Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Special Issue [1]2022 : 189-196

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
REVIEW ARTICLE **OPEN ACCESS**

Adsorption of Hexavalent Chromium for Waste Water Remediation by Various Adsorbents - A Review Article

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ABSTRACT
Now-a-days because ofthe aggressive world population increment, rapid industrialization, agricultural and household activities, civilization leads to high levels contamination of water in terms of inorganic andorganic pollutants.Chromium presence in industrial effluents has become a big problem worldwide as hexavalent state of chromium is highly toxic to living organism because ofits ability to generate reactive species of oxygen in cells. On the Other hand the trivalent chromium is less toxic and also serves as an essential element in small amounts. However, for the removal of hexavalent chromium numbers of researchers have done research and different types of adsorbent materials have been mostly used for this purpose. But sometimes all adsorbent materials are not capable to adsorb contaminants after certain limit of concentration and these pollutants are remains as it is in nature which may producemany other problems in environment. This review article represents the information about the adsorption of hexavalent chromium metal ions from aqueous medium using different adsorbent materials like different clay along with clay mineral, nanomaterials like carbon nanotube, nanoplates, nanosheets as well as nanocomposites, MOFs, biosorbents, Ferrites, Composites, etc. Along with this, the adsorption capacity of various adsorbent materials for the hexavalent chromium also presented in details addition with pH, initial metal ion concentration and contact time. This paper discussed also the adsorption mechanism and kinetics of adsorption process directions of removal of hexavalent chromium from water, hence to save the aqueous medium from extreme contamination.
Keywords: *Hexavalent chromium, Metal organic frameworks, Adsorption, Waste water treatment, Isotherm, Kinetic Study.*

Received 09.02.2022 Revised 121.03.2022 Accepted 11.04.2022

INTRODUCTION

One of the major and serious environmental risks is the pollution of water bodies due to the discharge of hazardous chemicals such as chromium[1]. Chromium element, generally present in nature chiefly in two most common forms which that trivalent chromium and hexavalent chromium. At higher level of contamination Cr(III) would be a concern in drinking water because of it has relatively low toxicity. The presence of Cr(VI) in water indicates a huge risk for health of human life. For instance, its existence show different toxicological along with carcinogenic effects in the body of human, including renal, hepatic and respiratory problems as well as skin lesions [2].In industries like metallurgical industries, chromium metals are mostly and mainly used for ferro-alloys, manufacturing process[3].
In various industrial manufacturing processes chromium compounds are used such as, leather tanning, chrome plating, manufacturing of pigments as well as dyes, wood preservation process etc. and along with these processes arising the waste water which contains chromium in high level and which is very harmful for not only environment but also to the human health. Chromium use in extensive form has led to serious problems of water pollution[4]. Hexavalent chromium or Cr(VI), as one of the hazardous heavy metals, has attracted increasing attention due to its toxicity, carcinogenicity along with the threat to the health and safety of aquatic organisms. For removal of Cr(VI) from industrial waste the conventional techniques are used, include in this electro chemical treatment, chemical precipitation, ion exchange, membrane process, and also liquid extraction etc.[5].In this review paper summarizes, the literature which considering the various reaction conditions of adsorption along with metal ions initial

concentration, interaction time, adsorbent dose, and pH of the solution etc. Also, covered the adsorption capacities of various adsorbent materials used for removal of hexavalent chromium from wastewater.

FACTORS AFFECTING ON ADSORPTION OF CHROMIUM(VI) BY VARIOUS ADSORBENT MATERIALS:

In this review article make up the research paper considering the various conditions for adsorption together with initial concentration of metal ion, contact time, dose of adsorbent and pH of the solution etc. Also, summarizes the adsorption capacities of various modified as well as non-modified adsorbents for removal of chromium from aqueous medium.

Effect of pH

The pH is paramount variable of the adsorption system of Cr(VI) solutions. The factor pH on which the adsorption of Hexavalent Chromium depends, susceptibly,[6]. The results of pH effects of various adsorbent are given in Table No.1. The pH range for removal of Cr(VI) was best attain range in between 1-9. Henna indicated higher adsorption capacity for Cr was 545 mg/g along with pH range 9 [22].The increasing of pH is resulted the decreasing of the adsorption uptake. It is seen that for hexavalent chromium adsorption the acidic pH is more suitable. With the increasing pH, the adsorption capacity decreased. From all data given in Table no.1, shows that for most of adsorbents the suitable pH is 2 for adsorption of Hexavalent Chromium.

Effect of Initial Concentration

The removal percentage of Cr(VI) by various adsorbents tabulated in Table No.2 using different initial concentrations of Chromium. The initial concentration range is in between 15 mg/L – 100 mg/L. The Rice husk graphene oxidenanomaterial reported the maximum removal capacity was 943 mg/g shows at pH 4 [27]. Multiwalled carbon nanotube indicates minimum adsorption efficiency 1.5 mg/g, pH 4 at initial concentration 30 mg/L [32].

Effect of Adsorbent dose

In order to understand the effect of various adsorbent dosages on the adsorption of Hexavalent Chromium, experiments were carried with pH range in between 2-8 at room temperature. Different adsorbent materials with adsorbent dose were investigated in given Table No.3. The tabulated data indicate that maximum adsorption capacity was obtained at higher adsorbent dose, because of increase in surface area of adsorbent. Adsorbent dose indicated in the range between 0.5-5 g/L, in which Modified anion exchange resin (EDE-D301) shows high adsorption capacity 290 mg/g at adsorbent dose 0.6 g/L with pH 4.5[39].

Effect of Contact Time

Information in Table no.4 indicate that, the contact time have vital role in adsorption of Hexavalent Chromium. (GO-MS) nanosheet shows maximum adsorption capacity 438.10 mg/g in just 5 min at pH 2 [47].

Effect of Temperature

Generally, all researchers do their research experiments at Room Temperature, as it is suitable for easy work. Following Table no. 5 presented information about adsorption capacity at respective temperature.

ADSORPTION ISOTHERM AND KINETICS OF CHROMIUM:

Adsorption Isotherm

Adsorption isotherm followed by various adsorbents is given in Table No.6. Most of the adsorbent material followed Langmuir isotherm very well.

Kinetics

Following tabulated adsorbents in Table no.7 showed pseudo second order kinetics specifically.

Table No. 1 Effect of pH

Adsorbent	pH	Adsorption Capacity mg g-1	Ref
Orange peels	2	7.14	**[7]**
1. CM-DP (Chemically modified Date pit) 2. CM-OS (Chemically modified Olive stone	2	82.63 53.31	**[8]**
PANI@NC600	1	198.04	**[9]**
GO-CS@MOF [Zn(BDC)(DMF)]	3	144.92	**[10]**
Amino-functionalized MIL-101(AFMIL)	3.51	44	**[11]**
PAN/chitosan/UiO-66-NH2	3	372.6	**[12]**
Nano-FeOOH coating activated carbon	6.8	_	**[13]**

Graphene Coated Iron Oxide (GCIO) Nanoparticles	2.0	352.11	**[14]**
Fe-Fe2O3@PHCP magnetic Nanochains	2	229.0	**[15]**
α -Fe2O3@C nanocomposite	3	76.92	**[16]**
Aniline formaldehyde condensate (AFC) polymer	2-4	_	**[17]**
Bermuda grass activated carbon (BGAC)	2	403.23	**[18]**
Aerogel GO–COS	2	519.8	**[19]**
Polyethyleneimine cross-linked graphene oxide (GO-PEI)	2	436.20	**[20]**
Amino silaneegraphene oxide (GO) composites 1.pN- 2. psN- 3. pssN-GO	3	 189.47 208.22 260.74	**[21]**
Henna	9	545	**[22]**

Table No.2: Effect of Initial Concentration

Adsorbent	pH	Initial Concentratio Mg/L	Adsorptio Capacity mg g-1	Ref
Arginine-functionalized polyaniline/FeOOI (Arg-PANI@FeOOH) composite	2	100	682.30	**[23]**
Magnetic zeolite-Chitosan (MZC) composite	2	200	_	**[24]**
Biochar derived from municipal sludge	_	54.43-213.84	25.27	**[25]**
Natural zeolite based hollow fibre ceramic membrane (HFCM)	4	40	_	**[26]**
Rice husk-Graphene Oxide Nanomaterial	4	_	943.39	**[27]**
CNMs	2	50	_	**[28]**
Beads:- 1. Plain chitosan beads 2. Chitosan/β-cyclodextrin beads	4	 75 100	 400 555.56	**[29]**
Zn-MOF/chitosan (ZnBDC/CSC) composite	5	80	225	**[30]**
Vanadium pentoxide@chitosan @MOFs (V2O5@Ch/Cu-TMA)	3	15	_	**[31]**
CS/MWCNTs/ Fe	4	30	1.54	**[32]**

Table No.3: Effect of Dose

Adsorbent	pH	Dose	Adsorption Capacity mg g-1	Ref
Citric acid-incorporated cellulose nanofibrous mats	2	0.4 gm	_	**[33]**
Halloysite-bentonite clay/magnesite nanocomposite	8	0.5 gm	199	**[34]**
Aluminum hydroxide nanoparticles	5	1 g/L	120	**[35]**
Corn stalk-based activated carbon	4.5	2.5 g/L	89.5	**[36]**
Activated carbon from animal bone waste (Fe3O4-BAC)	3	5 g/L	27.86	**[37]**
Graphene oxide-magnetic (GO-Fe3O4)	2	0.1 g	3.197	**[38]**
Modified anion exchange resin (EDE-D301)	4.58	0.6 g/L	290	**[39]**

Table No.4: Effect of Contact Time

Adsorbent	pH	Interaction Time (Min)	Adsorption Capacity Mg g^{-1}	Ref
Date Palm Empty Fruit Bunch (DPEFB)	2	120	70.49	**[40]**
Super hydrophilic Co-AlLDH@Fe2O3/3DPCNF	2	60	400.40	**[41]**
Hydrolytically stable citrate capped Fe3O4@UiO-66-NH2 MOF	3	180	743	**[42]**
Polyaniline@magnetic chitosan Nanomaterials (PANI@MCTS)	2.0	15	186.6	**[43]**
Ion-imprinted polymers with Fe3O4 nanoparticles	2	50	201.55	**[44]**
Cassava sludge-based activated carbon	4.11	34.87	_	**[45]**
Chitosan grafted graphene oxide (CS-GO) nanocomposite	2	420	104.16	**[46]**
Graphene oxide-mesoporous silica (GO-MS) nanosheets IIPs (GO-MSN-AAPTS)	2	5	438.10	**[47]**
sludge-based adsorbents (SBAs)	2.5	60	15.3	**[48]**
Carbon nano-onions (CNOs)	7.0	24 Hr	23.529	**[49]**

Table No. 5: Effect of Temperature

Adsorbent	pH	Temp	Adsorption Capacity mg g-1	Ref
MNC@PmPDs	2	25^0 C	240.44	**[50]**
Ni0.6Fe2.4O4-UiO-66-PEI	3	25^0 C	428.6	**[51]**
MIL-100(Fe)	4.4	25^0 C	30.45	**[52]**
NGO3DH-MSSB	1.0	25^0 C	350.42	**[53]**
ZnO-GO nanocomposites	8.02	30^0 C	_	**[54]**
green algae	2	45^0 C	_	**[55]**

Table No.6: Adsorption Isotherm

Adsorbent	pH	Adsorption Capacity mg g-1	Isotherm	Ref
MIL-100(Fe)	2	30.45	Langmuir	**[56]**
MNC@PmPD2	_	240.44	Langmuir	**[57]**
1. 2D β-FeOOH nanobundles (NBs) 2.2D β-FeOOH nanobundles (NBs)	_	68.3 83.4	Langmuir Langmuir	**[58]**
Mim GO sponge GO Sponge EDA-GO sponge	2 2 2	208 123.5 126.6	Langmuir	**[59]**
The porous paper sludge-based activated carbon (psAC)	5.25	54.04	Elovich and Freundlich	**[60]**
Magnetized natural zeolite and polypyrrole (MZ-PPY) Composite	5	_	Both Yoon–Nelson and Thomas models	**[61]**
Gelatin and yeast materials (GeleYst)	1.0-2.0	500	Langmuir and D-R isotherm	**[62]**
Quaternary amine-grafted organosolv lignin (QA-g-OL)	2	_	Freundlich	**[63]**
a sludge-based biochar adsorbent 1.quenched biochar (Q-BC) 2.unquenched biochar (U-BC)	1	 291.54 91.46	Langmuir	**[64]**
Fe3O4@UiO-66@UiO-67/CTAB	2	932.1	Elovich	**[65]**

Table No. 7: Kinetics Study

Adsorbent	pH	Adsorption Capacity mg g-1	Isotherm	Ref
Magnetic natural zeolite-Polypyrrole (MZ-PPy) composite	2	434.78	Pseudo second order	**[66]**
Co-monomer Polymer (EDE-D301)	4.58	298.00	Pseudo second order	**[67]**
Graphene oxide/chitosan/ferrite (GCF) nanocomposite	2	270.27	Pseudo second order	**[68]**
Fabricated RGO- Hat hybrids	_	45.24	Pseudo second order	**[69]**
Amino-functionalized MIL-101(Cr), or AFMIL	3.9	44	Pseudo second order	**[70]**
Cu-BTC	7	_	Pseudo second order	**[71]**
ZIF-67 MOF@aminated chitosan composite beads	2	119.05	Pseudo second order	**[72]**

CONCLUSION

Removal of hazardous materials from waste water adsorption plays a very significant role.This review paper gives comprehensive information about adsorption of hexavalent chromium for waste water remediation using various adsorbent materials. In this review article reveals that, various adsorption capacities for various adsorbent materials. The results suggested that as time increases the adsorption capacity also increased. The equilibrium data were analyzed using the different Isotherm models from this Langmuir isotherm better fitted for most of the adsorbent materials. Adsorption kinetics was modeled by using the pseudo first and second order kinetic equation. In conclusion, the MOFs have broad application prospects in the removal of toxic and harmful pollutants like chromium in water based on its excellent structural characteristics. The tabular data gives the information of effect of initial concentration, pH, interaction time, temperature, adsorption isotherms and kinetics of chromium adsorption capacity with various adsorbents.

ACKNOWLEDGMENT:

Author expresses her gratitude to the Balwant College,Vita and DST-FIST, New Delhi for the support.

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CITATION OF THIS ARTICLE

P Shikalgar, P Ghatge, P Kumbhar, S Patil, S Kolekar, A Sartape. Adsorption of Hexavalent Chromium for Waste Water Remediation by Various Adsorbents - A Review Article. Bull. Env.Pharmacol. Life Sci., Spl Issue [1] 2022 : 189-196