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Potential of Biochar as Cost Effective Adsorbent in Removal of Heavy Metals Ions from Aqueous Phase: A Mini Review

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ABSTRACT

Due to industrialization and increasing population, wastewater treatment has become a big challenge. There are numerous techniques such as ion-exchange, adsorption, membrane filtration, coagulation, flocculation, floating and electrochemical approach developed for the remediation of contaminants from wastewater. But, now it is necessary to develop an approach which should has high efficiency, less expensive and environmental friendly, so that limitation of existing techniques can be overcome. Recent developments of biochar have attracted the researchers into this area. Different methods are discovered to synthesized biochar for the removal of pollutants from wastewater. In this review, biochar are elaborated and critically discussed which have reported for the removal of metallic pollutants present in waste water.

1. Introduction

Today, environmental pollution has become one of the most global problem. Out of which water pollution is also a big concern because of rapid industrialisation and urbanisation. Approximately 1 billion people of the world do not get safe water and about 2 million losses their life every year due to polluted water (Gleick *et al.*, 2003). Moreover World Health Organisation (WHO) specified that climate change will increase this problem of potable water for the half of the global people (World Health Organization). According to United Nation scheme world would have shortage of 40% water next 15 years. Polluted water is also very hazardous for water bodies as every year it causes death of 1 million marine, according to UNESCO (WWAP 2015).

Water pollution is caused by various pollutants such as organic, inorganic which are added by the industries. Among them heavy metal ions are the greatest threats to the environment, a living organism because these cannot be biodegraded and they are highly venomous nature (Shannon *et al.*, 2008; Range *et al.*, 2012). There are various natural and anthropogenic sources of heavy metals in aqueous solution, as shown in Figure 1. Discarding of heavy metals increased water pollution day by day throughout the world. The existence of heavy metals ion in the water sources (river, ponds, lakes and sea) caused serious threat to both flora and fauna. They are not contaminated surface but also caused the contamination of ground water (via leakage or rain) (Keiluwei *et al.*, 2009). So earth water consist different hazardous heavy metals. Therefore to reduced the risk of heavy metals, its essential to remediate heavy metals from the aqueous solution. To remediate heavy numerous technologies such ion exchange, reverse osmosis, membrane filtetration, coagulation flotation and adsorption. Amongst these techniques adsorption is optimize techniques due to low cost, easy operation and high efficiency (Kumar *et al.*, 2011). The utilization of low cost adsorbent such as biochar is the innovative method to remediate heavy metals from the aqueous solution. Biochar is a black carbon produced by thermal decomposition (pyrolysis) of biomass, which consist high amount of carbon in the absent of oxygen or oxygen deficient environment. Biochars playing a numerous function due to which researcher attracted towards utilization of biochars as less expensive adsorbent for the remediation of heavy metals. Biochars mainly removed

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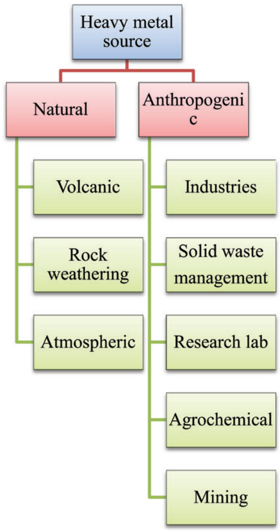
heavy metals from the water by physiochemical interaction (Kołodyn *et al*., 2012; Hollister *et al*., 2013).



Figute 1: Sources of heavy metals contaminate in water.

2. Mechanism

Heavy metals can be removed from the water by different mechanism for example complexation, electrostatic interaction, physical sorption and precipitation. Due to surface heterogeneity biochars shows higher sorption capacity for removal of heavy metal as activated carbon. In literature number of biochars given which have higher surface area as well as perfectly distributed pore network together with mesopores (2-50nm), macropores (>50nm) and micropores (<2nm) (Mukherjee *et al.,* 2011). Biochars shows higher affinity towards heavy metal due to higher pore volume and surface the reason behind this the metallic ion may be sorbed physically on the surface of biochar and retained inside the pore . There are number of biocahs which carry negative charge and have ability to adsorbed positively charged metal by electrostatic interaction. Biochars carried functional group and specific ligands may be attracting with many metals to form complexes otherwise their solid minerals phase precipitated (Cao *et al.,* 2009; Inyang *et al.,* 2012; Kim *et al.*, 2013).

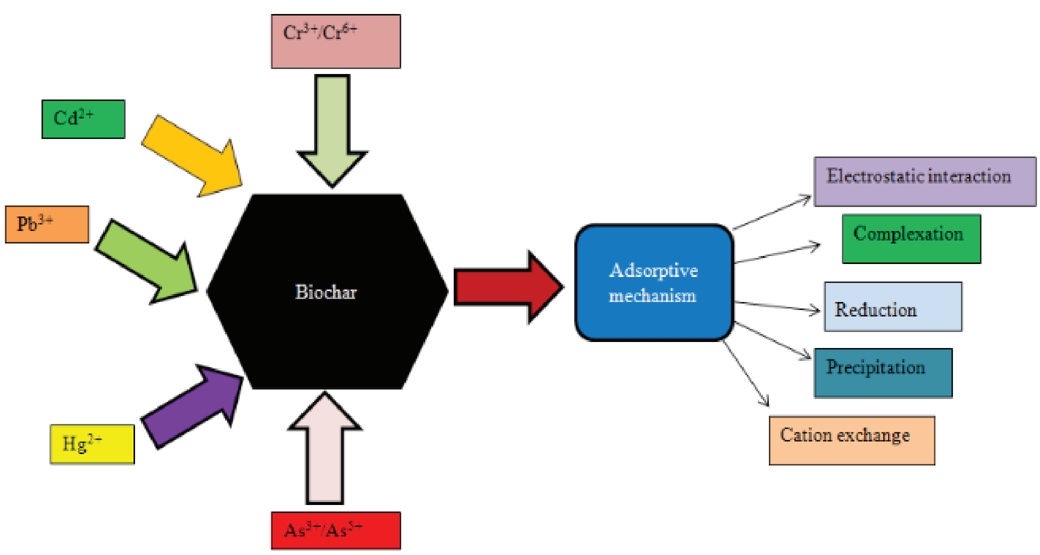


Figure 2: Mechanistic representation of removal of heavy metal ions from aqueous solution

3. Application of Biochar for Water Treatment

Biochars possess high porous volume, greater surface area, efficiently remove contaminant from the water and functional group with unique characteristics. On the basis of the literature survey about 45% biochars utilized to remove heavy metals from the aqueous solution. In the current world the contamination of aqueous solution with heavy metals has been become a big issue. Therefore today researcher attracted towards the utilization of biochar to remediate heavy metals from aqueous solution. Examples of the most toxic heavy metals are arsenic (As), zinc (Zn), mercury (Hg), nickel (Ni), cadmium (Cd), (Cr), copper (Cu), lead (Pb), uranium (U), chromium and aluminum (Al) Sun *et al.*, 2011; Hollister *et al.*, 2013).

4. Literature Survey

Year of Publication	Title	Remarks	Reference
2019	Biobased magnetic metal-organic framework nanocomposite: Ultrasound-assisted synthesis and pollutant (heavy metal and dye) removal from aqueous media.	**Adsorbent:** Metal organic frameworks (Fe_3O_4@ESM) **Methods of Synthesis**: Low temperature co precipitation **Adsorbate:** Cu(II) and BIR 18 dye. **Raw material:** Eggshell **Parameters:** pH, equilibrium time, adsorbent dose. **Characterization techniques:** FTIR, ESM, XRD **Adsorption capacity:** 344.8 mg/g for Cu(II) and 250.8 mg/g for BIR 18 dye.	(Mahmoodi *et al.*, 2019)
2019	Adsorption of metal ions with biochars derived from biomass wastes in a fixed column: adsorption isotherm and process simulation.	**Adsorbent:** Biochar **Methods of synthesis**: Pyrolysis **Adsorbate:** Cr(III) and Cu(II) **Raw material:** Wood and water caltrop shell **Parameters**: Temperature, pH, contact time, adsorbent dose. **Characterization techniques**: FTIR, AAS, ESM, XRD **Adsorption capacity**: Wood biochar and water caltrop shell biochar shows 67.7mg/g and 78.5 mg/g, respectively for Cr and Cu 49.8 mg/g and 48.5 mg/g for Cu.	(Zhang *et al.*, 2019)
2018	Synthesis of highly-efficient functionalized biochars from fruit industry waste biomass for the removal of chromium and lead.	**Adsorbent:** Biochars **Methods of Synthesis**: Pyrolysis **Adsorbate:** Cr(III) and Pb(II) **Raw material:** Fruit **Parameters:** Temperature, pH, contact time adsorbent dose. **Characterization techniques**: FTIR, BET, SEM and XRD **Adsorption capacity:** 28.7 mg/g and 23.8 mg/g by using PSuA and ASuA respectively for Pb and 28.7 mg/g and 23.8 mg/g by using PSuA and ASuA respectively for Cr.	**(Pap *et al.*, 2018)**
2018	Removal of Cu(II), Cd(II) and Pb(II) ions from aqueous solutions by biochars derived from potassium rich biomass.	**Adsorbent:** Biochar. **Methods of Synthesis**: Pyrolysis **Adsorbate:** Cu(II), Cd(II) and Pb(II) **Raw material:** Banana pell and cauliflower **Parameters**: Temperature, pH, equilibrium time adsorbent dose. **Characterization techniques**: ICP–OES, Carlo-Erba NA-1500, BET, SEM, EDS-AMETEX and XRD **Adsorption capacity:** BB shows efficiency for Pb(II), Cu(II) and Cd(II) 98.2, 46.4 and 7.4%respectively while CB shows 74.6, 34.2 and 6.4% respectively.	(Ahmad *et al.*, 2018)
2017	Stabilization of nanoscale zerovalent iron (nZVI) with modified biochar for Cr(VI) removal from aqueous solution.	**Adsorbent:** Biochar (nZVI@HCl-BC) **Method of Synthesis**: Pyrolysis **Adsorbate**: Cr(VI) **Raw material:** Cronstalk. **Parameters**: Temperature, pH, contact time adsorbent dose. **Characterization techniques**: FTIR, BET, SEM, XRD. **Adsorption (%):** 70%	(Dong *et al.*, 2017)
2017	Enhanced lead and cadmium removal using biochar-supported hydrated manganese oxide (HMO) nanoparticles: Behavior and mechanism.	**Adsorbent:** Biochar-supported hydrated manganese oxide (HMO) nanoparticle. **Adsorbent Synthesis**: Slow pyrolysis **Adsorbate:** Cd(II) and Pb(II) **Raw material:** Peanuts shell **Parameters**: Temperature, pH, equilibrium time. **Characterization techniques**: FTIR, BET, TEM, EDS, SEM. **Adsorption (%):** For Pb(II) and Cd(II) 84% and 87% respectively.	(Wan *et al.*, 2017)

2016	Sorption Process of Date Palm Biochar for Aqueous Cd (II) Removal: Efficiency and Mechanisms.	**Adsorbent:** Biochar. **Methods of Synthesis**: Slow pyrolysis **Adsorbate**: Cd(II). **Raw material:** Date palm **Parameters**: Adsorbent dose, pH, equilibrium time. **Characterization techniques**: FTIR, BET, TEM, EDS, SEM. **Adsorption:** 43.58 mg/g.	(Usman *et al.*, 2016)
2016	Effectiveness of Sunflower Seed Husk Biochar for Removing Copper Ions from Wastewater: a Comparative Study.	**Adsorbent:** Biochar **Method of Synthesis**: Pyrolysis **Adsorbate**: Cu(II). **Raw material:** Sunflower seed husk **Parameters**: Adsorbent dose, pH, temprature. **Characterization techniques**: FTIR, BET, TEM, SEM. **Adsorption (%)**: 81%.	(Saleh *et al.*, 2016)
2015	Manganese oxide-modified biochars: preparation, characterization, and sorption of arsenate and lead.	**Adsorbent:** Manganese oxide-modified biochars. **Methods of Synthesis**: Slow pyrolysis **Adsorbate**: Cd(II). **Raw material:** Pine wood stock **Parameters**: Adsorbent dose, pH, equilibrium time. **Characterization techniques**: FTIR, BET, TEM, EDS, SEM. **Adsorption (%)**: For As(IV) and Pb(II) 0.91g/kg and 47.05 g/kg respectively.	(Wang *et al.*, 2015)
2014	Arsenic and chromium removal from water using biochars derived from rice husk, organic solid wastes and sewage sludge.	**Adsorbent:** Biochars. **Method of Synthesis**: Pyrolysis **Adsorbate**: As(V). **Raw material:** Rice husk, organic solid waste and sludge. **Parameters**: Adsorbent dose, pH, equilibrium time. **Characterization techniques**: FTIR, BET, TEM, SEM. **Adsorption (%)**: Remove 95% Cr(VI) while for As(V) removal efficiency is 53% which is lower than Cr(VI) lower.	(Agrafioti *et al.*, 2014)
2014	Biochar pyrolytically produced from municipal solid wastes for aqueous As(V) removal: Adsorption property and its improvement with KOH activation.	**Adsorbent:** Biochar. **Methods of Synthesis**: Slow pyrolysis **Adsorbate**: As(V). **Raw material:** Pine Municipal solid wastes. **Parameters**: Equilibrium time. pH. **Characterization techniques**: FTIR, BET, SEM. **Adsorption capacity**: For As(IV and Pb(II) 0.91g/kg and 47.05 g/kg respectively.	(Jin *et al.*, 2014)
2013	Chemically Modified Biochar Produced from Conocarpus Wastes: An Efficient Sorbent for Fe(II) Removal from Acidic Aqueous Solutions.	**Adsorbent:** Modified . **Method of Synthesis**: Pyrolysis **Adsorbate**: Fe(II). **Raw material:** Pine wood stock **Parameters**: Adsorbent dose, pH, equilibrium time. **Characterization techniques**: FTIR, BET, TEM, EDS, SEM. **Adsorption capacity**: For As(IV) and Pb(II) 0.91g/kg and 47.05 g/kg respectively.	(Usman *et al.*,2013)

2013	Biosorption of chromium onto native and immobilized sugarcane bagasse waste biomass	**Adsorbent:** Biochar. **Method of Synthesis**: Slow pyrolysis **Adsorbate**: Cr(VI). **Raw material:** Sugarcane. **Parameters**: Contact time pH, and adsorbent dose. **Characterization techniques**: FTIR, BET, SEM. **Adsorption (%):** 73% Cr(VI) remove .	(Ullah *et al.*, 2013)

4. Concluding Remarks

Adsorption is the best techniques for the elimination of heavy metals from contaminated water due to its low cost, easy to operate and environmentally friendly. Recently, an urgent need has arisen to develop efficient, economically and green adsorbent for the elimination of arsenic ion. Therefore, biochar as an adsorbent are considered the promising adsorbents owing to their unique characteristics like greater surface area, highly porous structure and better functionality. This review focussed on systematically development of different biochar for heavy metals ions removals. Adsorption data is best fitted in pseudo second order kinetic model and Langmuir and Freundlich isotherm model. By critically analyzing biochar give information about the further research in the field of nanoadsorbents. In nutshell, this review discussed the recent progress and better understanding of biochar to remediate heavy metals ions efficiently.

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