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Sushil Bachale
M-Tech., Dept. of Chemical Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh, India.

Dr. Sarita Sharma
Associate Prof., Dept. of Chemical Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh, India.

Dr. Ashok Sharma
Associate Prof., Dept. of Chemical Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh, India.

Dr. Sanjay Verma
Associate Prof., Dept. of Chemical Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh, India.

Correspondence
Sushil Bachale
M-Tech., Dept. of Chemical Engineering, Ujjain Engineering College, Ujjain, Madhya Pradesh, India.

Removal of lead (II) from aqueous solution using low cost adsorbent: A review

Sushil Bachale, Dr. Sarita Sharma, Dr. Ashok Sharma and Dr. Sanjay Verma

Abstract
This review paper presents the various low cost adsorbents for the removal of lead (II) from contaminated water. If high concentration of lead present in aqueous solution causes many health diseases and it is toxic for human's body systems i.e. skeleton, nervous and digestive system. The lead level must be maintained at certain limits. According to World Health Organization the permissible limit of lead concentration in drinking water is 0.01mg/lit. Low cost adsorbent used in adsorption process for removal of lead from contaminated water. It is easily available in our environment. Adsorption process is simple and cost effective method for removal of lead from contaminated water by using several low cost adsorbents.

Keywords: Polypyrrole, adsorbent, adsorption process, lead, aqueous solution

1. Introduction

Metals and their compounds are indispensable to the industrial, agricultural, and technological advancement of any nation. The numbers of applications of metals for commercial uses continue to grow with the developments in modern science and technology (Badmus *et al*., 2007) [3]. Lead is one of the heavy metals that are often found in industrial wastewater and its discharge into the environment poses a serious threat due to its toxicity to aquatic and terrestrial lives. It is a group IV element on the periodic table which is remarkably highly resistant to corrosion in most acid and naturally occur as element buried in the earth crust in insoluble and biologically inoffensive forms (Ogunleye *et al*., 2014) [19].

Among the different heavy metals, lead is one of the common and most toxic pollutants into the natural waters from various industrial activities such as metal plating, oil refining (Yarkandi, 2014) [33] and manufacturing of storage batteries, television tube, printing, paints, pigments, photographic materials, gasoline additives, matches and explosives brought about lead bearing wastewater (Patterson J.W. 1985) [22]. Lead contamination of the environment is primarily due to anthropogenic activities, making it the most ubiquitous toxic metal in the environment (Badmus *et al*., 2007) [3].

Nearly 100 countries, mostly developing, still use leaded petrol. Evidence from Europe, Japan, Mexico, and the USA suggests that phasing out leaded petrol is the most effective way of reducing the general population's exposure to lead, although other sources are also important (Silbergeld E., 1995) [27]. Many developing countries have been actively engaged in lead reduction programmes, particularly in respect of leaded petrol, "the mistake of the twentieth century". Bangladesh, China, Egypt, Haiti, Honduras, Hungary, India, Kuwait, Nicaragua, Malaysia, and Thailand have, for example, made dramatic efforts to phase out leaded petrol in recent years. Success in this endeavour requires government commitment, incentive policies, a broad consensus among stakeholders and public understanding, acceptance and support (Lovei M., 1999) [14].

Exposure to Lead is widely recognized as a major risk factor for several human diseases once it goes beyond the World Health Organisation (WHO) maximum permissible limit (3-10$\mu g \cdot L^{-1}$) in drinking water (Needleman H.L. *et al*., 1999) [17]. It forms complexes with Oxo-groups in enzymes to affect virtually all steps in the process of haemoglobin synthesis and porphyrin metabolism. Other problems associated with toxic levels of lead exposure are encephalopathy, seizures and mental retardation, anemia and nephropathy.

Hence, lead must be removed as much as possible from industrial effluents to prevent environmental hazard from its discharge (Ogunleye *et al*., 2014) [19].

Adsorption of metal ions by several functionalized polymers based on amines derivatives such as ethylenediamine, polyacrylamides, poly-4-vinylpyridine, polyethyleneimine and aniline formaldehyde condensate has been reported. Polypyrrole was used in the removal of fluoride ions from aqueous solution by conducting Polypyrrole. Conductive polymers such as polyaniline, polypyrrole, and polythiophene, have attracted so much research interest in wide range applications such as rechargeable batteries, electromagnetic interference (EMI) shielding, antistatic coatings, gas sensors, optical devices and removal of heavy metals (Reyad 2015) [24].

1.1 Sources of lead in the environment

Unlike overt lead toxicity, where there is usually one identifiable source, low-level environmental exposure to lead is associated with multiple sources (petrol, industrial processes, paint, solder in canned foods, water pipes) and pathways (air, household dust, street dirt, soil, water, food). Evaluation of the relative contributions of sources is therefore complex and likely to differ between areas and population groups (Schirnding YE.V., 1999) [28].

2. Health Effects of Lead Containing Water

Exposure to lead can have a wide range of effects on a child's development and behaviour. Blood lead levels less than 10 micrograms per decilitre (μg/dL) are associated with increased behavioural effects, delayed puberty, and decreases in hearing, cognitive performance, and postnatal growth or height. Some of these health effects are found even at low blood lead levels less than 5μg/dL, including lower IQ scores, decreased academic achievement and increases in both behavioural problems and attention related behaviours. [35]

2.1 Lead and children

Many researchers have been conducted recently on children with moderately raised blood lead levels associated with environmental exposure. The potential for adverse effects of lead exposure in children is heightened because:

1. Intake of lead per unit body weight is higher for children than for adults.
2. Young children often place objects in their mouths, resulting in dust and soil being ingested and, possibly, an increased intake of lead.
3. Physiological uptake rates of lead in children are higher than those in adults.
4. Young children are undergoing rapid development, their systems are not fully developed, and consequently they are more vulnerable than adults to the effects of lead (Tong S., *et al* 2000) [32].

Lead exposure has been linked to a number of health effects in adults. As a general rule, the more lead you have in your body, the more likely it is you'll have health problems. High blood lead levels greater than 15μg/dL are associated with cardiovascular effects, nerve disorders, decreased kidney function, and fertility problems.

Table 1: Health Effects of lead on Human Health. (Links)[35]

Blood Lead Level	Health Effects
Blood lead levels below 5μg/dL	**Children:** Decreased academic achievement, IQ, and specific cognitive measures; increased incidence of problem and attention-related behaviours **Adults:** Decreased kidney function, maternal blood lead associated with reduced fetal growth
Blood lead levels below 10μg/Dl	**Children:** Delayed puberty, reduced postnatal growth, decreased IQ and hearing **Adults:** Increased blood pressure, risk of hypertension, and incidence of essential tremor

3. Adsorption

The adsorption technology involving the removal of toxic metals from wastewaters has directed attention to adsorption. The ability of biological materials to accumulate heavy metals from wastewater through metabolically mediated or physico-chemical pathways of uptake Algae, bacteria and fungi and yeasts have proved to be potential metal adsorbent. (Prabhakar and Rao., 2014) [25].

4. Removal of Lead Using Low Cost Adsorbents

4.1 Lead Remediation by Adsorption

Adsorption is considered one of the most efficient technologies for Lead removal in drinking water when compared to other technologies for Lead removal based on initial cost, flexibility and simplicity of design, and ease of operation and maintenance. The efficiency of this technique mainly depends on adsorbents (Stoica Ligia *et al.*, 2012) [31].

Adsorption depends on ions (adsorbate) in fluid diffusing to the surface of a solid (adsorbent), where they bond with the solid surface or are held there by weak intermolecular forces.

Adsorption of Lead on to solid absorbent usually occurs through three phases:

1. diffusion or transport of Lead ions to the external surface of the adsorbent from bulk solution across the boundary layer surrounding the adsorbent particle, called external mass transfer;
2. Adsorption of Lead ions on to particle surfaces;
3. The adsorbed Lead ions probably exchange with the structural elements inside adsorbent particles depending on the chemistry of solids, or the adsorbed fluoride ions are transferred to the internal surfaces for porous materials (intra particle diffusion). (Stanić Mirna Habuda *et al.*, 2014) [30].

Several adsorbent materials have been tried in the past to find out an efficient and economical treating agent. Some of those adsorbents are Rice husk and Maize cobs, Coconut Leaf powder and activated Carbon, Sour sop seeds, coffee husk, Waste Tire Rubber Ash, Raw Banana Stalk, Palm Kernel Shell Charcoal (PKSC), Agro-Waste, Tea waste and Polypyrrole (PPy) conducting polymer, papaya seeds, etc. Adsorption methods are adopted for removal of lead and these methods are suitable when lead is present in low concentration.

4.2 Advantage of low-cost adsorbents over conventional adsorbents

1. The efficiencies of removal of lead ions of various nonconventional adsorbents vary between 40% and 100% depending upon the characteristics and particle size of adsorbent. A combination of adsorbents can also be used effectively in treatment.
2. Nonconventional adsorbents are relatively cheaper compared to conventional ones and are easily available resulting in savings in cost.
3. Nonconventional adsorbents require simple alkali or/and acid treatment for the removal of lead before their application and to increase efficiency.
4. Since the cost of these adsorbents is relatively low they can be used once and discarded.
5. Nonconventional adsorbents require less maintenance and supervision. Separation is possible to segregate the nonconventional adsorbents from the effluents before their disposal.
6. These nonconventional adsorbents can be disposed of easily and safely. Used adsorbents can be reused as a filler material in low-lying areas and hence their disposal does not pose any serious problem. (Jamode *et al.*, 2004) [11].

4.3 Advantage of adsorption process

4.3.1 Cheap: The cost of the adsorbent is low since they often are made from abundant or waste material.

4.3.2 Metal Selective: The metal adsorbing performance of different types of biomass can be more or less selective on different metals. This depends on various factors such as type of bio-mass, mixture in the solution, type of biomass preparation and physico-chemical treatment.

4.3.3 Regenerative: Adsorbent material can be possible to reuse after regeneration.

4.3.4 No Sludge Generation: No secondary problems with sludge occur with adsorption, as is the case with many other techniques, (for example, precipitation).

4.3.5 Metal Recovery: In case of metal, it can be recovered metal ion after being desorbed from the adsorbent materials.

4.3.6 Competitive Performance: Adsorption is capable of a performance comparable to the most similar technique, ion exchange treatment. Ion exchange is, as mentioned above, rather costly. (Prabhakar and Rao, 2014) [25].

4.4 Factors Affecting Adsorption

The following factors affect the adsorption process:

4.4.1 Effect of pH: The adsorption process: it affects the solution chemistry of the metals, the activity of the functional groups in the biomass and the competition of metallic ions. The pH of the solution is one of the most important parameters affecting the adsorption process. pH can influence the surface charge of the adsorbent, the degree of ionization also the species of adsorbate. In a particular pH range, most metal sorption is enhanced with pH, increasing to a certain value followed by a reduction when further pH increases. As it is known, change in the pH value could cause a change in the adsorption capacity. Therefore, the effect of different pH values was investigated in the present study. (Tulun and Bilgin, 2015) [5].

4.4.2 Effect of Initial Concentration: Initial concentration of metal ions can alter the metal removal efficiency through a combination of factors such as the availability of specific surface functional groups and the ability of surface functional groups to bind metal ions. Initial concentration of solution can provide an important driving force to overcome the mass transfer resistance of metal between the aqueous and solid phases. (Abas *et al*., 2013) [1].

4.4.3 Effect of Contact Time: The adsorption of metal ion by adsorbent also depends on the interactions of functional groups between the solution and the surface of adsorbent. Adsorptions can be assumed to be complete when equilibrium is achieved between the solute of solution and the adsorbent. However, specific time is needed to maintain the equilibrium interactions to ensure that the adsorption process is complete. (Abas *et al*., 2013) [1].

4.4.4 Effect of Temperature: Temperature plays a double role in the lead adsorption process. Temperature can impact the physical binding processes of lead to an adsorbent. However, temperature also can have a direct impact on the physical properties of an adsorbent, if thermally treated prior to exposure, so that adsorption capacities can be significantly altered. Most adsorption studies are conducted at room temperature in laboratory settings. For adsorption capacities attained under room temperature conditions may be higher than in the field as a result of increased temperatures. (Sreenivasa K *et al.*, 2015) [26].

5. Relevant Literature

This review has includes the different low adsorbents for the removal of lead (II) from contaminated water.

5.1 Use of Low Cost Adsorbents

Table 2 shows that the removal of lead (II) by using different adsorbents and its optimal parameters. Some low cost adsorbent used in this table which indicates that adsorbents were outstanding removal capabilities for lead in aqueous solution. Parameters which were shown in table 2 such as adsorbent dose, pH, contact time, percentage removal of lead determined by using several low cost adsorbent. Maximum adsorption occurs in between 2-8 pH. It is clear that maximum up take capacity takes place by low cost adsorbents used in adsorption process and it gives better removal efficiency of lead (II)

Table 2: Shows effects of various parameters on removed efficiency,

Name of adsorbents	pH	Dosages	Contact time	Removal %	References
Rice husk and Maize cobs	2.5- 6.5	1.5gm	120 min	98.5	Hefny *et al*., 2007
Sour sop seeds	5	1.0 g	120 min	40.6	Oboh *et al*., 2008
Spent tea leaf	Neutral	2gm	8hr	55.2	Liang *et al*., 2009
Waste Tire Rubber Ash	4-6.5	2 g/l	90 min	92.8	Mousavi *et al*., 2010

papaya seeds	5	10 to 50 mg/l -1000 mg/l	90 min	90	Egila *et al*., 2011
Aquatic Plants	4-8	15 plant	7 days	99.28	Divya *et al*., 2011
Palm Kernel Shell Charcoal (PKSC)	-	2.0 G/25ml	50 Min	89	Oluyemi *et al*., 2012
Coconut Leaf powder	7	2 gm	30-180 min	90	Hegazi, 2013
Tea waste	5-6	0.25 to 1.5g per 200ml	15-20min	96	Abas *et al*., 2013
Activated Carbon	5	0.2 g/ 200-ml solution	90 min	90	Abou *et al*., 2014
Raw Banana Stalk	4-8	100 mg/l-1000mg/l	180 min	63.97	Ogunleye *et al*., 2014
Polypyrrole (PPy) conducting polymer	7	0.08g per 25 ml of lead solution	8 hr	100	Mahmud *et al*., 2014
Coffee grounds	Neutral	0.5 mg/L	1 hr	87.2	Jurgita *et al*., 2014
Banana Stalk	8	0.90g	152 min	96.41	Ajala *et al*., 2015
Electrochemical	5-7	19 mg/l	120 Min	94	Bhakte *et al*., 2015
Agro-Waste	6	1.5g/ 100ml	60 Min	89.60	Draman *et al*., 2015

6. Conclusion
This review paper provides an overview of various low cost adsorbents in place of expensive commercial adsorbents used for the effective removal of lead from water. The efficiency of different adsorbents is depending on parameters such as pH, adsorbent dose, contact time, and temperature. The removal capacity increases by increasing dose of the adsorbent. Several low cost adsorbents like Rice husk, Maize cobs, Coconut Leaf powder, activated Carbon and polypyrrole are more efficiency. Used by many researchers in removing of lead from water. In future, these low cost adsorbents used can be for removal of lead in developing countries at domestic level.

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