Adsorption of Heavy Metals on Waste Tea Leaves: A Review

Hnin Yu Win[1]

Abstract

Heavy metal pollution is one of the environmental problems of global concern. The most important toxic metals found in industrial wastes include copper, cadmium, chromium and nickel. These metals can be toxic to organisms including humans even at low concentrations. Various methods are available for the removal of metal ions from aqueous solutions and adsorption is one of an effective purification used in industry especially in wastewater treatment. Moreover, in recent years, spent tea leaves or tea factory wastes have been reported to have potential to remove heavy metal pollutants. This paper reviews the potential of waste tea leaves as an adsorbent for the removal of toxic metals.

keywords: metal ion, waste tea

Introduction

Water pollution is the contamination of water bodies such as lakes, rivers, oceans, or ground water. Water pollution affects organisms and plants that live in these water bodies and in almost all cases it affects not only individual species and populations but also the natural biological communities. Water pollution occurs when contaminants are discharged directly or indirectly into water bodies without suitable treatment to remove harmful constituents. (Agrawal, et al. 2010)

Heavy metals include copper, silver, zinc, cadmium, gold, mercury, lead, chromium, iron, nickel and etc. Some heavy metals such as iron, cobalt and zinc are essential nutrients and some heavy metals such as ruthenium, silver and indium are relatively harmless but can be toxic in larger amounts or certain forms. Other heavy metals such as cadmium, mercury, and lead are highly poisonous. Heavy metal pollution is one of the environmental problems of global concern. The important heavy metals such as lead, copper, cadmium, zinc and nickel are among the most common pollutants found in industrial wastes and constitute the major source of various kinds of metal pollution in water.

A number of methods are available for the removal of metal ions from wastewater. These includes ion exchange[1], solvent extraction[2], reverse osmosis, electrodialysis[3], precipitation[4], flocculation[5], sorption[6], activated carbon adsorption and membrane separation processes[7]. Adsorption is one of an effective purification techniques used in industry especially in wastewater treatment. In recent years, the use of low-cost adsorbents, derived from agricultural residues or industrial by-products having biological activities have been developed and applied for the removal of heavy metals from metal-polluted water. Cell walls of tea leaves are made up of cellulose, hemicellulose, lignin and tannins. The functional groups from these constituents should be good potential as metal scavengers.

Tea-drinking and tea-eating is a part of Myanmar culture. Myanmar is one of the countries that cultivate best tea in the world. Myanmar is one of very few countries where tea is eaten as well as drunk. There is a saying in the country, "If it's meat, it's pork; if it's fruit, it's mango, if it's leaves, it's tea." Tea plantations in the country are mainly found in Northern Shan state, Southern Shan state, Kachin state and Chin state. The total tea plantation area is around 70,000 hectares with an annual production of 78 million kg green leaves. More than half of the total output is from Namhsan area, Northern Shan state.

There are different tea plucking standards: for instance, top tender buds for Silver Needle White tea, top bud and one leaf for Gold Needle Black tea and one bud and two leaves

[1] Associate Professor, Dr., Department of Chemistry, University of Mandalay

for high quality green tea and so on. Tea leaves are harvested manually with strict adherence to plucking standard. Nowadays, Myanmar people do not value good tea as much as they should. There are many tea shops in Myanmar and these shops have been using low quality tea leaves to serve green tea for customers. Local tea producers are now trying to raise local market and enter International markets. Therefore, high quality tea leaves must be collected by tea producers to make it possible for Myanmar tea to penetrate the International market. During tea harvesting, some overgrown woody shoots can be mixed in the tea harvest. In the tea production, this woody overgrown shoots will not be treated by tea factory and formed into tea factory waste. This paper reviews the potential of waste tea leaves as an adsorbent for the removal of toxic metals.

Preparation of Adsorbent

According to Malkoc et al., prior to the experiments, other soluble dirtiness and colored components were removed from tea waste by washing with distilled water for several times until a colorless solution of tea waste was spectrometrically observed at room temperature. Decolorized and cleaned tea waste was dried at room temperature for a few days.[8]

According to Cay et al., hydrolysable tannins and other soluble and colored components were removed from the tea wastes by washing with hot water at 80 °C until a colourless solution was spectrometrically observed at room temperature. A colourless solution of tea waste is normally observed in 15 washing cycle with hot water (80 °C).[9]

Characterization of Waste Tea Leaves

The physical and chemical characteristics such as moisture, water soluble components, insoluble components, ash, surface area, bulk density, particle size were done according to the standard procedure.

Table 1. Physical and chemical properties of waste tea[8,9]

Chemical characteristic	**Percent**	
	Cay et al.,	Malkoc et al.,
	Tea processing plants located in black sea region in Rize, Turkey	Tea plants located in black sea region in Giresun-Eynesil, Turkey
Moisture	11.01	11.01
Water soluble components	6.04	6.04
Insoluble component	80.24	80.24
Ash	2.97	2.97
Physical characteristic	-	-
Surface area (m^2/g)	-	0.39
Bulk density (kg/m^3)	328	113
Particle size (mm)	-	0.15-0.25

Effect of Solution pH

The most important parameter influencing the adsorption capacity is the pH of adsorption medium. To study the effect of pH on the biosorption of nickel (II) ions onto waste tea, the batch adsorptions were carried out in the pH range of 2.0-5.0. Malkoc et al., found that the maximum adsorption of nickel (II) ions was observed at pH 4.0 and the adsorption is significantly decreased when the pH is reduced to 2.0. At lower pH value, the H^+ ions compete with metal cation for the exchange sites in the system and thereby adsorption sites of waste tea for metal cation is decreased. Decrease in adsorption at higher pH is also due to the formation of soluble hydroxyl complexes.[8]

According to Cay et al., the adsorption percentages were found to be very low at strong acidic medium. After pH 3, the uptake amount of metal by waste tea increases sharply up to pH 5.5 and afterward they stay almost constant for greater pH. pH values over 8.0 were not studied since precipitation of heavy metals occurs. The optimum pH for Cu(II) and Cd(II) ion was found to be pH 5.5.[9]

Table 2. Effect of pH on Adsorption of Metals onto Tea Wastes[8,9]

References	Metal	Contact Time	Adsorbent Dose	pH range	Optimum pH
Cay et al.	Cu, Cd	1 hr	1g/L	1-8	5.5
Malkoc et al.	Ni	2 hr	10g/L	2-5	4
Malkoc et al.	Cr	1 hr	10g/L	2.5	2

Malkoc et al. discussed the concept of zeta potential to understand the effect of pH on the adsorption of Ni onto tea waste. The electrical potential at the surface of a particle is called zeta potential. It can be determined by the measurement of the velocity of particles in the electric field. At pH 3.0, 4.0, 5.0, 6.0 and 7.0 the zeta potentials of tea waste were found to be -14.5, -23.8, -22.5,-21.5 and-19.5 mV, respectively. The zeta potential values could not be measured due to the high ionic strength at pH 2.0. All samples indicated negative charge values that should be favorable to the attraction between active sites and positive charges of metal ions, resulting in electrostatic interaction. The tea waste at pH 4.0 gave the greatest zeta-potential value and this measurement indicated that negatively charged species present are in waste tea resulting in the electrostatic interaction between active sites and metal ions.[8]

Effect of Adsorbent Dosage

Effect of the dose of tea leaves wastes on metal adsorption was studied at fixed pH. Malkoc et al. investigated the effect of adsorbent dosage on removal of Ni (II) ion at pH of 4.0 and 200 mg/L initial Ni (II) ion concentration. Cay et al. studied the effect of dose of tea leaves wastes on removal of Cu (II) and Cd (II) ions from aqueous solution at pH 5.5 and 5 ppm initial concentrations. The total amount of metal ions removed from the solutions increases by increasing the amount of adsorbents as expected. This is due to the increase in the number of adsorbent particles surrounding the metal ions or ratio of adsorbent particles to metal ion. At the higher dosage of sorbent, the surface area increases and more adsorption sites are available for metal ions.[8,9]

Table 3. Effect of adsorbent dose on adsorption of metals onto waste tea leaves[8,9,10,11]

References	Metal	Contact Time	pH	Dose Range	Optimum Dose
Cay et al.	Cu, Cd	1 hr	5.5	0.2-4 g/L	1g/L
Malkoc et al.	Ni	2 hr	4	5-15 g/L	10 g/L
Malkoc et al.	Cr	1 hr	2	5-15 g/L	-

Effect of Agitation Rate

Malkoc and Nuhoglu studied the effect of agitation rate on the adsorption. The experiment was performed with a magnetic shaker at pH 4.0 and initial Ni(II) concentration of 100 mg/L. The agitation speed was varied from 3.0 to 8.0 rps (180, 360, 480 rpm). When agitating rate was increased from 180 to 480 rpm, adsorption capacity of waste tea increased from 7.89 to 8.59 mg/g. The removal efficiency increased weakly with increasing agitation rate because an agitation rate of 150 rpm was enough to remove nickel. When the agitation speed was increased from 180 to 480 rpm, the removal of Ni(II) ion increased from 78.9% to 85.9%.[8]

Effect of Temperature

Malkoc and Nuhoglu presented the effect of temperature on the adsorption of Ni(II) ions onto tea waste. When the temperature is increased from 25 to 60 °C, the sorption capacity for initial metal concentration 300 mg/L increased from 14.04 to 17.1 mg/g. The effect of temperature is fairly common and increasing the mobility of the metal cation. Furthermore, increasing temperatures may produce a swelling effect within the internal structure of the tea waste enabling metal cation to penetrate further.[12] At 25 °C for a nickel concentration of 50 mg/L after a 60 min of sorption time, while nickel concentration was measured as 5.87 mg/L, for 60 °C no nickel remained.

Conclusion

Waste tea was used for the removal of toxic metals such as Ni, Cu, Cd and Cr. The characterization of waste tea leaves revealed the high surface area for adsorption. Effect of pH, agitation rate, dose of adsorbent and temperature of metal adsorption onto tea waste were studied by various authors. According to the results, the waste tea could be used as a potential adsorbent for the removal of heavy toxic metals from industrial wastewater.

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