



Removal of toxic metal ions from aqueous solutions using biosorption technique: Review article

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Abstract

The aim of this article is to review the biosorption of metal ions by different biosorbents, such as agriculture waste, fruit peels, industrial waste, fungi and alga. All these types were studied in this work using several parameters.

The maximum uptake of the metals (expressed by mg metal/g biosorbent) has been adopted as a criterion for the metal recovery efficiency. It has been concluded that pH is the most important parameters governing the efficiency of such process. This study is covering the literatures during the last two decades.

Keywords: toxicity, metals, biomass, biosorption, recovery, removal

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INTRODUCTION

The complexes between metal ions and bisorbents are formed due to several suggested mechanisms such as ion exchange, chemisorption and chelation according to the chemical and physical attraction.

Agriculture waste are potent materials as biosorbents due to their contents of starch, cellulose and lignin which contain variety of functional groups containing nitrogen, oxygen, sulfur and other atoms which differ in their ability to form metal complexes according to the related substituents binding with these atoms (Salah 2016). Different types of biomass were studied as biosorbents such as deactivated protonated veast (Padma 2006), malpighia emarginata seed (Wallas 2018), sugarcane bagasse (Luisa 2019), ginkgo leaf (Yaoyao 2018), combined fruit waste (Ugya 2019), Brassica Campestris stem (Rabia 2018; Rostami, & Balmaki, 2018).sawdust of Picea abies (Urík 2009), rice bran (Muhammad 2007), date palm leaf (Salah 2014), coconut shell powder (Gabriela 2006), tobacco dust (Qi 2008), spent tea and coffee dusts (Syam 2009), chestnut shell (Yao 2010). Heavy metals biosorption by different types of fruit peels were investigated, such as lemon peels (Amit 2010), Pomelo peels (Wanna 2009), grapefruit peels (Meisam 2013), orange peels (Ningchuan 2011). Ponkan mandarin peels (Flavio 2006).

Fungal species are very important in metal biosorption as eco-friendly methods due to their active components in the cell wall, such as glucans, chitins and chitosans. Mechanism of metals biosorption by both live or dead fungal are categorized as metabolism independent while metabolism dependent mechanism is happened according to the coupling between metals and extracellular metabolites products by transport the metal ion across the membrane of the cell (Ebrahim 2013).

Radioactive isotopes are the most dangerous environmental materials, so theremoval of such isotopes from the areas that relate to people's lives such as the sources of drinking water, is an interesting fact to the scientists working in the nuclear field and the environmental researchers. Some radionuclides were removed by Taraxacum Officinale (Fuks 2016). Different radioisotopes, like 233U, 144Ce, 95Zr and transuranium isotopes such as ²³⁹Pu, ²⁴¹Am, ¹⁴⁷Pm were removed by biomass Rhizopus arrhizus (Dhami 1998). radiostrontium and uranium biosorption by alginate beads (Cem 2013, Cem 2009), Radioactive thorium by sargassum filipendula (Martac 2006).

RESULTS AND DISCUSSION

Uptake of metal ion which is expressed by q_e (mg metal / g biosorbent) is considered as the measure of biosorption performance, it could be expressed as Eq. (1).

$$q_e = (C_o - C_e) \times V/m \tag{1}$$

Where:

Co = initial concentration of metal ion (mg/L). C_e = final concentration of metal ion (mg/L) V= solution volume (Litre).

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Biosorbent	lon	Metal ions uptake mg/gm	Notes	Ref.
Deactivated protonated yeast	Cd(II)	*20 **37.8 ***86.3	pH=6.5 Biosorbent dosage =1g/L * Metal ion conc.=25mg/L ** Metal ion conc.=50mg/L *** Metal ion conc.=100mg/L	Padma 2006
Malpighia emarginata seed	Cd(II) Cr(III) Cu(II) Ni(II) Pb(II) Zn(II)	0.125 0.115 0.090 0.085 0.092 0.125	pH = 8.0 particle size = (105 – 120 mm), stirring (300 rpm), Contact time=60 min Biosorbent dosage = 0.8 g / 100 mL	Wallas 2018
Sugarcane bagasse	Cd(II) Pb(II)	0.146 0.154	pH=5 Metal ion conc.=10 mg/L glass columns, with dimensions of 1.5 cm, height of 50 cm Flow rate through the column of 1.6 mL/ min. Particle size > 0.594 mm (mean fraction), bed height of 28 cm and 7.15 g of biomass for filling	Luisa 2019
Ginkgo leaf	Th⁺⁴	103.8	pH=4 Contact time, 120 min; Biosorbent dosage = 2 g/ L. Particle size=150-200 mesh Metal ion conc.=100 mg/ L monozite mineral conc. Of Th= 121.6	Yaoyao 2018

m = mass of the biosorbent (gram)

Metal uptake depends on the initial conce- ntration of metal ion, the higher the metal concentration, the more the metal uptake (2).

As shown in table-1, different biomass were used with different metal ions, especially those of transition metals such as Cu(II)

Ni(II), Cd(II), Zn(II), Cr(III), Co(II), Hg(II), Fe(II), Au(I), Cr(VI), V(V), and actinides such as U(VI), Th(IV), highly toxic metal such as Pb(II), Hg(II), As(III), As(V), lanthanide such as Ce(III), Eu(III) in addition to Se (VI).

Regarding to the living system, Heavy metals are classified into essential and nonessential metals. Those which contribute in the cellular functions are essential metals such as Ni, Cu, Co, Cr, Fe, Zn, which present at very low concentrations level (nanomolar) in the body, but up of that range, they will be toxic. Nonessential metals such as cadmium, lead and mercury are not required to the cell, so any concentrations of this type of metals, will cause real toxicity (Jan 2018, Rathoure 2016).

Many scientists were interested in the recovery of toxic metal such as (Cr(VI), Pb(II), Hg(II), As(III), The toxicity of arsenic (As) ion is according to the strong binding between this ion and sulfhydryl groups (SH) present in cysteine which is one of the types of amino acids that make up the final structure of protein by disulfide bond. this binding results in disturb the structure of protein and loss their functions (Benjamin 2018).

Mercury ion is considered as a highly toxic to human, it can damage the brain and kidney, also, neurotoxicity is caused by organic compound such as methyl mercury (Ramesh 2007). Cadmium (Cd⁺²) and lead (Pb⁺²) are very dangerous toxic metals which cause mental retardation encephalopathy. (Cd⁺²), (Pb⁺²) in addition to (Hg⁺²) are classified as soft acids which prefer to bind with soft base (according to HSAB theory) such as thiol group which is the main component of enzyme leading to disturb their functions (Glen 2012).

Chromium is an essential element in the body and has some functions, but if its concentration is high, then it behaves as very toxic. Cr(VI) is the most toxic form of chromium ions because of its reduction ability to pentavalent ion which damage the deoxyribonucleic acid. Toxic chromium is released by various industries environment such as tanning, textile, to the electroplating, and mining. Hexavalent chromium is genotoxic, it can cause cancer and DNA mutations by damaging genetic information. Biosorption technique can be used to remove Cr(VI) by Escherichia coli, bacillus subtilis, pseudomonas aeruginosa, hydrolyzed olive cake, waste crab shells and spent tea coffee dusts as seen in Table 1.

Toxic actinide such as uranium and plutonium can be separated by chemical process (Salah 2011, Husam 2011). Uranium is highly toxic element, either as radioactive isotopes or its considerable chemical reactivity. Because uranium emits alpha particles, it is considered as carcinogenic. Kidney is the sensitive target for uranium; it accumulates in the renal tubular causing cellular necrosis in the wall. Several forms of cationic uranium are known especially hexavalent and tetravalent ions and both are toxic but hexavalent is more toxic than the other one. Comparing between ingested and inhaled uranium, the inhaled is more danger to the human body than ingested (Salar 2006). As shown in Table 1, biosorbents such as pistia stratiotes lemna, ginkgo leaf, biocomposite adsorbent, Zoogloea ramigera and immobilized aspergillus fumigatus beads are considered as the best biomaterials to resolve the contamination of uranium toxicity.

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Biosorbent	lon	Metal ions uptake	Notes	Ref.
 Waste rind of <i>Citrulus lanatus</i> Waste peel of <i>Citrus sinensis</i> Their combination 	Cr(III) Pb(II)	mg/gm *5.35 **4.04	pH=2 *Combine Fruit Peel **Citrulus lanatus Biosopat dosogo – 50/100 ml	Ugya 2019
			Biosorbent dosage = 50/100 mi Pb ion conc. =10mg/l Cr ion conc.=15mg/l Contact time=60 min	
Brassica Campestris stem	Ni(II)	1.1	pH =4	Rabia 2018
	Cr(II) Pb(II)	95 78	contact time=60 min Biosorbent dosage = 1 gm/50 ml Pb ion conc.=120 ppm 250 rpm, and at 60_C°)	
Sawdust of Picea abies	As(V)	9.259	pH=8 120 c time Biosorbent dosage = 0,5 g/50ml metal ion conc. =90 mg/l, sawdust modified with ferric oxybydroxides	Urík 2009
Protonated rice bran	Ni(II)	*39.76 **66.80 ***68.70	PH=6 *untreated rice bran **HCl treated =4h ***HCl treated =12 h Metal ion conc. =100 mg/L Contact time= 12 h	Muha-mmad 2009
Iraqi palm tree leaves	Cu(II)	25	pH =5 palm leveas ash burned at 300 C° metal ion conc. = 100 mg/l Mixing time = 1 hr. Shaking rate= 300 rpm Particle size = 300 um	Salah 2014
Green coconut shell powder	Cd(II)	285.7	pH =7 Metal ion conc. =100 mg/l. Biosorbent dosage = 5 g/l. pH yelue: 7 Context time: 2 b	Gabrie-la 2006
Tobacco dust	Pb(II),	39.6	pH=6.5-7.2	Qi 2008
	Cu(II), Cd(II), Zn(II)	36.0 29.6, 25.1	Biosorbent dosage =1g/L	
Canada Tan	Ni(II)	24.5	-11.4	Cuerry 2000
Coffee Dusts	CI(VI)	44.9 **39.0	Biosorbent dosage = 3 g/L Metal ion conc. =30mg/l Cr(VI) reduction by both tea and coffee dusts *By tea	Syam 2009
Chestnut shell	Cu(II)	12.56	**By coffee dust pH=5 Metal ion conc =50mg/l	Yao 2010
lemon peel	Co(II)	22	pH=6 At 25 ∘C. Biosorbent dosage = 10.0 g/ L 10 h	Amit 2010
Pomelo Peel	Cd(II)	21.83	pH =5 Biosorbent dosage = 0.1 g/ 100 ml Metal ion conc.=50 mg/l At 24 hr	Wanna 2009
Grapefruit peel	Cd(II) Ni(II)	42.09 46.13	pH=5 Biosorbent dosage = 4 g/L Metal ion conc.=50 mg/L	Meisam 2013
Chemically modified orange peel	Pb(II) Cd(II) Ni(II)	476.1 293.3 162.6	pH= 5.5 Metal ion conc.=50mg/L modified orange peel by gratted copolymerization	Ningch-uan 2011
Ponkan mandarin peel	Ni(II) Co(II) Cu(II)	1.92 1.37 1.31	pH=4.8	Flavio 2006
Waste powdered activated sludge biomass	Cu(II) Ni(II)	18.9 13.5	pH=7.0 for Ni(II) and 3.0 for Cu(II) Contact time of 60 min Cu(II) and 120 min Ni(II)	Sukru 2018
Activated	Cd(II)	18.08	pH=4	Addag-alla
sludge.	Zn(II) Cu(II) Ni(II)	5.71 3.94 4.06	At temperature=20°C, Mixing speed=600 rpm, Solution Biosorbent dosage = 10/250 mL	2009ັ
Ficus benghalensis L.	Pb(II)	28.6	pH=6. Contact time=20 min, Adsorbent Size=75 micrometer Metal ion conc.=20mg/L Biosorbent dosage = 0.1 g/30mL	Venkates-wara 2013
Phosphorylated dry baker's yeast	Cd(II) Cu(II) Pb(II), Zn(II)	0.88 1.08 0.91 1.17	pH=12 Contact time=10 min Metal ion conc.=100 ppm Biosorbent dosage = 0.5 mg/mL	Yoshih-iro 2019

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Nill is set12.1 			164		
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Co(f) 15.471 PE(f) [or core_=8 mg/L in 120 min. 8.719 As(fII) (or core_=80 mg/L in 120 min. 7.866 Co(II) (or core_80 mg/L in 120 min. Iomass Cu(II) N(III) 20.82 of fungus Aspergillus niger 20.82 Biomass pretreated with NaxCO ₂ (0.2N) Shaling=150 pm Contract time-3 hr. Hydrolyzad olive cake Zn(II) 5.51 Cr(VI) 3.38 Continuous Biosorbent Biosorbent dosage = 1 gl Temp + 30° C Contact time-2 hrs. Pe(III) 15.21 PH=4.5. Head in core_200mg/L incore-end 00mg/Biosorbent disorbent dosage = 1 gl Temp + 30° C Contact time-2 hrs. Temp + 30° C Limma sp U(V) 0.0266 PH=4 Contact time - 60 min Ludmi-time-s 2 hrs. Temp + 30° C Contact time - 60 min. Ludmi-time-time - 20 hrs. Zoogloea ramigera U 40.7 PH=3.5 Set(V) 0.75 Set (PI = 3.0) Viayara Cr(VI) 0.54 Cr(VI) + 2.20 Viayara V(V) 0.79 V (3. 1 3	Pb(II), As(III)	39,212	Ha(II) ion conc.=40 mg/L in 120 min.	
Bit Product		Co(II)	15 471	Pb(II) ion conc =80 mg/L in 120 min	
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Biomass of fungus Aspergillus niger Culli, Nulli, Nulli, 20.62 pH=5.0 Biomass pretreated with Na_CO ₁ (0.2N) Shaking=150 rpm Contact time=3 hr. Contact time=3 hr. Pb(II) Refault Bacillus subtilis Fe(II) 7.25 pH = 4.5. Metal ion conc.=200 mg/L (except for C which equal 100 mg/L). Pb(II) Srileks-1 Metal ion conc.=100 mg/I Biosorbent Biosorbent dosage = 1 g/I Temp.= 30°C Srileks-1 Metal ion conc.=100 mg/I Biosorbent dosage = 1 g/I Temp.= 30°C Srileks-1 Metal ion conc.=100 mg/I Biosorbent dosage = 1 g/I Temp.= 30°C Srileks-1 Metal ion conc.=100 mg/I Biosorbent dosage = 0.1 Metal ion conc.= 0.05 mg/L Vilayara U udm/H Zoogloea ramigera U 49.7 pH= 3.5 0.5 gm/L Vilayara Biosorbent dosage = 0.15 g/I Equilibrium time=30 min. Temp.= 30°C Vilayara Biosorbent dosage 4.0 mg / 20 mil In mmol/g Hul 200 Se(V) 0.75 Se (P/H = 3.0) Cr (PH = 3.0) Cr (PH = 3.0) Hul 200 Se (V) Se concentration = 2.2 mmol/L. Cr (PH = 2.0) Kolish-k Se concentration = 7.7 mou/L. A 24hr at room temperature Kolish-k Se concentration = 6.2 mmol/L. Cr (Dift = 2.0) Kolish-k Se concentration = 7.7 mou/L. A 24hr at room temperature Kolish-k Se concentration = 7.7 mou/L. A 24hr at room temperature Kolish-k Se concentration = 7.2 mmol/L. Cr (Dift = 2.0) Ye courd Hetal ion conc.=100 mg/L. Cr (Dift = 2.0) Ye courd Hetal ion conc.=100 mg/L. Cr (Dift = 2.0) <td>D'a ser a se</td> <td></td> <td>7.850</td> <td></td> <td>1</td>	D'a ser a se		7.850		1
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backing submits Petrin 7.25 P	Paoillus subtilis	Fo(II)	7.25	nH- 4.5	Srilaka hmi 2010
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				*For live *for dead	

CONCLUSION

- 2- It is considered as cheap and easy method.
- 1- Biosorption technique is classified as eco-friendly because it does not need to use environment harmful detergents.
- 3- Agricultural and industrial waste can be invested by biosorption technique as the aim of materials decontamination.

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- 4- Increasing the initial metal concentrations is important to get better metal uptake.
- 5- Pretreated biomass is mostly more efficient than untreated

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