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Biosorption of metal toxicants and other water pollutants by Corn (Maize) plant: A comprehensive review

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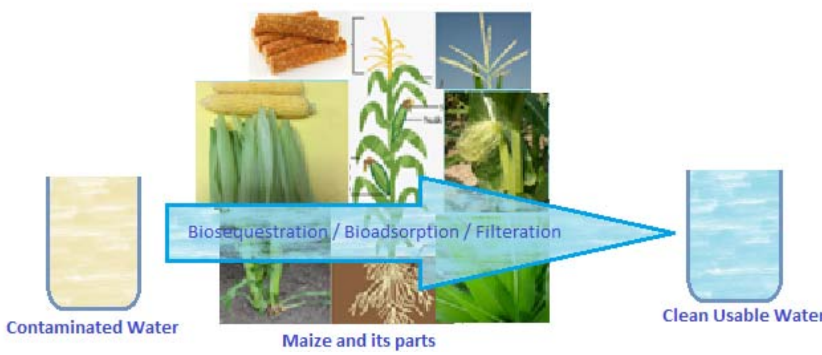
ABSTRACT



The water pollution is one of major environmental and health issue. Various contaminants from effluents originating from different sources (domestic and industrial) and toxic metal ions along with few toxic anions from natural resources (underground water toxicity) are major concerns for water unsuitability for human and other animals consumption. Many innovative technologies are being developed to treat contaminated water including adsorption or biosorption of contaminants from water using different plants and nanotechnology. Various studies have been performed for removal of harmful contaminants by plants as whole or different parts of plants such as maize cob, husk, onion peels, corn-cobs, coconut husk, etc. In this review, a comprehensive study of different literature reports for using Corn plant (Zea mays) for biosorption or adsorption of water pollutants have been discussed.

Keywords: Water pollutants, Metal toxicity, Biosequestration, heavy metal, toxic ions

INTRODUCTION

Water, the essential element of life, is present on over 2/3rd of Earth's surface, however, less than 1 percent of the earth's water is available as fresh water for sustaining life over earth. The planet's human population continues to grow and as a result an ever-increasing pressure is put on the planet's fresh water resources. The water resources are being used drop by drop due to human activities, thus affecting the quality and causing contamination. Poor water quality means water pollution.[1] Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). These activities have degraded the water quality by discharging harmful pollutants directly into water bodies hence, causing water pollution. This not only spell disaster for aquatic ecosystems, this might end up in households through interlined web chains and food webs[2] leading to contamination of fresh. The contaminants could be organic compounds or metal salts.

Metals are naturally present in nature in almost everything (in form of different salts and ions) and are inseparable part of living system. Many metal ions are toxic in nature or some may cause toxicity in higher concentrations. There have been significant studies dealing with the toxicity of metals in humans.[3] There are

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many toxic pollutants in water especially ionic pollutants like arsenic, cadmium, boron, fluoride, nitrate, carbonate, potassium, strontium, iron, chloride, sulphate, bicarbonate, magnesium, calcium, sodium.

Water quality issues due to geogenic and anthropogenic reasons have been reported from all over the world. Content of these ions in water effects the human, soil,[4] animal and plant systems.[5] Effects of various selected ions (metal cations and anions) on health[6] are as follows:

Arsenic: Arsenic (As, At. No. 33) is a metalloid found in many minerals, mostly in combination with sulfur and metals. During first world war and Vietnam war, it was used as chemical warfare agent, and lung irritant. Till now arsenic is known as the world's most poisonous element due to its toxicity. Some common environmental sources of arsenic exposure are air, water, and arsenic containing mineral ores. When the levels of arsenic rises in water, then, this causes contamination of water and becomes a source of exposure in the environment. The intake of arsenic through water causes Cancer of lungs, skin, bladder, liver and kidney,[7] respiratory diseases like the prevalence of cough, shortness of breath, and chest sounds. It also damages our skin and also causes skin lesions.[8]

Fluoride: Fluorine's simplest anion is fluoride (F. At. No. 9). Industries use salts and minerals of fluoride to produce hydrogen fluoride for flurocarbons. The fluoride ion resembles the hydroxide ion in terms of charge and size. Fluoride is present in water too. It's presence in water beyond certain levels causes various diseases that include dental fluorosis, skeletal fluorosis, cardiovascular effects, gastro intestinal disorder, endocrine Effects, neurological effects, reproductive rffects, developmental Effects, enzyme inhibition, genetic damage, effect on the pineal gland.[9]

Lead: Freshly cut Lead (Pb, At. No. 82) has a bluish-white color but when it is exposed to air it turns into a dull grayish color. It is shiny chrome-silver lusttous when it is in liquid form. Lead is extracted from ores. It is highly useful because of its relative abundance and low cost. It's use is avoided by some agencies. It is very poisonous if ingested or inhaled by both animals and humans as it gets accumulated in the soft tissues and bones. It's toxicity causes damage to the nervous system and leads to brain disorders.[10,11]

Nickel: There are large nickel iron meteorites which are not exposed to oxygen, such meteorites have nickel and thus such nickel occurs in the interior of meteorites although some nickel is present in food as well as water naturally but its level can be increased due to various human activities for example water and soil could be contaiminated by faucets which are nickel plated, dumping of nickel from minning and smelting into water, release of nickel in food because of cookware having steel - alloy cookware and dishes with nickel pigments. Atmosphere also gets polluted through refining of nickel metal and combustion of fossil fuels. Nickel gets transferred in human body through tobacoo smoke, jewellery's contact to the skin, use of shampoo and detergent. It causes cancer of nose, lungs, failure of respiratory system and allergic reactions.[12]

Chromium The crust of earth have chromium (Cr. At. No.24) as most abundant element. Chromium is also used in various industeries specially in the production of chromate and chromate pigments, food preservations, leather tanning, material of refractory, alloys that are known as super alloy and are used in jet engines and gas turbines etc. Chromium exists in two important stable states as trivalent [Cr (III)] and as hexavalent [Cr (VI)]. Cr(III) has a crucial role as micronutrient for various biological activities like insulin maintenance, lipid and glucose metabolism and deficiency of Cr(III) leads poor tolerance of glucose and occurance of diseases like glycosuria, hyperglycemia, cardio vascular disease, diabetes. It has been observed that many fresh vegitables, spices, cereals, drinking water and bread. Anthropogenic activities produce chromium's hexavalent form and its exposure to human is very harmfull and injurious to health. Smoke from cigrette and emissions from automobiles are the main medium for inhalation of chromium. There are various cancers and medical problems like dermatitis, ulcers of hands, renal and hepatic, perforation of the nasal septum occurs because of exposure to hexavalent chromium.

Manganese: In natural environment Manganese (Mn, At. No. 25) does not occur as a free element but found in minerals with iron. Manganese is used as alloy of metals mainly in stainless steels.[14] Manganese plays an important role in a human body, as it is responsible for the regulation of metabolism, development, proper functioning of antioxidant system. Excessive intake of or exposure to magnese leads manganese poisoning which causes motor skills' impairment, cognitive disorders, a neurodegenerative disorder which is known as manganism and this leads dopaminergic neuronal death.

Human activities along with natural conditions have resulted toxicity of water which causes severe problems. When it enters the life cycle process and is ingested by an organism in elevated levels; it results in severe health conditions. Therefore techniques and processes need to be evolved to minimize the levels of toxic metals. Many cost effective measures have been developed. The non-Hazardous Agro-waste materials are of low cost, eco-friendly and easy alternative in comparison of chemicals methods thar are used to remove heavy metals in order to reduce environmental pollution.

The Maize plant or Corn *Zea mays* (figure 1) is one of the cash crop which is used widely throughout the world. In India it is the third food crop which is grown largely. UP, Bihar, MP, Bihar, Himachal Pradesh, Rajasthan, Jammu and Kashmir, Punjab, Andhra Pradesh and Karnataka, are large cultivators of corn plant in India whereas Ukraine, South Africa, China, France, Argentina, Mexico are some large cultivators of corn plant in the world. Corn is also used widely as raw material in various industries like oil, starch, pharmaceuticals, food sweeteners, cosmetic, alcoholic beverage, gum, paper industries.

Corn Plant and its different parts has been studied for removal of pollutants from water by different methods. Ours laboratory research span in Nanomaterials,[6,16–22] biological applications of molecules,[23–31] drug development[27,29,32–43] and impact of water toxicity on plants. In this review, we have compiled and analyzed the different studies conducted towards use of corn plant or its parts[44] for removal of toxic metals, ions and other pollutants from water.

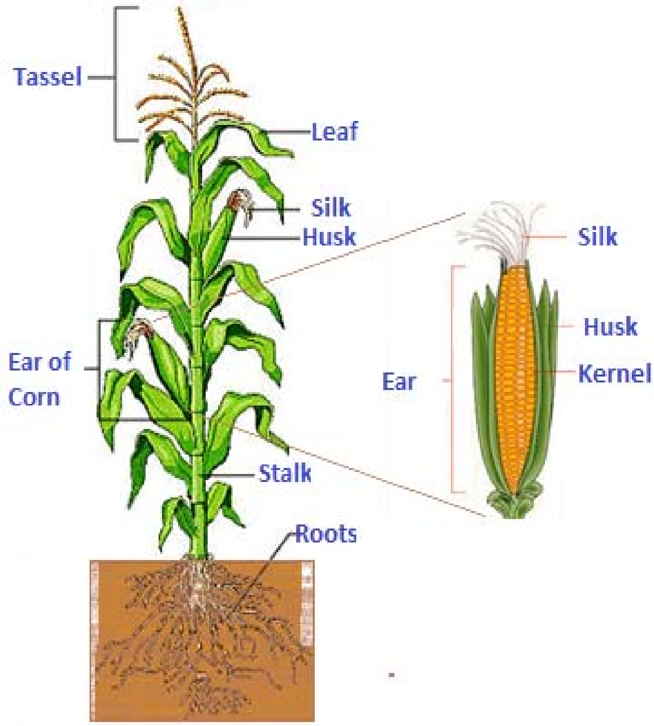

Figure 1: Different parts of Corn plant. (Source: Google images)

STUDIES ON ADSORPTION OF VARIOUS METAL IONS BY CORN PLANT PARTS

Different parts of corn plant like its stem, its fruit or flower has been used for removal of contaminants from water through the process of biosorption.

CORN COB AS AN ADSORBENT

Corn cob (figure 2) is lower stalky part obtained after removal of husk and seeds from kernel of ear of corn. Being the roughage part of corn, it can be used for the filteration of water through it as it can absorb or adsorb minerals from it. The crushed cron cob when padded in layer can serve an excellent filteration sieve which can be used for removal of mud from dirty water besides removal of toxicants or pollutants by the adsorption.

Figure 2. The Corn cob

A study conducted by P. Ezegbirika et.al.[45] has reported removal of heavy metal ions, Cd(II), Pb(II) and Zn(II) ions from aqueous solution by agricultural waste, such as corn-cobs. In this study examination of corn cob modified in thioglycolic acid was done by equilibrium sorption studies at 29 degree celsius. The sorption of the metal ions was studied under various conditions. In this experiment, firstly small pieces of corn cobs were made and such pieces were converted into powdered form after it was treated with dilute nitric acid solution and in last it was air dried after rinsing it with deionized water. The cobs were modified by treating the cobs meal material with thioglycollic acid solution at 29 degree Celsius. The mixture was then filtered and the cellulosic material was thoroughly washed with deionized water. 100ml of various concentrations (10.0mg/100ml-50.0mg/100ml) of the metal ions at constant metal ion-substrate contact period of 1 hour at 29 degree Celsius were taken and Sorption of Metal Ions on Modified Corn-Cob Equilibrium sorption of cadmium, lead and zinc ions on thiolated cellulosic material was carried out. It was observed that the cellulosic material adsorbed ions and there was uptake of the metal ions from acidic solutions (H^+ concentration between 0.01M and 0.001M) were examined). The unmodified corn cob had some degree of binding metal ions capacity, even though the rate of equilibrium was very slow which might be due to some heavier exchangeable functional groups. Generally, it was observed that at lower pH, the modified corn cob was able to sorb about 90% of the metal ions. The corn cob can also be used to prepare activated carbon and used for removal of metal ions.[45]

In a study by T.Vaughan et.al., modification of corncobs were done with the help of citric acid and phosphoric acid for improvement of corn cobs' natural capacity of adsorption. Five different metal ions that are cadmium, copper, lead, nickel, zinc were used individually or in the form of mixed solution to test the efficiency of modified corn cob. The adsorption capacity of corn cob is compared with the adsorption efficiency of commercial resins and other various elemnts. The findings of the study states that the modified corn cob have lower adsorption capacities in comparison of commercial resins but Duolite GT-37 have adsorption efficiency eqvivalent to adsorption efficiency of corn cob but its efficiency of adsorption is lower than the efficiency of Amberlite 200.C Arunkumar et.al.[47] conducted a study to explore the nature of corn cob in the influence of various parameters.[47] The authors analyzed the initial and final concentration of Ni (II) using UV- Double Beam absorption spectrophotometer at 394 nm. The corn cob collected cleaned and dried in oven. The results of this study revealed that Corn cob, a waste material has the potential to adsorb toxic heavy metal like Ni (II) from Industrial waste waters.[47]

Norozi et.al. in their research studied the adsorption capacity of corn cob for the removal of Mn(II) from aqueous solution.[48] The study also examined the performance of Corn cob for Mn(II) ions during the sorption process.[48] To predict the absorption process the relationship between thermodynamic parameters was used. The study reveals that the adsorption Mn(II) by Corn cob is endothermic as positive standard enthalpy change occurred which suggests there is an increase in temperature.[48]

In a research conducted by Goswami et.al. on cost effective bio-adsorbent from agriculture waste, corn cob was used as an adsorbent.[49] This research reveals that corn cobs adsorb surface pollutants and prevent their entry into the groundwater. Corncobs adsorb the suspended particles in the water which store heat and raise water temperature and thus indirectly help to decrease the temperature of water. Corn cobs were collected from the local farmers and then sun dried. A cob was taken and without piercing the other end, at the centre of the cob a hole was made. From a kitchen drain pipe 50ml of effluents was taken and passed slowly through the corn cob hole and the filtrate was collected and tested .Corn cobs were taken in five separate used bottles of 2 lt. capacity each containing 400 g of dried longitudinal sections, 400 g of dried small pieces, 400 g of powdered corn cobs, 400 g of activated charcoal of corncobs and 500 g fine sand(Last layer) each (Figure 3). Pre-treatment water was passed through these layers with known quantities of chemicals like Ca, Cu, Mg, Pb, Sr, Cr, robin blue, lac dye, shampoo, oils. The filtrate was collected and tested for the presence or absence of the chemicals mentioned. To find out the rate of adsorption by corn cob the pre and post treatment water was studied for various parameters like Total Suspended Solids, BOD, COD, Oil, Grease, dyes, Cu, Mg, Pb, Sr, Ca, and Cr.[49]

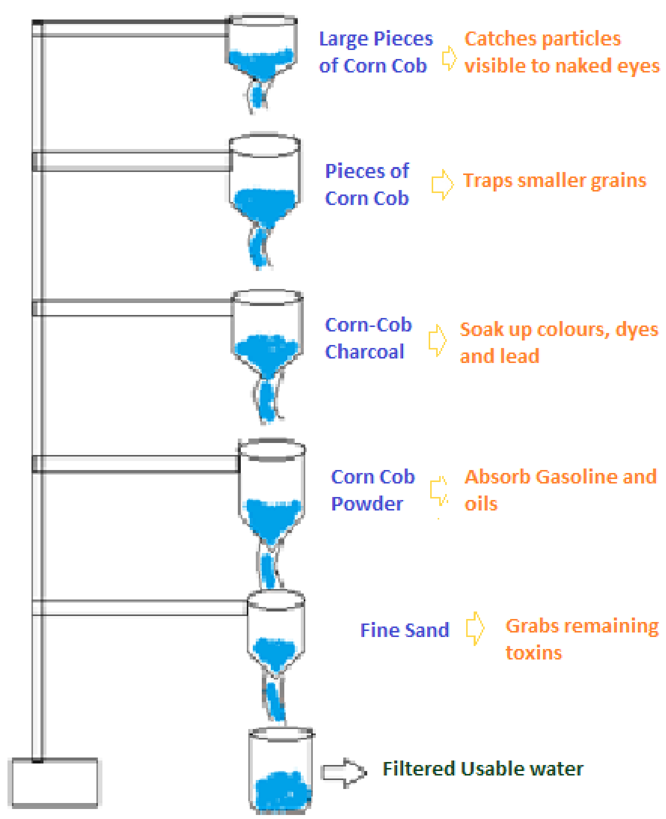

Figure 3: Experimental setup to identify the rate of adsorption by corn cob. Graphics recreated from the concept by Goswami et al.[49]

An artificial tank (figure 4) was also set up in which the corn cob pieces were tied to bamboo sticks buried in pond floor.[49] This setup immersed in water and left for two weeks to study the adsorption rate of corn cob. The results suggest that different pollutants present in the solution areadsorbed in the charcoaleffluents are adsorbed in different layers, most of the colored layers, small solid particles are adsorbed in the layer of and pieces of corn cobs and gasoline waste is adsorbed to its maximum levelin the powdered corn cob layers. It was also found that the rate of adsorption increases with the increase in the surface area of the adsorbents.[49]

The corn cob has the ability to absorb pollutants from grey water i.e., waste water as well. The capacity of corn cob to absorb pollutants from waste water increases more if the contact time is increased.[50]

In a selective study to evaluate the color and dye absorption capacity of Corn con, Yinghua Song et.al. showed the potential ability of corn cob to absord the different dyes. The crystal violet (a catonic dye) is a harmful dye that is used in different applications such asin biological marker, in veterinary drugs and in dermatological agents. Their study revealed that corncob should be modified and then used because the long-term contact with water will dissolve the soluble component of the corncob in water, and will cause the corncob to be dispersed in the aqueous solution. The results of equilibrium data showed that corncob modified with epichlorohydrin has the potential to treat dyes containing waste water.[51]

The problem associated with mercury pollution arises due to fossil fuel burning and industrial waste disposal. A modified Corn cob have been evaluated for sequestration of mercury. Corn cob was treated with $ZnCl_2$ to turn it to activated carbon as it played major role in activating microporous structures of carbon. The results showed that the chemically treated corn cob efficiently removed mercury up to 91.4% at 150 °C.[52]

Other chemically treated Corn cob can improve the selective absorption or enhaved absorption of contaminats from water. Nor Hakimin Abdullah et.al. in their study revealed that activated carbon from chemically treated corn cob can be efficiently used for waste water treatment. They chemically treated corn cob with potassium hydroxide to turn it to activated carbon. Then they tested activated carbon from corn cob treated with KOH in order to remove methyl orange (dye) from the treatment solution. The results of the study demonstrated that after treating corn cob with KOH the adsorption capacity of corn cob increased from 41.09% to 80.36%.[53]

In a similar study to remove dyes from contaminated industrial waste water Ismail et.al. demonstrated that treated corn cob has the potential to remove dye from dilute industrial effluents. They treated corn cob with 98% concentrated sulphuric acid in order to create a chemically active surface. Then they tested both treated and untreated corn cob in order to remove malachite green dye from industrial effluent. Three parameters were studied while conducting the experiment: dye concentration, adsorbent dosage and contact time. The results revealed that treated corn cob has the potential to remove malachite green dye.[54]

The activated carbon from corn cobs also have the potential to decrease heavy metal - iron, copper and lead content in industrial waste.[55]

Rene et.al. conducted a study that investigated the potential of chemically treated corn cob and rice husk to adsorb fluoride using the parameters of pH, contact time, initial fluoride concentration and adsorbent dose. The analysis of the experiment reveals that the activated carbon form of corn cob has the potential to adsorb fluoride from groundwater and thus it can be used as a potential bio adsorbent.[56]

***Corn COB** has potential for adsorption of Cadmium, Zinc, Lead, Copper, Nickel, Fluoride, and Iron ions, oil, malachite green dye from aqueous solutions.*

CORN TASSEL AS AN ADSORBENT

The Tassel is the topmost feathery part of the maize plant. It has fibrous structure and can be used for biosequestration of contaminats as indicatd by various studies conducted. A research conducted by M. Mambo et.al. used activated carbon made using maize tassel to increase the adsorption capacity of Pb(II) ions. Maize tassel was collected from Morris farm in Plucked off maize tassel from Northlea, Gweru, Zimbabwe was washed with water, and dried in sun for 5 days. The dried biomass was powdered, fractionated and finally washed it twice with 0.01M HCL in order to remove any metals on the biomass. Activated carbon was produced. Their results of the study reveal that modified corn tassel using HCL can be used to effectively remove Pb(II) ions from wastewater treatment plants.[57]

In another work by C. M Zvinowandaet. al. an experimental study was carried out using maize tassel powder. The results obtained from the study indicate that maize tassel has the potential to absorb and recoverPb(II). The results demonstrated that maize tassel has the potential to remove and recover heavy metals from aqueous solutions.[58]

O.F. Olorundare et. al. in their study prepared and used maize tassel in form of activated carbon[59] for adsorption of phenolic compounds from the environmental waste water samples. For this purpose, first the authors analyzed the molecules of bisphenol A(BPA), ortho-notrophenol (o-NTP), parachlorophenol (PCP) (all three determined and reported in wastewater), using gas chromatography and GC time-of-flight mass spectrometry. Modified corn tassel was tested for its adsorption capacity The results revealed that the modified maize tassel has the capacity to absorb phenolic compounds.[60]

U. Guyo et. al. in their study examined the surface capacity of maize tassel for the adsorption of Cd(II) on -magnetite nonohybrid adsorbent. Through scanning electron microscope characterized the synthesized maize tassel-magnetite nanohybrid for Cd(II) adsorption. The parameters were investigated using Anova. The results of the study determine that maize tassel-magnetite nonohybrid has the capacity for the adsorption of Cd(II).[61]

***Corn TASSEL** has potential for adsorption of Cadmium and Lead ions, and phenolic compounds.*

CORN LEAF AS AN ADSORBENT

A study conducted for testing the biosorption capacity of lead ions from aqueous solution by maize leaf reveals that the corn leaves can be good adsorbent to adsorb Pb(II) ions. The obtained maize leaves from a farm the Nigerian State- Ogun. The leaves were first and then rinsed with distilled water, dried in sun-and then finally cut into small pieces. The values obtained using the experiment reveals that maize leaf has the potential to remove lead from wastewaters.[62]

Mohammad Y. Eisa and Omar Hisham Fadil conducted a comparative study where they studied the adsorption of methyl

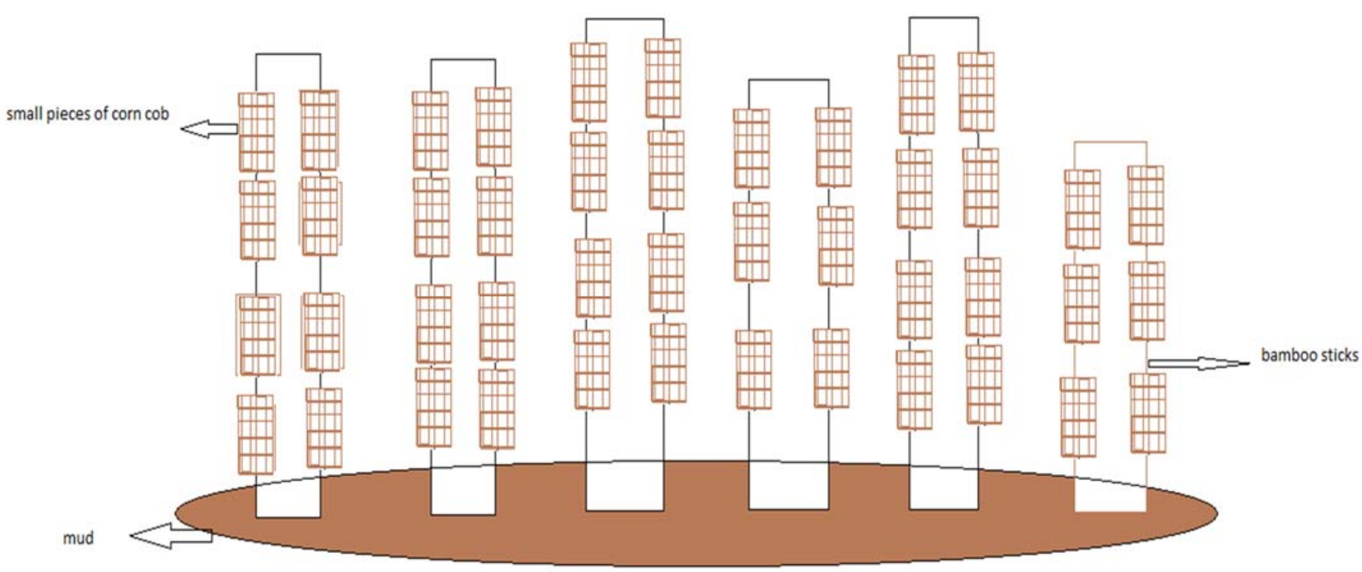

Figure 4: Artificial model to clean ponds and tanks. Redesigned graphical representation of work by Goswamiet. al.

orange dye(MO) using non- activated and activated corn leaves with HCL as an absorbent medium. The results were calculated and measured using variables – pH, temperature, initial dye concentration, quantity of adsorbent and contact time on removal efficiency. The results revealed that activated corn leaves showed better adsorption efficiency as compared to non- activated corn leaves. Moreover, adsorption efficiency increases as concentration of dye, adsorbent dosage and contact time are increased.[63]

Yu Zhang et. al. in their study treated corn leaves with sulfuric acid and hexadecyl trimethyl ammonium bromide to modify them. The modified leaves were used to remove Cr(VI) from waste water. Batch experiments were conducted and variables were studied. They identified that pH, adsorbent dosage, and temperature effect the adsorption of Cr(VI) onto modified corn leaves. The results of the study reveal that sulfuric acid modified leaves and hexadecyl trimethyl ammonium bromide modified leaves work as efficient biosorbents of Cr(VI).[64]

***Corn LEAF** has potential for adsorption of Lead, Chromium and methyl orange compounds.*

Corn husk as an adsorbent

The Corn husk is the peel off leafy part of the Corn ear. Being morphologically and functionally different than leaf, it can also find application in adsorption of contaminats.

A study has been conducted by Jadav and Jadav for the use of maize husk fly ash to remove fluoride.[65]This experimental study was conducted in phases where batch study was carried out in order to examine the effect of various parameters. The results of the study reveal that maize husk fly ash is a potential biosorbent for fluoride.[66]

Oana Maria Paşka, et. al., conducted kinetic and thermodynamic studies on methylene blue for biosorption using corn-husk. They conducted an experimental research during which they investigated different parameters of biosorbent dosage, concentration of dye, contact time, and temperature. The results obtained reveal that corn husk is useful for the removal of basic dye methylene blue from aqueous solutions.[67]

Another study conducted by Guo Lin et.al., used modified corn husk leaves for the removal of Hg(II) using the wastewater.. Corn husk leaves were modified using bismuthiol I. The study revealed that that the sorption phenomena was due to the chelation mechanism between nitrogen/sulfur groups and Hg(II). The experiment demonstrated that the adsorption is possible of mercury from wastewater with modified corn husk leaves.[68]

Another study conducted by Xu et.al. derived biochar from sawdust and corn husk by modifying them with $MgCl_2$ and MgO. The results of the study reveal that a derived biochar increases sorption capacity of corn husk for the sorption of anionic contaminants.[69]

Shubham Mishra et.al. conducted a study for to remove phenol and para- nitrophenol from aqueous solution using magnetized activated carbon from corn husk. To check the efficiency of the activated carbon derived from corn husk, the adsorbent (modified corn husk) was treated at two different temperatures, 250 degrees Celsius and 500 degrees Celsius. The derived adsorbents were used for the removal of phenolic compounds from aqueous solution. The results reveal that modified corn husk is an efficient biosorbent. The study also reveals that that the biosorption of phenol was exothermic in nature, on the other hand, biosorption of para- nitrophenol was endothermic in nature on both the adsorbents modified at different temperatures.[70]

***Corn HUSK** has potential for adsorption of fluoride, methylene blue dye, mercury, phenol and para-nitrophenol.*

Corn stalk as an adsorbent

Sareh Vafakhah et.al. conducted a study where they examined the adsorption capacity of modified corn stalk and tomato waste to remove Cu(II) ions from the contaminated samples in which they collected corn stalk &tomato waste, removed the leaves from the stalk and separated impurities from tomato waste. Each of them was cut into small pieces , passed through a sieve, separately washed thrice with distilled water and was dried in an oven until it reached a constant weight. The mixture was modified by oxidizing it with nitric acid solutions. The solution was heated for 2 hours at 50˚C. This study reveals that the adsorption capacity of modified corn stalk for Cu(II) ions increased 4.2 mg/g.[71]

In another work by M. Husseien, et. al., corn stalk was characterized by analytical techniques such as FTIR, X-ray, TGA and SEM. Also, the efficiency of corn stalk by modifying it-carbonization is demonstrated. Carbonyl groups, CH_2, andCH_3 that include ketones, esters and some bands related to lignin and hemicellulose are present in corn stalk as shown by FTIR results. The study reveals that corn stalk can be used below 200 °C. SEM images indicated that thesorption of dye and gas oil was greatly enhanced by the surface modification. The results indicate that biosolid like cornstalk could be employed as effective and low cost material for being used as sorbent materials.[72]

Many researches reveal that corn stalk can be used to absorb the pollutants like Cr(VI), cadmium ion,[73]dye and gas oil by increasing its adsorption capacity.

A. Usman et.al. conducted an experimental study to assess the sorption capacity of corn stalk for the elimination of Crystal Violet dye from aqueous solution. The findings of the study show that it is possible to use corn stalk to remove Crystal Violet dye from the aqueous solution. This study concluded that corn stalk can be used as a low cost absorbent to uptake crystal violet from aqueous solution.[74]

A study by W.Cao et.al. reveals that fixed-bed column filled with modified corn stalk(CS-AE) can be developed to remove Cr(VI) from aqueous solution and electroplating waste water. It is an experimental and its results shows that CS-AE column is suitable to remove Cr(VI) selectively in case of real waste water conditions. [75]

L.Zheng et.al. conducted study that described of adsorption of cadium ions from aqueous solution with the help of acrylonitrile (AN)-modified corn stalk (AMCS). This study reveals that AMCS is suitable and effective adsorbent to remove Cd(II) as AMIS have pore suitable size and (-CN) functional group. [76]

Another study by L.Zheng et.al. reveals that when corn stalk was grafted with the help of graft copolymerization, corn stalk contains cyano group (-CN) which leads more adsorption potential for Cd(II) than unmodified corn stalk the efficiency of AGCS for removal of Cd(II) increases.[77]

A study by D. Peng et.al. contains works to demonstrate hour corn works to demonstrate have corn stalk can be prepared to use as biosorbent for adsorbing oil. During the study corn stalk was modified by cellulose as a result of which efficient oil sorbent was produced. This study reveals that corn stalk was suitable and capable and eco friendly biosorption for oil.[78]

W. Song et.al. through their study showed the corn stalk can effectively remove nitrate from aqueous solution. The during the study corn stalk based on magnetic amine-cross linked biopolymer was synthesized to remove nitrate from aqueous solution as a result of which it was concluded in the study that MAB-CS is a novel bio-absorbent which is highly capable of effective removal of nitrate whereas it is effective in rapid separation from effluents simultaneously.[78]

A study by W.Cao et.al showed than Cr(VI) can be reduced simultaneously with biosorption with the help of corn stalk and this is achieved through the process of ion exchange.[79]

Another study by L.Zheng et.al. was an experimental study during which XMCS that is stalk xanthatcs was produced and the result of study shows that corn stalk xanthate have potential for excellent adsorption for Cd(II).[71]

***Corn STALK** has potential for adsorption of copper, dye, gas oil, chromium, cadmium, crystal violet dye, nitrates.*

CORN SILK AS AN ADSORBENT

The corn silk is fiber part that emerge on the top end of corn ear or corn kernel. The rich fibrous has potential to serve as sieve or filteration pad while modification introduced through chemical treatment or reactions can further improve the adsorption capacity of this part. As with other part of Maize plant, it has also been used for evaluation to absorb/adsorb dyes, metal ions and other contaminants of water.

Hongmei Yu *et.al.*conducted an experimental study where modified solid corn silk was used to remove metals from the aqueous solution. First the corn silk was modified using nitric acid in dilute form. The solid phase extractant was then used to remove Cu^{2+}, Co^{2+} and Ni^{2+} from water.The results of the study revealed that the extractant formed using corn silk were effective in removal of Cu^{2+}, Co^{2+} and Ni^{2+} from aqueous solution and the same extractant can be used a number of times continuously for more than eleven cycles.[80]

A study by M. Petrovic et. al was an experimental study in which corn silk was used first time for the elimination of lead from the aqueous solution during which it was found that corn silk is a good adsorbent of lead form aqueous solution which lead effective adsorption through ion-exchange mechanism.[81]

Study by X. Zhu et.al involves experiments in which corn silk that were modified by dilute nitric acid which leads a biosorbent which was used for the adsorption of Cu^{2+}. The result of the study reveals that modified corn silk is an adsorbent for copper in water.[82]

M. Petrovic et.al. conducted an experimental study to assess the potential of raw corn silk biosorbent. The finding of the study states that corn silk is a potential biosorbent for removing Cu^{2+} and Zn^{2+} from water, aloso the adsorption process is endothermic and spontaneous.[83]

A study by I. Mbarki has been conducted to evaluate the efficiency of biosorption of corn stigmata to eliminate methylene blue (MB)- a basic dye and indigo carmine (IC)- an acidic dye; this thermodynamic study demonstrated how corn stigmata act as a biosorpant on MB and IC in the presence of salt. The study concluded that corn stigmata fiber are suitable for the biosorption of the dyes from the aqueous solutions.[84]

A study by T.Akar et.al. reveals that corn silk tissue have high efficiency for biosorption of reactive dye from contaminated solution.[85]

A study by G. Mckay et.al. involved the use of maize silk power (MS) which is extracted from agricultural waste to remove methylene blue dye (MB) from aqueous solutions. The result of the study reveals that maize biomass waste is novel adsorbent for methylene blue dye.[86]

A study by E. Akan et.al. characterized corn silk or Lingno cellulosic waste and its adsorption capacity and mechanisms was studied. The study reveals that when Lignin cellulosic act as an adsorbent when treated with reactive dyes it have efficiency to remove reactive blue 19 and reactive red 218 from the contaminated media.[87]

R. Asadpour et al. in their experimental study explored the capacity of corn silk fiber to increase the absorbence oil in the aquatic environment. Initially, corn silk was tyreated with oleic acid to test for its sorption capacity. The adsorption mechanism was analyzed using Fourier transform infrared (FTIR) spectroscopy. Modified corn silk showed the capacity of oil sorption.[88]

S. Kakooei et al. conducted a study where they modified corn silk with acetic anhydride using N-bromosuccinimide (NBS) in order to improve its sorption capacity. The sorption capcity of raw and treated corn silk were examined. The results of the study revealed that treated corn silk has the better capacity to absorb oil sorbents from aqueous solution.[89]

***Corn SILK** has potential for adsorption of copper, cobalt, nickel, zinc, methylene blue dye, indigo carmine dye and oil..*

CONCLUSION

New technology combined with cost- effective materials is best suitable for solving the problem of contamination due to water pollutants. The corn or maize plant proves to be a good adsorbent of water pollutants and thus can potentially find use in purifying water. Its different part has shown promising adsorption capacity for sequestration of toxic metal and anions. The promises shown by adsorption of pollutants by this plant warrant its further evaluation and use for water toxicants removal.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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