scheme used to define on the basis of 16S rDNA gene sequence analysis which was, up until 1996. The genus *Brevibacillus* was first described by Migula (1900), and reclassified as a species belonging to the novel genus *Brevibacillus* by Shida *et al*. (1996). The shift toward a phylogenetic classification system dram antically affected the biological identity of the genus *Brevibacillus*, which was a relatively large and important group of Gam-positive. Currently, the genus *Brevibacillus* includes 20 species allotted to the novel genus *Brevibacillus*; namely: *B. brevis*, *B. agri*, *B. borstelensis, B. centrosporus*, *B. choshinensis*, *B. formosus, B. ginsengisoli, B. invocatus, B. laterosporus, B. levickii, B. limnophilus, B. parabrevis, B. reuszeri, B. thermoruber*, *B. aydinogluensis*, *B. fluminis*, *B. fulvus*, *B. ginsengisoli*, *B. massiliensis*, *B. nitrificans*, and *B. panacihumi* (Andersson *et al*.,1999; Logan *et al*., 2002; Goto *et al*., 2004; Allan *et al*., 2005; Baek *et al*., 2006; Parvez *et al*., 2009; Kim *et al*., 2009; Choi *et al*., 2010; Vos *et al*., 2011a; Sharma *et al*., 2012; Hugon *et al*., 2013). The general features of species from genus *Brevibacillus* has been reviewed by Panda *et al*. (2014).

Brevibacillus Spp. in Polluted Environments

The species of *Brevibacillus* have been isolated from the diverse environmental habitats, and geographical locations; this includes waste compost, oil fields, hot water springs, food, and food processing environments, volcanoes, and hydrothermal marine vents, pharmaceutical products, heat treatment of specimens, human clinical specimens, and from human illness or with insect pathogenicity (Gomri *et al*., 2018).

Biotechnological Applications of Brevibacillus Spp. Used In Bioremediation

Regarding to the biotechnological applications, different species of *Brevibacillus* were used previously for different bioremediation studies. Table 1 summaries the literary of some *Brevibacillus* species isolated in previous studies with their ecological distribution, and biotechnological applications.

TABLE 1. SUMMARIES OF ECOLOGICAL DISTRIBUTION, AND BIOTECHNOLOGICAL APPLICATIONS OF SOME *BREVIBACILLUS* SPECIES, PREVIOUSLY ISOLATED.

Brevibacillus species	Environmental source	Applications	Reference
B. levickii	Geothermal soils of northern Victoria L, and, Antarctica	Possessed an uptake system specific for L-glutamic acid	Allan *et al.*, 2005
B. invocatus	An outbreak of water-borne illness in four Swedish towns	Associated with an outbreak of waterborne illness	Logan *et al.*, 2002
Brevibacillus sp.	Coomassie brilliant blue- polluted soil	Degrade toluidine blue dye (TB)	Alhassani *et al.*, 2007
B. brevis	Nickel-contaminated soil	Nickel tolerant	Vivas *et al.*, 2006
B. brevis	Cadmium-polluted soil	Cadmium tolerance	Vivas *et al.*, 2003b
B. brevis	Cadmium-contaminated soil, Nagyhörcsök, Hungary	Cadmium tolerance	Vivas *et al.*, 2003a
B. brevis	Cadmium-contaminated soils	Cadmium bioaccumulation ability	Vivas *et al.*, 2005
B. laterosporus	Soil sediments, near a wastewater effluent outlet of a local cotton textile factory, Nakhonpathom, Thailand	Dye-decolorization	Lang *et al.*, 2013
B. brevis	Soil sediment, Guiyu, Guangdong Province, China	Biosorption , and biodegradation of triphenyltin	Ye *et al.*, 2013
Brevibacillus sp.	Lead and cadmium-polluted soil	Lead and cadmium absorbed	Ruiz-Lozano and Azcón, 2011
B. laterosporus	Microbial type culture collection, Chandigarh, India	Biodegradation of dissimilar dyes	Kurade *et al.*, 2011
B. laterosporus	Microbial type culture collection, Chandigarh, India	Biodegradation , and detoxification of textile dye	Kurade *et al.*, 2016
B. brevis	Soil, saontalpara, Haringhata, Nadia, India	Biotransformation , and bioaccumulation of arsenic	Banerjee *et al.*, 2013
Brevibacillus sp.	Arsenic-contaminated soil	Arsenic bioremediation	Mallick *et al.*,2014

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B. brevis	Wastewater Abeokuta, Ogun state, Nigeria	Removal of chromate	Wani *et al.*, 2016
Brevibacillus sp.	Indonesia's hot Springs	Alkaline protease	Wang *et al.*, 2012
B. agri	Engineering *B.agri* dihydropyrimidinase	Production of l-homophenylalanine	Lo *et al.*, 2009
Brevibacillus sp.	Diyadin hot Spring, Agri, Turkey	Removal of textile dyes	Bozoglu *et al.*, 2013
Brevibacillus sp.	Rhizosphere, arsenic-contaminated soil, Nadia, India	Bioremediation of arsenic	Mallick and Mukherjee, 2015
B. borstelensis	Hasanabdal hot spring water, Ercis, Van, Turkey	Fruit juice , and oil extraction	Demir *et al.*, 2014
B. thermoruber	Hot springs naturally enriched with mercury, Mount Amiata, Tuscany, Italy,	Reduced ionic mercury	Chatziefthimiou *et al.*, 2007
B. brevis	Marine sediments, Guiyu, Guangdong, China	Biosorption and biodegradation of pyrene	Liao *et al.*, 2015
B. thermoruber	Feather-contaminated soil	Degradation of native feathers	Sulimma *et al.*, 2013
B. brevis	Soil, Scheyern, Bavaria, Germany	Degradation of chiral fungicides meta laxyl and furala xyl	Sulimma *et al.*, 2013
B. nitrificans	Microbiological agent	Nitrogen removal in sewage treatment tanks	Takebe *et al.*, 2012
B. laterosporus	--------	Degradation of polyvinyl alcohol	Lim and Park, 2001
B. borstelensis GIGAN1	A river sludge in Guangzhou, China	Biodeodorization of thioanisole	Li *et al.*, 201
B. parabrevis	Water bodies located near to the carpet industries, Bhadohi, India	Bioremediation of Congo red dye	Talha *et al.*, 2017
B. laterosporus CrRPSD40	Marine sediments, Paradip port, Odisha, India	Reduction of chromium	Mohapatra *et al.*, 2017
B. agri DH-1	Soil	Remove dichlorobenzene	Yang *et al.*, 2017
B. invocatus C19	Egyptian Coke	Desulfurization of dibenzothiophene	Nassar *et al.*, 2013
B.agri CAT 37	Gas-washing wastewaters	Biodegradation of malodorous thiols	Chebbi *et al.*, 2015
B. laterosporus MTCC 2298	--------	Biodegradation of malachite green, triphenylmethane dyes	Gomare *et al.*, 2009
B. panacihumi ZB1	-----------	Biological treatment, COD	Er *et al.*, 2018
B. brevis	--------	Bioremediation of triphenyl phosphate	Wei *et al.*, 2018
B. parabrevis MTCC 12105	Pulp , and paper mill sludge	Pulp , and paper effluent degradation	Hooda *et al.*, 2018

Some *Brevibacillus* spp. have been applied in biodegradation of pollutants such as biodegradation of low-density of polyethene by *B. parabrevis* (Pramila *et al*., 2012), and of triphenyltin by *B. brevis* (Ye *et al*., 2013). Additionally, species of *Brevibacillus* sp. have been found to be able to biodegrade of keratins (Jaouadi *et al*., 2013) or oil recovery as has been studied in *B. brevis* (Ebrahim *et al*., 2008). *Brevibacillus* spp. also have the ability to act as a candidate biocontrol agents due to their capacities to produce extracellular neutral protease. The biocontrol potential of this species has been reported against nematode control (Tian *et al*., 2006), insects, *Lepidoptera* and *Coleoptera* (De Oliveira et al., 2004), *Musca domestica*, and *Aedes aegypti* (Ruiu *et al*., 2007). In addition to its pathogenicity against invertebrates, different strains *of B. laterosporus* showed a broad-spectrum antimicrobial activity especially against Bacteria, fungi, and mycobacteria (De Oliveira *et al*., 2004; Chandel *et al*., 2010; Hassi *et al*., 2012; Joo *et al*., 2015; Yang *et al*., 2016; Arumugam *et al*., 2017). Therefore, the wide ranges of using the *Brevibacillus* species were supported the potential used of this bacterium for cadmium removal.

II. Conclusion

In conclusion, Brevibacillus spp. expresses its attitudes like nickel, lead, chromate, arsenic and cadmium tolerant, biodegradation of pollutants and biocontrol agents. *Brevibacillus* spp. were isolated previously from cadmium-contaminated environments, and used for enhancing the uptake of cadmium by plant of contaminated soils (Vivas *et al*., 2003a; Vivas *et al*., 2003b; Vivas *et al*., 2005; Ruiz-Lozano and Azcón, 2011; Dourado *et al*., 2013). But none of any study has been used B. agri for cadmium removal, especially. To our knowledge, there is no study which identified the cadmium resistance of the *B. agri*. The above-mentioned features were confirming and concluded that *B. agri* could be one of the most appropriate bacterium or more right choice for cadmium bioremediation.

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