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CADMIUM BIOREMEDIATION BY BREVIBACILLUS SPP: A MINIREVIEW

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Abstract: This review examines the potential of Brevibacillus species in cadmium bioremediation, a critical environmental challenge due to the harmful effects of cadmium contamination. The review highlights the limitations of traditional chemical methods, such as precipitation, which are inefficient at low cadmium concentrations and costly. Instead, biological methods are increasingly favored for their cost-effectiveness, sustainability, and efficiency, particularly at dilute concentrations. The review focuses on the genus Brevibacillus, a group of bacteria known for their diverse environmental habitats and biotechnological applications. Specific species of Brevibacillus have demonstrated the ability to degrade pollutants and accumulate heavy metals, including cadmium. For example, B. agri has been identified as having significant potential for cadmium tolerance and bioaccumulation. The mechanisms employed by these bacteria include biosorption, bioaccumulation, and extracellular uptake, making them effective candidates for bioremediation strategies. The review emphasizes that while several Brevibacillus species have been applied in cadmium removal, further studies are necessary to fully explore the potential of B. agri and other species in various contaminated environments. The findings underscore the importance of leveraging microbial processes for environmental cleanup, especially in areas affected by heavy metal pollution.

Keywords: Adsorption; Bioaccumulation; Bioremediation; Brevibacillus agri; Cadmium.

1. 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 [1]. Surfactant-enhanced adsorption technology has applied widely to cadmium adsorption using a variety of surfactants such as agricultural wastes, granular activated carbon, industrial wastewater [2]. 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 [3]. 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 [4]. Reviews of [5], [6], [7], [8] 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 [9]. The first practice of bacteria for Cd bioremediation was explored in species of *Citrobacter* [10], [11], [12]. Subsequent these expectations, this *Citrobacter* was too considered for this purpose in different conditions [11], [13]. And later, more amendment method was applied for using *Citrobacter* sp. in Cd bioremediation such as in solutions supplemented with phosphatase substrate [14], [15]. Also, *Citrobacter* MCM B-181 was used for Cd bioremediation [16].

2. 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 [17], [18], [19]. A reviews of [5], [6] described the catabolic landscape and physiochemical mechanisms.

3. 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 [20]. 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 [21], and reclassified as a species belonging to the novel genus *Brevibacillus* by [22]. 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* [23], [24], [25], [26], [27], [28], [29], [30]. The general features of species from genus *Brevibacillus* has been reviewed by [31].

4. *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.

5. 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.

Some *Brevibacillus* spp. have been applied in biodegradation of pollutants such as biodegradation of low-density of polyethene by *B. parabrevis* [32], and of triphenyltin by *B. brevis*. Additionally, species of *Brevibacillus* sp. have been found to be able to biodegrade of keratins [33] or oil recovery as has been studied in *B. brevis* [34]. *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 [35], insects, *Lepidoptera* and *Coleoptera*, *Musca domestica*, and *Aedes aegypti* [36]. In addition to its pathogenicity against invertebrates, different strains *of B. laterosporus* showed a broad-spectrum antimicrobial activity especially against Bacteria, fungi, and mycobacteria [37], [38]. Therefore, the wide ranges of using the *Brevibacillus* species were supported the potential used of this bacterium for cadmium removal.

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	[37]
B. invocatus	An outbreak of water-borne illness in four Swedish towns	Associated with an outbreak of waterborne illness	[30]
***Brevibacillus* sp.**	Coomassie brilliant blue- polluted soil	Degrade toluidine blue dye (TB)	[39]
B. brevis	Nickel-contaminated soil	Nickel tolerant	[40]
B. brevis	Cadmium-contaminated soil, Nagyhörcsök, Hungary	Cadmium tolerance	[41]
B. brevis	Cadmium-polluted soil	Cadmium tolerance	[41]
B. brevis	Cadmium-contaminated soils	Cadmium bioaccumulation ability	[42]
B. laterosporus	Soil sediments, near a wastewater effluent outlet of a local cotton textile factory, Nakhonpathom, Thailand	Dye-decolorization	[43]
B. brevis	Soil sediment, Guiyu, Guangdong Province, China	Biosorption , and biodegradation of triphenyltin	[44]
[45]	Lead and cadmium-polluted soil	Lead and cadmium absorbed	[45]
B. laterosporus	Microbial type culture collection, Chandigarh, India	Biodegradation of dissimilar dyes	[46]
B. laterosporus	Microbial type culture collection, Chandigarh, India	Biodegradation , and detoxification of textile dye	[47]
B. brevis	Soil, saontalpara, Haringhata, Nadia, India	Biotransformation , and bioaccumulation of arsenic	[48]
***Brevibacillus* sp.**	Arsenic-contaminated soil	Arsenic bioremediation	[49]
B. brevis	Wastewater Abeokuta, Ogun state, Nigeria	Removal of chromate	[50]
Brevibacillus sp.	Indonesia's hot Springs	Alkaline protease	[51]
B. agri	Engineering *B.agri* dih-ydropyrimidinase	Production of l-homophenylalanine	[52]
***Brevibacillus* sp.**	Diyadin hot Spring, Agri, Turkey	Removal of textile dyes	[53]
***Brevibacillus* sp.**	Rhizosphere, arsenic- contaminated soil, Nadia, India	Bioremediation of arsenic	[54]
B. borstelensis	Hasanabdal hot spring water, Ercis, Van, Turkey	Fruit juice , and oil extraction	[55]
B. thermoruber	Hot springs naturally enriched with mercury, Mount Amiata, Tuscany, Italy,	Reduced ionic mercury	[56]

B. brevis	Marine sediments, Guiyu, Guangdong, China	Biosorption and biodegradation of pyrene	[57]
B. thermoruber	Feather-contaminated soil	Degradation of native feathers	[58]
B. brevis	Soil, Scheyern, Bavaria, Germany	Degradation of chiral fungicides metalaxyl and furalaxyl	[58]
B. nitrificans	Microbiological agent	Nitrogen removal in sewage treatment tanks	[59]
B. laterosporus	--------	Degradation of polyvinyl alcohol	[60]
***B. borstelensis* GIGAN1**	A river sludge in Guangzhou, China	Biodeodorization of thioanisole	[61]
B. parabrevis	Water bodies located near to the carpet industries, Bhadohi, India	Bioremediation of Congo red dye	[62]
***B. laterosporus* CrRPSD40**	Marine sediments, Paradip port, Odisha, India	Reduction of chromium	[63]
***B. agri* DH-1**	Soil	Remove dichlorobenzene	[64]
***B. invocatus* C19**	Egyptian Coke	Desulfurization of dibenzothiophene	[65]
***B.agri* CAT37**	Gas-washing wastewaters	Biodegradation of malodorous thiols	[66]
***B. laterosporus* MTCC 2298**	--------	Biodegradation of malachite green, triphenylmethane dyes	[67]
***B. panacihumi* ZB1**	-----------	Biological treatment, COD	[68]
B. brevis	--------	Bioremediation of triphenyl phosphate	[69]
***B. parabrevis* MTCC 12105**	Pulp , and paper mill sludge	Pulp , and paper effluent degradation	[70]
***B. agri* C15**	Cadmium-contaminated soil	Cadmium tolerance, cadmium bioaccumulation ability	[71], [72], [73]
***B. agri* C15 Cd^R**	Ultraviolet light mutagenesis of *B. agri* C15	Cadmium tolerance, cadmium bioaccumulation ability	[73], [74], [75]

6. Conclusion

This In conclusion, Brevibacillus spp. expresses its attitudes like nickel, lead, chro-mate, 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. 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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No Supplementary Materials.

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N. M. T. Jebril ; methodology, writing—original draft preparation, N. M. T. Jebril ; writing—review and editing, N. M. T. Jebril ; paraphrasing. The author has read and agreed to the published version of the manuscript.

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