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Heavy Metal Removal Efficiency of Tulsi *(Ocimum Sanctum)* from Water – A Review

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Abstract: *Presence of heavy metal concentration in water is generally resulting from industrial pollution. Certain amount of some metals in water is good for human health but their elevated concentration in water is toxic for us as it causes irreversible damage to the organs. Therefore it is essential to monitor concentration of metals in water and to adopt proper mitigation measures to remove their excess concentration. Adsorption is one of the economic and environmental friendly methods to remove metal contamination from water and many bioadsorbents are used for the purpose. This review will focus on ability of a medicinal plant Tulsi (Ocimum Sanctum) to remove heavy metals (Pb, Cd, Cr, Fe, Cu, Zn) from water.*

Keywords: Heavy metal, Toxic, Adsorption, Bioadsorbents, Ocimum Sanctum

I. INTRODUCTION

Industrial growth is essential for a country's development but it also causes a lot to environment. Addition of heavy metals to water bodies due to the industrial activities has become a major global concern. Discharge of effluents from Mining, mineral processing and metallurgical operations are the main source of addition of heavy metals to the water bodies [1]. The heavy metals once enter in the water system persist there for long duration due to its non-degradable nature and easily entered in human food chain through aquatic environment. Once they entered in living cells, they can be bioaccumulated and can cause severe health issues because they are harmful even though present in small concentration in the human body. Gastrointestinal and kidney dysfunction, vascular damage, immune system dysfunction, nervous system disorders, skin lesions, birth defects and cancer are some of the complications arises due to heavy metals toxic effects [2]. Therefore removal of heavy metals from water is essential for good human health. The common methods which are used for removal of heavy metals from water are adsorption [3,4], ion exchange [5, 6], chemical precipitation [7,8], membrane filtration [9, 10], reverse osmosis [11, 12], solvent extraction[13] and electrochemical treatment [14, 15]. But some of the methods required special techniques and some are very expensive which limits their use for removal of metals from water.

Adsorption is one of the effective methods for the purpose because this method is easy to operate with high efficiency and low cost [16]. The adsorbants such as carbon foam [17], activated carbon [18], zeolite [19], clay minerals [20, 21], organic polymers [22], and biochar [23], fly ash [24], reused sanding wastes [25], biomass [26], and water treatment residuals (WTRs) [27, 28], have been used for the removal of heavy metals by adsorption. Out of all these adsorbants, bioadsorbants are very important as they are the economic technology for removal of heavy metals from water and waste water. Both terrestrial and aquatic plants can be used for this purpose. Many researchers investigated heavy metal accumulation ability of medicinal plants such as *Acacia nilotica* (Babool), *Bacopamonnieri* (Brahmi), *Commiphorawightii* (Guggul), *Ficusreligiosa* (Peepal), *Glycyrrhizaglabra* (Mulethi), *Hemidesmusindicus* (Anantmul), *Salvadoraoleoides* (Jaal, Pilu), *Terminaliabellirica*(Bahera), *Terminaliachebula* (Harītak, Harad) and *Withaniasomnifera* (Ashwagandha) and results showed that they can be used for removal of heavy metals from aquatic environment [29 -32]. Utilization of adsorption capabilities of a medicinal plant for water purification is one of the cheapest and safe methods. Therefore this paper will focus on heavy metal removal ability of Tulsi (*Ocimum Sanctum*) from water.

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II. METHOD

The present study is a literature review addressing the ability of Tulsi plant of removal of heavy metals from water which can be an economic and easy method for purification of water. This ability of plant depends on pH of the medium, adsorbant dose, contact time between the adsorbate and adsorbent and concentration of metal. This systematic literature search was conducted using the Google search engine to access online academic publications indexed in Google Scholar, PubMed, Scopus and Web of Science.

Heavy Metal Pollution of Aquatic Environment

Water resources are generally polluted by the heavy metals through the effluent coming out from many industries such as fertilizer, electroplating, dye, pesticides, mining industries etc. When this polluted water enters in human food chain, these heavy metals entered in human body and when their concentration increases gradually and cross the safe limit they creates several health issues out of which some are life threatening. Therefore removal of these heavy metals from aquatic environment is essential for healthy life. The source of pollution of these metals and their effect on human health is mentioned in the Table 1.

Table 1: Heavy metal pollution and their effect on human health

Metal pollutant	WHO Permissible limit mg/L [33]	Source	Health effects	Reference
Pb	0.05	Industries such as mining, steel, automobile, batteries and paints, pesticides, leaded gasoline, and mobile batteries	Nausea, Encephalopathy, Headache and vomiting, Learning difficulties, Mental retardation, Hyperactivity, Vertigo, kidney damage, Birth defects, Muscle weakness, Anorexia, Cirrhosis of the liver, Thyroid dysfunction, Insomnia, Fatigue, gastrointestinal tract, damage to joints, reproductive system, and nervous system.	[34]
Cd	0.003	Smelting, metal plating, cadmium-nickel batteries, Phosphate fertilizers, pigments, alloy industries and copper refineries, petroleum products refineries, pesticides, plastics, polyvinyl and galvanized pipes production.	Hypertension, dulled sense of smell, anaemia, joint soreness, dry scaly skin, loss of hair and appetite, low production of T cells and, weak immune system, damage of kidney and liver, emphysema, and cancer	[35]
Cr	0.05	Electroplating, leather tanning, and textile industries, mining and metal works, steel and metal alloys production, paint manufacturing, wood and paper processing, dyeing industries	Liver and kidney damage, internal haemorrhage and respiratory disorders, carcinogenic to humans	[36]
Fe	0.30	Steel and iron industries	Fatigue, weight loss, and joint pain, stomach problems, nausea, vomiting, and other issues.	[37]
Cu	1.0	Production of wires for various industries such as electrical industries, automotive, and electronic appliances	Nausea, vomiting, diarrhoea, gastric (stomach) complaints, headaches and liver damage.	[38]

Zn	3.0	Municipal wastewater releases, coal-burning power plants; industrial methods involving metals; and atmospheric outcome	Vomiting, pain in stomach, decreased resistance power, cardiovascular effects, carcinogenic effects	[39]

So accumulation of these heavy metals in body can cause a lot to human health and drinking water is the main source of these metals for human beings. Therefore removal of heavy metals from water is very important for us. This paper will focus on removal of heavy metals Pb, Cd, Cr, Fe, Cu and Zn by medicinal plant Tulsi.

Tulsi (*Ocimum Sanctum*)

Ocimum Sanctum commonly known as Tulsi or Holy Basil is a member of Lamiaceae family (Table 2) and is very useful for its therapeutic potentials. Commonly available two varieties of Tulsi are black (Krishna Tulsi) and green (RamaTulsi); their chemical constituents are similar [1].

Table 2: Scientific Classification of *Ocimum Sanctum*

Kingdom	Plantae
Subkingdom	Tracheobionta
Class	Magnoliopsida
Order	Lamiales
Division	Magnoliophyta
Super division	Spermatophyte Seed plants
Genus	*Ocimum* L.
Species	O. tenuiflorum
Family	Lamiaceae
Binomial name	*Ocimumtenuiflorum* or *Ocimum sanctum* L.

Tulsi plant is used for its medicinal properties from 4000-5000 B.C and Chinese were first to use it as medicine [1]. Different parts of the plant (leaves, stem, flower, seeds) are used as medicines for the treatment of bronchitis, malaria, diarrhea, dysentery, skin disease, arthritis, eye diseases, insect bites and so on. The plant has also been suggested to possess anti-fertility, anticancer, antidiabetic, antifungal, antimicrobial, cardioprotective, analgesic, antispasmodic and adaptogenic actions. The active constituent 1-hydroxy-2-methoxy-4-allylbenzene (Figure 1), commonly known as Eugenol present in the plant is mainly responsible for its therapeutic actions [40].

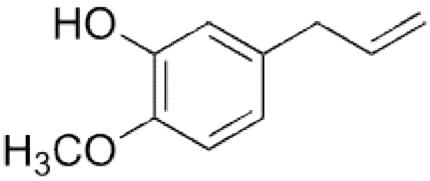

Fig. 1: Eugenol (1-hydroxy-2-methoxy-4-allylbenzene)

Researchers used this medicinally important plant as bioadsorbant for the removal of heavy metals from water and the result obtained by them is discussed further in this paper (Table 3).

III. Result

3.1 Adsorption of Heavy Metals by Tulsi

Tulsi plant is found throughout the eastern world tropics and well known for its medicinal as well as spiritual properties (Bast et al., 2014). This paper will discuss the metal adsorption properties of Tulsi which indicates that it can be used for removal of heavy metals from water. For this purpose researchers used Tulsi leaves alone as well as Tulsi leaves with combination of other adsorbent and achieve good results (Table 3).The rate of adsorption is affected by many factors such as adsorbent dose, contact time, initial concentration of metal ion, pH etc. which are discussed one by one in this paper.

3.2 Factors Affecting Adsorption Process

A. Effect of Adsorbent Dose

Adsorbent dose reflects the surface area which is available for adsorption. For lead [1, 42], cadmium [43] and iron [1] 3g and for chromium [43] 2g of Tulsi leave powder exhibit maximum adsorption capacity (Table 3). For copper maximum removal was obtained when Tulsi leaves were taken in combination with Methi leaves and Lemon leaves in 90:10 and 70:30 ratio respectively [45]. Similarly for zinc maximum removal efficiency was found for Calotropis Procera & Tulsi leaves and Custard Apple &Tulsi leaves combination in 60:40 and 80:20 ratios [45].

B. Effect of Contact Time

Contact time between adsorbent and adsorbate plays an important role in removal of metal ions by bioadsorbents. Maximum adsorption of metal ions were obtained in 180 minutes for lead [1, 42] and cadmium [1], 90 minutes for chromium [43] and 180 minutes for iron [1] when Tulsi leaves were taken alone as adsorbent (Table 3). For copper maximum removal was obtained when Tulsi leaves were taken in combination with Methi leaves and Lemon leaves in one day and ten days respectively whereas for zinc maximum removal efficiency was found for CalotropisProcera&Tulsi leaves and Custard Apple &Tulsi leaves combination in ten days and five days respectively [45].

C. Effect of Metal Ion Concentration

With increase in metal ion concentration removal efficiency increases as more and more ions are available for adsorption but after reaching to optimum dose of metal ion, the ratio of number of active sites and concentration of metal ion reduces which in turn reduces the removal efficiency. Optimum metal ion concentration for lead and cadmium were 10 mg/L [42], for chromium 25 mg/L [43] and for iron 1.82 mg/L [1] when Tulsi leaves were taken alone as adsorbent in batch mode of adsorption (Table 3). When Tulsi leaves powder and aluminium hydroxide is taken in combination in column mode of adsorption then this combination exhibit optimum concentration of chromium and iron 0.536 mg/L and 0.289 mg/L respectively for maximum removal [44].

D. Effect of pH

Particular pH of the solution is very important in adsorption of metal ion as pH indicates the competition of hydrogen ions with metal ions to occupy the active sites of adsorbent. It is evident from Table 3 that lead [1] exhibit maximum adsorption at pH 8 whereas chromium [43] and iron [44] exhibit maximum adsorption at pH 2 when Tulsi leaves are used as bioadsorbents alone in batch mode of adsorption but when Tulsi leaves powder is taken with aluminium hydroxide in combination in column mode of adsorption then this combination exhibit maximum removal of chromium and iron at pH 7.6.

E. Metal ion Removal Efficiency of Tulsi

It is evident from Table 3 that Tulsi leaves can efficiently remove 80 to 95% of lead ion [1, 42], 60% of cadmium ion [42] and 73.6% of iron [1] from water in batch mode of adsorption. When Tulsi leave powder and aluminium hydroxide is taken in combination in column mode of adsorption, it exhibit 93.77% removal efficiency for chromium but exhibit only 30.5% removal efficiency for iron [44].

When Tulsi leaves were taken in combination with Methi leaves and Lemon leaves, maximum removal efficiency of copper was obtained as 86.28% and 73.65% respectively whereas for zinc maximum removal efficiency was found for Calotropis Procera &Tulsi leaves and Custard Apple &Tulsi leaves combination as 71% and 79.61% respectively [45].

Table 3: Comparative study of removal of heavy metals from water by Tulsi plants

S. No.	Heavy metal	Parts of plant used	Water type	Adsorbent dose	pH	Conc. of ion	Contact time	Removal efficiency (%)	Reference
1	Pb	Leaves	food wastewater	3g	-	10 mg/L	180 min	80	[42]
	Cd	Leaves	food wastewater	3g	-	10 mg/L	180 min	60	
2	Cr	Leaves	Synthetic water	2 g	2	25 mg/L	90 min	23	[43]

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			samples						
3	Fe	Leaves	Synthetic water samples	3 g/50 ml	2	1.82 mg/L	210 min	73.62	[1]
	Pb	Leaves	Synthetic water samples	3 g/50 ml	8		180 min	95.63.	
4	Fe	Tulsi leaf powder + Aluminium hydroxide	Pharmaceutical waste water samples	Filter bed depth 12 cm	7.6	0.536 mg/L	-	30.597	[44]
	Cr	Tulsi leaf powder + Aluminium hydroxide	Pharmaceutical waste water samples	Filter bed depth 12 cm	7.6	0.289 mg/L	-	93.77	
5	Cu	Tulsi+Methi	Synthetic waste water sample	90:10	-		01 day	86.28	[45]
	Cu	Tulsi+Lemon	Synthetic waste water sample	70:30	-		10 days	73.65	
	Zn	CalotropisProcera + Tulsi	Synthetic waste water sample	60:40	-		10 days	71	
	Zn	Custard Apple + Tulsi	Synthetic waste water sample	80:20	-		05 days	79.61	

IV. CONCLUSION

Tulsi which is generally known for its medicinal properties is also having good efficiency for removal of metal ions such as lead, cadmium, chromium, iron, copper and zinc. Although the removal efficiency of Tulsi leaves for chromium is less in case of batch mode of adsorption but it increases when Tulsi leaves were taken in combination with aluminium hydroxide in column mode of adsorption. Various combination of Tulsi leaves with Methi leaves, Lemon leaves, CalotropisProcera and Custard Apple leaves also exhibit appreciable removal efficiency for metal ions such as copper and zinc. Therefore it is clear that Tulsi leaves can be used for removal of heavy metals from water. Combination of Tulsi leaves with leaves of other plants or adsorbents also enhance its metal ion removal efficiency in batch and column mode of adsorption. The water treated by Tulsi can be used for drinking purpose without any harm because of its medicinal properties. Hence this biomass is very useful for removal of heavy metals from water because it is easily available, has ability of adsorption of more than one metal ions, its use is safe, environment friendly and cost effective.

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