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Review Article

STATUS AND PROSPECTS OF BACTERIA/STRAINS TO CADMIUM RESISTANT AND THEIR DIVERSITY ISOLATED FROM WASTE SLUDGE

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Abstract

Cadmium creates toxicity within the atmosphere free through waste sludge/water released by industries such nuclear-power plants sludge victimization utilizes cadmium rods, discharge groundwater and it's harmful to any or all living organism in several forms like metabolic, plant growth, making toxicity etc. The present study shows the diversity of Cadmium resistance bacteria/strains isolated from Sewage water in past decades by researchers. Our literature review found a high Cadmium tolerance among the isolated bacteria ranging from 10μg/ml-3000μg/ml. *Pontoeaag glomerans* exhibited the highest resistance to cadmium.

Isolates were screened and characterized with biochemical and 16S rRNA-based sequencing methods. There are few reports are available for characterization by using 16S rDNA sequencing methods, but 16S rDNA sequencing has played a significant role in the accurate identification of bacterial isolates (its amplicon product shows highly and less conserved region but in case of 16S rRNA amplicon shows only highly conserved stretches in bacteria) and particularly important about bacteria with unusual phenotypic profiles, rare bacteria, slow-growing bacteria, uncultivable bacteria and culture-negative infections.

Identification of Microorganism related technology might provide an alternative or addition to the conventional method of metal removal or metal recovery. The identified Cadmium resistant bacteria would be useful for bioremediation of heavy metal contaminated sewage water.

In transferring this technology from laboratory to a large-scale application, a better understanding of all these aspects is necessary. Thus, developing biotechnological method that encompasses fields from genetic engineering to reactor engineering demands focused research in these directions, which may lead to the implementation of this technology on a larger scale and drive it toward being the most opted for technology.

Key words: Cadmium, nuclear power plants, a gram-negative rod, Bioremediation, Bioreactor, enzymatic detoxification.

Introduction

The worldwide population has risen from 5.3 to 7.3 billion. It shows quick industrialization developed the quality of living. However, this increases water pollution or toxic waste. Because the water is important source for living, contradictory methods have taken to therapy the waste material from water supplier. Whereas the records have reduced over the years, still 159 million folks utilize drinking water and 663 million people deficient in enhanced fresh water supplier WHO/UNICEF (2015). Environmental pollution is one among the foremost vital factors contributive to the obliteration of the biosphere. The main reason for heavy metal contamination is different human activities such as mining, agriculture, and various industrial methods Rajaganapathy *et al.* (2011). The concentration of heavy metals makes toxic to the soil, water and environment also which effect to the human life Rajbanshi (2008).

Physical and Chemical Properties of Cadmium:

Cadmium may be a substance with the image. In the standardized table, found in cluster 3-12 and categorized as a "Transition Metal". This can be ductile, malleable

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and bluish-white metal and able to conduct electricity and warmth. The atomic mass of cadmium is 112.411 amu, atomic number is 48, the Electronic configuration is [Kr] 4d ^{10}5s^{2} .The melting point and the Boiling point is 321.10C-594.040 K and 766.8^{0}C – 1038.150 K respectively.

Cadmium is soft, can be cut with a knife and is utilized in low friction, fatigue-resistant alloys, solders, dental amalgams, nickel- metallic element storage batteries, apparatus shields, and in rustproof electroplating. The universal uses are in Batteries – Nickel metallic cadmium, Pigments, Cadmium, Pigments, outside layer, and Plating Barrier to control nuclear reaction and T.V. In 1985, International Union of Pure Applied Chemistry (IUPAC) was Standardized a table which incorporates the cadmium component. The notable Russian, Dimitri Ivanovich Mendeleev, perceived the proper classification methodology of "the periodic table" for the 65 component that was best-known in his period. The Standardizes table currently acknowledges the additional time and then Dimitri Ivanovich Mendeleev recognized in their era however at rest all suitable into his assembling of the "Periodic Table" within which cadmium is only one element which will be established.

Cadmium Toxicity:

Cadmium quantity is rising in water and boost due to the anthropogenic roots, including with industrial waste, fertilization, and industries by-product. The cadmium contamination based on the economic behavior in the selective area and water possessions. Consequently, awareness of the cadmium migration and cadmium manipulate on water is tremendously vital Czech's submission *et al.* (2010) & Abbas (2014).

Cadmium is a particularly cyanogenetic metal that has no best-known essential role within the human body. High concentration of Cd. was reportable in industrial effluent, sediments, sewage water, mine, the ministry of industries, Thailand in 2005. These compounds are as acidic. Cadmium released toxicity into the atmosphere through industrial and agriculture activities, discharge groundwater and it is harmful to human as well as to crops in any ways like metabolic, plant growth, creating cytotoxicity etc. therefore some bacterial strain has been reportable as a cadmium-resistant. Chemical nature of cadmium is incredibly venomous to the atmosphere and will adversely influence the biological wastewater treatment. Environmental pollution will increase the metal toxicity of cadmium and high in several rustic, semi-urban and urban areas because of low to temperate sanitation. High concentrations of cadmium are extremely rusty resistant and are extensively utilized to coat metal section commonly in industrial hardware in addition as in vehicles, electronics, nautical and aerospace industries Herrero *et al.* (2005). The inhalational of Cadmium from the atmosphere causes unfavorable effects on a living organism and causes diverse types of diseases. In human beings, causes pulmonary irritation, on lung including bronchiolitis and emphysema, kidney disease, liver, carcinoma and nervous system, inhalational exposures from the atmosphere consist mainly of effects on the lung, such as pulmonary irritation. Long-term inhalation or oral exposure to cadmium leads typically to the build-up of cadmium in kidneys, and potential kidney disease ATSDR (1999). In animals, long-term breathing or oral exposure to cadmium causes harm full effects on the kidney, nephritic liver, lung, bone, immune system, blood, and nervous system. These disorders have a grievous harmful impact on human daily life. Whereas native populations are conscious to the greenhouse gasses, native authorities, if less involved regarding these metals that tend to be high in living and non-living suspended solids content among propensities for oxygen demand and containing prospective noxious metal salt residue. The activities involved in mining, construction, and expenditure of cadmium and more non-ferrous metals consequences the discharge of huge quantities of cadmium into the environment Schoeters (2006). Zinc relocates by Cadmium in several metalloenzymes and lots of the characters of cadmium toxicity are derived from a cadmium-induced zinc deficiency. Cadmium concentrates on the urinary organ, liver and numerous alternative organs and deems more poisonous than lead or mercury. It's venomous at levels simple fraction that of lead, mercury, aluminum, or nickel. Cadmium exposure is additionally increasing because of its utilize as a coating for iron, steel, and copper. It's additionally utilized in copper alloys, stabilizers in rubber and plastics, cigarette papers, fungicides and several alternatives merchandise. Usually, the atmosphere is contaminating through these industries effluent.

Economic Impact: The cadmium toxicity plays a negative role in plant growth and development. Cadmium is a heavy metal, extensively dispersed in the earth crust. Toxicity of Cadmium is rising in prevalence nowadays for many motivations. One of the first reasons is a deficiency of zinc in daily consumed foods. Against cadmium Zinc is defensive against, is altering into progressively deficient within the soil and consequently in foods. Food progressing and feeding of decontaminating foods further reduces the intake of zinc. The dissimilar industrial strategies like electroplating, mining, producing batteries, alloy, pigment, cement, fuel combustion, municipal and waste material sludge combustion and high phosphate fertilizers are liable for the discharge of giant quantity of cadmium within the atmosphere (Klaassen *et al.* 2009; Yazdankhah *et al.* 2010; Liu *et al.* 2013). After estimation, 30,000 tons of cadmium is discharged into the atmosphere annually Nriagu& Pacyna (1988).

Geologic environment and chronic diseases have a close relationship. Several studies had been conducted to interpret the relationship between geological environments. Elements are transported in water as either dissolved substances or essential elements of suspended residues; but, dissolved materials in rivers or streams have the enormous potential supply of most harmful effects. Later, they'll be accumulated in sediments of the river bottom or percolate into the subterranean water thereby inflicting contamination of groundwater, particularly wells. However, the quantity of contamination will depend on the proximity of the well to the geological source. Weathering consequences transport of Cd within the revering into the oceans and represents major flux of the global Cd. cycle. Besides, the excessive utility of phosphate manure within the agricultural areas enhanced the level of rich cadmium accumulation in fertilizers Raskin and Ensley (2000). Its influence variations within the germination method in addition as within the growth of roots, stems, leaves that finally decreases yield Arun*et al.* (2005). Cadmium contamination in water mainly in work zones and utilization of this contaminated water in irrigation. In India the yield of wheat, paddy and barseem are abridged (local animal feed plants) by 50% (Sharma and Mehrotra, 1993; Sharma and Pant, 1994; Sharma and Sharma, 1993). In drink, maximum concentration is 0.05 mg/l of cadmium recommended by World Health Organization. According to the study by National Botanical Research Institute, India, a high concentration of cadmium has been detected within the agricultural production from the affected villages. Besides, agriculture productions i.e. pumpkins, bottle guard, maize, and rice were also found contaminated. Those rural area economic conditions were sustained on horticulture, mostly Rose farming. The flower size was also terribly small, and stinks and their yield has dished by 60%. In this rural community, Vegetable grownup couldn't be sold-out in the town even at terribly low rates. This diminishes in production strips the daily fundamental earnings of farmers.

Health: Wastewater throughout the industries has the undying toxic effect on human health and the environment. Some heavy metals become toxic to the human body because they are not captured or absorbed by organisms. It can damage the cells and structure of the DNA. Toxicity of these metals is caused due to the displacement of essential metals from their binding sites Bruins *et al.* (2000). Very important respiratory enzymes easily fasten by cadmium compounds Nies (2003) leads to oxidative stress and cancer Banjerdkji *et al.* (2005). The uninhibited ejection of enormous amount of heavy metal including wastes produce enormous economic and tending burden significantly for the folks living that place (as the industries effluent excreted into the atmosphere and through food chain or organic phenomenon, influence human and animals from numerous evolution sources like industrial waste, automobiles emissions, mining activity and farming practices as well). Cadmium is unnecessary in folks for a biological function. Cadmium expires the kidney organ in each operating and general-purpose populations which are considered to be a target organ. After lots of studies, signify that smoking is additionally a source of cadmium, occurs by smokers and it damaged renal tubular accumulation of cadmium within the body. After kidney damage, it damages the skeletal within which bone cells are spoiled. It suggests that the mechanism of modification in calcium caused by cadmium that leads to osteoporosis. In addition, it's been noticed that carcinoma caused by inhalation of cadmium, however, it is not confirmed that the oral route of cadmium can be a cause of cancer Huff (2007). The vital cyanogenetic pollutant cadmium is used in nuclear power plants that found out at outskirts of rural and urban areas. But if the cadmium processing practices for work don't seem to be followed in step with guidelines they evidenced trouble in an exceeding range of health problems for the folks in those areas. In village areas wherever, primary health centers don't exist the situation becomes terribly critical if malpractices are followed for plants. Cadmium found naturally in food and drinking water, thus it makes its mode into the body mainly from nutritional intake. This accumulation, cadmium enters the environment through industries and work-related exposures. In aquatic life, the cause of the large establishment of Multiple Antibiotic Resistances (MAR) Microorganisms is due to the increase in the presence of heavy metals including cadmium. This Microorganism' causes' infections to living beings which may be complex to treatment with medicines. If cadmium enters the animal through injection or inhalation it motivates cancer, prostate, and lungs carcinomas Gallagher *et al.* (2010).

Cadmium-free by Industries:

High concentration of cadmium was reportable in industrial effluent, sediments, mine, the ministry of industries, Thailand in 2005. Cadmium is used for various applications in industries. Besides industrial progress, environmental contaminants of industrial progress, environmental contaminants of toxic heavy metals like cadmium, lead, and nickel comes into the water bodies through industrial wastewater treatment plants are wide spreading throughout the world (Denise *et al.* 1989; Ajmal *et al.* 1998). This could be factual for developing countries like Asian country and China Raja *et al.* (2008). Contamination happens largely as an impact of human actions by the creation of wastewater in metals melting, electroplating, and metallurgy. The existing low market cost of cadmium motivates the industrial enlargement of a new purpose in addition to developnovel resources of productions to the environment not covered by the accessible guideline. As a result, bioremediation procedure and alternative biotechnological significance are needs to pollutants sanitization pro every prospect judgment by the government. The treatment of heavy metals contaminated by wastewater plants has become additional vital through metal-resistant Microorganisms Shakibaie *et al.* (2008). HQ-1 is the most resistant bacterial strain and it is isolated from zinc-lead mine Qing *et al.* (2007). The undeveloped population is conscious of the pollution caused by the industrialization, but the urban population is more in trouble due to their unawareness of metal toxicitythroughcontaminated sewage-sludge. Government authorities ought to take steps to make them aware about contaminated by wastewater plants and their tendency to raise inorganic and organic suspended solids content among susceptibility for high oxygen demand and holding potentially contaminated metal salty remains. The government should ensure to follow treatment technologies by these industries to reduce toxic pollutants from wastewater or industrial sewage sludge. The proper utilization of treatment technologies can decrease the toxic concentration of cadmium from waste matters that accidentally combine with clean water and agricultural soils. If treatment technologies don't seem to be used properly threat can increase to potable water and farmland. If treatment technologies don't seem to be used properly threat can increase to potable water and farmland. In ecology, cadmium effects on the quality of land and water. Sewage sludge and wastewater released from industries cause toxic effects to the plants, human and environment Rehman *et al.* (2008). Normally, natural water contaminated by this industrial wastewater, it is hazardous to our aquatic ecosystem Chen *et al.* (2006a). Cd. survives in the 2+ oxidation form in dissimilar salts such as oxide, sulphide or sulphate and cadmium chloride Valko *et al.* (2005). Bacteria, fungi, and algae are dissimilar biomass types, has been monitored and considered extensively by authors in ancient times with the intent of highly competent metals elimination biological systems (Viraraghavan 1995; Vieira and Volesky, 2000). Hence the accumulation and distribution of heavy metals in water and environment affecting to the water reservoir due to which aquatic organism affected (Cataldo *et al.* 2001; Hobbelen *et al.* 2004; Koukal *et al.* 2004; Okafor and Opuene, 2007; Mohiuddin *et al.* 2010). Therefore, it is necessary to use different treatments or techniques to slow down this alarming growth of heavy metals Aminov (2010).

Biological Treatment:

The biological half-life of cadmium is extraordinarily high and recognized as human cancer declared by International Agency for Research on Cancer IARC (1993). Thus, cadmium pollution got the awareness of ecologists all over the world. IARI provided adequate evidence regarding cadmium. In the current record of substances that are human carcinogens induced-lung tumor and a few pieces of knowledge regarding cadmium induced-prostrate and urinary organ tumors.

In environmental biotechnology metal, resistant bacteria are used in the Bioremediation of metal toxins from sewage water. This method is used for removing the toxic agents and it is an eco-friendly as well as more effective method to the environment Singh and Tripathi (2007). It's been established that bioremediation may be efficient and favorable to chemical and physical ways of managing environmental pollutants along with wastes. Developed ways of biodegradation of metal are raising supported advances in biological science and method engineering. Recently urbanized and new gene-probe ways will set up their profusion at a definite location. In bioremediation (in situ), bio filters and bioreactors new tools and techniques are contributive to the go fast of this rapid-screening assays will acknowledge organisms competent to degrade unconcealed wastes field. This process contains some conditions like as the infiltration of water consist of oxygen and nutrients or other electron acceptors for the treatment of surface water Vidali (2001). Bacteria have the capability to contain a variety of contaminants in each organic and inorganic, it's vital to understand from the start that Microorganisms unable to demolish metals. However, Microorganisms will manipulate the quality of metal within the atmosphere by changing their physical and/or chemical characteristics. Major edges of such form of Microorganisms simply biodegrade to natural compounds; waste substance degradation & cleanup of waste-site action will be improved by this procedure Vidali *et al.* (2001). Bioremediation may be an important feature of environmental biotechnology using metal-resistant bacteria to removes metal pollutants from sewage water Kermani *et al.* (2010). Economically bioremediation may be a less complicated ways comparatively chemical treatment method Abbas *et al.* (2014). (Moreover, the innovative bioremediation technology for bioaccumulation of cadmium onto natural microbes' population like bacteria and algae are completely informed by several investigators. Abbas *et al.* (2014).

Metals and Microorganisms

Heavy metals discharge through sewage water is hazardous to the atmosphere and their consequences on the biological system are terribly rigorous. It has been reported that Microorganisms become adapted to food chain by the acquisition of specific resistance systems Founou *et al.* (2016). Microorganisms become receptive because of higher concentration of heavy metals. Consequently, to eliminate cadmium from sewage water, require of biodegradable, inexpensive, replacement and effectual methods. A lot of research has been clarified that algae, bacteria, yeast, fungi, molds, and protozoa will eliminate cadmium from the effluent or contaminated water Coelho *et al.* (2015). After research has clarified that algae, bacteria, yeast, fungi, molds, and protozoa will eliminate the cadmium from the effluent or contaminated water and can reduce the concentration of heavy metals from the environment Volesky (1986). For the deduction of cadmium, Microorganisms play a positive role in the environment. In history, several investigations are approved for the segregation of cadmium-resistant bacterial strains. *Pseudomonas putida*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Pseudomonas syringae*, *Pseudomonas fluorescens*, *Comamonas testosteroni, Staphylococcus aureus*, *Alcaligenes eutrophus*, *Gluconobacter oxydans*, *Bacillus subtilis, Staphylococcus lugdunensis*, *Alcaligenes xylosoxidans*, *Ralstonia metallidurans*, *Lactobacillus plantarum*, *Serratia liquefaciens*, *Klebsiella planticola*, *Paenibacillus* sp. and *Bacillus thuringiensis* are the instance of bacteria which have been mainly studies Amoozegar *et al.* (2012).

Conventional processes like ion exchange, bio-piles, electrochemical treatment, reverse osmosis, chemical precipitation, bio-slurries and land-filling, phytoremediation and oxidation or reduction are utilized for the removal of cadmium from soil and water resource. There are many disadvantages of this process, for instance; high protection, they are not biodegradable, turn out toxins throughout the secondary treatment process, and in reverse osmosis, they are incapable to eliminate vaporized pollutants. So, there is a need for innovative, expansive and ecological treatments (Vinod and Sashidhar 2011; Singh and Gadi 2012; Abbas *et al.* 2014c.). Bioremediation is outlined as a method which utilized in plants or enzymes, Microorganisms required to take care of the contaminated location for recovering their healthy condition Glazer and Nikaido (1995). Because of economic inputs and low value, this methodology is additionally good than conservative method. Bioremediation is a definite resolution for the elimination of transition metals because of its highly efficient and ecological possessions Gaur *et al.* (2014).

Cadmium produce complicated oxides with zinc, copper ore, lead, carbonates, and sulfides consequently it exists in the mixed variety within the environment (Monachese *et al.* 2012). $CdSO_4$ and $CdCl_2$ are soluble in the water comparing cadmium compound Darwish *et al.* (2016). Dissimilar resources discharged cadmium into atmosphere assembled as natural sources comprises earth's outer layer Kesler and Simon (2015). Based on arithmetical knowledge as shown in Table 1, the overall evaluation worldwide air discharges near about 3000 tons in 1995 Richardson *et al.* (2001) be estimated that the cadmium liberates by evaluation sources surpass than by ordinary resources. Consumption of cadmium is condensed within the countries wherever it releases within the air has been weakened. Mainly through agriculture, it enters the food because plants absorb cadmium from the air, deposition or fertilizer during biomagnifications as well as bioaccumulation. The re-suspension of sand in highly polluted regions creates infection of yields along with exposing to living organisms during respiration Martin *et al.* (2014). These toxic elementsgenerate contacts in human life and crops as shown in Table 2 which clarifies that cadmium quantity is noxious within the daily foodstuff diet in several countries. The US National Toxicology Program and International Agency for Research on Cancer are classified that the cadmium causes cancer in the human. Cadmium creates the genomic mutation within the humans that persuade cancer in the organs like pituitary glands, pancreas, and lever, prostate, adrenal, and hematopoietic system Filipic (2012). Several methods are used by Microorganisms to manage cadmium stress like cadmium growth, enzymes detoxification, cadmium efflux and its ions confiscation. The cadmium's redress from sewage water by dissimilar Microorganisms has elevated high expectation for the ecological and gainful loom. This assessment intends to supply present progress of Cd-resistant mechanisms in bacteria and their industrialized function, and outlook. This widespread study has been accepted in 2015–2016 Sains Malaya, Penang, Malaysia, University.

Table 1: Two examples of estimated global emission of cadmium to the atmosphere from natural sources

Source category[b]	Cadmium emission[a] in tones /year			
	Richardson *et al.* (2001)		Nriagu (1989)	
	Mean	5-95th percentile	Mean	Range
Release of soil particles during dust storms, etc,.	24,000	3000-69,000	210	10-400
Sea salt spray	2000	103-67000	60	0-110
Volcanic emissions	1600	380-3800	820	140-1500
Natural fires	13,000	4400-30,000	110	0-220
Vegetation, pollen and spores	_	_	190	0-1530
Meteoritic dust	0.0002	0.00004-0.0004	50	0-100
Total	41,000	15.000-88.000[a]	1300	150-26000[b]

[a] Statistical figures for total emissions are derived by statistical calculations and not by simple addition of source-specific figures Richardson *et al.* (2001)
[b] Sum as reported by Nriagu (1989)

Cells are capable to acclimatize and restart development behind a few times if the concentration of the cadmium is low. However, in tainted environments not only with heavy metals, species diversity however additionally with organic pollutants and metabolic activities of the bacteria are condensed, and therefore the metal-tolerant bacterial population are urbanized Knotek-Smith *et al.* (2003) with genus of *Pseudomonas* in addition to acidophilic bacteria prevailing Dopson *et al.* (2003) and Babichand Stotzky (1985).

Bacteria, the biomass of algae and fungi are best-known to absorb otherwise accrue metal particles (Tsezos, 1985; Gadd, 1988; Volesky, & Holan, 1995). The capacity of metal bioaccumulation through several gram-negative bacteria genera like *Pseudomonas ptudia* Highametal. (1984), *Escherichia coli* Cohen *et al.* (1991), *Pseudomonassyringae* Cabral (1992), *Pseudomonasaeruginosa* Hassen *et al.* (1998) were recognized on the manufacture of intracellular cadmium-binding proteins. Besides, *Alcaligenes eutrophus* (*Ralstonia metallidurans*) strain CH_{34}, additionally gram-negative rod and referred to as heavy metal's biosorbent (Diels & Mergeay, 1990; Nies, 1992). These toxic metals have long biological half-lives and extensive habitation, over all in industrial nation's cadmium, comprises a serious drawback Friberg (1975). As it is prevalence within the environment largely hazardous to living organisms Diels (1997). The recognition of further bacterial strains that would uptake metals with elevated potency and specificity has attracted escalating awareness from each medicinal and biotechnological vision.

In physiological and molecular provisions determine and characterize new resistant bacterial strains from cultural microbe community inhabiting cadmium contaminated sewage sludge. Shown in Table 3 and Graph 1:

Metal resistance mechanism in bacteria:

The cadmium ions infected to the sewage water from which cadmium resistant Microorganism population are collected, it was studied by Katarina *et al.* (2004). Diminutive cadmium's resistant gram-negative rods prevailed between bacteria from the bacterial area.

To segregates six Microorganism sp., eight biochemical tests consigned, *Alcaligenes xylosoxidans*, *Comamonas testosteroni*, *Klebsiella planticola*, *Pseudomonas putida*, *Pseudomonasfluorescens*, and *Serratia liquefacient*. Cadmium particle (Cd^{2+}) were capable to eliminate cadmium-resistant bacteria segregates from resolution and therefore the potency of Cd^{2+} exclusion associates to the amount of furthermore manufactured proteins within the cell portions Kermani *et al.* (2010).

Among bacteria collaborating in contaminated atmosphere communities, those genera prevail, that is understood to be concerned in biodegradation of organic pollutants. They are usually belonging to the genera *Pseudomonas, Comamonas or Acinetobacter* (Kupka & Sevcik, 1995; Proksova *et al.* 1997; Barberio & Fani, 1998; Ferrero *et al.* 1999) all of those being a gram-negative bacterium. However, bacterial cells simply preoccupied to the Cd^{2+}, presumptively by the Mn^{2+} uptake system, and may therefore critically harm the cells in many ways: cadmium may be a strong oxidative agent VanBogelen *et al.* (1987), reduces DNA replication (Mitra *et al.* 1975; Nystrom & Kjelleber 1987), and it composed the deoxyribonucleic acid additional prone to nucleolytic assault leading to single-strand deoxyribonucleic acid breaks Mitra & Bernstein (1977).

Cadmium remediation mechanismin bacteria:

In the eukaryotic Microorganisms, the main mechanism is the binding with polythiols for the detoxification of cadmium and a few toxic metals additionally. Sidewise, some methods are additionally recognized as the resistant Microorganism against the heavy metals as given in Fig. 1. These mechanisms have a major function in such circumstances wherever an elevated quantity of heavy metals does not have any

Table 2: Daily intake of cadmium via Food: country examples (Abbas *et al.*, 2017)

Country	Type of consumption data/intake study	Average dietary intake ug of cadmium per kg body weight per day	Population source	Information source
Submission	To this assessment			
Australia	Total diet study by Food Standards Australia	0.08-0.24	Males 25-34 years	Australia's submission (2005)
	New Zealand 2002			
		0.07-0.022	Females 25-34 years	
		0.11-0.29	Boys 12 years	
		0.09-0.22	Girls 12 years	
		0.18-0.57	Toddler 2 years	
		0.13-0.68	Infant 9 months	
Burkina Faso	Total diet study calculated from average total daily assuming an average weight of 60 kg	0.28	_	Burkina Faso's submission (2005)
Finland		0.17	-	NFA (2002) submitted by Finland
Japan	Total diet studies in 10 locations	0.43	-	Japan's submission (2005)
Mexico	Calculated from average total daily intake assuming an average weight of 60 kg	4.88	Population of Mezquital Valley in Hidalgo	Mexico's submission (2005)
Reported previously (based on WHO 2004)				
Australia	Disappearance	0.15	-	WHO (2004)
Canada	Total diet study	0.22	-	WHO (2004)
China	Total diet study	0.21-0.51	Adult females	WHO (2004)
		0.13	Adult females	WHO (2004)
Czech Republic	Total diet study	0.26	-	WHO (2004)
Denmark	National consumption survey	0.28	-	WHO (2004)
France	Household consumption survey	0.22	-	WHO (2004)
Germany	Total diet study	0.18		WHO (2004)
	National consumption survey	0.19	Males	
		0.16	Females	
Greece	Total diet study	0.74	-	WHO (2004)
	Not specified	0.94		
Italy	National consumption survey	0.33	-	WHO (2004)
Japan	Duplicate diet study	0.36	-	WHO (2004)
		0.31		
Netherlands	National consumption survey	0.33-0.40	Males aged 16-70 years	WHO (2004)
		0.31-0.38	Females aged 16-70 years	
New Zealand	Total diet study	0.40/0.24	Young males	Vanoort *et al.* (2000)
		0.33/0.19	Adult males	
		0.33/0.16	Females	
		0.24	Female vegetarians	

harmful consequence of cell division against bacteria Mota *et al.* (2015). The resistant genesare mainly situated on R plasmids. Generally, R plasmid survives clinically within the human being segregates pathogens such as *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* etc Chen *et al.* (2014). The

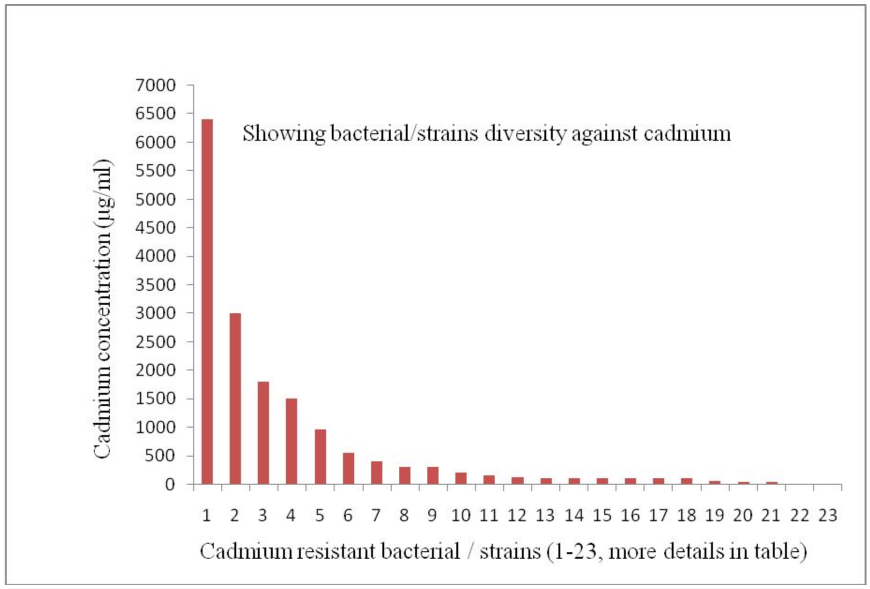
Table 3: Diversity of Bacteria/strains isolated from sewage and waste water at different cadmium concentrations

S.No.	Cadmium Resistant /Tolerant bacteria	Molecular Characterization	Concentration (µg/ml)	Culture media	Source of Isolation	References
1	*Pseudomonas aeruginosa*	No	6400	Muller-Hinton agar	Sewage water	Kermani, A. *et al.* (2010)
2	*Pantoeaagglomerans JCM 1236*	16S rDNA	3000	Eosin methylene blue (EMB)agar	Sewage water	Bhagat, N. *et al.* (2016)
3	*Bacillus* sp.	No	1800	Nutrient agar	Sewage water	Nath, S. *et al.* (2012)
4	*Klebsiella pneumonia*	16S rDNA	1500	Luria-Bertani agar	Waste water	Shamim, S. *et al.* (2012)
5	*Klebsiealla pneumonia* and *Pseudomonas aeruginosa*	No	950	Nutrient agar	Waste water	Yamina, B. *et al.* (2014)
6	*Pseudomonas* sp.*M3* and RZCd1	16S rDNA	550	Nutrient agar	Waste water	Abbas, S. Z. *et al.* (2014)
7	*Klebsiella* sp.	16S rRNA	400	Luria- Bertani agar	Wastewater	He. Y. *et al.* (2015)
8	*Pseudomonas,Staphylococcus* and *E.coli*	No	300	Nutrient agar	Wastewater	Kaur, S .*et al.* (2015)
9	*Flavobacterium spp.*	No	300	nutrient agar	Sewage water	Rajbanshi, A. (2008)
10	*Proteus Volgaris*(BC1), *Pseudomonas aeruginosa* (BC2), *Acinetobacter radioresistens* (BC3), *Pseudomonas aeruginosa*	(BC5)	200	Luria- Bertani (LB) agar	Sewage water	Raja, C. E.*et al.* (2009)
11	PNSB strains, *Rhodomiummarinum* NW16 and *Rhodobactersphaeroides* KMS24	No	150	HMs	Marine water	Panwichian, S. *et al.* (2011)
12	*Alcaligeneseutrophos* CH34 strains	No	120	Nutrient agar	Wastewater	Mahvi, A. H. & L. Diels (2004)
13	*Bacillus* sp., *Enterobacter* sp., *Aeromonas* sp., *Bacillus* sp., *Aeromonas* sp., and *Pseudomonas* sp.	16S rRNA	100	Zobell marine agar	Industrial waste water	Mathivanan, K. & R. Rajaram (2014)
14	*Pseudomonas aeruginosa* and strain BC15	16S rDNA	100	Luria- Bertani agar	Wastewater	Raja, C. E .*et al.* (2006)
15	*Enterobacter mori* and *Eentrobacter* sp. WS12	16S rDNA	100	Luria- Bertani agar	Waste-water	Abbas, S. Z. *et al.* (2014)
16	*Microccocus* sp.	16S rRNA	100	Nutrient agar	Wastewater	Benmalek, Y. & M. L. Fardeau, (2016)
17	*Bacillus Jeotgli* strain U_3	No	100	Nutrient agar	Sediments	Green Ruiz, C.R. *et al,* (2007)
18	*Pantoea* sp. RL32.2, *Salmonella enterica*and *Enterobacter* sp.	16S rDNA	100	Luria- Bertani (LB) agar	Wastewater	Abbas, S. Z. *et al.* (2014)
19	*Pseudomonas Putida, Pseudomonas fluorescens, Klebsiellaplanticola, Klebsiellaplanticola, Alcaligenesxylosoxidans, Alcaligenesxylosoxidans, Serratia liquefaciens, Comamonas testosterone*	16s rDNA	50	Nutrient agar	Sewage water	Chovanova, K. *et al.* (2004)

Table 3 Continue ....

Table 3 Continue ....

S.No.	Cadmium Resistant /Tolerant bacteria	Molecular Characterization	Concentration (µg/ml)	Culture media	Source of Isolation	References
	and ARDRA strain					
20	*Acitinobacter, Arthobacter, Bacillus& Pseudoman*	16S rRNA	40	Luria- Bertani agar	Wastewater	Tendulkar, A. *et al.* (2016)
21	*Salmonella enteric* 43C	16S rRNA	30	Luria-Bertani agar	Industrial waste water	Khan, Z. *et al.* (2016)
22	*Klebsiellaoxytoca* and strain *Ksherichia coli* JM83	16S rDNA	10	Nutrient broth(NB)	Waste water	Khleifat, K. M. *et al.* (2009)
23	Strains of *Pseudomonas, strains of .Pfragi and P.Korrensis, Eentrobacterludwigii*	16S rDNA	3	Zo Bells Marine (ZMA) agar	Sewage water	Neethu, C. S. *et al.* (2015)



Graph 1: Diversity of Bacteria/strains isolated from sewage and waste water at different cadmium concentrations.

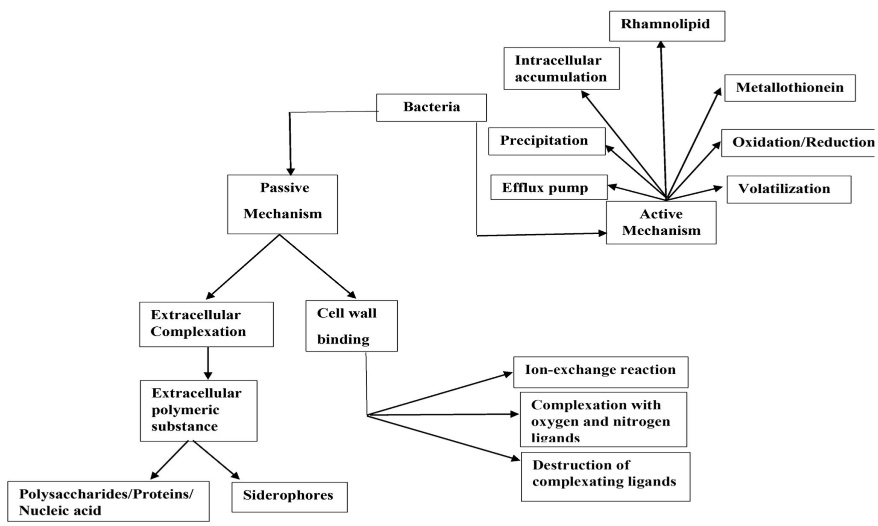


Fig. 1: General cadmium resistance mechanisms operating in bacteria (Abbas *et al.,* 2017)

following methods are concerned with cadmium resistance bacteria. Fig. 1 General cadmium resistance mechanisms operating in bacteria (Abbas *et al.*, 2017).

Efflux mechanisms:

Efflux pumps incorporate integrated membrane proteins for the contaminated metals, antibiotics and pollutant agent's from within the bacteria into the atmosphere. The *S. aureus* is recognized for the efflux system Andersen *et al.*(2015), as represented in Fig. 2. 20 efflux pumps proteins are characterized on the chromosome or plasmids in S. aureus Schindler *et al.* (2015). The drug-resistant efflux systems are resistance to heavy metals. It is established in the *S.aureus* are categorized in the 5 crust protein families: (a). RND-the resistance-nodulation-division super family, (b). ABC-The ATP binding cassette super family, (c). MATE -The multidrug and toxin extrusion family, (d). SMR-The small multidrug resistance family and (e). MFS-The

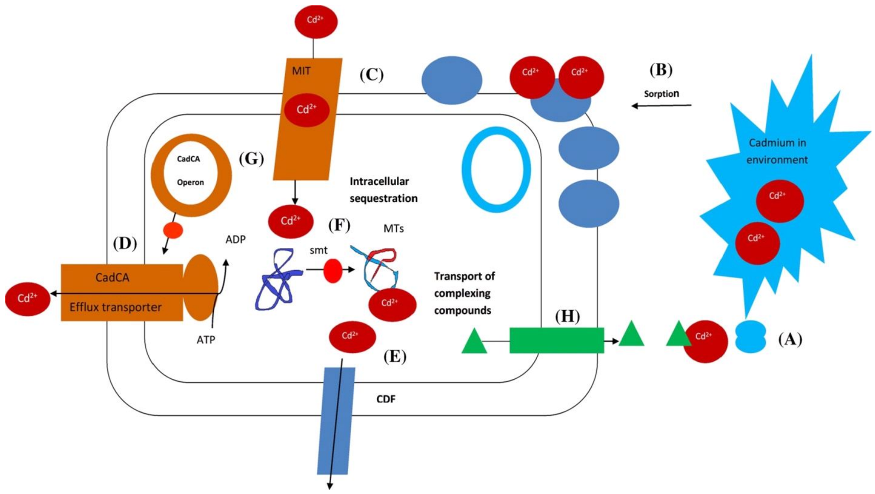


Fig: 2: Graphicaloverview of cadmium and bacterial synergism Abbas *et al.* (2017).

major facilitator super family.

In gram-negative bacteria because of RND transporters, the resistance power against multidrug is a gift. Recently, AcrB (homolog of the *E. coli* protein) is discovered within the *S. aureus*. ABC carrier has four conserved domains: 2 nucleotide-binding domains and 2 transmembrane domains. For instance, chromosomally encoded Sav 1866 and AbcA are staphylococcal ABC transporters. Primarily based on in vitro knowledge, ABC efflux pumps MsrA works with alternative transmembrane proteins because it is made of a nucleotide-binding domain. ATP hydrolysis assists ABC transporters. The hydrolysis and binding of ATP motivated to the energy-dependent conformational alter and overall translocation cycle of the material is determined. Plasmid-mediated Vga proteins are MsrAin the*S. aureus*, ABC transporters incorporate ATP-binding domains lacking transmembrane allies Lewis *et al.* (2012). Twelve transmembrane helices and 400–700 amino acids are present in MATE efflux proteins. In the *S. aureus*, MATE protein is only categorized by the MepAJang (2016). The *Staphylococcal* SMR transporters recognized thus far contain SMR (QacC, QacD or Ebr), QacG, QacH, and Qac J. All these proteins are minor comparing efflux pump proteins and holding on plasmids that proliferate between the bacteria Costa *et al.* (2013). Among *Staphylococcal* efflux pumps the MFS has been the most widely studied and consist of NorA, NorB, NorC, LmrS, QacA, QacBMdeA and SdrM, efflux pumps. These characteristically categorize into 12-14 membrane-spanning helices and contain 380 to 520 amino acids that enclose an oversized cytoplasm orb between helices 6 and 7, forming the distinctive MFS creases Yan (2013). In the*S. aureus*, MFS transporters are chromosomally encoded apart from QacA and QacB. And four transmembrane helices and regarding 110 amino acids are present in SMR transporters Wassenaar *et al.* (2015).

Within S. aureus, numerous ways are used for the development of the resistance against cadmium and cad A method is involved because it codes designed for an energy-dependent efflux mechanism Herzberg *et al.* (2016). Another gene cadB concerned in alternative resistance methods resembling a change in the binding location. The cadB gene gives the resistance to cadmium and additionally alternative heavy metals; however, the position of cadA and cadB genes is similar on a plasmid Wheaton *et al.* (2015). Fig. 2 Graphical overview of cadmium and bacterial synergism Abbas *et al.* (2017).

Environmental Cd (II) ions; Biosorption of Cd(II) on the protein and carbohydrate of bacterial wall; CMIT-metal transporter inside the cell; DcadCA protein (efflux transporter); ECDF (cation diffusion facilitator); Fintra cellular sequestration: transcription and translation of Smt metal lothione in on bacterial chromosome to protect against the adverse effect of these Cd ions; GcadCA operon on *S. aureus* plasmid: Hexport of chelating compounds, which combine with Cd (II) ions directly outside to form complexes, which cannot invade intocell.

Enzymes that make impermeable bacterial cell wall impermeable to the cadmium

In the gram-positive and gram-negative bacteria, this material penetrates as a venomous in the cell because of the different substrate of manganese and zinc transport system respectively. But chromosomally these systems are present in coded form Filice *et al.* (2016). This impermeable arrangement is the most excellent version with in the *Bacillus subtilis* where it's connected with the chromosomal mutation consequently; the membrane of manganese transport system barren the entrance of a cadmium Zheng *et al.* (2016).

Bindings of Cadmium ions:

Intracellular proteins are bonded with the cadmium (bacterial metallothioneins and metallochaperones), cell wall (exopolysaccharides) or at an exterior fraction, a strategy is approved by the cadmium-resistant bacteria. For instance, in some bacteria cadmium binds to the capsular surface such as *Arthobacter viscous* and *klebsiella aerogenesis*, while cadmium binds with insoluble cell-bound $CdHPO_4$ in some bacteria and stores mutants inside the cell like *Citrobacter* Coelho *et al.* (2015). It is believable that whether the first perform of binding proteins within the cell is to confiscate and micronutrients are stock up within the cell or also enlarge the violence to the cadmium. Although, the ability of a semipermeable membrane to bind with cadmium, this can be not a consideration of as a resistance mechanism. Have metallothioneins bacteria the capability to combine with Cd^{2+} and Zn^{2+} and are little cysteine-rich proteins Naik & Dubey (2017). One of the objectives of metallothioneins is too inferior the concentrations of free particlesin the cytoplasm and cytoplasmic metal cation-binding proteins. In metallothioneins the amino acids series are not homologous, therefore they do not have any relevancy the growth of animal metallothioneins. Metallothionein smtA the primary bacteria were typified in *Synechococcus* PCC 7942 purposes as confiscates and detoxifies Cd^{2+} and $Zn^{2+.}$ This wild-type strain binds more cadmium than the mutant lacking smtA gene. Afterward, smtA is also established in the *Anabaena* PCC 7120, *Pseudomonas putida* and *P. aeruginosa* Malekzadeh and Shahpiri (2017). The accretion of the gene in cadmium is additionally involved in recent times Mori *et al.* (2016). A clone 247-11C is isolated from overall 3301 arbitrarily designated clones from an aquatic sponge *Styllisa mass* and by the radioisotope; cadmium accumulation or connecting genes were displayed. Cadmium accumulation characterized by the clone 247-11C with the help of open reading frame, established by them. Further, this process was also examined through gel electrophoresis method and renowned the functional protein named as Cdae-1. The Cdae-1consists of a single peptide and domain harboring an E (G/A) KCG pentapeptide motif. Once this gene was cloned in E. coli, then the cadmium accumulation range was increased than non-clone E. coli strain. The Cdae-1 process is completely different to join with cadmium from the opposite cadmium-binding proteins like phytochelatins and metallothioneins because of in the Cdae-1 are most important amino acids are there. Mostlybacteriahave a charge-mediated mechanism within the cell wall or enclose that can absorb an elevated level of dissolved cadmium ions. Generally, exopolysaccharides (EPSs) are used in the binding of bacteria with cadmium. In exacting, uronic acid-rich EPSs have the high cadmium binding capability. An inducible resistance mechanism is the EPSs that are developed within the response to metals Bramhachari and Nagaraju (2017).

Different bacteria species have numerous cadmium-binding skills at different exterior circumstances; such as, the capacity of cadmium binding was equal in *Alcaligenes xylosoxidans*, however at the similar temperature with changeable pH, *A. eutrophus* CH34 have the elevated cadmium-binding aptitude than *A. xylosoxidans* Chakravarty and Banerjee (2012) additionally approved that cadmium biosorption is additionally influenced by certain situations. They remote a cadmium resistant, acidophilic, gram-negative and heterotrophic bacterial strain known as *Acidiphillium symbiotic.* The domino effect of TEM, SEM, and FTj]9R of *A. symbiotic* fixed that within the cell envelope the anionic functional group was a gift and it absolutely was the foremost vital agent of cadmium binding to this bacterium Rajesh *et al.* (2014).

The 248.62 mg of the cadmium per gram of biomass is adsorbing by A. symbiotic at pH 6.0. The adsorption of the cadmium during this bacterium happens through the complicated formation and electrostatic reaction, whereas this anionic functional group was barren by chemical modifications Duet *et al.* (2016). Furthermore, studied that however, the cadmium adsorption by Bacillus cereus is manipulated by environmental situations Huang *et al.* (2014). They noted that cadmium adsorption mechanisms, cell morphology, and growth entirely depend on the concentration of cadmium. Once the concentration of cadmium was decreased, the intracellular cadmium accretion was increased and at high concentration of cadmium, the extracellular adsorption was also increased. As a result, for cadmium elimination capability, the bacterial species and experimental conditions have a key role.

Cadmium-resistant bacteria

Microbial diversity because of its ability has gained abundant attention in bioremediation and keeps on the track for identification of recent in a position strains, as solely a moment fraction of the microbial strains within the atmosphere is investigated. Microbial populations are typically gifted of the metal impure surroundings and may bear toxic awareness of toxic heavy metals Narayani and Shetty (2013). Toxic heavy metals acceptance is usually assessed by the willpower of minimum inhibitory concentration against the experiment of Microorganisms. Against the strain, the metal's MIC is outlined because of the lowest concentration of the metal that reduces the development of the Microorganisms Vipra *et al.* (2013).

Various strains have MIC against cadmium is extraordinarily high. The *Cupriavidust aiwanensis* KKU2500-3, *P. aeruginosa* KKU2550-8, *P. aeruginosa* KKU2550-9 and *P. aeruginosa* KKU2550-20 they were remote from Thai Jasmine rice (*KaoHom Mali* 105) may oppose cadmium up to200mg/L $CdCl_2$ and 500 mg/L $CdCl_2$, severally Siripornadulsil(2013). Stanbrough *et al.* (2013) additionally, remote *Achromobacter* sp. strain AO22 from soil and communicated a 100mg/L its resistance against the cadmium. The *Halomonas* BVR 1 that wassanitized from effluents of the electronic trade may additionally bear up to 250 mg/L at pH 8.0 of a cadmium Rajesh *et al.* (2014), the *Citrobacter* sp. JH 11-2 that was additionally isolated from soil removal locations close to inclined electronic industry demonstrated 300mg L-1 that was the highest MIC against cadmium. Shim *et al.* (2015). The bacterial strains remoted from coastal sediments of Vietnam were *Pseudomonas abietaniphila*, *Acinetobacter brisouii*, *Planococcus rifietoensis* and *Exiguobacterium aestuarii* additionally demonstrates high resistance against cadmium 130,100, 400 and 60mg/ L severally Bhakta *et al.* (2014). Abbas *et al.* (2014a, b), these four bacterial strains were isolated from the industrialized effluent of Penang, Malaysia. The *Salmonella enterics*, *Pantoea* sp. RL32.2 and *Enterobacter* sp. OCPSB1 may bear the concentration of cadmium up and about 410, 750 and 550 mg/L, severally, whereas *Pseudomonas* sp. M3 MIC was 550 mg mL-1 against cadmium. Halimoon and Mustapha (2015) additionally remotes the uncultivated strains symbolized as MH1, MH4, MH6, and MH15 and MH21. TheMH1 and MH21 may resistant up to 200 mg L-1 and MH4, MH6, and MH15 are able to oppose up to 50 mg/ L of the cadmium. However, in the solution of cadmium chloride, the *Pseudomonasmendocina* strain E67 was additionally opposed to 100 mg/ L of cadmium Mathivanan and Rajaram (2014).

A few strains demonstrate less resistant level against cadmium as Varghese (2012). A strain that was additionally isolated from Mangrove sediments named as *Bacillus safensis* that was showed only 20mg/L resistant level in opposition to cadmium Priyalaxmi *et al.* (2014). This truth makes stronger the speculation that bacterial redress will affect extremely contaminated locations in addition to multifaceted rivers included cadmium focused on the legal inspection of the strains to employ. The data on the relative rate of the isolate within the company of cadmium can sort an additional significant contribution pro the procedure.

Cadmium takes up by bacteria:

In general, the removal of heavy metals through Microorganisms contained two methods biosorption and bioaccumulation. In Biosorption procedure metal ions are involved that are engrossed by Microorganisms through the biochemical reactions together with complicated and ions exchange.

The different bacterial strains and their cadmium elimination capability with different experimental circumstances are showed above Table 3.

Future perspectives:

With the numerous confront benefits and therefore the new attractive progress, bioremediation is viewing itself as a talented method to elevate removal of cadmium from the polluted location. But to find it in the meadow, several environmental, technological, economic, and social restrictions are nevertheless to be dominated.

Genetic modification of bacteria:

In the industries, the use of cadmium is growing yearly, and it generates consciousness regarding its environmental effects, accretion, and cadmium contaminated. The metal binding proteins like phytochelatins and metallothioneins are notified in bacteria for metal resistant, and these proteins demonstrate the increased capability to combine with Cd Singh *et al.* (2011). In recent times, genes encode phytochelatins/ metallothioneins have been cloned from plants and fungi transfer into *E. coli.* It illustrated to high affinity and bioaccumulation of main particles of metals, cadmium from contaminants of many components Khan *et al.* (2015).

The invention to the elimination of pollutants from the environment through genetically engineered bacteria provides an innovative treatment. The transfers of Cd resistance genes in the aquatic plants are also raisingbe cause of natural hyperaccumulators are not ablebecause they are low biomass and growing at a low rate. By the utilization of this cell engineering technology (somatic hybridization and cell fusion) cadmium-resistant genes from bacteria could be inserted into polyploid aquatic plants, as a result, they are more active in transpiration and bigger in size.

By the enhancing high capacity of Cd resistant bacteria, we would be able to control the environment pollution.

Proposed Methodology:

Effluent samples were collected from the different waste contaminated region for the isolation of cadmium resistant bacteria and analysis in the laboratory. Here we are presenting schematic representation of step wise procedure.

Fig.3 Schematic representation of step wise procedure

Anticipation Catalog:

In developing counties, heavy metals rising due to industrialization with this environmental pollution also increasing. Cadmium toxicity is increased within the ruler and urban areas because of low to sensible decontamination. Cadmium in sewage water is the main region of contamination and increasing differing types of diseases in a living organism. High toxic level of heavy metals influences in different methods on the properties of structural and permeability properties of internal membranes and organelles, nutrient imbalance cause inhibition of enzymes decreases in tempo of photosynthesis and transpiration Green *et al.* (2003), reactive oxygen and free radicals formation stimulates anxiety in germs Beri *et al.* (1990), development in germination Setia *et al.* (1989), yield and quality of germ Beri and Setia (1995) and induce harmful anatomical and particularly form of crop plants Liu and Kottke (2004) and Sridhar *et al.* (2005). But on another hand, biochemistry and biotechnological application lead recognition and engineering previous known cadmium resistant bacterial strains have not the ability to remedy toxicity of cadmium contaminated sludge water and air resources lead to a harmful major food chain route for human exposure.

Conclusion

Heavy metals wield their venomous effects on Microorganisms through various mechanisms, and bacteria tolerate these surroundings and perhaps be segregated and go for their bioremediation within the contaminated sites with the potential application Piotrowska-Seget *et al.* (2005). It is clearly indicated that domestic waste and industrial waste are dependable for the event of bacterial resistant at the side of the danger to human health and atmosphere Nath *et al.* (2012). However, be relevant different techniques like further studies and practical application of those organisms bacteria *Pseudomonas* sp., *Staphylococcus* sp. and *Escherichia coli* it's necessary to the treatment of heavy metals surrounding sludge water Kaur *et al.* (2015).

All along, the cadmium bioremediation is advance and has got much attraction because it's more inexpensive, secure and biodegradable for the environment. Thus, it is compulsory to show for Microorganism town to attest they are environmental helpful before field tryout, terminated soils and save water.

There is no correct steadiness between natural and human population exploitation of cadmium, consequently, another method, and the Cd removal from effluents came into survival. It must get a basic data of bioremediation, to use at industrial scale and develop the most well-organized and workable level, abounding analysis within the laboratory studies. In these methods, a lot of precautions ought to be taken for the Cd-resistant bacteria and therefore the bacteria are central machinery and these Cd-resistant bacteria are also against antibiotics. Recently, Cd-resistant genes ought to be transported from mutated bacteria into the normal bacterial environment. In an exceedingly closed system for sludge water treatment, these bacteria can is used, and afterward, this water ought to be discharged into the rivers and canal so the development of bacteria susceptible to antibioticswill be in growth within the atmosphere and antibiotic-resistant bacteria gradually eliminate. Every methodology has merits and demerits. however, we tend to utilize this technology for growth. Characterized cadmium removal pathways, identify the enzymes and genes concerned in Cd resistance exhibit fields for more analysis.

Conflict of Interest: The authors declare that they have no conflict.

References

Abbas, S.Z., M. Rafatullah, N. Ismail and M. I. Syakir (2017). A review on sediment microbial fuel cells as a new source of sustainable energy and heavy metal remediation: mechanisms and future prospective. *International Journal of Energy Research*, **41(9)**:1242-1264.

Abbas, S.Z., M. Rafatullah, N. Ismail and J. Lalung (2014). Isolation, identification, and characterization of cadmium resistant Pseudomonas sp. M3 from industrial wastewater. *Journal of Waste Management*, Article ID 160398, 6 pages.

Abbas, S.Z., M. Riaz, N. Ramzan, M.T. Zahid, F.R. Shakoori and M. Rafatullah (2014c). Isolation and characterization of arsenic resistant bacteria from wastewater. *Brazilian Journal of Microbiology*, **45(4)**: 1309-1315.

Ajmal, M., A. Mohammad, R. Yousuf and A. Ahmad (1998). Adsorption behaviour of cadmium, zinc, nickel and lead from aqueous solution by *Mangiferaindica*seed shell. Indian. *J. Environ. Health,* **40 (1)**: 5-26.

Aminov, R.I. (2010). A brief history of the antibiotic era: lessons learned and challenges for the future. *Frontiers in Microbiology*, **1**: 134.

Amoozegar, M.A., N. Ghazanfari and M. Didari (2012). Lead and cadmium bioremoval by Halomonas sp., an exopolysaccharide-producing halophilic bacterium. *Progress in Biological Sciences*, **2(1)**: 1-11.

Andersen, J.L., G.X. He, P. Kakarla, R.KC, S. Kumar, W.S. Lakra and M.F. Varela (2015). Multidrug efflux pumps from Enterobacteriaceae, Vibrio cholerae and Staphylococcus aureus bacterial food pathogens. *International Journal of Environmental Research and Public Health*, **12(2)**: 1487-1547.

ATSDR. Toxicological Profile for Cadmium (1999). Agency for Toxic Substances and Disease Registry; p. 434

Australia's submission (2005). Information about cadmium in

Australia. Prepared by the Australian Government for the United Nations Environment Programme. Australia Government, 12

Babich, H. and G. Stotzky (1985). Heavy metal toxicity to microbe-mediated ecologic processes: a review and potential application to regulatory policies. *Environmental Research*, **36(1)**: 111-137.

Banjerdkij, P., P. Vattanaviboon and S. Mongkolsuk (2005). Exposure to cadmium elevates expression of genes in the OxyR and OhrR regulons and induces cross-resistance to peroxide killing treatment in Xanthomonascampestris. *Applied and environmental microbiology*, **71(4)**: 1843-1849.

Barberio, C. and R. Fani (1998). Biodiversity of an Acinetobacter population isolated from activated sludge. *Res. Microbiol.,* **149**: 665–673.

Benmalek, Y. and M.L. Fardeau (2016). Isolation and characterization of metal-resistant bacterial strain from wastewater and evaluation of its capacity in metal-ions removal using living and dry bacterial cells. *International Journal of Environmental Science and Technology*, **13(9)**: 2153-2162.

Beri, A. and R.C. Setia (1995). Assessment of growth and yield in Lens culinaris Medic. var. masar 9-12 treated with heavy metals under N-supplied conditions. *Journal of the Indian Botanical Society*, **74(1-4)**: 293-297.

Beri, A., R.C. Setia and N. Setia (1990). Germination responses of lentil (*Lens culinaris*) seeds to heavy metal ions and plant growth regulators. *J. Pl. Sci. Res*, **6**: 24-27.

Bhagat, N., M. Vermani and H.S. Bajwa (2016). Characterization of heavy metal (cadmium and nickle) tolerant Gram negative enteric bacteria from polluted Yamuna River, Delhi. *African Journal of Microbiology Research*, **10(5)**: 127-137.

Bhakta, J.N., Y. Munekage, K. Ohnishi, B.B. Jana and J.L. Balcazar (2014). Isolation and characterization of cadmium- and arsenic-absorbing bacteria for bioremediation. *Water, Air & Soil Pollution*, **225(10)**: 2151.

Bramhachari, P.V. and G.P. Nagaraju (2017). Extracellular polysaccharide production by bacteria as a mechanism of toxic heavy metal biosorption and biosequestration in the marine environment. In *Marine Pollution and Microbial Remediation,* Springer, Singapore, pp- 67-85.

Bruins, M.R., S. Kapil and F.W. Oehme (2000). Microbial resistance to metals in the environment. *Ecotoxicology and Environmental Safety*, **45(3)**: 198-207.

Burkina Faso's submission (2005). Contribution of Burkina Faso to the study on lead and cadmium. SemceIdrissa, Ministry of Environment and Life Quality.

Cabral, J.P. (1992). Selective binding of metal ions to Pseudomonas syringae cells. *Microbios (United Kingdom)*, **71**: 47– 53.

Cataldo, D.H., D. Boltovskoy, J. Stripeikis and M. Pose (2001a). Condition index and growth rates of field caged Corbicula fluminea (*Bivalvia*) as biomarkers of pollution gradients in the Paraná river delta (Argentina). *Aquatic Ecosystem Health & Management*, **4(2)**: 187-201.

Chakravarty, R. and P.C. Banerjee (2012). Mechanism of cadmium binding on the cell wall of an acidophilic bacterium. *Bioresource Technology*, **108**: 176-183.

Chen, H. (2006). Recent advances in azo dye degrading enzyme research. *Current Protein and Peptide Science*, **7(2)**: 101-111.

Chen, L., B. Mathema, K.D. Chavda, F.R. DeLeo, R.A. Bonomo and B.N. Kreiswirth (2014). Carbapenemase-producing Klebsiella pneumoniae: molecular and genetic decoding. *Trends in Microbiology*, **22(12)**: 686-696.

Chovanová, K., D. Sládeková, V. Kmet, M. Proksova, J. Harichová, A. Puskarova and P. Ferianc (2004). Identification and characterization of eight cadmium resistant bacterial isolates from a cadmium-contaminated sewage sludge. *Biologia*, **59(6)**: 817-827.

Coelho, L.M., H.C. Rezende, L.M. Coelho, P.A. de Sousa, D.F. Melo and N.M. Coelho (2015). Bioremediation of polluted waters using Microorganisms. In *Advances in Bioremediation of Wastewater and Polluted Soil*. InTech.

Cohen, I., R. Bitan and Y. Nitzan (1991). The effect of zinc and cadmium ions on *Escherichia coli* B. *Microbios*, **68(276-277)**: 157-168.

Costa, S.S., C. Mourato, M. Viveiros, J. Melo-Cristino, L. Amaral and I. Couto (2013). Description of plasmid pSM52, harbouring the gene for the Smr efflux pump, and its involvement in resistance to biocides in a meticillin-resistant Staphylococcus aureus strain. *International Journal of Antimicrobial Agents*, **41(5)**: 490-492.

Darwish, A.M., W.H. Eisa, A.A. Shabaka and M.H. Talaat (2016). Investigation of factors affecting the synthesis of nano-cadmium sulfide by pulsed laser ablation in liquid environment. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **153**: 315-320.

Denise, P., P. Higham, J. Sadler and D. Michael (1989). Cadmium Resistance in*Pseudumunas putida:* Growth and Uptake of Cadmium. *J. General Microbiology,* **131**: 2539-2544.

Diels, L. (1997). Methods in Biotechnology. Bioremediation protocols. *Humana Press Inc., Totowa, New Jersey*, **2** :283-295.

Diels, L. and M. Mergeay (1990). DNA probe-mediated detection of resistant bacteria from soils highly polluted by heavy metals. *Applied and Environmental Microbiology*, **56(5)**: 1485-1491.

Dopson, M., C. Baker-Austin, P.R. Koppineedi and P.L. Bond (2003). Growth in sulfidic mineral environments: metal resistance mechanisms in acidophilic micro-organisms. *Microbiology*, **149(8)**: 1959-1970.

Du, H., W. Chen, P. Cai, X. Rong, K. Dai, C.L. Peacock and Q. Huang (2016). Cd (II) sorption on montmorillonite-humic acid-bacteria composites. *Scientific Reports*, **6**: 19499.

Duruibe, J.O., M.O.C. Ogwuegbu and J.N. Egwurugwu (2007). Heavy metal pollution and human biotoxic effects. *International Journal of Physical Sciences,* **2**: 112-118.

Ferrero, M., R. Bosch and E. Garcia-Valdes (1999). Diversity of bacterial naphthalene-degrading genes in the mediterranean sea. In: *6th Symposium on Bacterial Genetics and Ecology, University of Florence*, Italy, pp 64.

Filice, F.P., M.S. Li, J.D. Henderson and Z. Ding (2016). Mapping Cd2+-induced membrane permeability changes of single live cells by means of scanning electrochemical microscopy. *Analytica Chimica Acta*, **908**: 85-94.

Filipiè, M. (2012). Mechanisms of cadmium induced genomic instability. *Mutation Research/Fundamental and Molecular Mechanisms of Mtagenesis*, **733(1)**: 69-77.

Founou, L.L., R.C. Founou and S.Y. Essack (2016). Antibiotic resistance in the food chain: a developing country-perspective. *Frontiers in Microbiology*, **7**: 1881.

Friberg, L. (1975). Toxic metals and their implications for human health. In *Proceedings of the International Conference on Heavy Metals in the Environment,* **1**:21-34.

Gadd, G.M. (1988). Accumulation of metals by Microorganisms and algae. *Biotechnology. Special Microbial Processes*, **6(b)**: 401-433.

Gallagher, C.M., J.J. Chen and J.S. Kovach (2010). Environmental cadmium and breast cancer risk. *Aging (Albany NY)*, **2(11)**: 804.

Gaur, N., G. Flora, M. Yadav and A. Tiwari (2014). A review with recent advancements on bioremediation-based abolition of heavy metals. *Environmental Science: Processes & Impacts*, **16(2)**: 180-193.

Glazer, A. and H. Nikaido (1995). Environmental applications microbialn biotechnology: fundamentals of applied microbiology. *WH Freeman* and Company, New York, pp 561–614.

Green, C.E., R.L. Chaney and J. Bouwkamp (2003). Interactions between cadmium uptake and phytotoxic levels of zinc in hard red spring wheat. *Journal of Plant nutrition*, **26(2)**: 417-430.

Green-Ruiz, C.R., V.A. Rodríguez-Tirado, A.C. Carrasco-Valenzuela and B. Gómez-Gil (2007, May). Potentially Toxic Element Uptake by Bacillus jeotgali Strain U3: A Natural Attenuation Mechanism in polluted sediments from Estero de Urías Coastal Lagoon (SE Gulf of California). In *AGU Spring Meeting Abstracts*.

Hajalilou, B. and F. Khaleghi (2009). Investigation of hydrogeochemical factors and groundwater quality assessment in Marand Municipality, northwest of Iran: A multivariate statistical approach. *Journal of Food, Agriculture & Environment*, **7(3&4)**: 930-937.

Hassen, A., N. Saidi, M. Cherif and A. Boudabous (1998). Effects of heavy metals on Pseudomonas aeruginosa and Bacillus thuringiensis. *Bioresource Technology*, **65(1-2)**: 73-82.

He, Y., X. Guo, S. Xiang, J. Li, X. Li, H. Xiang and J. Chen (2016). Comparative analyses of phenotypic methods and 16S rRNA, khe, rpoB genes sequencing for identification of clinical isolates of Klebsiella pneumoniae. *Antonie Van Leeuwenhoek*, **109(7)**: 1029-1040.

Herrero, R., P. Lodeiro, C. Rey-Castro, T. Vilariño and M.E.S. De Vicent (2005). Removal of inorganic mercury from aqueous solutions by biomass of the marine macroalga Cystoseirabaccata. *Water research*, **39(14)**: 3199-3210.

Herzberg, M., L. Bauer, A. Kirsten and D.H. Nies (2016). Interplay between seven secondary metal uptake systems is required for full metal resistance of Cupriavidusmetallidurans. *Metallomics*, **8(3)**: 313-326.

Higham, D.., P.J. Sadler and M.D. Scawen (1984). Cadmium-resistant Pseudomonas putida synthesizes novel cadmium proteins. *Science*, **225(4666)**: 1043-1046.

Hobbelen, P.H.F., J.K. Koolhaas and C.A.M. Van Gestel (2004). Risk assessment of heavy metal pollution for detritivores in floodplain soils in the Biesbosch, the Netherlands, taking bioavailability into account. *Environmental Pollution*, **129(3)**: 409-419.

Huang, F., C.L. Guo, G.N. Lu, X.Y. Yi, L.D. Zhu and Z. Dang (2014). Bioaccumulation characterization of cadmium by growing Bacillus cereus RC-1 and its mechanism. *Chemosphere*, **109**: 134-142.

Huff, J., R. M. Lunn, M. P. Waalkes, L. Tomatis and P. F. Infante (2007). Cadmium-induced cancers in animals and in humans. *International Journal of Occupational and Environmental Health*, **13(2)**:202-212.

IARC (1993). Beryllium, cadmium, mercury, and exposures in the glass manufacturing industry. Working Group views and expert opinions, Lyon, 9-16 February. *IARC Monogr. Eval. Carcincog. Risks Hum.,* **58**: 1-415.

Jang, S. (2016). Multidrug efflux pumps in Staphylococcus aureus and their clinical implications. *Journal of Microbiology*, **54(1)**: 1-8.

Kapoor, A. and T. Viraraghavan (1995). Fungal biosorption-an alternative treatment option for heavy metal bearing wastewaters: a review. *Bioresource Technology*, **53(3)**: 195-206.

Katarina, C., S. Darina, K. Vladimir, P. Miloslava, H. Jana, B. Andrea Puškrov and P. Ferianc (2004). Identification and characterization of eight cadmium resistant bacterial isolates from a cadmium-contaminated sewage sludge*, Biologia. Bratislava*, **59**: 817-827.

Kaur, S., H.P. Kaur and R. Rani (2015). Isolation and characterization of heavy metal and antibiotic resistant bacteria from industrial effluents. *World J. Pharmacy and Pharmaceutical Sciences*, **4(9)**: 765-772.

Kermani, A., M.F. Ghasemi, A. Khosravan, A. Farahmand and M.R. Shakibaie (2010). Cadmium Bioremediation by Metal-Resistant Mutated Bacteria Isolated From Active Sludge Ofindustrial Effluent. *Iranian Journal of Environmental Health, Science and Engineering*, **7(3)**: 229-286.

Kesler, S.E. and A.C. Simon (2015). *Mineral resources, economics and the environment*. Cambridge University Press.

Khan, Z., A. Rehman, S.Z. Hussain, M.A. Nisar, S. Zulfiqar and A.R. Shakoori (2016). Cadmium resistance and uptake by bacterium, Salmonella enterica 43C, isolated from industrial effluent. *AMB Express*, **6(1)**: 54.

Khan, Z., M.A. Nisar, S.Z.M. Hussain, M.N. Arshad and A. Rehman (2015). Cadmium resistance mechanism in Escherichia coli P4 and its potential use to bioremediate environmental cadmium. *Applied Microbiology and Biotechnology*, **99(24)**: 10745-10757.

Khleifat, K.M., K. Nawayseh, N.R. Adjeroud, A.M. Khlaifat, I.H. Aljundi and K.A. Tarawneh (2009). Cadmium-resistance plasmid affected Cd^{+2} uptake more than Cd^{+2} adsorption in Klebsiellaoxytoca. *Bioremediation Journal*, **13(4)**: 159-170.

Klaassen, C.D., J. Liu, and B.A. Diwan (2009). Metallothionein protection of cadmium toxicity. *Toxicology and Applied Pharmacology,* **238(3)**: 215-220.

Knotek-Smith, H.M., L.A. Deobald, M. Ederer and D.L. Crawford (2003). Cadmium stress studies: Media development, enrichment, consortia analysis, and environmental relevance. *Biometals*, **16(2)**: 251-261.

Koukal, B., J. Dominik, D. Vignati, P. Arpagaus, S. Santiago, B. Ouddane and L. Benaabidat (2004). Assessment of water quality and toxicity of polluted Rivers Fez and Sebou in the region of Fez (Morocco). *Environmental Pollution*, **131(1)**: 163-172.

Kupka, D. and I. Ševèík (1995). Biosorption and Bioremediation, In: T. Macek, K. Demnerova and M. Mackova (eds) *Czech Society for Biochemistry and Molecular Biology,* Prague, pp 4–5.

Lewis, V.G., M.P. Ween and C.A. McDevitt (2012). The role of ATP-binding cassette transporters in bacterial pathogenicity. *Protoplasma*, **249(4)**: 919-942.

Liu, D. and I. Kottke (2004). Subcellular localization of cadmium in the root cells of Alliumcepa by electron energy loss spectroscopy and cytochemistry. *Journal of Biosciences*, **29(3)**: 329-335.

Liu, Y., T. Xiao, Z. Ning, H. Li, J. Tang and G. Zhou (2013). High cadmium concentration in soil in the Three Gorges region: geogenic source and potential bioavailability. *Applied Geochemistry*, **37**: 149-156.

Mahvi, A.H. and L. Diels (2004). Biological removal of cadmium by Alcaligeneseutrophus CH34. *International Journal of Environmental Science & Technology*, **1(3)**: 199-204.

Malekzadeh, R. and A. Shahpiri (2017). Independent metal-thiolate cluster formation in C-terminal Cys-rich region of a rice type 1 metallothionein isoform. *International journal of biological macromolecules*, **96**: 436-441.

Martin, R., K. Dowling, D. Pearce, J. Sillitoe and S. Florentine (2014). Health effects associated with inhalation of airborne arsenic arising from mining operations. *Geosciences*, **4(3)**: 128-175.

Mathivanan, K. and R. Rajaram (2014). Tolerance and biosorption of cadmium (II) ions by highly cadmium resistant bacteria isolated from industrially polluted estuarine environment.

Mexico's Submission (2005) Information on sources of exposure to lead and cadmium in Mexico. Federal Commission for the Protection against Sanitary Risk. Health protection.

Mitra, R.S. and I.A. Bernstein (1977). Nature of the repair process associated with the recovery of Escherichia coli after exposure to Cd^{2+}. *Biochemical and Biophysical Research Communications*, **74(4)**: 1450-1455.

Mitra, R.S., R.H. Gray, B. Chin and I.A. Bernstein (1975). Molecular mechanisms of accommodation in Escherichia coli to toxic levels of Cd^{2+}. *Journal of Bacteriology*, **121(3)**: 1180-1188.

Mizoue, T., T. Yamaji, S. Tabata, K. Yamaguchi, E. Shimizu, M. Mineshita and S. Kono (2005). Dietary patterns and colorectal adenomas in Japanese men: The Self-Defense Forces Health Study. *American Journal of Epidemiology*, **161(4)**: 338-345.

Mohiuddin, K.M., H.M. Zakir, K. Otomo, S. Sharmin and N. Shikazono (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. *International Journal of Environmental Science & Technology,* **7(1)**: 17-28.

Monachese, M., J.P. Burton and G. Reid (2012). Bioremediation and human tolerance to heavy metals through microbial processes: a potential role for probiotics. *Applied and Environmental Microbiology*, **78**:6397-6404. AEM-01665.

Mori, T., K. Iwamoto, S. Wakaoji, H. Araie, Y. Kohara, Y. Okamura and H. Takeyama (2016). Characterization of a novel gene involved in cadmium accumulation screened from sponge-associated bacterial metagenome. *Gene.*, **576(2)**: 618-625.

Mota, R., S.B. Pereira, M. Meazzini, R. Fernandes, A. Santos, C.A. Evans and P. Tamagnini (2015). Effects of heavy metals on Cyanothece sp. CCY 0110 growth, extracellular polymeric substances (EPS) production, ultrastructure and protein profiles. *Journal of Proteomics*, **120**: 75-94.

Mustapha, M.U. and N. Halimoon (2015). Screening and isolation of heavy metal tolerant bacteria in industrial effluent. *Procedia Environmental Sciences*, **30**: 33-37.

Naik, M.M. and S.K. Dubey (2017). Lead-and mercury-resistant marine bacteria and their application in lead and mercury bioremediation. In *Marine Pollution and Microbial Remediation,* Springer, Singapore, pp 29-40.

Narayani, M. and K.V. Shetty (2013). Chromium-resistant bacteria and their environmental condition for hexavalent chromium removal: a review. *Critical Reviews in Environmental Science and Technology*, **43(9):** 955-1009.

Naseem, S., S. Hamza, E. Bashir, T. Pirzada, and M.M.A. Talpur (2013). Trace element geochemistry of groundwater of Winder, Balochistan, Pakistan and its appraisal for irrigation water quality. *British Journal of Applied Science & Technology*, **3(1)**: 182.

Nath, S., B. Deb and I. Sharma (2012). Isolation and characterization of cadmium and lead resistant bacteria. *Global Advanced Research Journal of Microbiology*, **1(11)**: 194-198.

Neethu, C.S., K.M. Rahiman, E. Rosmine, A.V. Saramma and A.M. Hatha (2015). Utilization of agro-industrial wastes for the production of lipase from Stenotrophomonas maltophilia isolated from Arctic and optimization of physical parameters. *Biocatalysis and Agricultural Biotechnology*, **4(4)**: 703-709.

NFA (2002): Riskiraportti: Elintarvikkeiden ja talousvedenkemiallisetvaarat. [Risk Report: chemical hazards of food and drinking water]. National Food Agency, Valvontaopas-sarja 2/2002, Helsinki, Finland (in Finnish).

Nies, D.H. (1992). Resistance to cadmium, cobalt, zinc, and nickel in microbes. *Plasmid*, **27(1)**: 17-28.

Nies, D.H. (2003). Efflux-mediated heavy metal resistance in prokaryotes. *FEMS Microbiology Reviews*, **27(2-3)**: 313-339.

Nriagu, J.O. (1989). A global assessment of natural sources of atmospheric trace metals. *Nature*, **338(6210)**: 47.

Nriagu, J.O. and J.M. Pacyna (1988). Quantitative assessment of worldwide contamination of air, water and soils by trace metals. *Nature*, **333(6169)**: 134-139.

Nyström, T. and S. Kjelleberg (1987). The effect of cadmium on starved heterotrophic bacteria isolated from marine waters. *FEMS Microbiology Letters*, **45(3)**: 143-151.

Okafor, E.C. and K. Opuene (2007). Preliminary assessment of trace metals and polycyclic aromatic hydrocarbons in the sediments. *International Journal of Environmental Science & Technology*, **4(2)**: 233-240.

Panwichian, S., D. Kantachote, B. Wittayaweerasak and M. Mallavarap (2011). Removal of heavy metals by exopolymeric substances produced by resistant purple nonsulfur bacteria isolated from contaminated shrimp ponds. *Electronic Journal of Biotechnology*, **14(4)**: 2-2.

Piotrowska-Seget, Z., M. Cycon, J. Kozdroj (2005). Metal-tolerant bacteria occurring in heavily polluted soil and mine spoil. *Appl. Soil Ecol.,* **28**: 237–246.

Priyalaxmi, R., A. Murugan, P. Raja and K.D. Raj (2014). Bioremediation of cadmium by Bacillus safensis (JX126862), a marine bacterium isolated from mangrove sediments. *Int. J. Curr. Microbiol Appl. Sci.*, **3(12)**: 326-335.

Prokšová, M., J. Augustín and A. Vrbanová (1997). Enrichment, isolation and characterization of dialkyl sulfosuccinate degrading bacteria Comamonasterrigena N3H and Comamonasterrigena N1C. *Folia Microbiol.,* **42**: 635–639.

Qing, H. U., M.N. Dou, X. Y. Qi, X.M. Xie, G. Q. Zhuang, and Y.A.G. Min (2007). Detection, isolation, and identification of cadmium-resistant bacteria based on PCR-DGGE. *Journal of Environmental Sciences*, **19(9)**: 1114-1119.

Raja, C.E., K. Anbazhagan and G.S. Selvam (2006). Isolation and characterization of a metal-resistant Pseudomonas aeruginosa strain. *World Journal of Microbiology and Biotechnology*, **22(6)**: 577-585.

Raja, C.E., Selvam, G.S. & K.I.Y.O.S.H.I. Omine (2009, November). Isolation, identification and characterization of heavy metal resistant bacteria from sewage. In *Int Joint Symp on Geodisaster Prevention and Geoenvironment in Asia*, pp 205-211.

Raja, S., R. Raghunathan, X.Y. Yu, T. Lee, J. Chen, R.R. Kommalapati and J.L. Collett Jr. (2008). Fog chemistry in the Texas–Louisiana gulf coast corridor. *Atmospheric Environment*, **42(9)**: 2048-2061.

Rajaganapathy, V., F. Xavier, D. Sreekumar and P.K. Mandal (2011). Heavy metal contamination in soil, water and fodder and their presence in livestock and products: a review. *Journal of Environmental Science and Technology*, **4(3)**: 234-249.

Rajbanshi, A. (2008). Study on Heavy Metal Resistant Bacteria in Guheswori Sewage Treatment Plant. *Our Nature*, **6(1)**: 52-57.

Rajesh, V., A.S.K. Kumar and N. Rajesh (2014). Biosorption of cadmium using a novel bacterium isolated from an electronic industry effluent. *Chemical Engineering Journal*, **235**: 176-185.

Raskin, I. and B.D. Ensley (2000). *Phytoremediation of toxic metals*. John Wiley and Sons.

Rehman, A., F.R. Shakoori and A.R. Shakoori (2008). Heavy metal resistant freshwater ciliate, Euplotesmutabilis, isolated from industrial effluents has potential to decontaminate wastewater of toxic metals. *Bioresource technology*, **99(9)**: 3890-3895.

Richardson, G.M., R. Garrett, I. Mitchell, M. Mah-Poulson and T. Hackbarth (2001). Critical review on natural global and regional emissions of six traces metals to the atmosphere. *Prepared for the International Lead Zinc Research Organisation, the International Copper Association, and the Nickel Producers Environmental Research Association*.

Schindler, B.D., E. Frempong-Manso, C.E. DeMarco, C. Kosmidis, V. Matta, S.M. Seo and G.W. Kaatz (2015). Analyses of multidrug efflux pump-like proteins encoded on the Staphylococcus aureus chromosome. *Antimicrobial Agents and Chemotherapy*, **59(1)**: 747-748.

Schoeters, G., E.D. Hond, M. Zuurbier, R. Naginiene, P. Van den Hazel, N. Stilianakis and J.G. Koppe (2006). Cadmium and children: exposure and health effects. *Acta Paediatrica*, **95**: 50-54.

Setia, R.C., N. Setia, K.L. Ahuja and C.P. Malik (1989). Effect of 'Mixtalol' on growth, yield and yield components of Indian mustard (*Brassica juncea*). *Plant growth Regulation*, **8(2)**: 185-192.

Shakibaie, M.R., A. Khosravan, A. Farmhand and S. Zare, (2008). Application of metal resistant bacteria by mutational enhancement technique for bioremediation of copper and zinc from industrial wastes. Iran. *J. Environ. Health. Sci. Eng.,* **5**: 251-256.

Shamim, S. and A. Rehman (2012). Cadmium resistance and accumulation potential of Klebsiella pneumoniae strain CBL-1 isolated from industrial wastewater. *Pakistan Journal Zoology*, **44**: 203-208.

Shanker, A.K., C. Cervantes, H. Loza-Tavera and S. Avudainayagam (2005). Chromium toxicity in plants. *Environment International*, **31(5):** 739-753.

Sharma, D.C. and C.P. Sharma (1993). Chromium uptake and its effects on growth and biological yield of wheat. *Cereal Research Communications*, 317-322.

Sharma, D.C. and R.C. Pant (1994). Chromium uptake and its effects on certain plant nutrients in maize (*Zea mays* L. cv. Ganga 5). *Journal of Environmental Science & Health Part A*, **29(5)**: 941-948.

Sharma, D.C. and S.C. Mehrotra (1993). Chromium toxicity effects on wheat (*Triticum aestivum* L. cv. HD 2204). *Indian Journal of Environmental Health*, **35(4)**:330-332.

Shim, J., J.W. Kim, P.J. Shea and B.T. Oh (2015). Biosorption of cadmium by Citrobacter sp. JH 11-2 isolated from mining site soil. *Separation Science and Technology*, **50(14)**: 2134-2141.

Singh, J.S., P.C. Abhilash, H.B. Singh, R.P. Singh and D.P. Singh (2011). Genetically engineered bacteria: an emerging tool for environmental remediation and future research perspectives. *Gene.*, **480(1)**: 1-9.

Singh, N., and R. Gadi (2012). Bioremediation of Ni (II) and Cu (II) from wastewater by the nonliving biomass of Brevundimonasvesicularis. *Journal of Environmental Chemistry and Ecotoxicology*, **4(8)**: 137-142.

Singh, R.P., G. Dhania, A. Sharma and P.K. Jaiwal (2007). Biotechnological approaches to improve phytoremediation efficiency for environment contaminants. In *Environmental bioremediation technologies*. Springer, Berlin, Heidelberg. pp 223-258.

Siripornadulsil, S. and W. Siripornadulsil (2013). Cadmium-tolerant bacteria reduce the uptake of cadmium in rice: potential for microbial bioremediation. *Ecotoxicol Environ. Saf.*, **94:**94–103.

Sridhar, B. M., S.V. Diehl, F.X. Han, D.L. Monts and Y. Su (2005). Anatomical changes due to uptake and accumulation of Zn and Cd in Indian mustard (*Brassica juncea*). *Environmental and Experimental Botany*, **54(2)**: 131-141.

Stanbrough, R., S. Chuaboonmee, E.A. Palombo, F. Malherbe and M. Bhave (2013). Heavy metal phytoremediation potential of a heavy metal resistant soil bacterial isolate, Achromobacter sp. strain AO22. *Apcbee Procedia*, **5**: 502-507.

Tendulkar, A., Wei. Yan Yi and V. Murali Krishnan (2016). Isolation, identification and characterization of potential bacteria from Malaysian water showing resistance to cadmium, copper and iron. *Journal of Scientific Research and Development*, **3 (5)**: 216-220.

Tsezos, M. (1985). The selective extraction of metals from solutions by Microorganism. *Can. Metal. Quart.,* **24**: 141–144.

Valko, M.M.H.C.M., H. Morris and M.T.D. Cronin (2005). Metals, toxicity and oxidative stress. *Current Medicinal Chemistry*, **12(10)**: 1161-1208.

VanBogelen, R.A., P.M. Kelley and F.C. Neidhardt (1987). Differential induction of heat shock, SOS, and oxidation stress regulons and accumulation of nucleotides in Escherichia coli. *Journal of Bacteriology*, **169(1)**: 26-32.

Vanoort, R., P. Cressey and K. Silvers (2000) 1997/98 New Zealand Total Diet Survey. Part 2: Elements. Report prepared for the Ministry of Health.

Varghese, R. (2012). Bioaccumulation of cadmium by Pseudomonas sp. isolated from metal polluted industrial region. *Environmental Research, Engineering and Management*, **61(3)**: 58-64.

Vidali, M. (2001). Bioremediation. an overview. *Pure and Applied Chemistry*, **73(7)**: 1163-1172.

Vieira, R.H. and B. Volesky (2000). Biosorption: a solution to pollution. *International Microbiology*, **3(1)**: 17-24.

Vinod, V. and R. Sashidhar (2011) Bioremediation of industrial toxicmetals with gum kondagogu (Cochlospermumgossypium): a natural carbohydrate biopolymer. *Indian J. Biotechnol.,* **10**:113–120**.**

Vipra, A., S.N. Desai, R.P. Junjappa, P. Roy, N. Poonacha, P. Ravinder and S. Padmanabhan (2013). Determining the minimum inhibitory concentration of bacteriophages: potential advantages. *Advances in Microbiology*, **3(02):** 81.

Volesky, B. (1986) Biosorbent materials. Biotechnol. *Bioeng Symp.,* **16**:121–126.

Volesky, B. and Z.R. Holan (1995). Biosorption of heavy metals. *Biotechnology Progress*, **11(3)**: 235-250.

Wassenaar, T., D. Ussery, L. Nielsen and H. Ingmer (2015). Review and phylogenetic analysis of qac genes that reduce susceptibility to quaternary ammonium compounds in Staphylococcus species. *European Journal of Microbiology and Immunology*, **5(1)**: 44-61.

Wheaton, G., J. Counts, A. Mukherjee, J. Kruh and R. Kelly (2015). The confluence of heavy metal biooxidation and heavy metal resistance: implications for bioleaching by extreme thermoacidophiles. *Minerals*, **5(3)**: 397-451.

WHO (2004). Cadmium (addendum). WHO Food Additives Series: 52. First draft. World Health Organisation, Geneva, Switzerland.

World Health Organization, WHO/UNICEF Joint Water Supply, & Sanitation Monitoring Programme. (2015). *Progress on sanitation and drinking water: 2015 update and MDG assessment*. World Health Organization.

Yamina, B., B. Tahar, M. Lila, H. Hocine and F.M. Laure (2014). Study on cadmium resistant-bacteria isolated from hospital wastewaters. *Advances in Bioscience and Biotechnology*, **5(08)**: 718.

Yan, N. (2013). Structural advances for the major facilitator superfamily (MFS) transporters. *Trends in biochemical sciences*, **38(3)**: 151-159.

Yazdankhah, A., S.E. Moradi, S. Amirmahmoodi, M. Abbasian and S.E. Shoja (2010). Enhanced sorption of cadmium ion on highly ordered nanoporous carbon by using different surfactant modification. *Microporous and Mesoporous Materials*, **133(1)**: 45-53.

Zheng, L., W. Abhyankar, N. Ouwerling, H.L. Dekker, H. van Veen, N.N. van der Wel and C.G. de Koster (2016). Bacillus subtilis spore inner membrane proteome. *Journal of Proteome Research*, **15(2)**: 585-594.