Global J. Environ. Sci. Manage., 2(2): 135-144, Spring 2016
DOI: 10.7508/gjesm.2016.02.004

REVIEW PAPER

Parthenium hysterophorus: Novel adsorbent for the removal of heavy metals and dyes

***S.A. Bapat*[1], *D.K. Jaspal*[2,*]**

[1]*Symbiosis Institute of Research and Innovation, Symbiosis International University, Lavale, Pune 412115, India*

[2]*Symbiosis Institute of Technology, Symbiosis International University, Lavale, Pune 412115, India*

Received 28 September 2015; revised 20 November 2015; accepted 1 December 2015; available online 1 March 2016

ABSTRACT: Heavy metals and dyes are major contributors in contamination of water streams. These contaminants enter into our eco- system, thus posing a significant threat to public health, ecological equilibrium and environment. Thus a combined discharge of these contaminants results in water pollution with high chemical oxygen demand, biological oxygen demand, color, particulate matter, suspended particles and odor. The mounting pollution of the water bodies has attracted attention of the researchers towards the development of novel techniques and materials for water pollution. The paper describes the use of such a material *Parthenium hysterophorus*, a weed, explored for water purification. The potential of the weed has been tested for several heavy metals and dyes as described in this paper. As per literature the weed is capable of showing adsorption tendency up to 90% in certain cases for some heavy metals and dyes. Powdered weed, activated carbon, ash etc. of *Parthenium* have been employed for the removal process.

KEYWORDS: *Adsorption; Dye; Heavy metal; Isotherms; Parthenium hysterophorus; Wastewater*

INTRODUCTION

Nowadays, water pollution has become a global issue. Heavy metals and dyes are the major contributors towards the contamination of water streams. Effluent released from metal plating, mining, radiator, battery manufacturing, fertilizer and fungicide manufacturing is the main source of heavy metal contamination (Kadirvelu *et al.*,2002; Rengaraj *et al.*,2003; Saifuddin and Kumaran, 2005; Barakat, 2011; Marzouk *et al.*, 2013; Kyzas and Kostoglou, 2014; Karbassi and Pazoki, 2015). Similarly effluent released from textile manufacturing, dye manufacturing, paper-pulp mills, and tannery industrypours dye contaminants into the water streams (Zawahry and Kamel, 2004; Allen and Koumanova, 2005; Rajamohan, 2009; Kanawade and Gaikwad, 2011; Soni *et al.*, 2012; Saltabas *et al*., 2012; Gupta *et al.*, 2015).

*Corresponding Author Email: *dipikaj@sitpune.edu.in*
Tel.: +91 922 563 5349; Fax: +91 203 911 6260

Note. Discussion period for this manuscript open until June 1, 2016 on GJESM website at the "Show Article".

Some of the heavy metals like, Lead, Cadmium, Chromium, Zinc, Nickel, and Mercury are the most toxic heavy metals which can cause reduced growth and development, nervous system damage, development of autoimmunity, rheumatoid arthritis, kidney failure, skin and eyes allergies, respiratory irritation etc., in addition to being carcinogenic (Abas *et al*., 2013; Sanghamitra *et al.*, 2012; Barakat, 2011; Hadi and Bano, 2009; Babel andKurniawan, 2004; Park and Jung, 2001). Several classes of dyes such as basic, acidic, reactive, direct, azo, mordent, sulfur and vat dyes are the important classesused extensively by the textile, paper and leather industries which are the major pollutants (Bhatnagarand Minocha, 2006; Klemola, 2008; Pramanik *et al.*, 2011; Sivashankar *et al.*, 2013; Topsakal *et al.*, 2013). Many physical and chemical processes like flocculation-coagulation (Moghaddam *et al.*, 2010; Gupta *et al.*, 2012), flotation (Matis and Mavros, 1991; Shakir *et al.*, 2010; Princa *et al.*, 2015), precipitation

(Charentanvarak, 1999; Becker *et al.,* 2012; Fu *et al.*, 2012; Golbaz *et al.*, 2014), electro kinetic coagulation (Parga *et al.,* 2005; Mansoorian *et al.*, 2014; Rincon and Motta, 2014), ion exchange (Tiravanti *et al.*,1997; Rengaraj *et al.*, 2001; Tor *et al.*, 2005), membrane filtration (Rashidi *et al.*, 2014; Ahmad *et al.*, 2002; Kozlowski and Walkowiak, 2002), electro chemical destruction (Juttner *et al.*, 2000; Gomes *et al*., 2011; Rocha *et al.*, 2011), irradiation-ozonation (Glaze *et al*., 1987; Martins *et al*., 2006; Dong *et al*., 2007; Tehrani *et al*., 2010), photo degradation (Gupta *et al.*,2011, 2012; Saleh and Gupta, 2012a), electro deposition (Elsherief, 2003; Ras and Ghizellaoui, 2012; Llanos *et al*., 2013), ultra-filtration with resins (Ghosh and Bhattacharya, 2006), reverse osmosis (Kadirvelu *et al.,* 2002; Ipek, 2005; Mohsen *et al*., 2007; George *et al*., 2015), adsorptionwith activated carbon and nano composites (Sharma and Forster, 1996; Jain *et al*., 2003; Saleh *et al*., 2011; Saleh and Gupta, 2012b; Gupta *et al.,* 2011, 2013; Marzouk *et al*., 2013) have already been investigated for the removalof toxic heavy metals and dyes. The major drawback associated with all these techniques is the high cost of application, complicated procedures, sludge generation, generation of by-products with long retention time (Gautam *et al.,* 2014). Among the mentioned methods, adsorption using activated carbon has been reported to be one of the most versatile, dynamicand superior technique to quarantine the heavy metals and colorants (Sharma and Forster, 1996; Khalkhali and Omidvari, 2004; Marzouk *et al.*, 2013; Sivakumar, 2015), but the high cost of regeneration and limited application for large scale has motivated the researchers to develop biologically originated/ environmental friendly, economically feasible and technologically sound alternatives, with same efficiency ascommercial activated carbon (Gupta and Ali, 2001; Gupta and Nayak, 2012; Gupta *et.al*., 1998, 2005, 2011, 2012; Mittal *et.al*., 2009, 2010).

Parthenium hysterophorus a novel adsorbent

Parthenium hysterophorus is often found in the open lands, developing residential colonies, near railway tracks, at the roadsides, at highways, near drainage lines and sewage plants, at the dumping grounds etc. Due to its high fecundity or growth rate, adaptability in various environmental conditions and ability to dominate various types of natural habitat it spreads all over to cover a larger area. Unfortunately the weed entered in India as a contaminant in wheat grains brought from USA in 1954 (Under Public Law 480) (Singh *et al*., 2008; Javaid and Riaz, 2012; Bhoyar *et al*., 2014). Congress grass, White top, Santa maria, Gajarghas are some of the regional names of weed (Patel, 2011; Saini *et al*., 2014; Khaket *et al*., 2015). *Parthenium* weed shows many adverse effects on agriculture, biodiversity, animal health and human health. The pollens of *Parthenium hysterophorus* induce the health issues such as burning sensation in respiratory track and allergies on skin, eyes, nose, and mouth. (Aneja *et al*., 1991; Qureshi *et al*., 2014). The weed is also dangerous to animals with respect to tainting of milk and meat (Parashar *et al*., 2009; Patel, 2011; Kushwaha and Maurya, 2012).

After various unsuccessful attempts and strategies to remove the weed by physical, chemical and biological measures leading to only a temporary solution, researchers found out a novel way to use of this weed as a "biosorbent" in dried form, for removal of hazardous heavy metals, toxic dyes and colorants from waste water. *Parthenium* has been used in several forms, such as powdered biomass of plant parts or whole weed, ash or activated carbon and acid activated biomass for the extinction of the said contaminants which in detail have been incorporated in this review.

Several adsorption studies carried out utilizing *Parthenium*, the noxious weed (Roy and Shaik, 2013) have been discussed at length in this research paper. The paper mainly focuses on highlighting the studies carried out using *Parthenium hysterophorus*, as a non-living biomass as a low cost, environmental friendly biosorbent for the removal of heavy metals and dyes pollution. Research on isothermal analysis including Langmuir and Freundlich also are a part of the manuscript.

Parthenium hysterophorus for removal of heavy metals

Kadirvelu *et al.*, 2002; carried out studies on activated carbon prepared from *Parthenium* for the elimination of Nickel, Ni(II) from aqueous solution. Authors reported that with increased in pH from 2 to 10, the metal ion removal was also found to increase. Based on the kinetics data authors fixed one of the crucial parameters i.e. stirring time to 6 hr. Rate constant calculation suggested that adsorption was a first order reaction. Adsorption followed Langmuir and Freundlich isothermal models.

Removal of mercury Hg(II) using *Parthenium* carbon was also demonstrated by Kadirvelu *et al*., 2002.

Authors concluded that adsorption was assisted by acidic pH in comparison to basic due to formation of $Hg(OH)_2$. Linear relation between amount of mercury adsorbed and agitation time validate the Lagergrens equation and thus confirming first order kinetics.

Cadmium Cd(II) was removed from waste water by using dried Parthenium adsorbent (Ajmal *et al.*, 2006). Impact of various limiting parameters were studied by authors which suggested that acidic pH was most favorable. Kinetics obeyed second order rate equation. Langmuir and Freundlich adsorption isotherm fitted well for the adsorption data. Adsorption was endothermic and spontaneous.

Acid activated charred biomass of *Parthenium* was used for elimination of Nickel, Ni(II) from stimulated water matrix (Lata *et al*., 2008c). Adsorption was pH sensitive and pH 5.0 was found to be optimum for the process. Rate constant calculation suggested that adsorption was second order reaction. FTIR spectra of adsorbent, showed the presence of alcoholic and carbonyl functional groups. Authors proposed that these functional groups probably played the role of "active sites" for Nickel adsorption.

Effective adsorption of Cr(VI) from the aqueous solution by using ash of *Parthenium hysterophorus* has also been investigated in the study (Singh *et al*., 2008). Adsorption was found inversely proportional to pH, particle size and adsorbate concentration, whereas directly proportional to temperature. Langmuir and Freundlich adsorption isotherms could also be well correlated with the results. Linear hike of chromium adsorption with time suggested the compliance of first order kinetics.

The dried powder of *Parthenium* was utilized (Khan, 2008) for Cd(II) adsorption. The physicochemical parameters were closely monitored, pH of solution was found crucial. Adsorption increased with increased initial concentration and dosage of adsorbent. Adsorption was endothermic and spontaneous in nature. Regression coefficient of 1.0 for pseudo second order equation implied second order kinetics. The desorption experiments carried out in continuation with 0.1M HCl showed 82.0% recovery.

Mineral acid activated *Parthenium* adsorbent was utilized to quarantine the toxic pollutant p-creosol (Singh *et al*, 2008). Superiority of adsorbent was established by parallel experimentation on commercial activated carbon. Process variables in batch operation were altered and impact on adsorption was studied by authors. pH showed vital role in adsorption process, and ideal value is 6.0. *Parthenium* adsorbent followed Freundlich, Redlich-Peterson, and Fritz-Schlunder isotherms, whereas commercial activated carbon followed Radke-Prausnitz and Fritz-Schl under isotherms. Both adsorbents showed first order kinetics model. Authors demonstrated an eco-friendly way for pollution control.

The biosorption of Nickel, Ni(II) using ash of *Parthenium hysterophorus* was studied by Singh *et al*., 2009. At low initial concentration and at high pH the adsorption increased drastically from 67% to 97%. Metal ion removal was favorable at pH 11.0, thus variation in mentioned process parameters greatly affected biosorption. Adsorption followed Lagergren'skinetic equation.

Apte *et al.*, 2011; studied the utilization of dried powder of leaves and stem of *Parthenium hysterophorus* for the reduction of excess of chlorides. The efficiency of biosorption was dependent upon the pH, Initial chloride concentration and contact time. The authors demonstrated that with an increased chloride concentration biosorption decreased and the equilibrium contact time was 120 min.

The potential of adsorbent prepared from dried *Parthenium hysterophorus* weed for the removal of hexavalent chromium was studied by Venugopal and Mohanty, (2011). Authors varied various process parameters to estimate the mechanism of adsorption. Authors suggested that adsorption took place in three steps i) Bulk diffusion ii) film diffusion iii) surface adsorption and found that it followed pseudo- second order kinetics. Authors proposed that pore diffusion and film diffusion were the rate determining steps with the help of Weber and Morris model. The FTIR graphs of adsorbent before and after adsorption were recorded to estimate the functional groups responsible for biosorption. The shifting of FTIR frequencies from 3400 to 3450 1/cm and 1424 to 1245 1/cm with varying intensities proved the presence of carboxyl, amine, alkane and amide groups as chromium binding sites.

Singh, *et al.*, (2015) demonstrated the elimination of Chromium (VI) using dried carbon slurry and ash of *Parthenium hysterophorus* with a special emphasis on intra particle diffusion phenomenon. Various batch experiments with varying process parameters were explored by authors for the studied adsorbent, to demonstrate the presence of Intra particle diffusion as key limiting step. Crank Nicholson's equation and finite

difference approximations were utilized by authors to elaborate the diffusion process. Langmuir and Freundlich adsorption isotherms were best fitted for *Parthenium* ash and carbon slurry respectively. Kinetics followed Lagergrens equation. The linear rise of amount of solute adsorbed with half power of contact time conform the presence of intra particle diffusion. Table 1 summarizes several adsorbents which have been used for removal of heavy metals.

Parthenium hysterophorus for dye removal

The removal of methylene blue, malachite green, Rhodamine B, Procion orange, Acid violet 17 dyes and Chromium(VI), Mercury(II), Iron(II), Nitrates metal ions with carbonized *parthenium* treated with sulfuric acid and ammonium per sulphate was studied by Sivaraj and Subburam, (2002). With an increase in the contact time, the removal capacity increased. Physico-chemical properties of *parthenium* carbon were thoroughly determined by authors. Lata *et al*., (2008a) used mineral acid activated *parthenium* carbon to remove Rhodamines B dye from synthetically prepared dye solution. The influence on adsorption efficiency due to factors like agitation time, pH, adsorbate concentration and quantity of adsorbent was studied. The optimum pH was 7.0 and contact time 60 mins. for adsorption to occur. The particle size of adsorbent material was in the range of 0.3 -1.0 mm. The Linearity plot of pseudo second order rate equation and the value of regression coefficient suggested the second order kinetics for adsorption. Sum of error square (SSE) equation was utilized to verify the kinetic model. FTIR spectra of untreated adsorbent showed 3385.9 1/cm, 1708.5 1/cm and 1037.4 1/cm frequencies which were shifted to 3448.1 1/cm, 1891.2 1/cm and 1083.4 1/cm respectively in dye bound adsorbent. Authors proposed that the inflection in the FTIR frequencies, in exhausted adsorbent were due to binding of hydroxyl, carbonyl and carbon-oxygen functional groups in dye molecules. Similarly the SEM image of unused adsorbent showed porous surface morphology which in turn changed to rough in nature due to dye

Table 1: *Parthenium hysterophorus* for removal of heavy metals

Heavy metal	Experimental adsorbent	Outcomes	Important observations	References
Nickel(II)	Activated carbon of whole weed	Maximum adsorption capacity 54.35 mg/g at pH 5.0 and 20°C	The successful recovery was proposed for Ni(II) with Hydrochloric acid as eluent	Kadirvelu *et al.*, (2002)
Mercury(II)	Activated carbon of whole weed	Maximum adsorption capacity 10mg/g at pH 5.0 and 30°C	Adsorption was highly pH sensitive.	Kadirvelu *et al.*, (2002)
Cadmium(II)	Dried powder of whole weed	Maximum adsorption percentage 99.7% at pH range 3-4.	Desorption with 0.1M Hydrochloric acid was well established.	Ajmal *et al.*, (2006)
Nickel(II)	Sulphuric acid treated Parthenium carbon	Maximum adsorption capacity 17.24 mg/g	Pseudo second order kinetic equation fitted well with adsorption data.	Lata *et al.*, (2008)
Chromium(VI)	Ash of whole weed	Maximum removal 63.97% at pH 2.0	Average rate constant was 7x 10^{-2} 1/min	Singh *et al.*, (2008)
Cadmium(II)	Dried powdered biomass of whole weed	Maximum removal percentage was 99.16%	Efficient Breakthrough capacity of 280 mL of Cd(II) was established by column technique.	Khan, (2008)
Nickel(II)	Ash of whole weed	Rate constant of adsorption was found to be 6.82 x 10^{-2} /min at 25°C	Adsorption was exothermic in nature.	Singh *et al.*, (2009)
Chlorides(I)	Dried powder of leaves and stem of weed	30-34% Chloride removal was achieved at lab scale.	The adsorption was greatly affected by pH. The optimum pH is 7 to 7.5.	Apte *et al.*, (2011)
Chromium(VI)	Dried powder of whole weed	Maximum biosorption capacity 24.5 mg/g	Adsorption was found to be spontaneous and exothermic in nature.	Venugopal and Mohanty, (2011)
Chromium(VI)	Ash of whole weed	Rate constant 0.0568 1/min.	Adsorption obeyed first order kinetics.	Singh, *et al.*, (2015)

adsorption. Presence of bulky and shiny particles on the surface of exhausted adsorbent supported the observation.

Elimination of malachite green dye from aqueous solution using mineral acids activated *parthenium* biosorbent was demonstrated (Lata *et al*., 2008b). Adsorption was higher, at lower dye concentration and higher dosage of adsorbent. Equilibration time of 90 min. was observed to be ideal for all studied concentrations.

A comparative adsorption of acid blue 92 dye by using ashes of three different biosorbents namely cow dung, mango stone, *Parthenium* leaves with commercial activated carbon was studied. (Purai and Rattan, 2010) pH and initial dye concentration were monitored. Ash of Parthenium leaves and commercial activated carbon showed higher adsorption at acidic pH, whereas cow dung and mango stone ash exhibited satisfactory adsorption at neutral and basic pH respectively. A great agreement in the regression value (0.99) for Langmuir adsorption isotherm was observed. Sequestration of safranin dye from aqueous solution with the help of dried, powdered *parthenium* was evaluated by Shrivastava, (2010). Authors demonstrated that optimum contact time of 40 min was suitable for all studied concentrations. Nearly constant value of rate constant implied that adsorption proceeded via second order dynamics.

A significant utilization of *Parthenium* weed for preparation of activated carbon by physical and chemical activation techniques was established (Sivaraj *et al*., 2010). Physical activation by heating (400-800°C), chemical activation by zinc chloride and various acids was demonstrated by the authors. The yield of activated carbon and various characterization parameters like pH, conductivity, specific gravity, bulk density, porosity, moisture, volatile matter, ash, surface area, metal content, soluble matters were thoroughly evaluated. Scanning electron microscopy (SEM) imaging was employed for surface characterization analysis which conform the amorphous and porous nature of zinc chloride activated carbon. The amorphous nature of adsorbent was in turn responsible for high surface area and high adsorption

Table 2: *Parthenium hysterophorus* for removal of dyes

Dye	Experimental Adsorbent	Outcomes	Important observations	References
Methylene blue, Malachite green, Rhodamine B, Procion orange, Acid violet 17	Sulfuric acid and ammonium per sulphate treated carbonized weed.	Affinity order of Parthenium carbon is Methylene blue > Malachitegreen> Rhodamine B > Acid Violet 17>Procion orange	Retention time of 90 min. was reported to be sufficient for total elimination	Sivaraj and Subburam, (2002)
Rhodamine B	Sulphuric acid treated weed carbon	Maximum adsorption capacity 18.52 mg/g	The maximum dye removal was 99.2% at pH 7.0	Lata *et al.*, (2008a)
Malachite green	Phosphoric acid, sulfuric acid treated weed biomass and commercial activated carbon.	Commercial activated carbon showed 2.01 and 2.63 times more adsorption capacity than phosphoric acid treated and Sulphuric acid treated adsorbent.	Langmuir isotherm well expressed the adsorption data.	Lata *et al.*, (2008b)
Acid blue 92	Ash of leaves of the weed.	Maximum biosorption capacity 4.84 mg/g	Adsorption was highly pH sensitive	Purai and Rattan, (2010)
Safranine	Dried, powdered weed.	Maximum adsorption capacity 89.3 mg/g.	Adsorption followed Langmuir isotherm model.	Shrivastava, (2010)
Methylene blue	Charred biomass of weed.	Maximum dye removal 99.9%	Recovery was highly pH sensitive.	Chatterjee *et al.*, (2012)
Methylene blue	Dried powder of untreated weed.	Maximum adsorption capacity 23.8 mg/g	Ideal pH for adsorption was 8.0	Mulugeta and Lelisa, (2014)

Table 3: Various forms of adsorbents prepared from *Parthenium hysterophorus*

Adsorbent	Activated carbon of whole weed	Dried powder of whole weed	Acid activated adsorben	Ash of whole weed
Adsorbates: (Heavy metals/ dyes removed)	Nickel(II), Mercury(II)	Cadmium(II), Chloride, Chromium(II), Safranine, Methylene blue	Nickel(II), Methylene blue, Malachite green, Rhodamine B, Procion orange, Acid violet 17	Chromium(II), Chromium(VI), Nickel(II), Acid blue 92 dye, Methylene blue
References:	Lata *et al*., (2008c) Kadirvelu *et al.*, (2002)	Ajmal *et al.*, (2006) Khan, (2008) Apte *et al.*, (2011) Venugopal and Mohanty, (2011) Shrivastava, (2010) Mulugeta and Lelisa, (2014)	Lata *et al*., (2008a, 2008b) Sivaraj and Subburam, (2002)	Singh *et al.*, (2008, 2009) Purai and Rattan, (2010) Chatterjee *et al.*, (2012), Singh *et al.*, (2015)

efficiency. Authors concluded that the zinc chloride impregnated carbon exhibited a maximum surface area of 1089.26 m^2/g. Thus authors suggested the various alternatives to commercial activated carbon.

The ability of mineral acid and zinc chloride activated charred *parthenium* biomass adsorbent for the sequestration of methylene blue dye was studied by Chatterjee *et al.*, (2012). The response surface methodology and ANOVA statistical tool was utilized to set the process parameters. Study demonstrated that 25 mg/L initial dye concentration, 35°C process temperature, 0.22 g adsorbent dosages and pH 7.0 were the optimum conditions for adsorption to occur. Based on the intra particle diffusion phenomenon the authors suggested that adsorption fitted well in second order kinetics. Physicochemical parameters of charred *parthenium* were thoroughly estimated. Scanning electron microscopy imaging was used to establish the topography of adsorbent material, which showed the porous nature of adsorbent. This porous nature was in turn responsible for high adsorptive capacity. FTIR spectra of charred and spent charred *parthenium* was also recorded which showed the presence of hydroxyl, carbon- carbon, carbon-hydrogen bonding in both adsorbent. FTIR frequencies corresponds to nitro compounds at 1570 1/ cm, 1560 1/cm were exclusively found in spent charred charcoal due to adsorption of methylene blue dye.

Finely ground, raw / untreated *Parthenium hysterophorus* weed was used as biosorbent for elimination of cationic methylene blue dye (Mulugeta and Lelisa, 2014). Physico-chemical parameters for adsorption were monitor carefully. Dye removal was higher at the beginning and with time it diminished due to loss of available active site of adsorption. High pH was found favorable for adsorption due to enhanced protonation at adsorbent surface. Langmuir isotherm equation well explained the adsorption phenomenon.

Parthenium hysterophorus was used for the bio synthesis of titanium nano-particles by Khan and Fulekar, (2015). Authors successfully demonstrated the photo degradation of dye Reactive red 31 with this bio synthesized nano-particles in presence of solar radiation. Impact of varying substrate concentration against photo degradation was studied by authors. Dye degradation was checked using UV-VIS Spectroscopic tool by continues absorbance measurement. Thus the authors demonstrated a novel way to utilize *parthenium* weed. Table 2 summarizes the use of the adsorbent for the removal of dyes.

Table 3 shows the use of several categories of the adsorbents prepared from *Parthenium* for the removal of heavy metals and dyes.

CONCLUSION

The novelty of the biosorbent lies in its eco-friendliness, economic significance and comparable efficiency with commercial activated carbon. Thus the review explores a diverse way of utilization of this plant in the form of an emerging novel adsorbent for the removal of dyes and heavy metals from waste water.

ACKNOWLEDGEMENT

One of the authors (SB) acknowledges the support provided by Symbiosis Institute of Technology, Symbiosis International University, Lavale, Pune, India to carry out this research activity.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

REFERENCES

Abas, S.N.A.; Ismail, M.H.S.; Kamal, M.L.; Izhar, S., (2013). Adsorption process of heavy metals by low cost adsorbent: A review. J. World appl. Sci., (28): 1518-1530 **(13 pages).**

Ahmad, A.L.; Harris, W.A.; Syafiie.; Seng, O.B., (2002). Removal of dye from wastewater of textile industry using membrane technology. J. Teknol., (36): 31-44 **(14 pages).**

Ajmal, M.; Rao, R.A.; Ahmad, R.; Khan M.A., (2006). Adsorption studies on *Parthenium hysterophorus* weed: removal and recovery of Cd (II) from wastewater. J. Hazard. Mater., (135): 242-248 **(7 pages).**

Allen, S.; Koumanova, B., (2005). Decolorisation of water/ wastewater using adsorption a review. J. Chem. Tech. Metallurgy., (40): 175-192 **(18 pages).**

Aneja, K.R.; Dhawan, S.R.; Sharma, A.B., (1991). Deadly weed partheniumhy sterophorus I and its distribution, Ind. J. Weed Sci., (23): 14-18 **(5 pages).**

Apte, S.S.; Apte, S.S.; Kore, V.S.; Kore S.V., (2011). Chloride removal from waste water by biosorption with the plant biomass. Universal J. Environ. Res. Tech., (1): 416-422 **(7pages).**

Babel, S.; Kurniawan, T., (2004). Cr(VI) removal from synthetic wastewater using coconut shell charcoal and commercial activated carbon modified with oxidizing againtsagainst and/ or chitosan. Chemosphere, (54): 951-967 **(17 pages).**

Barakat, M., (2011). New trends in removing heavy metals from industrial wastewater. Arabian J. Chem., (4): 361-377 **(17 pages).**

Becker, F.; Rodriguez, D.; Schwab, M., (2012). Magnetic removal of cobalt from wastewater by ferrite co-precipitation. Procedia Mater. Sci., (1): 644-650 **(7 pages).**

Bhatnagar, A.; Minocha, A., (2006).Conventional and non-conventional adsorbents for removal of pollutants from water: A review. Ind. J. Chem. Tech., (13): 203-217**(15 pages).**

Bhoyar, M.G.; Gavkare,O.J.; Reddy C.M.; Ghumare, V.S., (2014). Possible uses of parthenium- An agricultural waste. J. Indust. Pollut. Control, (30): 309-312 **(4 pages).**

Charerntanvarak, L., (1999). Heavy metal removal by chemical coagulation and precipitation. Water Sci. Tech., (39): 135-138 **(4 pages).**

Chatterjee, S.; Kumar, A.; Basu, S.; Dutta, S., (2012). Application of response surface methodology for methylene blue dye removal from aqueous solution using low cost adsorbent. Chem. Eng. J., (181): 289-299 **(11 pages).**

Dong, Y.; He, K; Zhao, Bo; Yin, Y.; Yin, L.; Zhang, A., (2007). Catalytic ozonation of azo dye active brilliant red X-3B in water with natural mineral brucite. Catalysis Communications, (8): 1599-1603 **(5 pages).**

Elsherief, A.E., (2003). Removal of cadmium from simulated wastewaters by electrodeposition on spiral wound steel electrode. Electrochim. Acta., (48): 2667-2673 **(7 pages).**

Fu, F.; Xie, L.; Tang, B.; Wang, Q.; Jiang, S., (2012). Application of a novel strategy- Advanced Fenton chemical precipitation to the treatment of strong stability chelated heavy metal containing wastewater. Chem. Eng. J., (189): 283-287 **(5 pages).**

Gautam, R.K.; Mudhoo, A.; Lofrano, G.; Chattopadhyaya, M.C., (2014). Biomass derived biosorbants for metal ions sequestration: adsorbent modification and activation methods and adsorbent regeneration. J. Environ. Chem. Eng., (2): 239-259 **(21 pages).**

George, J.S.; Ramos, A.; Shipley, H.J., (2015). Tanning facility wastewater treatment: Analysis of physical- chemical and reverse osmosis methods. J. Environ. Chem. Eng., (3): 969-976 **(8 pages).**

Ghosh, G.; Bhattacharya, P., (2006). Hexavalent chromium ion removal through micellar enhanced ultra-filtration. Chem. Eng. J., (119): 45-53 **(9 pages).**

Glaze, W.; Kang, K.; Chapin, D., (1987). The chemistry of water treatment processes involving ozone, hydrogen peroxide and ultraviolet radiation. Ozone Sci. Eng., (9): 335-352 **(18 pages).**

Golbaz, S.; Jafari, A.J.; Raflee, M.; Kalantary, R.R., (2014).Separate and simultaneous removal of phenol, chromium and cynide from aqueous solution by coagulation/ precipitation; Mecanism and theory. Chem. Eng. J., (253): 251-257 **(7 pages).**

Gomes, L.; Miwa, D.W.; Malpass G.R.P.; Motheo, A.J., (2011). Electrochemical degradation of the dye reactive orange 16 using electrochemical flow cell. J. Braz. Chem. Soc., (22): 1-16 **(16 pages).**

Gupta, V.K.; Ali, I., (2001). Removal of DDD and DDE from wastewater using bagasse fly ash, a sugar industry waste. Water Res., (35): 33-40 **(8 pages).**

Gupta, V.K.; Ali, I., Saleh, T.A.; Nayak, A.; Agarwal, S., (2012).Chemical treatment technologies for waste - water recycling- an overview. RSC Advances, (2): 6380-6388 **(9 pages).**

Gupta, V.K.; Ali, I.; Saini, V.K.; Gerven, T.V.; Bruggen, B.V.D.; Vandecasteele C., (2005). Removal of dyes from wastewater using bottom ash. Ind. Eng. Chem. Res., (44): 3655-3664 **(10 pages).**

Gupta, V.K.; Gupta, B.; Rastogi, A.; Agarwal, S.; Nayak, A., (2011). Pesticides removal from wastewater by activated carbon prepared from waste rubber tire. Water Res., (45): 4047-4055 **(9 pages).**

Gupta, V.K.; Jain, R.; Mittal, A.; Saleh, T.A.; Nayak, A.; Agarwal, S.; Sikarwar, S., (2012). Photo-catalytic degradation of toxic dye amaranth on TiO2/UV in aqueous suspensions.Mater.Sci. Eng. C., (32): 12-17 **(6 pages).**

Gupta, V.K.; Jain, R.; Nayak, A; Agarwal, S.; Shrivastava, M., (2011). Removal of hazardous dye –Tartrazine by photo degradation on titanium dioxide surface. Mater. Sci. Eng. C., (31): 1062-1067 **(6 pages).**

Gupta, V.K.; Khamparia, S.; Tyagi, I.; Jaspal, D.; Malviya, A., (2015). Decolorization of mixture of dyes: A critical review. Global J. Environ. Sci. Manage., 1(1): 71-94 **(24 pages)**.

Gupta, V.K.; Kumar, R.; Nayak, A.; Saleh, T.A.; Barakat, M.A., (2013). Adsorptive removal of dyes from aqueous solutions onto carbon nanotubes: A review. Adv. Colloid Interface Sci., (193): 24-34 **(11 pages).**

Gupta, V.K.; Mittal, A.; Jhare, D.; Mittal, J., (2012). Batch and bulk removal of hazardous coloring agent Rose Bengal by adsorption techniques using bottom ash as adsorbent. RSC Advances, (22): 8381-8389 **(9 pages).**

Gupta, V.K.; Nayak, A., (2012). Cadmium removal and recovery from aqueous solutions by novel adsorbents prepared from

orange peel and Fe_2O_3 nano-particles. Chem. Eng. J., (180): 81-90 **(10 pages).**

Gupta, V.K.; Saleh, T.A.; Agarwal, S., (2011). Synthesis and characterization of alumina-coated carbon nano tubes and their application for lead removal. J. Hazard. Mater., (185): 17-23 **(7 pages).**

Gupta, V.K.; Sharma, S.; Yadav, I.S.; Mohan, D., (1998).Utilization of Bagasse fly ash generated in the sugar industry for the removal and recovery of phenol and p-nitrophenolfrom wastewater. J. Chem. Tech. Biotech., (71): 180-186 **(7 pages).**

Gupta, V.K.; Shrivastava, S.K.; Mohan, D.; Sharma, D., (1998). Design parameters for fixed bed reactors of activated carbon developed from fertilizer waste for the removal of some heavy metal ions. Waste Manage. (17): 517-522 **(6 pages).**

Hadi, F.; Bano, A., (2009). Utilization of *Parthenium hysterophorus* for the remediation of lead- contaminated soil. Weed Bio. Manage., (9): 307-314 **(8 pages).**

Ipek, U., (2005). Removal of Ni(II) and Zn(II) from an aqueous solution by reverse osmosis. Desalination, (174): 161-169 **(9 pages).**

Jain, A.K.; Gupta, V.K.; Bhatnagar, A; Suhas., (2003). A comparative study of adsorbent prepared from industrial waste for removal of dyes. Sep. Sci. Tech., (38): 463-481 **(19 pages).**

Javaid, A.; Riaz, T., (2012). *Parthenium hysterophorus* L., An alien invasive weed threatening natural vegetations in Punjab, Pakistan. Pak. J. Bot., (44): 123-126 **(4 pages).**

Juttner, K.; Galla, U.; Schmieder, H., (2000). Electrochemical approaches to environmental problems in the process industry. Electrochim. Acta., (45): 2575-2594 **(20 pages).**

Kadirvelu, K.; Senthilkumar, P.; Thamaraiselvi, K.; Subburam, V., (2002). Activated carbon prepared from biomass as adsorbent: elimination Elimination of Ni(II) from aqueous solution. Bioresour. Tech., (81): 87-90 **(4 pages).**

Kadirvelu, K.; Sivasankari, C.; Jambuligam, M.; Pattabhi, S., (2002). Activated carbon from *parthenium* as adsorbent: Adsorption of Hg (II) from aqueous solution. Ind. J. Chem. Tech. (9): 499-503 **(5 pages).**

Kanawade, S.; Gaikwad, R., (2011). Removal of Methylene blue from effluent by using activated carbon and water hyacinth as adsorbent. Int. J. Chem. Eng. and Applications, (2): 317-319 **(3 pages).**

Karbassi, A.R.; Pazoki, M., (2015). Environmental Qualitative assessment of rivers sediments. Global J. Environ. Sci. Manage., 1(2):109-116 **(8 pages).**

Khaket, T.P.; Aggarwal, H.; Jodha, D.; Dhanda, S.; Singh, J., (2015). *Parthenium hysterophorus* in current scenario: A toxic weed with industrial, agricultural and medicinal applications. J. Plant Sci., (10): 42-53 **(12 pages).**

Khalkhali, R.; Omidvari, R., (2004). Adsorption of mercuric ion from aqueous solution using activated carbon. Polish J. Environ. Studies, (14): 185-188 **(4 pages).**

Khan, M.A. (2008). Studies on some non-conventional adsorbents and their possible use in the removal of heavy metals and organic pollutants from waste water. Ph.D. Dissertation, The Aligarh Muslim University, India.

Khan, R.; Fulekar, M.H., (2015). Photo catalytic degradation of a textile dye Reactive Red 31 using phyto synthesized titanium nano particles under solar irradiation. Desalination Water Treat., (56): 2438-2446 **(9 pages).**

Klemola, K., (2008). Cytotoxicity and spermatozoa motility inhibition resulting from reactive dyes and dyed fabrics. Natural Environ. Sci., (241): 1-68 **(68 pages).**

Kozlowski, C.; Walkowiak, W., (2002). Removal of chromium (VI) from aqueous solution by polymer inclusion membranes. Water Res., (36): 4870-4876 **(7 pages).**

Kushwaha, V.B.; Maurya, S., (2012). Biological utilities of *Parthenium hysterophorus*. J. Applied Natural Sci., (4): 137-143 **(7 pages).**

Kyzas, G.Z.; Kostoglou, M., (2014). Green adsorbents for waste water: A critical review. Materials, (7): 333-364 **(31 pages).**

Lata, H.; Garg, V.K.; Gupta, R.K., (2008a). Adsorptive removal of basic dye bychemically activated parthenium biomass: equilibrium Equilibrium and kinetic modeling. Desalination, (219): 250-261 **(12 pages).**

Lata, H.; Garg, V.K.; Gupta, R.K., (2008c). Sequestration of nickel from aqueoussolution onto activated carbon prepared from *Parthenium hysterophorus* L. J. Hazard. Mater., (157): 503-509 **(7 pages).**

Lata, H.; Gupta, R. K.; Garg, V. K., (2008b). Removal of basic dye from aqueous solution using chemically modified *Parthenium hysterophorus* Linn. biomass. Chem. Eng. communications, (195): 1185-1199 **(15 pages).**

Llanos, J.; Rodrigo, M.A.; Perez, A.; Canizares, P.; (2013). Treatment of Cu/Zn wastes by combined PSU- electro deposition processes. J. Environ. Manage. (116): 181-185 **(5 pages).**

Mansoorian, H.J.; Mahyi A.H.; Jafri, A. J., (2014). Removal of lead and zinc from battery industry waste water using electrocoagulation prosess: Influence of direct and alternating current by using iron and stainless steel rod electrodes. Sep. Purif. Tech., (135): 165-175 **(11 pages).**

Martins A.; Canalli, V.M.; Azevedo, C.M.; Pires, M., (2006). Degradation of pararosaniline (C.I. Basic Red 9 monohydrochloride) dye by ozonation and sonolysis. Dyes and Pigments, (68): 227-234 **(8 pages).**

Marzouk, I.; Chaabane, L.; Dammak, L.; Hamrouni, B., (2013). Application of Donnandialysis coupled to adsorption onto activated alumina for chromium (VI) removal. American J. Analytical Chem., (4): 420-425 **(6 pages).**

Matis, K.; Mavros, P., (1991). Recovery of metals by ion flotation from dilute aqueoussolutions. Separation Sep. and Purification. Reviews., (20): 1-48 **(48 pages).**

Mittal, A.; Kaur, D.; Malviya, A.; Mittal, J.; Gupta, V.K., (2009). Adsorption studies on the removal of coloring againt phenol red from wastewater using waste material as adsorbents. J. Colloid Interface Sci., (337): 345-354 **(10 pages).**

Mittal, A.; Mittal, J.; Malviya, A.; Gupta, V.K., (2010). Removal and recovery of chrysoidine Y from aqueous solutions by waste materials. J. Colloid Interface Sci., (344): 497-507 **(11 pages).**

Mittal, A.; Mittal, J.; Malviya, A.; Kaur, D.; Gupta, V.K., (2010). Decolorisation treatment of hazardous triarylmethane dye, Light green SF (yellowish) by waste material adsorbents. J. Colloid Interface Sci., (342): 518-527 **(10 pages).**

Mittal, A.; Mittal, J; Malviya, A.; Gupta, V.K., (2009). Adsorptive removal of hazardous anionic dye Congo red from waste water using waste materials and recovery by desorption. J. Colloid Interface Sci., (340): 16-26 **(11 pages).**

Moghaddam, S.; Moghaddam, M.; Arami, M., (2010). Coagulation/flocculation process for dye removal using sludge from water treatment plant: Optimization through response surface methodology. J. Hazard. Mater., (175): 651-657 **(8 pages).**

Mohsen Nila, M.; Montazeri, P.; Modarress, H., (2007). Removal of Cu^{2+} and Ni $^{2+}$ from wastewater with a chelating agent and reverse osmosis processes. Desalination, (217): 276-281 **(6 pages).**

Mulugeta, M.; Lelisa, B., (2014). Removal of Methylene blue (Mb) dye from aqueous solution by bioadsorption onto untreated *parthenium hysterophorus* weed. Modern chem. Appl., (2): 1-5 **(5 pages).**

Parashar, V.; Parashar, R.; Sharma, B.; Pandy, A., (2009). Parthenium leaf extract mediated synthesis of silver nano particles: A novel approach towards weed utilization. Digest J. Nano mater. Bio structures, (4): 45-50 **(6 pages).**

Parga, J.; Cocke, D.; Valverde, V.; Gomes, A.; Kesmez, M.; Moreno, H.; Wear, M.; Mencer, D., (2005). Characterization of electro coagulation for removal of chromium and arsenic. Chem. Eng. Tech., (28): 605-612 **(8 pages).**

Park, S.; Jung, W., (2001). Removal of chromium by activated carbon fibers plated with copper metal. Carbon Sci., (2): 15-21 **(7 pages).**

Patel, S., (2011). Harmful and beneficial aspects of *parthenium hysterophorus*: an update. Biotech, (1): 1-9 **(9 pages).**

Pramanik, S.; Mohammad, A.; Sina, A.; Mohammad, J.; Datta, S.; Mohammad, U., (2011). Natural adsorbents for dye effluent of high strength COD and their microbiological analysis. Chem. J.,(1): 29-35 **(7 pages).**

Princa, M.; Adamovic, S.; Dalmacija, B.; Rajic, L.; Trickovic, J.; Rapajic, S., Tomin, M.B., (2015). The electrocoagulation/ flotation study: The removal of heavy metals from the waste fountain solution. Process Safety Environ. Protec., (94): 262-273 **(12 pages).**

Purai, A.; Rattan, V.K., (2010).Acid blue 92 (Leather dye) removal from waste water by adsorption using biomass ash and activated carbon. Carbon Letters, (11): 1-8 **(8 pages).**

Qureshi, H.; Arshad, M.; Bibi, Y., (2014). Invasive flora of Pakistan: a A critical analysis. Int. J. Biosci., (4): 407-424 **(18 pages).**

Rajamohan, N., (2009). Equilibrium studies on sorption of an anionic dye onto acid activated water hyacinth roots. African J. Environ. Sci. Tech., (3): 399-404 **(6 pages).**

Ras, H.; Ghizellaoui, S., (2012). Determination of anti-scale effect of hard water by test of electrodeposition. Procedia Engineering., (33): 357-365 **(9 pages).**

Rashidi, H.R.; Sulaiman, M.N.; Hashim N.A.; Hassan, R.C.; Ramli, M.R., (2014). Synthetic reactive dye wastewater treatment by using nano- membrane filtration. Desalination Water Treat., (2014) 1-10 **(10 pages)**.

Rengaraj, S.; Cheol, J.; Younghun, K.; Jongheop, Yi., (2003). Kinetics of removal of chromium from water and electronic process waste water by ion exchange resins: 1200H, 1500H and IRN97H. J. Hazard. Mater., (102): 257-275 **(19 pages).**

Rengaraj, S.; Kyeong, Y.; Seung, M., (2001). Removal of chromium from water and wastewater by ion exchange resins. J. Hazard. Mater, (87): 273-287**(15 pages).**

Rincon, G.J.; Motta, E.J., (2014). Simultaneous removal of oil and grease and heavy metals from artificial bilge water using electro- coagulation/flotation. J. Environ. Manage, (144): 42-50 **(9 pages).**

Rocha, J.H.; Fernandes, N.S.; Souza, K.R.; Dasilva, D.R.; Quiroz, M.A.; Martinez Huitle, C.A., (2011). Electrochemical decolorisation process of textile dye in the presence of NaCl at boron doped diamond electrode. Sustain. Environ. Res., (21): 291-298 **(8 pages).**

Roy, D.C.; Shaik M.M., (2013). Toxicology, phytochemistry, bioactive compounds and pharmacology of *parthenium hysterophorus*. J. Medicinal Plants Studies, (1): 126-141 **(16 pages).**

Saifuddin, N.; Kumaran, P., (2005). Removal of heavy metal from industrial waste water using chitosan coated oil palm shell charcoal. Electron. J. Biotech., (8): 43-53 **(11 pages).**

Saini, A.; Aggarwal, N.K.; Sharma, A.; Kaur, M.; Yadav, A., (2014). Utility potential of *parthenium hysterophorus* for its strategic management. Advances Agri., (2014): 1-16 **(16 pages).**

Saleh, T.A.; Agarwal, S.; Gupta, V.K., (2011). Synthesis of MWCNT/MnO2 and their application for simultaneous oxidation of arsenite and sorption of arsenate. Applied Catalysis B: Environ. (106): 46-53 **(8 pages).**

Saleh, T.A.; Gupta, V.K., (2012a). Photo-catalyzed degradation of hazardous dye methyl orange by use of composite catalyst consisting of multi-walled carbon nano tubes and titanium dioxide. J. Colloid Interface Sci., (371): 101-106 **(6 pages).**

Saleh, T.A.; Gupta, V.K., (2012b). Column with CNT/ magnesium oxide composite for lead (II) removal from water. Environ. Sci. Pollut. Res., (19): 1224-1228 **(6 pages).**

Saltabas, O.; Teker, M.; Konuk, Z., (2012). Biosorption of cationic dye from aqueous solution by water hyacinth roots. Global Nest J., (14): 24-31 **(8 pages).**

Sanghamitra, P.; Rao, P.V.V.; Naidu, G.R.K., (2012). Uptake of Zn(II) by an invasive weed species *parthenium hysterophorus* L. Applied Ecology Environ. Res., (10): 267-290 **(24 pages).**

Shakir, K.; Elkafrawy, A.F.; Ghoneimy, H.F.; Beheir, S.G.E.; Refaat, M., (2010). Removal of Rhodamine B (a basic dye) and troron (an acidic dye) from dilute aqueous solutions and wastewater simultaneously by ion flotation. Water Res., (44): 1449-1461 **(13 pages).**

Sharma, D.; Forster, C., (1996). A comparison of the sorbtive characteristics of leaf mould and activated carbon columns for the removal of hexavalent chromium. Process Biochem., (31): 213-218 **(6 pages).**

Shrivastava, V.S., (2010). Thebiosorption of safranine onto *parthenium hysterophorus* L: equilibrium and kinetics investigation. Desalination and Water Treatment, (22): 146-155 **(10 pages).**

Singh, R.K.; Kumar, S.; Kumar, S.; Kumar, S., (2008). Development of parthenium based activated carbon and its utilization for adsorptive removal of p-cresol from aqueous solution. J. Hazard. Mater., (155): 523-535 **(13 pages).**

Singh, R.S.; Kumar, P.; Mondal, M.K., (2015). Intra particle diffusion during adsorption of Cr(VI) on carbon slurry and *parthenium hysterophorus*. Int. J. Chem. Environ. Eng., (6): 15-21 **(7 pages).**

Singh, R.S.; Singh, V.K.; Mishra, A.K.; Tiwari, P.N.; Singh, U.N.; Sharma Y.C., (2008). *Parthenium hysterophorus*: A novel adsorbent to remove Cr (VI) from aqueous solutions. J. Applied Sci. Environ. Sanitation, (3): 177-189 **(13 pages).**

Singh, R.S.; Singh, V.K.; Tiwari, P.N.; Singh, J.K.; Sharma, Y.C., (2009). Biosorptionstudies of nickel on *parthenium hysterophorus* ash. Environ. Tech., (30): 355-364 **(10 pages).**

Sivakumar, D. (2015). Hexavalent chromium removal in a tannery industry wastewater using rice husk silica. Global J. Environ. Sci. Manage., 1(1): 27-40 (14 **pages**).

Sivaraj, R.; Rajendran, V.; Gunalal, G.S., (2010). Preparation and characterization of activated carbons from parthenium biomass by physical and chemical activation techniques. Electron. J. Chem., (7): 1314-1319 **(6 pages).**

Sivaraj, R.; Subburam, V., (2002). Activated parthenium carbon as an adsorbent for the removal of dyes and heavy metal ions from aqueous solution. Bioresour. Tech., (85): 205-206 **(2 pages).**

Sivashankar, R.; Sivasubramanian, V.;Sathya, A.; Pallipad, S., (2013). Biosorption of hazardous azo dye Metanil yellow using immobilized aquatic weed, International conference on future trends in structural, civil, environmental and mechanical engineering. Bangkok, Thailand 13-14 July.

Soni, M.; Sharma, A.; Shrivastava, J.; Yadav, J., (2012). Adsorptive removal of methylene blue dye from an aqueous solution using water hyacinth root powder as a low cost adsorbent.International J. Chem. Sci. Applications, (3):338-345 **(8 pages).**

Tehrani Bagha, A.R.; Mahmoodi, N.M.; Menger, F.M., (2010). Degradation of a persistent organic dye from colored textile wastewater by ozonation. Desalination, (260): 34-38 **(5 pages).**

Tiravanti, G.; Petruzzelli, D.; Passino, R., (1997). Pretreatment of tannery waste waters by an ion exchange process for Cr(III) removal and recovery. Water Sci. Tech., (36): 197-207 **(11 pages).**

Topsakal, N.H.; Digrak, M.; Kertmen, M., (2013). Removal of Remazol navy blue textile dye by using agaricusbisporusbiomass.Digital proceeding of ICOEST-Cappadocia, Nevsehir, Turkey, 18-21 June.

Tor, A.; Buvukerkek, T.; Cengelolu, Y.; Ersoz, M., (2005).Simultaneous recovery of Cr (III) and Cr (VI) from the aqueous phase with ion- exchange membranes. Desalination, (171): 233-241 **(9 pages).**

Venugopal, V.; Mohanty, K., (2011). Biosorptive uptake of Cr(VI) from aqueous solution by *parthenium hysterophorus* weed: equilibrium, Kinetics and thermodynamic studies. J. Chem. Eng., (174): 151-158 **(8 pages).**

Zawahry, M.; Kamel, M., (2004). Removal of azo and anthraquinone dyes from aqueous solutions by eichhorniacrassipes. Water Res., (38): 2967-2972 **(6 pages).**

AUTHOR (S) BIOSKETCHES

Bapat, S.A., Ph.D., Research Scholar, Symbiosis Institute of Research and Innovation, Symbiosis International University, Lavale, Pune 412115, India. Email: *shreyasbapat111@gmail.com*

Jaspal, D.K., Ph.D., Associate Professor, Symbiosis Institute of Technology, Symbiosis International University, Lavale, Pune 412115, India. Email: *dipikaj@sitpune.edu.in*

How to cite this article:

Bapat, S.A. Jaspal, D.K., (2015). Parthenium hysterophorus: Novel adsorbent for the removal of heavy metals and dyes. Global J. Environ. Sci. Manage., 2(2): 135-144.

DOI: 10.7508/gjesm.2016.02.004

URL: http://gjesm.net/article_15237_1931.html