J. Int. Environmental Application & Science, Vol. 3 (2): 101-141 (2008)

Heavy metal pollution and its control through nonconventional adsorbents (1998-2007): a review

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Contamination of water by toxic heavy metals has been a major environmental problem since long. Some of the past episodes of heavy metal contamination in the aquatic environment have increased the awareness about their toxicity. The outbreak of Minamata and Itai itai diseases in Japan; discovery of conversion of inorganic mercury into methyl mercury and its accumulation in human body through food chain, particularly, through fish and the carcinogenic nature of certain inorganics and metals have led to the refocusing of the attention of environmentalists on the abatement of heavy metal pollution. Heavy metals cause direct toxicity to humans and other living beings due to their presence in aquatic environment beyond the permissible limits. Some of these metals are bio-accumulative and detrimental to human health. Heavy metals when discharged in water bodies through wastes also affect the aquatic life and destroy their self-purification power. The sources and health effects of some widely used metals are given in Table 1. The direct discharge of heavy metal containing wastes into water bodies or sewers is to be checked in order to reduce the environmental impact.

The heavy metals have great affinity for sulphur and attack sulphur bonds in enzyme making them immobilized. They also bind to cell membrane and affect the transport processes through the cell wall. Mercury(II), Cadmium(II) and Lead(II) have been found to be effective enzyme inhibitors. Mercury in the form of methyl mercury is the most toxic species. It causes energy deficiency in brain cells and disorders in the transmission of nerve impulses(De, 1992).

The heavy metals even at relatively low concentrations are toxic to biological processes and thus prevent the effective degradation of organic wastes. Adenosine triphosphate, carbonic anhydrase, cytochrome oxidase are some of the key enzymes which help in the synthesis of heme, are inhibited by Pb(II)(De, 1992).Arsenic(III) compounds coagulate proteins. The enzymes that generate cellular energy in the citric acid cycle are adversely affected by As(III). The activity of the pyruvate dehydrogenase is inhibited since it forms a complex with As(III), which prevents the generation of ATP molecules(De, 1992).

In view of the above facts, it is important to prevent water pollution due to heavy metals. Research is now been focused to develop suitable technologies either to prevent heavy metal pollution or to reduce it to very low level. This can be achieved either by decreasing the afflux of heavy metals to the receiving bodies(rivers, sewer and lake, etc.) or by their removal from contaminated media. If heavy metal pollution arises from anthropogenic activities then it can be prevented but if it is of natural origin then it is unavoidable.

Various treatment technologies have been developed for the removal of heavy metals from water and wastewater. The most widely used conventional methods for removing heavy metals from wastewater include ion exchange, chemical precipitation, reverse osmosis, evaporation, and

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membrane filtration. The type of treatment technique required for a particular industry depends upon the nature; composition and flow rate of the effluent together with the quality control needed to be achieved. The effectiveness of the treatment plant can be optimized by adopting any one of the above technique or the appropriate combination of two or more techniques. But most of these methods suffer from some drawbacks, such as high capital and operational cost or the disposal of the residual metal sludge, and are not suitable for small-scale industries(Kobya et al., 2005). Besides high capital and operational cost conventional methods have inadequate efficiencies at low concentrations, particularly in the range of 1 – 100 mg/l(Davila et al., 1992; Kapoor & Viraraghavan, 1995; Wilde & Benemann, 1993)

Adsorption is one of the promising processes for the removal of heavy metals from water. The process is suitable even when the metal ions are present in concentration as low as 1mg/l(Chong & Volesky, 1995). Activated carbon(powdered or granular) has been used for the removal of Pb, Cd and other heavy metals especially when associated with organic particulate matter in water(Sorg et al.1978; Huang & Smith, 1981). Hydroxides of Alumina, Iron(Cowan et al. 1991; Gerth & Bruemmer, 1983) been used as adsorbents for the removal of heavy metals. However, the cost of adsorbent becomes relatively high when pure sorbents are used therefore there is an increasing trend for substituting the pure sorbents with natural by-product in order to make the process economically feasible. The use of non-conventional adsorbents for the removal of heavy metals has been reviewed by Rai and Upadhyay(Rai et al, 1998). The non-conventional adsorbents may be classified as:

1. **Inorganic adsorbents**: They may be natural minerals, ores, clay and waste materials from various industries like fly ash, metallurgical solid wastes like bauxite red muds etc. Minerals like Montmorillonite have been used to remove Pb(II) and Cd(II)(Srivastava et al, 1989), Kaolinite was used to accumulate Zn(II)(Singh, et al., 1988), Illite to remove Pb(II)(Chantawong et al., 2001), Bentonite was used to adsorb Cr(VI)(Khan et al., 1995), Activated red mud was used to trap Ni(II) and Cr(II)(Zouboulis & Kydros, 1993, Pradhan et al., 1999). Oxidized anthracite was used for the removal of Cd, Cu and Pb(Petrov et al., 1992).

2. **Organic adsorbents**: A large number of waste materials of organic origin like dead leaves of trees, bark, roots, seed shells, oil cakes and saw dust from various plants in the form of powder have been utilized for the removal of heavy metals and their adsorption properties have been explored. In addition to these adsorbents wool, albumin, feathers, waste rubber, hair, waste tealeaves, bagasse, rice husk etc. have also been used as organic non-conventional adsorbents(Rai et al, 1998). Exhausted coffee was used to remove Cd(II) and Cr(VI)(Orhan & Buyukgungor, 1993), Formaldehyde-polymerized peanut skin was used to remove Cd(II) and Pb(II) removal(Randall et al., 1978), Untreated sawdust was used to remove Cr(VI) from tannery effluents(Baryant et al., 1992; Zarraa, 1995), Leaf mould was used to remove Cr(VI)(Sharma & Foster, 1994). Activated carbon from hazelnut shells was used for the adsorption of Co(II) from aqueous solution(Demirbas, 2003). Activated carbon from coconut coir pith was used for the removal for Cd(II) from aqueous solution(Kadirvelu & Namasivayam, 2003).

3. **Biosorbents**: They included biomass of algae fungi, and peat moss etc. The advantages of biosorption are low cost, high efficiency of heavy metal removal from dilute solutions, regeneration and possible metal recovery. Filamentous fungi have been found to possess a high potential of accumulating Cu, Ni, Co and uranium in aqueous solutions(Siegel et al, 1990). It has been reported that the biomass of brown algae of the sargassum family possesses a metal binding capacity superior to other organic and inorganic sorbents(Holan et

al, 1993; Holan & Volesky, 1995; Volesky & Holan, 1995; Kratochvil and Volesky, 1997). Several researchers have concluded that the major mechanism of heavy metal uptake by algae(Crist et al, 1990; Kratochil et al, 1995). Peat moss(Spint et al, 1995) is ion exchange, Brown marine macroalgae was used to remove Cd(II)(Lodeiro et al., 2005). However, direct application of living fungal cells as biosorbents for heavy metals is unfavourable due to the resistance of living cells to metal ions. Sargassum seaweed was used to accumulate Cd and Cu(Davis et al., 2000), C. Vulgaris was used for the removal of Cd(II)(Aksu, 2001), Sphagnum moss peat was used to remove Cu(II) and Ni(II) from aq. medium(Ho et al., 1994; Ho et al., 1995).

In our laboratory the removal of heavy metals from industrial wastewater by adsorption process is being carried out since last-twenty years. Various low cost adsorbents have been studied for the removal and recovery of toxic metals like Cr, Ni, Cu, Cd, Zn, Pb etc. the work has been nationally and internationally recognized. A summery of the work done in our laboratory is being presented in following paragraphs.

Atomic absorption spectrophotometric studies were carried out to detect the presence of Cd and Zn in the samples of commercial fertilizers, producing soils, barren soils and river water samples. The analysis of fertilizer samples and monitoring of soil and water samples have shown that fertilizers are rich in Cd and Zn. Soils and water samples are widely contaminated with high concentrations of Cd and Zn(Khan et al., 1981)

Uptake of Cadmium by microbes at different temperatures was studied at pH. 7. Glycine was used as a source of carbon for microorganisms in BOD bottles at 20, 30, 40 and 50˚C with varying concentrations of Cadmium. The influence of temperatures on the toxic effects of Cadmium was studied with respect of K values at various temperatures showed that Cadmium is highly toxic at 50˚C, but at 30 and 40˚C K values increased showing vigorous multiplication of bacteria even in the presence of Cadmium. The removal of Cadmium from water phase after 8 days was found to be appreciable.(Ajmal et al., 1982)

Toxic metals like lead, bismuth, mercury and zinc-uranyl were found to repress carbonaceous oxygen demand. The biological seed was developed from trade waste of Glaxo laboratories. Three concentrations 5, 10 and 15 mg/l of the metals were used to observe the repression of carbonaceous oxygen demand of amino acid methionine used as substrate. The metals lead, bismuth, mercury and zinc uranyl singular and in combination effectively repressed the BOD of methionine without affecting COD. Therefore the wastes containing these metals should not be discharged into waterways without treatment in order to avoid pollution hazards and poisoning(Ajmal et al., 1983)

The physico-chemical characteristics of Ganges river water and distribution of nine metals in the submerged plant and fish has been studied. The parematers color, turbidity, total dissolved solids, pH, total alkalinity, chloride, sulphate, phosphate, NO_3-N, NO_2-N, dissolved oxygen, BOD and COD showed that at various sampling stations deterioration in the quality of water at downstream is severe. However, due to a self-purification phenomenon, significant increase in the dissolved oxgen at the next sampling station was noted. A high fluctuation in the accumulation of metals in the submerged plants and fish was found from one sampling station to another due to domestic sewage and industrial effluent discharged into river(Ajmal et al., 1984)

Electroplating wastes from industrial sites are analyzed for color, turbidity, pH, alkalinity, sulfate, chloride, N-ammonia, N-nitrate, acid hydrolysable P, dissolved oxygen, BOD, COD, chromate and Cr(VI). The effect of these wastes on saprophytic and nitrifying bacteria was studied with varying concentration of the waste using sucrose substrate as a source of C chain for microorganisms. The use of clay content was found to be suitable media for the removal of Cr(VI) from the wastes(Ajmal et al., 1984).

A study was made of the effect of water hardness at different concentrations(viz. 0, 80, 120, 160, 240, 320, 400 and 480 mg/l as $CaCO_3$) on the toxicity of Cadmium metal(5 mg/l) as sulphate to saprophytic and nitrifying bacteria, with respect to the rate constant(K) and ultimate BOD which were calculated from BOD data(15 days) using Thomas Graphical Method. Glucose was used as a source of carbon for microorganisms. It was observed that the toxicity of cadmium to microorganism decreased with increasing hardness and reached maximum at 320 mg/l as $CaCO_3$ for nitrifying and 400 mg/l as $CaCO_3$ for saprophytic bacteria.(Ajmal & Khan, 1984)

The distribution of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in plants and fish of Yamuna River from Delhi and Allahabad a distance of about 840 Km, at five sample stations was determined in the year 1981. The results have shown wide variations in the heavy metal levels from one sampling station to the other.(Ajmal et al., 1985)

The concentrations Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn metals in water and sediments of Yamuna River were determined by atomic absorption spectrophotometry. The data showed that there was considerable variation in the concentrations of elements from one sampling station to the other which may be due to the variation in the quality of industrial and sewage wastes being added to the river at different sampling stations.(Ajmal et al., 1985)

A study was conducted to determine the levels of heavy metals Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn along with physico-chemical parameters in ground waters of Aligarh city. Twenty-seven samples of hand pump water and twenty-three samples of municipal water supply were collected from different localities of the Aligarh city, five times during the period of two months at intervals of 12 days. The samples ware analysed for physico chemical characteristics and heavy metal contents.(Ajmal & Raziuddin, 1986)

The concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the water, sediments, fish and plants of the river Hindon, U.P., India, at seven sampling stations, were analyzed. Considerable variations in the concentration between water, sediments, fish and plants were noted(Ajmal et al., 1987).

The distribution of heavy metals viz. Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the water, sediments, plants fish samples collected from the Kali Nadi(India) have been determined. The studies have shown that therewas considerable variation in the concentration of heavy metals from one sampling staion to the other which may be due to the variation in the quality of indutrial and sewage wastes being added to the river at different places(Ajmal et al., 1988).

Heavy metal ions such as Cr, Ni, Cu, Cd and Zn have been removed from the electroplating wastes using Fe(III) hydroxide as adsorbent. The maximum removal of these metal ions(79%) occurred at pH 8 to 9. Anions were found to play a negative role in the adsorption phenomenon. Metal ions sorption has been found to decrease with the increasing anionic concentrations. The methodology proposed might provide an inexpensive and economical procedure for the removal and recovery of toxic metals from electroplating wastes. These investigations have shown that the treatment could be applied for the removal of heavy metal ions such as Ni, Cr, Zn and Cd from the effluent prior to their discharge into the aquatic environment. The optimum abatement conditions have been determined and found to be mainly dependent on the pH of the system(Ajmal et al, 1993).

The adsorption of metals from aqueous solutions of Pb(II), Zn(II) and Cd(II) on naturally occurring pyrolusite has been studied. The chemical stability of pyrolusite has been determined in NaOH, H_2SO_4, $HN0_3$, HCl, NaCl and NH_4Cl solutions of various concentrations. Adsorption of metal ions followed the order Pb(II) > Zn(II) >Cd(II) the maximum adsorption of Pb(II)(100%) occurred at pH 7. The relation between the amount of Pb(II) adsorbed per unit weight of pyrolusite and the concentration of Pb(II) at equilibrium followed the Freundlich adsorption isotherm. The efficiency of pyrolusite has been demonstrated by removing lead from synthetic wastewater. 100% and 96% removal of lead have been achieved from synthetic wastewater containing 5 mg/l and 120 mg/l of Pb(II) respectively at pH 7. The result of these studies suggest that pyrolusite might provide and economical method for the removal of lead from industrial wastewater(Ajmal et al, 1995).

Phosphate treated saw dust showed remarkable increase in sorption capacity of Cr(VI) as compared to untreated sawdust. The adsorption process was found to be pH dependent. Total(100%) adsorption of Cr(VI) was observed in the pH range < 2 for the initial Cr(VI) Concentration of 8-50 mg/l. The effect of various adsorbent doses at pH 2 confirmed Langmuir adsorption isotherms. 100% removal of Cr(VI) from synthetic waste as well as electroplating waste containing 50 mg/1 Cr(VI) was achieved by batch as well as by column processes. The adsorbed Cr(VI) on phosphate treated saw dust was also recovered(87%) using 0.01 M sodium hydroxide. The results obtained from column as well as by batch processes were found to be almost identical(Ajmal et al, 1996).

Mangifera indica(Mango) seed and seed shell powders were studied for their possible application in the removal of Cu(II) from wastewater. The adsorption of Cu(II) on the powder of Mango seeds and seed shell was found maximum at pH 6 and followed Freundlich type adsorption Isotherm The overall process was spontaneous and exothermic in nature. The total adsorption on each adsorbent increased with the increase in temperature between 30-50 ^{0}C and then decreased up to 60 ^{0}C. More over, it was found that the seed shell of *Mangifera indica* had higher sorption capacity than that of the seed powder for Cu(II). The presence of Ca(II), Mg(II), and K(I) decreased the percent adsorption of Cu(II) on these adsorbents(Ajmal et al, 1997).

Sawdust, an inexpensive material has been utilized as an adsorbent for the removal of Cu(II) from wastewater. The effect of contact time, pH concentration, temperature, dose and particle size of the adsorbent and salinity on the removal of Cu(II) has been studied. The equilibrium nature of copper(II) adsorption at different temperatures(30-50 ^{o}C) has been described by the Freundlich and Langmuir isotherms and a tentative mechanism has also been proposed. The thermodynamic parameters such as free energy, entropy and enthalpy changes for the adsorption of Cu(II) have also been computed and discussed. The Kinetics and the factors controlling the adsorption process have also been studied. In order to widen the applicability of the removal technique, the optimized method was applied for the removal of Cu(II) from Ganga river water. The removal efficiency was found to be 63%. In the river water sample, the adsorption capacity was slightly decreased, probably due to the presence of other major cations like calcium and magnesium. The process was found to be economically feasible and easy to carry out(Ajmal et al, 1998).

The fruit peel of orange(*Citrus reticulate*) is a low cost adsorbent, which is abundantly available in India as waste material. The ability of fruit peels of orange to remove Zn(II), Ni(II), Cu(II), and Pb(II) and studied. The adsorption was found in the order Ni(II)>Cu(II)>Pb(II)>Zn(II). The extent of removal of Ni(II) was found to be dependent on sorbent dose, initial concentration, pH and temperature. The adsorption followed first order Kinetics. The process was found to be endothermic showing monolayer adsorption of Ni(II) with a maximum adsorption of 96% at 50 ^{0}C for an initial concentration of 50 mg/l at pH 6. Thermodynamic parameters were also computed. Desorption was possible with 0.05 M HCl and was found to be 95.83% in Column and 76% in Batch process respectively. The spent adsorbent was regenerated and recycled thrice. The removal and recovery was also done in wastewater and found to be 89% and 93% respectively(Ajmal et al, 2000).

Kyanite, a commercial mineral has been utilized as an adsorbent for the removal of heavy metals such as Ni(II) Cr(VI) and Cu(II) from electroplating wastewater. The effect of particle size of the adsorbent, salinity and hardness, both in natural and wastewater on the adsorption of Cu(II) have been studied. The adsorption of metal ions seems to be ion-exchange process. The adsorbed metal ions from electroplating wastewater were recovered by batch as well as by column operation using dilute HCl solution. The column operation was found to be more effective compared to batch process. Removing Cu(II) along with other metal ions present in electroplating wastewater has demonstrated the utility of the kyanite. A concentration of Cu(II) ions as high as 8 mg/l in the waste can be reduced to 1.5 mg/l. The adsorbed Cu(II) ions could also be recovered with 0.05 M HCl. However, the percent recovery of Cu(II) is increased by column operation(80%) under similar conditions(Ajmal et al, 2001).

Adsorption behaviour of Ni(II), Zn(II), Cd(II) and Cr(VI) on untreated and phosphate treated rice husk(PRH) showed that adsorption of Ni(II) and Cd(II) was greater when phosphate treated rice husk was used. Adsorption of Cd(II) was dependent on contact time, concentration, temperature, adsorbent dose and pH of the solution. The Langmuir Constants and thermodynamic parameters have been calculated at different temperatures. It was found that recovery of Cd(II) from Synthetic wastewater by column operation was better than batch process. The effect of initial metal ion concentration, contact time, temperature and pH on Cd(II) adsorption by sawdust was investigated in batch mode studies. The equilibrium data could be described well by Langmuir and Freundlich isotherm equations. The Lagergren constants of adsorption are also reported. The study showed that sawdust could be used as an efficient adsorbent material for the removal of Cd(II) from water. 97% removal of Cd(II) was observed at 20 mg/l initial Cd(II) concentration. The thermodynamic parameters indicate that process is endothermic and spontaneous. The maximum adsorption occurs at pH 6. Desorption studies show that column operation provides better results(23%) than batch process(18%) However desorption in either case is not satisfactory(Ajmal et al, 2003).

The adsorption behavior of various heavy metals on mustard oil cake(MOC) was studied. The maximum adsorption of Cu(II) was observed followed by Zn(II), Cr(VI), Mn(II), Cd(II), Ni(II) and Pb(II). The adsorption of Cu(II) was found to be dependent on initial concentration of solution, pH, adsorbent dose, temperature and contact time. The adsorption followed pseudo-first-order and second-order kinetics but pseudo-second-order kinetic model was better obeyed since experimental data agreed well with theoretical data. Thermodynamic parameters were also evaluated. The adsorption process was found to be endothermic and spontaneous in nature. Attempts were also made to desorb Cu(II) from the adsorbent and regeneration of the spent adsorbent. The breakthrough and exhaustive capacities were found to be 5 and 10 mg/g, respectively(Ajmal et al., 2005)

The efficiency of parthenium weed as an adsorbent for removing Cd(II) from water has been studied. Parthenium is found to exhibit substantial adsorption capacity over a wide range of initial Cd(II) ions concentration. Effect of time, temperature, pH and concentration on the adsorption of Cd(II) was investigated by batch process. Pseudo-first-order and Pseudo-second-order models were evaluated. The kinetics data for the adsorption process obeyed second-order rate equation. The equilibrium data could be described well by the Langmuir and Freundlich isotherms. Thermodynamic parameters such as ΔH, ΔS and ΔG. were calculated. The adsorption process was found to be endothermic and spontaneous. The maximum adsorption of Cd(II) ions(99.7%) in the pH range 3–4 indicated that material could be effectively utilized for the removal of Cd(II) ions from wastewater. The desorption studies showed 82% recovery of Cd(II) when 0.1M HCl solution was used as effluent (Ajmal et al., 2006).

Table: 1 Sources and Health Effects of some widely used heavy metals

Metal	Sources	Health Effects
1. Cadmium	Coal combustion, metal plating, phosphatic fertilizers water pipes, tobacco smoke, zinc mining etc.	Cardiovascular diseases, hypertension, cancer, kidney damage.
2. Chromium	Anodizing, cooling towers, dyes, electroplating, inks, paints, tanning etc.	Cancer
3. Copper	Pulp and paper, electrical goods, utensil, electronics, chemicals etc. fertilizers	Severe mucosal irritation, cancer
4. Iron	Steel, machinery, dye, textile, medicine etc.	Cancer(suspected)
5. Lead	Battery Industry, auto exhausts, paints etc.	Affects nervous and renal systems causes weakness headache, brain damage, convulsions, constipation, and cancer.
6. Mercury	Chlor-alkali industry, coal combustion, electrical batteries	Nerve damage, death kidney and brain damage.
7. Nickel	Coal, diesel oil, metal plating, steel and non ferrous alloys tobacco smoke etc.	Lung cancer, respiratory problems
8. Zinc	Galvanizing, alloys, rayon, paper etc.	Cancer

Table: 2 Non-conventional adsorbents used for the removal of heavy metals from wastewater 1998-2006

Adsorbent	Metal removed	Adsorption / Desorption	Conditions	Reference
Fly ash	Cu, Pb, Zn, Cd, Cr(III), Ni	40-100%	pH 1-10	Ricou et al, 1998
Polyethylene terphthalate fiber	Cu, Co, Fe(III)			Yigitoglu et al, 1998
Red mud	Cu, Zn, Ni, Cd			Lopez et al., 1998
Cladophora sp	Cu		Column process flow rate 1.12 ml/min	Asku & Yener, 1998
Biomass of medicago soliva(alfalfa)	Cd, Cr, Pb, Zn	7.4 mg/g to 43 mg/g	pH 5 Recovery by 0.1M HCl by column process	Gardea Torresday 1998
Fly ash	Cu, Pb, Zn			Gupta et al, 1998
Acid sandy Soil	Cd		pH 3.6-4.3	Wilkins et al, 1998
Hematite	Cd	98%	pH 9.2	Singh et al, 1998
Blast furnace slag	Pb, Zn, Cd, Cu, Cr(III)			Lopez et al, 1998
Biosorption by sea weeds	Cr(III), Cr(VI)			Kratochvil et al, 1998
Carbon	Cr(III), Cr(VI) Pb, Zn			Lalvani et al, 1998
Pea	Pb			Ho et al, 1998
Formaldehyde cross linked *saccharomyces cerevisiae*	Cr(VI)	Sorption capacity 6.3 mg/g pH 2.5		Zhao & Duncan, 1998
Biosorption on filamentous fungi	Ni			Mogollon et al, 1998
Peat	Co, Cd, Ni Cu, Zn			McKay et al, 1998
Apple residues	Cu, Pb, Cd			Lee et al, 1998

Modified titanium oxide	Pb, Cd, Hg			Subha et al, 1998
Crab shell particles	Pb	99% Removal		Lee et al, 1998
Rice husk	Pb			Khalid et al, 1998
Blast furnace slag	Pb(II)	95-97% adsorption at pH 5.9-6		Dimitrova & Mehandgiev, 1998
Rhizopus arrhizus	Cu, Zn			Sag et al, 1998
Biosorption by magnetite immobilized cell of *Pseudomonas putida*	Cu	96% adsorption. Recovery 95% with 6N HCl		Chua et al, 1998
Adsorption by different plant species	Cr(III), Cr(VI)			Kleiman & Cogliatti, 1998
Chitosan	Cu(II)	4.7 mg/g of Cu(II) was adsorbed at pH 6.2		Wan Ngah & Isa, 1998
Living Mycelium of White-rot fungus *Phanerochaete crysosporium*	Cu(II)	3.9 mM Cu / g of dry mycelium was adsorbed		Sing & Yu, 1998
Sargassum algal biomass	Cu(II)			Kratochvil & Volesky, 1998
Iron rich material	Cr(VI)			Sengupta, S. 1998
Activated carbon	Cr(VI)			Bandyopadhyay & Biswan, 1998
Fire clay	Ni			Bajpai, S.K., 1999
Bone charcoal	Cr(VI)	90% adsorption pH-1		Dahbi et al, 1999
Lime treated montmorillonite	Zn			Tsai & Vesiland, 1999
Dried chlorella vulgaris	Cu, Cr(VI)	pH 2 for Cr(VI) pH 4 for Cu		Asku et al, 1999
Polyacrylic acid	Cr			Heitz et al, 1999
Natural zeolite	Pb, Cu, Cd, Zn			Yuan et al, 1999
Japanese red pipes	Cr(VI)	95% adsorption pH 2-3		Aoyama et al, 1999
Aspergilus niger	As, Pb, Cd, Cu, Ni			Kapoor et al, 1999
Industrial biomass	Zn, Cu, Ni			Zonboulis et al, 1999
Quaternized rice hulls	Cr(VI)		Column process recovery with 0.5M NaOH solution	Low et al, 1999
Hydrocalcite	Cr(VI)	95.7% recovery by 0.1M NaOH		Manju et al, 1999
Fly ash and fly ash/line	Cu, Zn, Pb			Ricou et al, 1999
Rice husk	Hg			Khalid et al, 1999
Oak ridge Y-12 plant	Hg			Hollerman et al, 1999
Oil Shale refining	Cd(II), Cu(II), Ni(II)			Gharaibeh et al, 1999
Loess and clay	Pb(II), Cu(II), Zn(II), Cd(II)	Used for recycling of waste water		Kroik et al, 1999
Biosorption pretreated biomass	Cd	90% adsorption at pH 5		Matheickal et al, 1999
Spent grain	Cd(II), Pb(II)	Sorption capacities 17.3 and 35.5 mg/g		Low et al, 2000
Natural bentonite	Cd,(II), Zn(II)	pH is important factor		Xia & He., 2000

Sheep hair	Cr(VI)	Maximum adsorption at pH 0.75-1.25 and 3.25-3.75		Sarvanam et al, 2000
Black locus leaves	Cr(VI)	Maximum adsorption at pH 3.		Aoyama et al, 2000
Activated carbon(agricultural waste)	Hg(II), Pb(II) Cd(II), Ni(II), Cu(II)	Adsorption increase with increase in pH from 2 to 6		Kadirvelu et al, 2000
Fe–oxide impregnated activated carbon	As(III), As(VI)			Reed et al, 2000
Pyrolusite	Cd(II)	Temp 30ºC, pH 7 Conc. 1-100 mg/l		Koyanaka et al, 2000
Iron oxide coated sand	Cu(II)	Removal 74.9% conc. 5mg/l time 20min, adsorbent 30g/l		Kwak et al, 2000
Hazelnut shell	Cr(VI)			Cimino et al, 2000
Coconut husk	Hg	99.4% adsorption pH 6		Sreedhar & Anirudhan, 2000
Granular activated carbon	Cd(II), Cu(II)	Adsorption increases with pH		Gabaldon et al, 2000
Coniferous leaves	Cr(VI)	Adsorption of Cr(III) increases with increase in pH		Aoyama et al, 2000
Recycled iron material	Pb			Smith & Amini, 2000
Pyrite	Cu(II)		Oxidation is accompanied by the reduction of Cu(II) to Cu(I).	Weisener & Gerson, 2000
Peat	Zn, Cd		Peat columns are able to retain the main interferent on adsorption of Zn and Cd ions in solution.	Petroni et al., 2000
Fly ash	Ni(II)	96% Ni(II) removal		Ricou Hoeffer et al., 2000
Manganese oxide	As ions		As ion concentration was decreased to 2.3mg/l from 10mg/l in 20 min at pH 4.5-5.0	Kasai et al., 2000
Sawdust	Cu		Provide strong evidence to support the hypothesis of adsorption mechanism.	Yu et al., 2000
Avena monida(Oat) biomass	Cr(VI)		Cr(VI) is reduced to Cr(III) in polluted water	Gardea-Torresdey et al., 2000
Anaerobically digested sludge	Cd(II), Cu(II), Ni(II), Zn(II)	Affinity of the sludge was Cu(II)>Cd(II)> Zn(II)>Ni(II)		Artola et al., 2000
Cow dung cake	Cr(VI)	Cr(VI) removal is 90%.		Das et al., 2000
Dried animal bones	Zn			Banat etal., 2000
Red mud	As	1st order rate expression and obeys Langmuir model. As(III) adsorption was exothermic and As(V) was		Altundogan et al., 2000

		endothermic.		
Tyre Rubber	Cu(II)			Al-Asheh & Fawazi Banat, 2000
Transcarpathian Clinoptilolite	Cd(II)			Vasylechko et al., 2000
Acidic Manganese chloride	Cu, Ni, Co, Pb, Fe			Diniz etal., 2000
Tea leaves	Ni(II), Cr(III)	Max adsorptions were 7.97 and 5.91 mg/g.		Nishioka et al., 2000
Effloresced coal	Pb(II), Cu(II), Zn(II), Ni(II)	Removal rate was 97% at pH.4 and 20°C.		Mei J., 2000
Lignite-based Cabon	Ni(II), Cu(II)			Samra S.E., 2000
Barks of eucalyptus and *Cassia fistula*	Cr, Cu	Eucalyptus bark is more efficient in removal of Cr and Cu then *Cassia fistula*		Tiwari et al., 2000
Rice straw	Cr(VI)			Samanta et al., 2000
Polyhydroxyethyl- -methacrylate	Heavy metal ions	Maximum adsorption ratio was as high as 99%		Arpa et al., 2001
Bone char	Cd, Cu, Zn ions		Cd and Zn sorptions onto bone char are primarily film-pore diffusion controlled.	Cheung et al., 2001
Nitrified lignite	Cr			Wang et al., 2001
Red mud	Pb, Cr			Gupta et al., 2001
Aluminium based coagulant	As			Gregor, J., 2001
Chitosan	Cr(VI)			Tang et al., 2001
Aspergillus niger biomass	Pb(II)			Jianlong et al., 2001
Poly(hydroxyethyl methacrylate) adsorbents with Thiazolidine Groups	Hg(II)	Max desorption ratio was as high as 99%		Arpa et al., 2002
Brucite	Metal ions			Izotov & Skiter, 2002
Methacrylamidocysteine containing Porous Poly(hydroxyethylmethacrylate) Chelating Beads	Heavy metal ions	Max adsorption capacity was 1058.2 mg/g for Cd(II).		Denizli et al., 2002
Activated Carbon	Au-CN species			Mc Grath et al., 2002
Geothite-coated sand	Cd			Lai et al., 2002
Natrolite and Clinoptilolite rich tuffs	Molybdate ions			Faghihian et al., 2002
Iron Coated Sand	As			Petrusevski et al, 2002
Fly Ash of Poultry Litter	Cr(III)			Kelleher et al., 2002
Amino-Functionlized MCM-41 and SBA-1	Chromate, Arsenate			Yoshitake et al., 2002

Kaolinite	Pb, Cd			Coles & Yong, 2002
Sawdust	Heavy metals			Shukla et al., 2002
ACCs	Cu, Ni, Pb			Faur-Brasquet et al., 2002
Sludge Ash	Ni(II)			Weng, Chih-Huang, 2002
MgO(100)	Metal ions			Campbell & Starr. , 2002
Poly(N-vinyl formamide/ Acrylonitrile) Chelating Fibers	Heavy Metal Ions			Lin et al., 2002
Keratin Composed Biosorbents	Heavy metals			Banat et al., 2002
Activated and Non-activated Date-pits	Cu, Zn ion	non-activated date-pits adsorption Cu^{2+} and Zn^{2+} ions as high as 0.15 mmol/g and 0.09 mmol/g		Banat et al., 2002
Activated Carbons	Hg(II)			Kannan & Rajakumar, 2003
Aquatic Plant(Myriophyllum spicatum)	Heavy Metal			Keskinkan et al., 2003
Modified Activated Carbons	Cu, Zn, Ni, Cd			Saha et al., 2003
Freshwater alga *Chlorella kesslerii*	Pb			Slaveykova & Wilkinson, 2003
Olive Mill Residues	Cu			Veglio et al., 2003
Orange Waste	Arsenate, Arsenite Anions			Ghimire et al.,2003
Chitosan	Hg(II)			Jeon & Holl., 2003
Bentonite	Ni(II)			Tahir & Rauf., 2003
Ferrous Saponite	Cr(VI)			Parthasarathy et al., 2003
Humic Acids Extracted from Brown Coals	Metal Ions			Martyniuk & Wickowska, 2003
Activated Carbon from Almond Husks	Zn(II)	92% Zn(II) removal		Hasar et al., 2003
Natural and Modified Radiata Bark Pine	Copper			Montes et al., 2003
Cellulose Graft Copolymers	Heavy Metal Ions			Guclu et al., 2003
Savanna Acid Soil	Copper	65% Cu sorbed	$pH \geq 3.0$,	Agbenin, 2003
Recycled-wool-based Non woven Material	Pb(II)			Radetic et al., 2003
SO_2Treated Activated Carbon	Cd(II)			Macias-Garcia et al., 2003
Chitosan	Metal Ions			Navarro et al., 2003
Concrete Particles	Silver			Begum, S., 2003
Thai Kaolin and Ballclay	Heavy Metal		kaolin adsorption was: Cr > Zn > Cu ≈ Cd ≈ Ni > Pb and for ballclay was: Cr > Zn > Cu > Cd ≈ Pb > Ni.	Chantawong & Harvey., 2003
Zeolites synthesized from Fly ash	Heavy Metals		Synthesized zeolites adsorption capacity was higher than fly ash.	Yanxin et al.,2003

Fungus *Penicillium canescens*	Heavy Metal Ions	Max adsorption capacities were 26.4 mg/g for As(III), 54.8 mg/g for Hg(II), 102.7 mg/g for Cd(II) and 213.2 mg/g for Pb(II).		Say et al., 2003
Synthetic Zeolites	Zn(II)			Badillo-Almaraz et al., 2003
Bagasse Fly Ash	Cd, Ni			Gupta et al., 2003
Natural Condensed Tannin	Lead			Zhan & Zhao, 2003
Sea Nodule	Lead			Bhattacharjee et al., 2003
Chitosan	Lead			Ng et al., 2003
Chemically-treated Chicken Feathers	Copper, Zinc Ions			Al-Asheh & Banat, 2003
Grafted Silica	Cu(II), Pb(II)			Chiron et al., 2003
Calcined Mg-Al-CO_3 Hydrotalcite	Cr(VI)			Lazaridis & Asouhidou, 2003
Neutralized Red Mud	Arsenate			Genc et al., 2003
Low-cost Adsorbents	Heavy Metal Ions			Wang et al., 2003
Sheep Manure	Copper, Cadmium Ions	Maximum uptakes for 100 ppm Cu^2 and 100 ppm Cd^2 ions were 17.8 mg/g and 10.8 mg/g.		Kandah et al.,2003
Organosolv Lignin	Copper(II)			Acemiolu et al., 2003
Sepiolite	Cu(II), Zn(II)			Vico, L. I. 2003
Goethite	Phosphate, Arsenate			Gao & Mucci, 2003
Functionalized Silica	Heavy Metal Ions			Bois et al., 2003
Kaolinite	As(V)			Cornu et al., 2003
Anilinepropylsilica Xerogel	Cu(II)			Pavan et al., 2003
Activated Carbon from Furfural	Hg(II)			Yardim et al.,2003
Iron Oxyhydroxide	Hexavalent Uranium			Wazne et al., 2003
Sewage Sludge Ash	Cu(II)			Pan et al., 2003
Clinoptilolite	Cu(II), Fe(III), Cr(III)			Inglezakis et al., 2003
Goethite	Cu(II), Ni(II), Cd(II)			Buerge-Weirich & Behra, 2003
Sol-Gel Silica Doped with 1-(2-Pyridylazo)-2-Naphthol	Cd Ions	Sol gel loaded with 0.09 mmol PAN/g, had a capacity of 0.044 mmol Cd/g		Khan et al., 2003
Penicillium chysogenum mycelium	Ni^{2+}	*Penicillium chysogenum* Ni^{2+} adsorption mycelium was 40-45 mg g^{-1} (using 200mg $Ni^{2+}l^{-1}$), two times of the mycelium adsorbent.		Su & Wang, 2003
Gibbsite	As(III)			Weerasooriya et al., 2003

Mineral Matrix of Tropical Soils	Heavy Metals	Ultisol and Alfisol soils adsorption was in the order of 50.76 and 64.52 mmol kg^{-1}, whereas some Oxisols showed the lowest values, in the order of 23.92 and 30.86 mmol kg^{-1}		Fontes & Gomes, 2003
Montmorillonite-Al hydroxide	Zn(II)			Janssen et al., 2003
Rare earth metal-doped iron oxide	As(V)		(Ce(IV)doped adsorbent(CFA4) has the highest adsorption capacity.	Yu et al., 2003
Alumina or Chitosan	Heavy metals			Cervera et al., 2003
Low-Rank Coal(leonardite)	Zn		Effective removal of Zn^{2+} was demonstrated at pH values of 5-6.	Sole & Casas, 2003
Goethite	Hg(II), Cd(II)			Backstrom et al., 2003
Indigenous Low-cost Material	Cr(VI)			Sharma, 2003
Gellan Gum Gel Beads	Heavy Metal			Lazaro et al, 2003
Hydrolyzed Polyacrylonitrile Fibers	Cu(II)			Deng et al., 2003
Goethite	Uranium(VI)			Missana et al.,2003
Thiol Functional Adsorbent	Hg(II)			Nam et al., 2003
Pseudomonas Putida	Cd, Cu, Pb, Zn	80% removal for all metals		Pardo et al., 2003
Kaolinite, Illite and Montmorillonite	Barium			Atun & Bascetin 2003
Dithiocarbamate grafted on mesoporous silica	Hg			Venkatesan & Srinivasan, 2003
Rhizopus arrhizus	Cr(VI), Cu(II), Cd(II) Ions			Sa et al., 2003
Calcined Zn/Al Hydrotalcite-like Compound(HTlc)	Fluoride			Das et al., 2003
Loess with high carbonate content	Cu			Jinren, 2003
Palm Fruit Bunch and Maize Cob	Fe, Mn			Nassar et al., 2003
Activated and Non-activated Oak Shells	Cu(II)		Cu(II) uptake increased with decreasing sorbent conc or with an increase in Cu(II) conc or pH.	Al-Asheh et al., 2003
Novel Dye-doped Sol-Gel Silica	Co			Khan et al., 2003
Date Pits	Cd(II)			Banat et al., 2003
Micaceous Mineral of Kenyan Origin	Cu(II)	Adsorption capacity of 0.850 g/g for Cu^{2+}		Attahiru et al., 2003
Powdered Marble Wastes	Cu(II)	100% Cu(II) remov		Ghazy et al., 2003
Clinoptilolite Mineral	Lead, Barium			Cakicioglu-Ozkan & Ulku, 2003
Sugarcane Bagasse Pith	Cd(II)			Krishnan &

				Anirudhan, 2003
Granular Ferric Hydroxide	Arsenic			Thirunavukkarasu et al ., 2003
Vineyard soils of Geneva	Cu(II)			Celardin et al., 2003
Peat	Metal Ions			Ko et al., 2003
Chicken Feathers	Heavy Metals			Al-Asheh et al., 2003
Na-montmorillonite	Heavy Metals		.	Abollino et al., 2003
Natural Materials	Pb(II)			Abdel-Halim et al., 2003
Calcium Alginate Beads Containing Humic Acid	Cr			Pandey et al., 2003
High-performance Activated Carbons	Cr			Hu et al., 2003
Galena(PbS) and Sphalerite(ZnS)	Arsenite		Arsenite sorbed appreciably only at pH > ~5 for PbS and pH ~4.5 for ZnS, behavior distinct from its adsorption on other substrates	Bostick et al., 2003
Rice Straw	Selenate			Zhang & Frankenberger Jr, 2003
2-aminothiazole-modified silica gel	Cu, Ni,, Zn	Adsorption capacities for each metal ion were(mmol g^{-1}): Cu(II)=120, Ni(II)=110 and Zn(II)=090		Roldan et al., 2003
Organic Manure	Cu(II)			Bolan et al., 2003
Penicillium chrysogenum	Metal Ions			Tan & Cheng,2003
A 1.10 Phenanthroline-grafted Brazilian Bentonite	Cu(II)			De Leon et al.,2003
Caustic Treated Waste Baker's Yeast Biomass	Cu(II)			Goksungur et al.,2003
Activated Carbon	Pb(II), Cd(II), Cr(VI)			Rivera-Utrilla et al., 2003
Pseudomonas Putida 5-x Isolated from Electroplating Effluent	Cu(II)			Wang et al., 2003
Turbid River water	Cu, Ni			Herzl et al., 2003
Regenerated Sludge from a Water Treatment Plant	Cu(II), Pb(II)			Wu et al., 2003
Chitosan	Zn^{2+}			Zhiguang et al., 2003
Sand	Heavy Metals			Awan et al., 2003
Tea Leaves and Coffee Beans	Mercury			Kiyohara et al., 2003
Low Cost Materials	Iron, Manganese			Nassar et al., 2003
Iron-Conditioned Zeolite	Arsenic			Onyango et al., 2003
Carbonaceous Materials Prepared from Bamboo and Coconut Shell	Nitrate Anion			Ohe et al., 2003
Sawdust Carbon	Arsenic(III)			Nagarnaik et al., 2003
Vaterite Modification of Calcium Carbonate	^{90}Sr, ^{90}Y			Berdonosov & Berdonosova, 2003
Activated Coke from	Hydrogen Sulfide			Mitomo et al., 2003

Wood Pellet				
Activated Carbon from Acidic Media: Nitrate and Sulfate Media	Silver			Jia & Demopoulous, 2003
Iron Oxide-Coated Sand	Arsenic			Thirunavukkarasu & Viraraghavan 2003
Low Cost and Waste Material	Cu(II), Cd(II)	Removal efficiency of entonite and compost were reaching 99% for Cu when Cd is also present, for initial solution conc of up to 100 mg l^{-1}		Ulmanu et al., 2003
Bone Charcoal	Cu, Zn			Wilson & Pulford, 2003
Activated Carbon from Coconut Coirpith	Cd(II)			Kadirvelu & Namasivayam, 2003
Sulfate-modified Iron Oxide-coated Sand(SMIOCS)	Arsenic(III)			Vaishya & Gupta,2003
Muloorina Illite and Related Clay Minerals	Cd(II)			Lackovic et al., 2003
Crosslinked chitosan	Vanadium(V), Tungsten(VI)			Qian et al, 2004
Silica-dithizone	Hg(II)			Cestari et al, 2004
Activated Neutralised Red Mud	Arsenic			Genc-Fuhrman et al, 2004
Chryseomonas luteola TEM05	Cr, Al			Ozdemir & Baysal, 2004
Natural Zeolite	Zn, Cu, Pb			Peri et al, 2004
Aluminium oxide	Ferrocyanide			Bushey & Dzombak, 2004
Cross linked Alginate Gel Beads	Cu, Mn			Gotoh et al, 2004
Alginate-Chitosan Hybrid Gel Beads	Divalent Metal ions			Gotoh et al, 2004
Geothite	Heavy Metal Cations			Kosmulski & Mczka, 2004
Ceratophyllum demersum	Heavy Metal			Keskinkan et al, 2004
Ecklonia maxima	Heavy Metal			Feng & Aldrich, 2004
Streptomyces coelicolor A3(2)	Ni(II), Cu(II)			Ozturk et al, 2004
Tree Fern	Cd(II)			Ho & Wang, 2004
Brown, Green and Red Seaweeds	Cd			Hashim & Chu,2004
Wood Saw dust	Heavy metal ions			Sciban & Klasnja,2004
Chinese Reed (*Miscanthus sinensis*)	Cr(III)			Namasiyam & Holl, 2004
Activated alumina	Flouride			Ghorai & Pant, 2004
Chlorella vulgaris	Cu			Chu & Hashim, 2004
Bone char	Metal ions			Choy et al, 2004
Hematite	Phosphate			Huang, X., 2004
Bagasse Fly Ash	Pb, Cr			Gupta & Ali, 2004
Savanna Alfisol	Cu, Zn			Agbenin & Olojo, 2004

Iron oxide Tailings	Phosphate			Zeng et al, 2004
Treated Sawdust	Cr			Garg etal, 2004
Zn(IV) substituted ZnAl/MgAl-layered Double Hydroxide	Cr(VI), Se(II)			Das et al, 2004
Humic substance	Cu(II)			Alvarez-Puebla et al, 2004
Aluminium Impregnated Mesoporous Silicates	Phosphate			Shin et al, 2004
Montmorillonite	Quaternary Ammonium salts			Kozak & Domka, 2004
Activated Rice Husk and Activated Alumina	Cr(VI)			Bishnoi et al, 2004
Hazelnut shell	Cr(VI)			Kobya, 2004
Alumina particles	Ni(II)			Hong etal, 2004
Fontinalis antipyretica	Cd(II), Zn(II)			Martin et al, 2004
Fe-modified Steam Exploded Wheat Straw	Cr(VI)			Chun et al, 2004
Alginate coated Loofa Sponge Disc	Cd			Iqbal, 2004
Peat	Cu			Petroni & Pires, 2004
Poly acrylonitrile-immobilized dead cells of *Saccharomyces Cerevisiae*	Cu(II)			Godjevargova & Mihova, 2004
Montmorillonites	Cu			Ding & Frost,2004
Herbaceous Peat	Cu(II)			Gundoan et al, 2004
Mangenese Dioxide Complex	Co, Ni, Cu,, Zn			Kanungo et al, 2004
Bone char	Metal ions			Ko et al, 2004
Granular Activated Carbon	Fe(III), Fe(III) NTA Complex			Kim, 2004
Geothite	Cadmium, Phosphate			Wang & Xing, 2004
Chitosan	Cu			Wan et al, 2004
Moroccan Stevensite	Metal ions			Benhammon et al, 2005
Moroccan Stevensite	Hg(II), Cr(VI)			Benhammou et al., 2005
Amberlite IR-120 Synthetic resin	Cu, Zn, Ni, Pb, Cd ions			Demirbas et al., 2005
Sea Nodule Residues	Pb(II)			Agrawal et al., 2005
Black gram husk(BGH)	Pb, Cd, Cu, Ni,, Zn	Max heavy metals adsorption was 49.97, 39.99, 33.81, 25.73 and 19.56 mg/g BGH biomass for Pb, Cd, Zn, Cu and Ni, respectively		Saeed et al, 2005
Bentonite	Cd(II), Zn(II)			Lacin et al., 2005
Montmorillonite	Hg(II)			Green-Ruiz, 2005
H3PO4-activated Rubber Wood Sawdust	Cu(II)			Kalavathy et al., 2005
Mulch	Heavy Metals			Jang et al., 2005
Activated Carbon Prepared from Waste Apricot by Chemical Activation	Ni(II)			Erdogan et al., 2005
Cu-ZSM-5 Zeolite	Cu(II)			Kazansky & Pidko, 2005

Fly Ash	Boron		Öztürk & Kavak, 2005
Polyacrylamide-bentonite and Zeolite Composites	Pb(II)		Ulusoy & Simsek, 2005
Calcite	Fluoride		Turner et al., 2005
Keratin Powder Prepared from Algerian Sheep Hooves	Hg(II)		Touaibia & Benayada, 2005
Chemically Modified Activated Carbons	Cr(VI)		Zhao et al., 2005
Natural Goethite	Pb(II), Zn(II)		Abdus-Salam & Adekola, 2005
Peat and Solvent-extracted Peat	Fe(II), Pb(II)		Minihan et al., 2005
Chitosan Flakes	Ni(II)	Adsorption being pH dependent.	Zamin et al., 2005
Modified Sugarcane Bagasse	Cr(VI)		Garg & Sud, 2005
Activated Carbons Prepared from Coconut Shells by Chemical Activation with KOH and $ZnCl_2$	Cr		Bendezu et al., 2005
Sawdust	Cu(II)		Larous et al., 2005
Kaolinite	Pb, Cd		Hepinstall et al., 2005
Activated Alumina and Activated Carbon	As(III)		Manjare et al., 2005
Chitosan Functionalized with 2[-bis-(pyridylmethyl)aminomethyl]-4-methyl-6-formylphenol	Cu(II), Cd(II),, Ni(II)		Justi et al., 2005
Granular Activated Carbon	Iron, Manganese		Jusoh et al., 2005
Bacterial Biofilm	Zn(II)		Toner et al., 2005
Alumina	Molybdate, Nickel		Al-Dalama et al., 2005
Magnetite	Arsenite, Arsenate		Yean et al., 2005
Used Black Tea Leaves	Cr(VI)	Max Cr(VI) adsorption was at initial Cr(VI) concentration <150 mg/L; initial solution pH 1.54-2.00; processing temperature < 50 °C	Hossain et al., 2005
Activated Carbon	Cr(III)		Lyubchik et al., 2005
Modified Lignin	Cr(III), Cr(VI)		Demirbas, A., 2000
Clays	Pb(II)		Gupta et al., 2005
Bentonite	Zn(II)		Kaya et al., 2005
Crab Shells	Ni(II)		Pradhan et al., 2005
Treated Granular Activated Carbon	Pb(II)		Goel et al., 2005
Corncob Particles	Cu(II), Cd(II)		Shen & Duvnjak, 2005
Palm Kernel Fibre	Pb(II)		Ho & Ofomaja, 2005

Pretreated Biomass of Neurospora crassa	Pb(II), Cu(II)			Kiran et al., 2005
Maghemite Nanoparticles	Cr(VI)			Hu et al., 2005
Iron Oxide-coated Cement(IOCC)	As(V)			Kundu & Gupta, 2005
Rice Bran	Cr(VI)			Singh et al., 2005
Coir and Dye Loaded Coir Fibres	Pb(II)			Shukla & Pai., 2005
Coconut fiber and sawdust waste biomass containing chelating agents	As(V), Pb(II), Hg(II)	As(V) is adsorbed more	Max adsorption was at pH 2 and 12 whereas minimum adsorption occurred at pH 6-8.	Igwe et al., 2005
Maize Cob and Husk	Zn(II), Cd(II), Pb(II) Ions	495.9 mg/g for Zn(II), 456.7 mg/g for Pb(II), 493.7mg/g for Cd(II)		Igwe et al., 2005
Hydroxylapatite and Bone-char	As(V)			Sneddon et al., 2005
Activated Carbon from Oat Hulls	As(V)			Chuang et al., 2005
Low-rank Coal(Leonardite)	Cd(II), Pb(II)			Lao et al., 2005
Paenibacillus polymyxa Cells and their(EPS) Exopolysaccharid	Cu(II)	Max biosorption value was 1602 mg/g with purified EPS at 0.1 mg/ ml particularly promising for use in field applications.		Acosta et al., 2005
Polymerized Banana Stem	Pb(II)			Noeline et al., 2005
Nipa Palm(Nypa fruticans Wurmb) Biomass	Pb(II), Cu(II)	Desorption increases with increase in contact time, reaching 75.3 and 63.7% in acid reagent, 18.9 and 14.06% in basic reagent and 3.35 and 2.44% in distilled water for Pb(II) and Cu(II), respectively, at a contact time of 140 min.		Wankasi et al., 2005
Protonated Macroalga *Sargassum muticum*	Cd(II)			Lodeiro et al., 2005
Bead Cellulose Loaded with Iron Oxyhydroxide	Arsenic			Guo & Chen, 2005
Cu(II) Polymethacrylate Formed by Gamma Radiation	Pb(II)			Barrera-Díaz et al., 2005
Cellulose/Chitin Beads	Pb(II)			Zhou et al., 2005
Aminated Chitosan Bead	Hg(II)			Jeon & Park, 2005
4-vinyl pyridine grafted poly(ethylene terephthalate) fibers	Cr(VI)	Maximum adsorption capacity was found to be 263.16 mg/ g		Yigitoglu & Arslan, 2005
1,5,9,13-tetrathia cyclohexadecane-3, 11-diol Anchored Poly(p-chloro methylstyrene-ethylene glycoldimethacrylate) Microbeads	Pb(II), Cd(II), Hg(II), Cr(III)			Malci et al., 2005
Phosphate Rock	Cu(II)			Sarioglu et al., 2005

Natural Kaolin	Cu(II), Zn(II), Co(II)		Ceylan et al., 2005
Modified Jute Fibres	Cu(II), Ni(II), Zn(II)		Shukla & Pai, 2005
Chemically Modified Australian Coals	Cd(II)		Burns et al., 2005
Surface Soils of Nuclear Power Plant Sites in India	Zn(II)		Dahiya et al., 2005
Natural and Oxidized Corncob	Cd(II)		Leyva-Ramos et al., 2005
Mn Oxide-Coated Granular Activated Carbon	Cu(II), Cd(II)		Fan & Anderson, 2005
Zeolite and Sepiolite	Pb(II)		Turan et al., 2005
Biomass of the Marine Macroalga Cystoseira Baccata	Hg(II)		Herrero et al., 2005
Amine-Modified Zeolite	Pb, Cd		Wingenfelder et al., 2005
Amazon Soils	Hg(II)		Miretzky et al., 2005
Carbon Sorbent Containing a Pyrimidine-Polyamine Conjugate	Zn(II), Cd(II)		García-Martín et al., 2005
Activated Carbons	Cr(VI)		Khezami & Capart, 2005
Activated Carbon	Pb(II)		Zhang et al., 2005
Bone Char	Cd(II), Cu(II),, Zn(II)		Choy & McKay, 2005
Immobilized Pinus sylvestris Sawdust	Pb(II)		Taty-Costodes et al., 2005
Hydrous Al(III) Floc in the Presence of a Modified Form of Polyethylenimine	Cd(II)		McCullagh & Saunders, 2005
Kaolinite	Cu(II)		Peacock & Sherman, 2005
Aluminum-Pillared Bentonite	Vanadium(IV)		Manohar et al., 2005
Microporous Titanosilicate Ets-10	Pb(II), Cu(II),, Cd(II)		Lv et al., 2005
Iron Oxide-coated Sand	As(III)		Gupta et al., 2005
Cross-linked Chitosan	Cr		Rojas et al., 2005
PEI-Modified Biomass	Cu(II), Pb(II), Ni(II)		Deng & Ting, 2005
Shales belonging to the Proterozoic Vindhyan basin, central India, and a black cotton soil, Mumbai, India	Pb(II), Cd(II)		Paikaray et al., 2005
Modified Pine Tree Materials	Ni(II)		Argun et al., 2005
Treated Granular Activated Carbon	Pb(II)		Goel et al., 2005
Sawdust	Ni(II)		Shukla et al., 2005
Agricultural Waste ‘rice Polish’	Cd(II)		Singh et al., 2005
Zero-valent Iron	As		Bang et al., 2005

Commercial activated carbon(CAC) and chemically prepared activated carbons(CPACs) from raw materials such as straw, saw dust and dates nut	Cd(II)	Straw carbon showed the maximum adsorption capacity towards Cd(II)		Kannan & Rengasamy, 2005
Chitosan-based Polymeric Surfactants	Cr(VI)			Lee et al., 2005
Decaying Tamrix Leaves	Pb(II)			Zaggout, F.R., 2005
Activated Carbons	Cr(VI)			Khezami & Capart, 2005
Immobilized Pinus sylvestris Sawdust	Pb(II)			Taty-Costodes et al., 2005
Crosslinked Amphoteric Starch Containing the Carboxymethyl Group	Pb(II)			Xu et al., 2005
Bone Char	Cu, Cd, Zn			Cheung et al., 2005
Aluminum-Pillared Bentonite	Vanadium(IV)			Manohar et al., 2005
Vermiculite	Cd(II), Pb(II)			Abate et al., 2005
Biomass of the Marine Macroalga Cystoseira Baccata	Hg(II)			Herrero et al., 2005
Amine-Modified Zeolite	Pb, Cd			Wingenfelder et al., 2005
Amazon Soils	Hg(II)			Miretzky et al., 2005
Activated Carbon	Cd(II), Zn(II)			Leyva-Ramos et al., 2005
Peanut Hulls through Esterification Using Citric Acid	Co(II), Ni(II)	Maximum adsorption capacities, for Co(II) and Ni(II) were 28.7 mg/g ; 270.3 mg/g and 5 mg/g ;175.4 mg/g on native and peanut hulls citrate, respectively.	The optimum pH for the adsorption of cobalt(II) ions onto the peanut hulls citrate was 7.0.	Hashem et al., 2005
Iron Complexed Protein Waste	Chromium(VI)			Fathima et al., 2005
Zr-loaded Lysine Diacetic Acid Chelating Resin	As(V), As(III)			Balaji et al., 2005
Activated Carbon	Cu(II), Pb(II)			Machida et al., 2005
Palm Kernel Fibre	Pb(II)			Ho & Ofomaja, 2005
Chemically Modified Thin Chitosan Membranes	Cu(II)			Cestari et al., 2005
Powder carbon steel	Chromate			Campos & Buchler, 2005
Natural Bentonite	Pb(II), Ni(II)			Donat et al., 2005
Polarized Activated Carbons	Copper, Silver, Zinc Cations			Goldin et al., 2005
Polarized Activated Carbon Modified by Quercetin	Copper, Calcium Cations			Goldin et al., 2005
Tree Fern	Pb(II)			Ho, Yuh-Shan, 2005
Iron Oxide-coated Sand	As(III)			Gupta et al., 2005
Collagen Fiber Immobilized Bayberry Tannin	Pt(II), Pd(II)			Wang et al., 2005

Rhizopus arrhizus	Zn(II)			Preetha & Viruthagiri, 2005
Maize Cob	Cd, Pb, Zn	% Sorption is 71% for Zn(II), 32% for Cd(II), 30% for Pb(II)		Abia & Igwe, 2005
Chemically Modified Australian Coals	Cd(II)			Burns et al., 2005
Turkish Brown Coals	Cr(III)			Gode & Pehlivan, 2005
Dye Loaded Groundnut Shells and Sawdust	Cu(II), Ni(II), Zn(II)			Shukla & Pai, 2005
Acidic Polysaccharide Gels	Pb(II)			Dhakal et al., 2005
Chitosan-Cellulose Hydrogel Beads	Copper			Li & Bai, 2005
Siderite	Lead			Erdem & Özverdi, 2005
Cross-linked Chitosan	Cr			Rojas et al., 2005
Solvent-Impregnated Resins Containing Cyanex 272	Zn			Shiau et al., 2005
Immature Coal(leonardite)	Ni(II), Cu(II)			Zeledon-Toruno et al., 2005
Agave lechuguilla Biomass	Cr(VI)			Romero-Gonzalez et al., 2005
Carbonaceous Adsorbents Prepared from Rubber of Tyre Wastes	Mercury			Manchón-Vizuete et al., 2005
Lewatit-anion Exchange Resins	Cr(VI)			Gode & Pehlivan, 2005
Caladium Bicolor(wild Cocoyam)	Pb2+, Cd2+	Sorption capacity obtained were 49.53 and 65.50 mM/g for Pb(II), Cd(II)		Horsfall Jr. et al., 2005
Carboxylate-functionalized Polyacrylamide Grafted Lignocellulosics	Co(II)			Shibi & Anirudhan, 2005
Carbon Aerogel	Pb, Hg, Ni			Goel et al., 2005
Bentonite	Cu(II)			Al-Qunaibit et al., 2005
Kaolinite	As(V)			Quaghebeur et al., 2005
Soil Clay	Cesium			Bergaoui et al., 2005
Carrot Residues	Cr(III), Cu(II), Zn(II)			Nasernejad et al., 2005
Iron(III) Hydroxide-Loaded Sugar Beet Pulp	Cr(VI)			Altundogan, 2005
Active Carbon	Pb(II)			Qadeer et al., 2005
Various Cereals from Korea	Cd(II), Pb(II)			Park et al., 2005
Amberlite IR-120 Synthetic resin	Cu(II), Zn(II), Ni(II), Pb(II), Cd(II)			Demirbas et al., 2005
Activated Eucalyptus Bark	Cr(VI)			Sarin et al., 2006
Agricultural Waste Maize Bran	Pb(II)			Singh et al., 2006
Palm Shell Activated Carbon	Pb(II)			Issabayeva et al., 2006

Novel Cross Linked Xanthated Chitosan	Cr(VI)	Sankararamakrishnan et al., 2006
Composite Sewage Sludge/industrial Sludge-based Adsorbents	Cu(II)	Seredych & Bandosz, 2006
Graphene Layer of Carbonaceous Materials	Pb(II)	Machida et al., 2006
Macroporous Epoxy-triethylenetetramine Resin	Hg(II)	Pan et al., 2006
Polyacrylamide Grafted Crosslinked Poly(vinyl Chloride) Beads	Hg(II)	Liu & Guo, 2006
Phenolated Wood Resin	Cr(III), Ni(II), Zn(II), Co(II)	Kara et al., 2006
Poly(4-vinyl Pyridine) Beads	Cr(VI)	Arslan et al., 2006
Clinoptilolite	Ag(I)	Akgul et al., 2006
Clay Mineral	Cd(II), Zn(II), Mg(II), Cr(VI)	Fonseca et al., 2006
Ulva Fasciata Sp. a Marine Green Algae	Cu(II)	Kumar et al., 2006
Manganese Oxide Coated Sand	Cu(II), Pb(II)	Han et al., 2006
Manganese Oxide Coated Sand	Cu(II), Pb(II)	Han et al., 2006
Pyrite and synthetic iron sulphide	Cu(II), Cd(II), Pb(II)	Ozverdi & Erdem, 2006
Immobilized Pseudomonas Aeruginosa PU21 Beads	Pb(II)	Lin & Lai, 2006
Hydrous Manganese Dioxide	Cd(II)	Tripathy et al., 2006
Husk of Lathyrus sativus	Cd(II)	Panda et al., 2006
Iron Oxide-coated Fungal Biomass	As(III), As(V)	Pokhrel & Viraraghavan, 2006
Montmorillonite and Kaolinite	Sr	Basçetin & Atun, 2006
Oryza sativa L. Husk and Chitosan	Pb(II)	Zulkali et al., 2006
Highly Mineralized Peat	Cd(II)	Gabaldón et al., 2006
Kaolinite Clay	Pb(II), Cd(II)	Adebowale et al., 2006
Sugar Beet Pulp and Fly Ash	Zn(II), Cu(II)	Pehlivan et al., 2006
Activated Carbon from Agricultural Waste Material and Fabric Cloth	Cr(III)	Mohan et al., 2006
Waste of Tea Factory	Ni(II)	Malkoc & Nuhoglu, 2006
Heteroatoms in Activated Carbon	Cr(VI)	Valix et al., 2006
Iron and Manganese	Cu(II)	Mohan & Chander, 2006
Solid Humic Acid from the Azraq Area, Jordan	Cu(II), Ni(II)	El-Eswed & Khalili, 2006
Activated Carbo-aluminosilicate Material from Oil Shale	Cr(VI)	Shawabkeh, R.A., 2006

Calcined Aluminum Oxyhydroxide(boehmite)	Arsenious Ion			Ogata et al., 2006
Chitosan-Coated Perlite Beads	Cd(II)			Hasan et al., 2006
Acid Soils	Cu(II), Zn(II)			Arias et al., 2006
Goethite and Birnessite	Cu(II)			Huerta-Diaz, 2006
Synthetic Goethite	Arsenate			Lakshmipathiraj et al., 2006
Activated Carbon from Sugar Industrial Waste	Cr(III)			Fahim et al., 2006
Microwave Stabilized Heavy Metal Sludge	Cu(II)			Hsieh et al., 2006
Chemically-modified Biomass of Marine Brown Algae Laminaria japonica	Pb(II)			Luo et al., 2006
Dual-functional Ion Exchange Resins from Agricultural By-products	CrO_4^{2-}, Cu^{2+}			Marshall & Wartelle, 2006
Arable and Forest Soils	Cd(II)			Palágyi et al., 2006
Sorel's Cement	Cr(VI)	Adsorption capacity 21.4 mg Cr(VI) /g of Sorel's Cement		Hassan et al., 2006
Natural Bentonite Clay	Co(II)			Shahwan et al., 2006
Lignocellulose Adsorption Medium(LAM)	Arsenic			Kim et al., 2006
Activated Carbon	Cr(VI)			Yavuz et al., 2006
Tamarind hull-based adsorbent	Cr(VI)			Verma et al., 2006
Kaolinite, montmorillonite, and their modified derivatives	Cu(II)			Bhattacharyya & Gupta, 2006
Restricted Phyllomorphous Clay	Pb(II)			Giannakopoulos et al, 2006
Coconut Copra Meal	Cd(II)			Ho & Ofomaja, 2006
Peach and Apricot Stones	Pb(II)	Pb(II) adsorption 93% for Apricot and 97.64% for Peach.		Rashed, M.N., 2006
Grape Stalk Wastes Encapsulated in Calcium Alginate Beads	Cr(VI)			Fiol et al., 2006
Cross-linked Carboxymethyl-chitosan Resin	Zn(II)			Sun & Wang, 2006
Thin Vanillin-Modified Chitosan Membranes	Cu(II)			Cestari et al., 2006
Radiation Crosslinked Chitosan	Cr(VI)			Ramnani & Sabharwal, 2006
Cotton Boll	Cu(II)			Ozsoy & Kumbur, 2006
Crosslinked Carboxymethyl-chitosan Resin	Pb(II)			Sun et al., 2006
Tectona Grandis L.f.(teak Leaves Powder)	Cu(II)			King et al., 2006
Iron Oxide-coated Cement(IOCC)	As			Kundu & Gupta, 2006
Haro River Sand	Cd(II)			Ahmed et al., 2006

Particulate Organic Matter in Soil	Pb, Cu,, Cd		Guo et al., 2006
Acacia Nilotica Bark	Cr(VI)		Rani et al., 2006
Industrial Solid Waste Fe(III)/Cr(III) Hydroxide	Mo		Namasivayam & Prathap, 2006
Chemically Modified and Unmodified Agricultural Adsorbents	Pb(II), Ni(II)		Abia & Asuquo, 2006
Kaolinite	Cd(II)		Harris et al., 2006
Tamarindus indica Seeds	Cr(II)		Agarwal et al., 2006
Wheat Bran	Cd(II)		Singh et al., 2006
Spirulina platensis	Cr(III)		Li et al., 2006
Cross-linked Starch Phosphate Carbamate	Pb(II)	Maximum adsorption capacity evaluated from the Langmuir isotherm towards Pb(II) is 2.01 mmol/g.	Guo et al., 2006
$ZnCl_2$ Activated Coir Pith Carbon	Molybdate		Namasivayam & Sangeetha, 2006
Manganese Nodule Leached Residue Obtained from NH_3–SO_2 Leaching	Cr(VI)		Mallick et al., 2006
Kraft Lignin	Cu(II), Cd(II)		Mohan et al., 2006
Manganese Oxide Coated Zeolite	Cu(II), Pb(II)		Zou et al., 2006
Natural and Crosslinked Chitosan membranes	Hg(II)		Vieira & Beppu, 2006
Natural Clino-pyrrhotite	Cr(VI), Cr(III)		Lu et al., 2006
Cu(II)-, Ni(II)-, or Co(II)-doped Goethite	As(V)		Mohapatra et al., 2006
Kaolinite-based Clays	Cd(II)		Hizal & Apak, 2006
Zn-Al Layered Double Hydroxide Intercalated with EDTA	Cu(II), Cd(II), Pb(II)		Pérez et al., 2006
Dried Activated Sludge	Cu(II), Pb(II)		Wang et al., 2006
Calcite	Cu(II), Zn(II),, Pb(II)		Elzinga et al., 2006
Kaolinite	Cu(II)		Li & Dai, 2006
Waste Acorn of *Quercus ithaburensis*	Cr(VI)		Malkoc et al., 2006
Pyrite	Cd(II)		Borah & Senapati, 2006
Chaff	Cu(II), Pb(II)		Han et al., 2006
Carbon Sorbent Derived from Fruit Shell of *Terminalia Catappa*	Hg(II)		Inbaraj & Sulochana, 2006
Silica-immobilized Humin	Pb(II)		Contreras et al., 2006
Tea Factory Waste	Cr(VI)		Malkoc & Nuhoglu, 2006
Eucalyptus Bark	Cr		Sarin & Pant, 2006
Oryza sativa L. Husk	Pb(II)		Zulkali et al., 2006
Cassava(manihot Sculenta Cranz.)	Cr(VI)		Horsfall Jr. et al., 2006
Coir Pith	Co(II), Cr(III), Ni(II)		Parab et al., 2006
Green Coconut Shell Powder	Cd(II)		Pino et al., 2006
Li/ Al Layered Double	Cr(VI)		Wang et al., 2006

Hydroxide				
Kaolinite and Montmorillonite	Pb(II)			Bhattacharyya & Gupta, 2006
Spirogyra Species	Cu(II)			Gupta et al., 2006
Treated Rice Husk	Cd(II)			Kumar & Bandyopadhyay, 2006
Ceiba Pentandra Hulls	Cu(II), Cd(II)			Rao et al., 2006
Palm Kernel Fiber	Pb(II)			Ho & Ofomaja, 2006
Schwertmannite and Goethite	Cu(II)			Jönsson et al., 2006
Polymer-grafted Banana(*Musa paradisiaca*) Stalk	Pb(II), Cd(II)			Shibi & Anirudhan, 2006
Magnetic Chitosan Nanoparticles	Co(II)			Yang-Chang et al., 2006
Brown Coals	Cr(VI)			Gode & Pehlivan, 2006
Heavy metal precipitant *N*,*N*-bis-(dithiocarboxy) piperazine	Cu(II)			Fu et al., 2006
Bagasse Fly Ash	Cd(II), Ni(II)			Srivastava et al., 2006
Glycidyl methacrylate chelating resin containing Fe_2O_3 particles	Cu(II)			Donia et al., 2006
Methacrylic Acid/ acrylamide Monomer Mixture Grafted Poly (ethylene Terephthalate) Fiber	Cu(II), Ni(II), Co(II)			Coskun et al., 2006
Activated Hazelnut Shell Ash and Activated Bentonite	Cr(VI)			Bayrak et al., 2006
Chitosan and Chitosan/PVA Beads	Cu(II)			Ho, Yuh-Shan, 2006
Activated Carbon	Cu(II)			Boari et al., 2006
Zeolites	Zn(II)			Ören & Kaya, 2006
N, O-carboxymethyl-chitosan	Cu(II)			Sun & Wang, 2006
Mesoporous Silica Chemically Modified with 2-mercaptopyrimidine	Cd(II)			Pérez-Quintanilla et al., 2006
Fe(III)/Cr(III) Hydroxide	Selenite			Namasivayam & Prathap, 2006
Modified Sodium Alginate	Cd(II)			Hashem & Elhmmali, 2006
$ZnCl_2$ Activated Coir Pith Carbon	Cr(VI)			Namasivayam & Sangeetha, 2006
Filamentous Algae Spirogyra Species	Hg(II)			Rezaee et al., 2006
Wine-Processing Waste Sludge	Pb(II)			Yuan-Shen et al., 2006
Mesoporous Silicate MCM-41	Cd(II), Pb(II)			Oshima et al., 2006
Modified and Unmodified Maize Husk	Co(II), Fe(II), Cu(II)			Igwe et al., 2006
Arbuscular Mycorrhizal Maize (*Zea mays* L.)	Zn, Cd, P			Shen et al., 2006
Fungi Biomass	Cr(VI)			Louhab et al., 2006

Chitosan Sorbent	As			Chen & Chung, 2006
Chitosan Coated Montmorillonite	Cr(VI)			Fan et al., 2006
Vegetable Biomass	Pb, Fe			Bun-ei et al., 2006
Granular Activated Carbon and Natural Zeolite	Zn(II)			Meshko et al., 2006
Bagasse Fly Ash	Cd(II), Zn(II)			Srivastava et al., 2006
Agave lechuguilla Biomass	Cr(III)			Romero-González et al., 2006
Cassava(Manihot sculenta Cranz) Tuber Bark Waste	Cd(II), Cu(II), Zn(II)			Horsfall et al., 2006
ZnO Loading to Activated Carbon	Pb(II)			Kikuchi et al., 2006
Clays and Modified Clays	Boron			Karahan et al., 2006
Kaolinite-based Clay Minerals Individually and in the Presence of Humic Acid	Cu(II), Pb(II)			Hizal & Apak, 2006
Clays	Ni(II)			Gupta & Bhattacharyya, 2006
Anaerobic Granular Biomass	Pb(II), Cd(II), Cu(II), Ni(II)			Hawari & Mulligan, 2006
Activated Carbon from Alkaline Impregnated Hazelnut Shell	Cu(II)			Sayan, E., 2006
Tannic Acid Immobilised Activated Carbon	Cu(II), Cd(II), Zn(II), Mn(II), Fe(III)			Uçer et al., 2006
Modified Coir Fibres	Ni(II), Zn(II), Fe(II)			Shukla et al., 2006
Coir Based Adsorbent	Ni(II)			Nityanandi et al., 2006
Waste Tea and Coffee adsorbents	Cu(II), Zn(II), Cd(II), Pb(II)			Utomo et al., 2006
Purified Carbon Nanotubes	Zn(II)			Lu & Chiu, 2006
Montmorillonite	Cu(II)			Qin & Shan, 2006
Poly(ethylene terephthalate)-g-Acrylamide Fibers	Pb(II)	Adsorption was as 39.57 mg/g fiber for Pb(II) for the copolymer with a graft yield of 15.7%. Desorption of Pb(II) from reactive fibers were found to be 96% by 5 M HNO_3		Coskun & Soykan, 2006
Live and Pretreated Biomass of *Aspergillus flavus*	Cr(VI)			Deepa et al., 2006
Chelating Cellulose	Cu(II)			Connell et al., 2006
Cellulosic-adsorbent Resin	Cu(II)			Bao-Xiu et al., 2006
Diatom Surface	Cd(II), Pb(II)			Gelabert et al., 2006
Pretreated *Aspergillus niger*	Cu(II), Pb(II)			Dursun et al., 2006
Multi-amine-grafted Mesoporous Silicas	Pb(II), Cu(II), Cd(II), Zn(II), Hg(II)		The fresh dry samples were found to show much	Zhang et al., 2007

			higher adsorption capacity than the aged ones	
Chitosan-Coated Perlite Beads	Co(II)		A first order reversible rate equation is used to understand the kinetics of metal removal and to calculate the rate constants at different initial concentrations	Kalyani et al., 2007
Natural and Acid Activated Kaolinite and Montmorillonite	Co(II)		Acid activation enhances the adsorption capacity of kaolinite and montmorillonite.	Bhattacharyya & Gupta, 2007
Sugarcane Bagasse	Cd(II)			Ibrahim et al., 2007
Chemically Treated Newspaper Pulp	Zn(II)	Zn(II) loading was 9.20 mg/g for 10.31 mg/l initial zinc concentration at pH 5.80	Zn(II) loading on TNP was dependent on initial zinc concentration	Chakravarty et al., 2007
Degreased Coffee Beans(DCB)	Cu(II), Zn(II), Pb(II), Fe(III), Cd(II)	90% desorption of Cd(II) was achieved	DCB behaves as a cation exchanger.	Kaikake et al., 2007
Turkish Brown Coals	Cr(VI)	Max adsorption of 11.2 mM of Cr(VI)/g for Ilgın (BC_1), 12.4 mM of Cr(VI)/g for Beyşehir (BC_2), 7.4 mM of Cr(VI)/ g for Ermenek (BC_3) and 6.8 mM of Cr(VI)/g for activated carbon(AQ-30) was achieved at pH of 3.0	The adsorption reached equilibrium in 80 min	Arslan & Pehlivan, 2007
Synthetic Nanocrystalline Mackinawite(FeS)	Hg(II)			Jeong et al., 2007
Red mud and its mixtures with haematite, china clay and fly ash	As(III)		As(III) removal by adsorbents is diffusion controlled	Singh et al., 2007
Unmodified and EDTA-modified Maize Husk	Cd(II), Pb(II), Zn(II)		Sorption process was found to be physiosorption process	Igwe & Abia, 2007
Activated Carbon (Chemviron C-1300)	Cu(II)			Kalpakli & Koyuncu, 2007

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