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# Phytoremediation of heavy metals and its mechanism: A brief review

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**ABSTRACT**

In this study a review has been carried out for the uptake of toxic pollutants by various plants from water and soil. Phytoremediation is an emerging technology for the cleaning of soil and water and cheap in comparison to other technologies. The mechanism of the uptake of toxic pollutants is discussed.

*Keywords: Phytoremediation, chlorophyll, phytoextraction, macrophyte, pollutant, hyper accumulator*

## INTRODUCTION

The phytoremediation process introduced in 1991, is meant to "to heal again with plants" or "to cure evil with plants". In other words, this process has the capability to convert contaminated wastewater or ground water to usable form for the environment. The Greek word "phyton means plant" and the latin word "remediare which means remedy" are combine and form the word phytoremediation. In the process of phytoremediation, the plants are utilized for the removal, transfer, stabilization or destruction of contaminants from soil and ground water.[1] The plants are used to remediate contaminants by the uptake or transpiration of contaminated water.[2] The phytoremediation can be defined as "the use of plant for the cleaning of water or soil". In the process of phytoremediation, the plants take nutrients through roots, volatilize water through leaves and formed a transformation system to metabolize organic compounds and heavy metals.[3] Plants consume large amount of toxic elements and nutrients out of which only small amounts of toxic elements are harmful or they affects the plants only at higher concentration. Phytoremediation process is the use of specialized plants to clean up contaminated soil and ground water. When plants are exposed to high levels of contaminants, they will injured or die. Those sites, where the contaminants are spread within the root zone of plants, are best-suited sites for the use of phytoremediation.[4] This becomes relatively inexpensive because it uses the same equipment and supplies used in agriculture.

There is a continuous increase in contaminated substances from various industry and social and agricultural activities due to careless disposal of these toxic substances in the land areas, surface water and ground water. These toxic pollutants eg. metals and organic contaminants cause major effects on natural resources and environment viz. plants and animals. The industrial wastewater is then used for the agricultural purposes and the presence of toxic pollutants in water affects the fertility of land for example in various developing countries around 900,000 hectares of agriculture land is processed but the industrial wastewater. In other words, the farmers depend onto the industrial wastewater for their land dye to limited access for the treated water and rapid growth of industry. Various processes for treating the water is introduced for example biological, physical and chemical but they are very costly and only applicable for the small amount of wastewater.[5] Hence, an alternative process for wastewater treatment is introduced i.e phytoremediation, which is a plant-based technology, which uses the various plants for the treatment of wastewater and removes the toxic pollutants from wastewater. This treatment process is relatively cheap and considered the most suitable option for various countries. Phytoremediation can be used together with constructed wet lands and natural wet lands. For phytoremediation, various plant species have been identified which can grow in different environmental conditions.[6]

## 2. TECHNIQUES USED FOR PHYTOREMEDIATION

**2.1 Constructed Wetland:** This type of system is generally applied for the treatment of waste water generated by the industries like glass, aluminium, refineries, electroplating etc. Wetlands are the manmade/Artificial water bodies which resembles like natural water bodies (examples- ponds, lakes etc). Wetlands are economical than

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the water treatment plants, so they are gaining popularity among industries day by day. Wetland system can also be more efficient if it is integrated with mechanisms like phytofiltaration, phytoextraction.

**2.2 Floating Platform:** Floating platform is the large structure floating on the surface of water. These types of platforms are very popular in Europe and America. Such types of platforms are constructed by the materials which can float on water easily, and the plants are grown on that. The terrestrial plants are used for the this type of platforms because they have very denser roots which helps in phytofiltaration, as a result they are very efficient in the treatment of waste water.

## 3. Advantages of Phytoremediation system

The phytoremediation techniques have various advantages over other conventional methods like adsorption, membrane separation techniques and other chemical methods because it is economical and no adverse effect on environment. In chemical methods like precipitation chemicals are used for the removal of pollutants but by coagulation, it results as the formation of huge amount of waste in the form precipitant.Surface water, drinking water and seawater are being polluted by many toxic elements through anthropogenic activities and also by many natural activities like volcanic, drought etc. Therefore, removal of pollutant from aquatic system is a so important and also for native system. Phytoremediation is technique that can be readily removed pollutant by aquatic macro-phytes or by other aquatic floating plants since the process involves bio-sorption or bio-accumulation of the dissolve pollutants from water. In aquatic systems, aquatic plants can be either floating on the water surface or submerged into the water. The moving aquatic hyperaccumulating plants consume pollutants by its roots while in the submerged plants pollutant uptake rate is by the whole plant.[49,50]

## 4. Applications of Phytoremediation

### 4.1 In-situ phytoremediation

In this method, live plants are used with the contaminated surface water for the phytoremediation process. Through this process, the contaminated material is not removed by the phytoremediation. In this mechanism, the toxic pollutants consumed by the plants get accumulated in the plant biomass and no transpiration of toxic pollutants take place. The plants after recovery or uptake of the toxic pollutants were harvested from the site for the disposal. Requirement for the in-situ approach is that the contaminants present in wastewater must be physically accessible to the roots of plants. The in-situ approach is least expensive strategy for phytoremediation.[7]

### 4.2 In-vivo phytoremediation

In this process, the live plants are grown in wastewater for the remediation of toxic pollutants. For surfaces where the contaminant is not physically accessible to the roots of the plants, In-vivo phytoremediation is applied. The contaminants are extracted by mechanical methods and then exposed to the plants selected for phytoremediation of toxic pollutants in temporary treatment area. This approach is more expensive than other approaches. Treatment can be doneat the site of contaminants or at another site[8].

### 4.3 In-vitro phytoremediation

In this methodology the components of live plants i.e. extracted enzymes are used for phytoremediation. In this approach the plants extract pollutants from contaminated site using enzyme mechanism. This approach could also be applied to temporary contaminated treatment area by transferring the plants from toxic pollutant site. Theoretically this approach is most expensive method because of the costs of preparing the plant enzymes but some plants released under stress that could result in less production costs. The time during which the enzyme remains active for breakdown of contaminants is another important factor for considering this approach[9].

## 5. Mechanisms of phytoremediation

Some of the factors given below affect the uptake and distribution of pollutants within living plants[10]

a) Physical and chemical characteristics of the toxic pollutants such as solubility in water, vapour pressure, molecular weight and octanol-water partition coefficient.

b) Environmental conditions such as pH, temperature, organic matter and soil moisture content.

c) Characteristics of plant biomass such as type of root, shoot and leaf of the plants system and type of enzymes.

The various mechanisms used by plants for phytoremediation are

### 5.1 Phytoextraction

Phytoextraction is also known as phytoaccumulation can be defined as the uptake of pollutants from wastewater by live plant in the root. This mechanism occurs when the contaminants taken by the plants is not completely degraded or consumed by the plants, resulting in an accumulation of the pollutants in different parts of the plant. Some of the aquatic macrophytes are hyperaccumulators absorb huge amount of pollutants in comparison to other plants. Therefore the plants after uptake of toxic pollutants either incinerated or send to recycle the metals. The level of contaminants in the plants down to the allowable limits before the disposal of the plant. After the incineration of toxic pollutants the ash must be disposed off in a hazardous waste landfill. The volume of ash should not exceed more than 10% of the volume of contaminated soil used for the experimentation. The process of phytoextraction removes various toxic heavy metals such as Chromium, Nickel, Zinc, Arsenic and Copper metals.

### 5.2 Phytopumping

In phytopumping, plants can be utilized to minimize or remove migration of the contaminants. In this mechanism, plants are treated as the organic pumps for the uptake of large volumes of the contaminated water as the part of transpiration process. The migration of contaminants in ground water is reduced after this mechanism. The plants, which are capable of pump out large amount of water, are used for this mechanism. This property of plants can provide an inexpensive alternative option to the mechanical pumping system for contaminated ground water in shallow aquifers[11].

### 5.3 Phytostabilization

This mechanism can be used to minimize migration of contaminants in soils through absorption and accumulation by the roots, adsorption onto roots or precipitation within the root zone of plants. The roots of plants have the ability to alter the soil environment conditions, i.e. pH and soil moisture content. This process uses this ability of plants. Mobility of contaminants, migration to the groundwater or air and bioavailability for entry into the food chain is reduced during this process. By this technique a vegetation cover at sites where natural vegetation is lacking due to high metal concentration in surface of soils or physical disturbances to materials at the surface is re-establish.[12]

### 5.4 Phytotransformation

Phytotransformation process is also called as phytodegradation. Phytotrasformation is the breakdown of contaminants through metabolic processes of plants or the external breakdown of contaminants through the release of enzymes. This process also refers to the uptake of contaminants with the subsequent breakdown, mineralization or metabolization by the plant through various internal enzymatic reactions and metabolic processes.[13]

### 5.5 Phytovolatilization

Phytovolatilization is a process in which plants convert a contaminant into a volatile form by volatilization process from the plants either from the leaf, stomata or stems of plants and then removing the contaminants from the soil or water at a contaminated site.[14]

### 5.6 Rhizodegradation

Rhizodegradation process is a biological treatment of contaminants by the enhanced fungal and bacterial activity in rhizosphere of some vascular plants. In the rhizosphere, the microbial density and activity of the root is decreased. The geochemical environment in the rhizosphere can moderate by plants and provides the ideal conditions for bacteria and fungi to grow and degrade organic contaminants. The litter of plant and exudates of root provides nutrients which reduce or eliminates the need of costly fertilizer additives. The roots of plants penetrate the soils, provide the zones of aeration, and stimulate aerobic biodegradation. Some molecules, which are released by root, die back and exudation resembles common contaminants and used as substrates[15].

## 6. Study on Phytoremediation for removal of Heavy metals

Various plant species used for the accumulation of heavy metals and uptake capacity of various plants for the accumulation of pollutant is given in table 1. M. Oves et al. 2013[16] performed a study on bacterial strain *Pseudomonas aeruginosa* OSG 41. This bacterial strain was isolated from the heavy metal contaminated water. B. Dhir et al. 2011[3] conducted a study of phytoremediation on *SalviniaNatans*, a fast growing free-floating aquatic weed was chosen for the study of removal of heavy metals Cr, Fe, Ni, Cu, Pb and Cd ranged between 6 and 9 mg/g dry wt., while the accumulation of heavy metals Co, Zn and Mn to the leaves of the plant was 4 $mgg^{-1}$ dry wt. P.A. Wani et al. 2010[17] studied the toxic effect of chromium was investigated on to the plant and microbial diversity. The chickpea plant for the phytoremediation of chromium. H.A. Baumann et al. 2009[18] carried out the experiments to investigate the effects of various heavy metals such as, Copper (Cu), Chromium (Cr), Zinc (Zn), Cadmium (Cd) and lead (Pb) on photosynthetic activity of plant was measured as pulse amplitude modulation (PAM). Photosynthesis activity and growth-survival scores were investigated. S. Magateli et al. 2009[19] carried out the experiments to examine the effects of toxic heavy metals such as cadmium (Cd), copper (Cu) and zinc (Zn) onto the aquatic macrophyte *Lemnagibba* were determined under controlled conditions. The phytoextraction of heavy metals from soil is a cost effective technology that represents the largest economic opportunities for the phytoremediation of heavy metals due to the need of the demands of process industries. P. Vajpayee et al. 2000[20]studied the uptake of chromium metal by the aquatic water plant European water lily of Nymphae alba L of family Nymphaeaceae grown at various level of Cr(VI) ranging from 1-200 µm accumulated chromium in concentration and duration-dependent manner. Due to the decline in fresh water supply some of the researcher studied the growth of plant in sewage water and the accumulation of toxic metals in plant[91]. The copper nanoparticle was also synthesized using the damdei green leaves which was used for the oxidation of o-dianisidine in presence of hydrogen peroxide[92]. In the literature medicinal value of various plants is also investigated.[93] The tropical plant species such as *Gyneriumsagittatum*, *Colocasiaesculenta* and *Heleconiapsittacorum* was used for the treatment of waste water.[94]

## Conclusion

Now a days the pollution created by the various man made activities is serious concerned. The toxic pollutant discharged by the various industries affects the whole ecosystem. There are various technologies are available for the treatment of waste water but these technologies have various drawbacks such as generation of secondary waste which again pollute the environment and not cost effective. Therefore phytoremediation is proved to be cost effective and eco-friendly technology. The waste effluent discharged by the various industries entered in to the river and ground water are cleaned by the various aquatic macrophytes such as water hyacinth grown nearby the discharged site. Therefore there is a need for the development of this technology for the benefits of living beings.

**Table 1**: Uptake capacity (mg/g) various plant species used for the accumulation of toxic pollutants

| Common name of plant | Scientific name of plant | Uptake of metals | Initial concentration (mg/l) | Exposure Time days | pH | % Removal | Uptake capacity $q_e$ (mg/g) | Reference |
|---|---|---|---|---|---|---|---|---|
| Wild radish | Raphanussativus L | Cr | 360, 630, 900, 1170, 1440 | 28 | Neutral | 20.18, 23.42, 30.80, 33.13, 49.48 | | D. Sayantan et al., 2013[21] |
| potatoes, carrots and onions | Daucuscarrota, Allium cepa, Solanumtuberosum | Ni, Cr | 0-250 | 180 | | | | S. Stasinos et al., 2013[22] |
| Garden snail | Helix aspersa | Pt, Cr | | 56 | | | 19 x $10^{-3}$ | T. Eybe et al., 2013[23] |
| Chickpea | Cicerarietinum L | Cr | 1800 | 5 | 6-8 | | .1085 | M. Oves et al., 2013[16] |
| Water velvet, duckweed | Azollapinnata and Lemna minor | Fe, Mn, Cu, Zn, Ni, Pb, Cr and Cd | 0.18 | 7 | 6.2 | 77.7 | 78.89 | S. Bharti et al., 2012[24] |
| Wand riverhemp | Sesbaniavirgata | Cu, Cr, Zn | 50-116 mg/kg | 30 days | 6 | | 0.0023-0.0028 | A. Branzini et al., 2012[25] |
| Sea Purslane | Halimioneportulacoides | Cr(VI) | 0 -30 | 7 | 1 | 60 | | B. Duarte et al., 2012[26] |
| Pond weed aquatic macrophyte | Potamogetonpusillus | Cr, Cu | 864, 1728, 3456, 6935 | 5, 10 or 15 | 7.5 | 28-56 | | M.V. Monferran et al., 2012[27] |
| Pea | Pisumsativum, | Cr(VI) | 20 -2000 | 28 | 7.8 | 55 | | E. Rodriguez et al., 2012[28] |
| Marine algae | Laminariadigitata | Cr(III) | 250 | | 4 | | 42 | I.M. Dittert et al., 2012[29] |
| Indian mustard | Brassica juncea | Se and Mo | | | | | | M. Schiavon et al., 2012[30] |
| Green algae | Micrasterias | Cr | 0.18 | 21 | 6 | 78 | | S. Volland et al., 2012[31] |
| Green alga | Monoraphidiumconvolutum | Cr(VI) | 0-100 | 5 | 7.4 | 82 | | R. Takami et al., 2012[32] |
| Chinese silver grass | Miscanthussinensis | Cr | 0, 9, 18, 36, 54, 90, 135, 180 | 3 | 5.8 | | 1.308 | S.A. Sharmin et al., 2012[33] |
| Giant reed | ArundodonaxL | As, Cd and Pb | | | | | | Y. Miao et al., 2012[34] |
| Amazon sword plant, Undulate cryptocoryne | Echinodorusamazinocusan d Cryptocoryneundulata | Fe, Cu, Zn, Cr, Ni, Mg, Mn, Ca | 5-20 | 7 | 7.4 | | 6.8 | Z. Sapci et al., 2012[35] |
| Sambungnyawa batik | Gynurapseudochina | Cr, Cu, Zn, Fe | 100 | 14 | 6 | | 0.8231 ± 0.005 | B. Mongkhonsin et al., 2011[36] |
| Red marine algae | Pterocladiacapillacea | Cr | 5-100 | | 7 | 80-85 | 66 | A. El Nemr et al., 2011[37] |
| Mushroom | Cucumisutillissimus | Cr(VI) | 0, 50, 100, 150 μg/g | 30 | 6.7 ± 0.02 | 83.05 | 5.6 ± 0.1 | G. Sinam et al., 2011[38] |
| Krambe | Crambeabyssinica | Cr | 0, 9, 18, 27, 36, 45 | 10 | | | | A. Zulfiqar et al., 2011[39] |
| Gramineae | Leersiahexandra Swartz | Cr(III) | 54 | 20 | 5.5 | | 2.131 ± 0.166 | J. Liu et al., 2011[40] |
| Floating water moss | Salvinianatans | Cr | 15 | 10 | 4.5-5 | 56.8 | 0.932 | B. Dhir et al., 2011[3] |
| Cord grass | Spartinaargentinensis | Cr | 0-3600 | 30 | 6.8 | 53 | 15.1 | S. Redondo-Gomez et al., 2011[41] |
| water-starwort | Callitrichecophocarpa | Cr(VI) | 9-126 | 21 | 6.6 | | 1 | J.Augustyno |

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|---|---|---|---|---|---|---|---|---|
| aquatic macrophyte | Sendtn | | | | | | | wicz et al., 2010[42] |
| Water spinach | Ipomoneaaquatica | Cr(III) | 10 | 14 | 6 | | 13.217 | J.C. Chen et al., 2010[43] |
| Smooth Mesquite | Prosopislaevigata | Cr(VI), Cd(II) | 0-612 | 50 | 360, 612 | | 5.035, 8.09 | L. Buendia-Gonzalez et al., 2010[44] |
| Rice paddy | Oryza sativa L. | Cr(VI) | 2.5, 5, 10, 25, 50, 75, 100 and 200 | 30 | 6-6.5 | 75 | | P. Sundaramoorthy et al., 2010[45] |
| Floating fern | Salvinia minima | Cr | | | | | | C. Prado et al., 2010[46] |
| Chickpea | Cicerarietinum L | Cr | 67.5 mg/kg | 90 | 7 | | | P.A. Wani et al., 2010[47] |
| Barbados nut | Jatrophacurcas L | As, Cr and Zn | 0, 25, 50, 100, 250 , 500 mg $kg^{-1}$ | 12 months | 7.0 ± 0.5 | | 0.0312 ± 0.0022 | S.K. Yadav et al., 2009[48] |
| Water hyacinth | Eichhorniacrassipes | Cr, Zn | 1, 5,10,20 | 11 | 8.3 ± 0.20 | 84 | 0.10, 1.13, 1.41, 1.71 | V.K. Mishra et al., 2009[49] |
| Water Hyacinth | Eicchorniacrassipes | Cr | 1-50 | 23 | 3.5 - 5.5 | | 4.93 | F.R.E. Quinones et al., 2009[50] |
| Spurge, Mullein, Tragacanth | Euphorbia macroclada(EU), Verbascumcheiranthifolium(VR), and Astragalusgummifer(AS) | Sr | | | | | | A. Sasmaz et al., 2009[51] |
| Poacea | Saccharumofficinarum L | Cr | | | | | | H. Xia et al., 2009[52] |
| Marine macroalgae | Ulvaintestinalis | Cu, Cr, Zn, Cd, Pb | | | | | | H.A. Baumann et al., 2009[19] |
| Green onion, moonlight ferns | Allium fistulosum, Pteriscretica cv Mayii | Pb, As | | | | | | Y. Cho et al., 2009[53] |
| Fat duckweed | Lemnagibba | Cd, Cu and Zn | | | | | | S. Megateli et al., 2009[20] |
| Eelgrass | Zostera marina | Cr | | 14 | | | | O. Mascaro et al., 2009[54] |
| Aquatic macrophytes | L. minor, S. polyrhiza, C. aquatica, C. palustris and E. canadensis | Cr | | | | | | R. Dosnon-Olette et al., 2009[55] |
| Aquatic macrophyte | Salviniaauriculata, Pistiastratiotes and Eichhorniacrassipes | Cr(VI) | 0.1-5 | 27 | 3.5-5.1 | | | F.R.E. Quinones et al., 2009[15] |
| Thorn apple | Daturainnoxia | Cr(VI) and Cr(III) | 0, 9, 18, 180, 360 | 7 | | | 0.57 | P. Vernay et al., 2008[56] |
| Sunflower | Helianthus annus | Cr | 20, 40, 60 mg/kg | 7 | 6.75 | | 0.00011 | F. Andaleeb et al., 2008[57] |
| Sunflower | Helianthus annus | Cr, Ni, Fe, Cd, As | 30 | 28 | | 4.88 | | M.C. January et al., 2008[58] |
| Hankow willows | Salix matsudanaKoidz | Cr(VI), Cr(III) | 1.92 | | | 78 | 0.00095 | X.Z. Yu et al., 2008[59] |
| Green Amaranth | Amaranthusviridis | Cr | 0.18, 1.8, 18 | 20 | 5.5 | 4.6, 16.8, 62 | | D. Liu et al., 2008[60] |
| Chinese brake | Pterisvittata | Cd, As | | | | | | X. Xiyuan et al., 2008[61] |
| Basket willow | Salix | Cr | | | | | | S. Quaggiotti et al., 2007[62] |
| Perennial ryegrass | Loliumperenne | Cr | 0-90 | 15 | | | 2.45 | P. Vernay et al., 2007[56] |

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|---|---|---|---|---|---|---|---|---|
| kiwifruit pollen | Actinidiadeliciosa | Cr | 2880- 13500 | | 7.4 | | | A. Speranza et al., 2007[63] |
| Green algae | Chlamydomonasreinhardti i | Cr | | | | | | M.C. Rodriguez et al., 2007[64] |
| Green alga | Ulvalactuca | Cr | 5-100 | | 1 | 92 | 10.61 | A. El-Sikaily et al., 2007[65] |
| Gramineae | Leersiahexandra Swartz | Cr | 10 | 15 | 6 | 58.5 | 2.978 | X.H. Zhang et al., 2007[66] |
| Genipapo or Huito | GenipaamericanaL | Cr | 30 | 34 | - | - | - | R.M.T. Barbosa et al., 2007[67] |
| Aquatic macrophytes | Salviniaherzogii and Pistiastratiotes | Cr | 1, 2, 4 and 6 | 1, 2, 5, 14, 31 | 6.87 | 33 | | N. Sune et al., 2007[68] |
| Water lily | Nymphaeaspontanea | Cr | 10 | 7 | 6 | | 2.119 | T.P. Choo et al., 2006[69] |
| Water hyacinth | Eichhorniacrassipes | Cr, Zn | | | | | | V.K. Mishra et al., 2006[70] |
| Giant Chinese silver grass | Miscanthus | Cr | 50-200 | 36 | 7.5 | 90-95 | | I. Arduini et al., 2006[71] |
| Fungi | Aspergillus sp. | Cr | 500 | 3 | 6 | 70 | | S. Srivastava et al., 2006[72] |
| elephant grass | Penisetumpurpureum | Cr | 10 and 20 mg Cr $dm^{-3}$. | 1 | | 97–99.6% | | C. Mant et al., 2006[73] |
| Water cabbage | Pistiastratiotes L | Cr | 0, 1.8, 7.2, 28.8 | 2 | 7.5 | | | S. Sinha et al., 2005[74] |
| Spinach | Spinaceaoleracea L | Cr, Fe | | | | | | P. Sinha et al., 2005[75] |
| Paddy rice | Oryza sativa Linnaeus | Cr | | | | | | P.Bhattacharyya et al., 2005[76] |
| Mustard | Brassica juncea cv | Cr(VI) | 0.036, 0.036, 0.36 | 15 | Neutral | | 0.075, 0.41, 0.897 | V. Pandey et al., 2005[77] |
| Watermoss, water cabbage | Salviniaherzogii, Pistiastratiotes | Cr | 1, 2, 4, 6 | 30-35 | 6.87 | 92.8 | 6.20 | M.A. Maine et al., 2004[78] |
| Field bindweed | Convolvulus arvensis L | Cd, Cr and Cu | 20 | 15 | 5.8 ± 0.2 | | 2.1 | J.L. Gardea-Torresdey et al., 2004[79] |
| Mosquito fern | Azollacaroliniana | Hg(II), Cr(III), Cr(VI) | 0.1, 0.5 and 1.0. | 12 | | 74 | 71 to 964 mg $kg^{-1}$dm | R. Bennicelli et al., 2004[80] |
| Yeast | Pichiaguilliermondii | Cr | 90 | 3 | 5.5 | | 0.4–0.9 | H. Ksheminska et al., 2003[81] |
| Watermelon | Citrullus | Cr | 9, 18, 36 | 24 | 6.8 | | 0.0039 | B.K. Dube et al., 2003[82] |
| Cabbage | Brassica oleracea | Cr | 90 | 42 | | | 19.549 | N. Pandey et al., 2003[83] |
| Basket willow | Salix | Pb, Zn and Cu | | | | | | I.D. Pulford et al., 2003[84] |
| Epiphytic alga | Pleurococcus sp. | Cr | | | | | | C. Cervantes et al., 2001[85] |
| Willd | Salvinia minima | Cr | 1-2 | 14 | 6.5 | | | P.B. Nichols et al., 2000[86] |
| Wild grass | Echinochloacolona | Cr | 1.25 | 10 | 6.8 | | 3 | G.R. Rout et al., 2000[87] |
| White water lily | Nymphaea alba L | Cr | | | | | | P. Vajpayee et al., 2000[88] |
| Cauliflower | Brassica oleracea | Cr, Co, Cu | 90 | 56 | | | 0.00099 | J. Chatterjee et al., 2000[89] |
| Paddy | Oryza sativa | Cr(III) and Cr(VI) | 0.09-4.5 | 120 | 7.5-8.2 | 90 | 0.00241 | S. Mishra et al., 1997[90] |

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