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Using Natural Absorbents to Clean Water Ways

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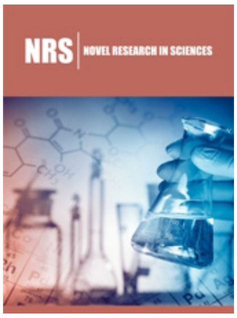

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Abstract

Water is a universal solvent that sustains life and there is an abundance on our planet. However, surface water has become increasingly polluted over the years due to anthropogenic activities. This has increased the cost of purifying surface water for domestic uses. Metal contaminants in surface water must be below the international accepted threshold limit, otherwise the water will not be safe to use for agriculture purposes and after purification, domestic purposes. Water purification can be achieved via synthetic and recently the use of natural selective adsorbents. There is a continual search for natural adsorbents because of its environmental safety, lost-cost preparation, compared to synthetic analogues. The natural adsorbents selected must also be sustainable, since life depends on a continuous supply of clean water. This paper survey research work done on selected adsorbents, with a view to its practical use worldwide. Amongst the adsorbents reviewed are grounded peanut shells, sugar cane residue (bagasse), activated carbon, rice husk, jack fruit leaf powder, coconut fibres, coconut shell, monkey thorn tree (Acacia galpinii), infused tea leves and even microorganism such as *Agaricus* macrospores.

Keywords: Surface water; Metal contaminants; Agriculture purposes; Selective adsorbents; Activated carbon; Rice husk; Coconut fibres; Infused tea leaves

Introduction

Water is a universal solvent that sustains all life forms. Much of the current concern with regards to environmental quality is focused on water, because of its importance in maintaining the human health and health of the ecosystem. Surface water is water on the surface of the planet, such as in a stream, river, lake, wetland, or ocean. It can be contrasted with groundwater and atmospheric water [1-7]. Providing sufficient quantities of high-quality water to satisfy our domestic, industrial and agricultural needs is an ongoing global problem. Increasing population size, climate change and pollution will only exacerbate the global status. There is no physical shortage of water on the planet earth as it covers 70% of the globe. However, 97% of the world water is saline and is thus non-drinkable, 2% is locked in glaciers and polar ice caps, resulting in 1% to meet humanity needs [7]. Guyana water need continual monitoring to assess the concentration of toxic elements [8]. Surface water plays a very vital role in economics and the functioning of ecosystems [9]. In Guyana, surface water is primarily used for agricultural, industrial and commercial purposes. Pollution of surface water, due to industrial effluents and municipal waste in water bodies is a major concern in Georgetown, Linden and many other regions in Guyana.

Surface water is usually rainwater that collects in surface water bodies, like oceans, lakes, or streams. Another source of surface water is groundwater that discharges to the surface from springs. Guyana has abundant surface and ground water supplies near all populated centers. Both surface and ground water resources are relied upon for water supply requirements. Heavy amounts of precipitation provide high amounts of surface runoff and ground water recharge. Most of the domestic water supply comes from ground water resources, while most of the water supply for agriculture (such as, sugarcane and rice) and industry comes from surface water.

Surface water pollution occurs when hazardous substances come into contact and either dissolve or physically mix with the water [10,11]. Contamination of surface water can occur when hazardous substances are discharged directly from an outfall pipe or channel or when they receive contaminated storm water runoff. On the other hand, direct discharges can come from industrial sources or from certain older sewer systems that overflow during wet weather. Surface water can also be contaminated when contaminated groundwater reaches the surface through a spring, or when contaminants in the air are deposited on the surface water. Contaminated soil particles carried by storm water runoff or contaminants from the air can sink to the bottom of a surface water body, mix with the sediment, and remain [12]. Contamination takes place largely in proximity to manufacturing areas, along main rivers, canals, and creeks. Pollutants in surface water can be untreated sewage, anthropogenic activities, industrial effluents and agro-chemical (fertilisers and pesticides) run-off. Excess fertilisers, when applied to crops are washed downstream and finds its way to water ways causing eutrophication. The same may be said of pesticides, which are detrimental to marine life. Others include organic compounds, heavy metals, bacteria, fungi, and petroleum products, hazardous material, sewage, leakage from landfills, heavy metals such as mercury from gold mining, lead and cadmium from anthropegenic activities. These pollutants found in the water ways, make it harmful to human health and causing a number of short and or long-term illnesses. These illnesses can range from; cancers of the bladder, kidney, skin, liver, neurologic and neurobehavioral disorders, cholera, hepatitis, typhoid, and diarrhea [13]. Thus, the levels of concentration of cations/ anions must be controlled in our water bodies [14-16]. Other toxic metal cations and anions in water include cadmium, mercury and lead [14-16]. These toxic metal ions must be below the international accepted threshold values. Heavy metals and ions enter the water from the various sources. But while some of these metals are important as micronutrients, having them in very high concentrations in the food chain can cause toxicity and can further impact the environment where aquatic ecosystems and their users can become endanger [17,18].

There is minimal purification of water via filtration and chlorination, which occurs inconveniently in Georgetown, Guyana, only when supplies are available and operational. To combat these issues in Guyana, the Guyana Water Inc. (GWI) was established with the task of delivering safe water for improved public health and sustainable economic development. Water pollution continues to be an emergent concern in Guyana and subsequent action is needed to help reduce and further resolve the problem. Thus, by improving the water treatment systems, Guyana can reduce and eliminate these issues [19].

Literature review

Status of Surface Water from Selected Areas of Coastal Guyana and Selective Removal of Pb^{2+} and Fe^{2+} using Pulverized Coconut Fibres have been reported [20]. Guyana's surface and domestic water needs constant monitoring to assess the concentration of toxic anions and cations. The status of surface water at five selected areas: Blairmont, Bath, Bushlot, Belladrum and Mahaicony surface water was assessed in terms of the parameters discussed. In all cases, the concentration of cations and anions were below the WHO standard. Only at Mahaicony surface water, the concentration of Cl^- was above the WHO standards. A pulverized plant material (coconut fibre from the plant *Cocos nucifera*) was used to aid in the removal of toxic metal ions from the surface water of selected areas or Mahaica-Berbice administrative region. Mahaica-Berbice was chosen as the study site, since it is well known for its large scale agricultural and industrial activities, which are major sources of surface water, and also due to the fact that surface water to be evaluated have not been previously analyzed. The adsorbents (coconut fibres) was selective in its removal of Pb^{2+} at Bushlot, Mahaicony and Belladrum surface water. Also, it showed selectivity for removal of Fe^{3+} at all cases, whilst the concentration of Mn^{2+} remained the same for treated and untreated water. For example, the concentration of Fe^{2+} in the surface water at Bath for treated and untreated water was (7.31±0.44mg/L) and (6.88±0.51mg/l) respectively. It was also shown to reduce the turbidity in all cases, whilst elevating the pH [20].

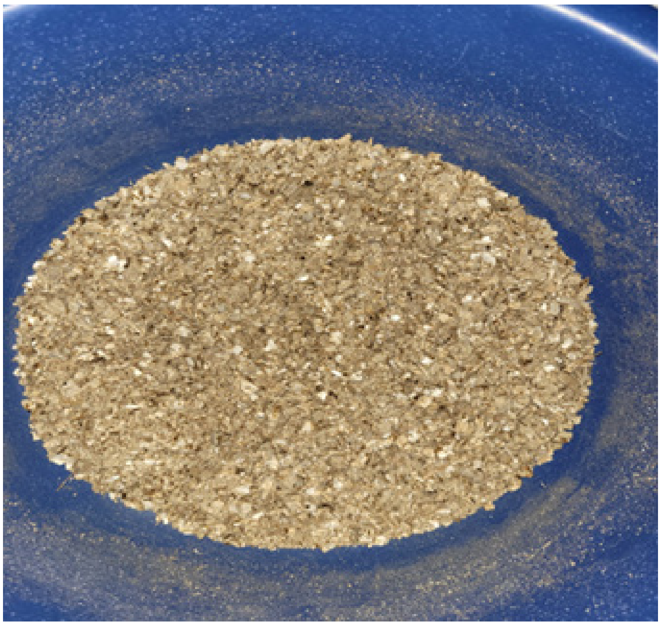

Figure 1: Image showing the blended peanut shells adsorbent.

A study was done, to compare the status of surface water taken from two different locations within the coastal areas of Guyana, before and after treatment with a peanut biomass adsorbent. The water samples were collected from Parika Bushy Park and Vreed En Hoop and stored in water bottles. It was then submitted for physical and chemical analyses using versatile standard methods. These include test for heavy metals cations (Pb, Fe, Zn, Cd, and Al), test for anions (chlorides, sulphates, phosphates) along with the physical parameters (turbidity and conductivity). There was no detection for the toxic lead and cadmium cations at either surface water. The adsorbent was effective in removing Fe^{2+} at both surface water as there was a decrease in concentration. For example, at

Vreed En Hoop surface water, the concentration of Fe^{2+} decrease from (8.42±2.14mg/L) to (5.56±3.42mg/L), 33.96% reduction, after treatment with the adsorbent. For the Al^{3+} cation, there was a decrease in the concentration of Al^{3+} from (5.97±0.67mg/L) to (4.20±1.90mg/L), 29.65%. For the SO_4^{2-} and Cl^- anions, there was a decrease in concentration at the Vreed En Hoop surface water, after treatment with the adsorbent. With SO_4^{2-}, the concentration decreases from 346±3.15mg/L to 293±1.77mg/L, 15.31%, whilst that for chloride, Cl-, decrease from 116±1.75mg/L to 102±1.70mg/L, 12.07% reduction. Thus, the peanut shell should find application in the removal of selective cations and anions from surface water [21]; Figure 1.

Literature review reports the potential use of aquatic macrophytes for the simultaneous removal of heavy metals such as Fe, Cu, Zn, Mn, Cr and Pb [15]. High metal removal percentages were reported for all metals. The removal of toxic metals: zinc, copper, mercury, cadmium or lead, from aqueous solutions by fungal biomass of *Agaricus macrosporus* is also noted [22]. The highest percentage uptake being of cadmium (96%).

The evaluation of a low-cost adsorbent in sugar cane residue or bagasse for the removal of toxic metal ions such as Cu^{2+}, Ni^{2+} and Zn^{2+} from wastewater of an electroplating factory has been reported. The removal percentage being 95.5%, 96.3% and 97.1% [23]. The removal of eleven metals (As, Se, Zn, Fe, Ni, Co, Pb, Mn, Hg, Cr and Cu) by plant biomass for the detoxification of industrial effluents for environmental protection has been noted [24].

A comparison of removal of dyes and metals using natural adsorbents such as activated carbon, rice husk, jack fruit leaf powder, coconut shell etc is reported. The research principle uses fixed bed column system for isolating and removing impuritie such as acid dyes, reactive azo dyes, food dyes and crystal violet dyes and metals such as lead, copper and cadmium from the water [25].

The use of natural clay, for selectively extracting lead ions from water has been reported [26]. Natural clay samples are composed mainly of silica, alumina, iron, and magnesium oxides. Results showed that clay samples preferably removed significant amounts of lead ions from water. The removal efficiency of lead ions was about 86.4mg/g of clay and followed pseudo-second-order kinetics. More than 95% of the total adsorptive capacity occurred within 30min.

Blais [27] compared natural adsorbents for metal removal from acidic effluent. Adsorption tests were carried out in acidic synthetic solutions. The most efficient adsorbents tested in decreasing order were oyster shells, cedar bark, vermiculite, cocoa shells, and peanut shells. In contrast, weak metal adsorption was demonstrated by red cedar wood, peat moss, pine wood, corn cobs and perlite. Metal adsorption capacities in acidic synthetic solution followed the sequence: $Pb^{2+} > Cr^{3+} > Cu^{2+} > Fe^{2+} > Al^{3+} > Ni^{2+} > Cd^{2+} > Mn^{2+} > Zn^{2+} >> Ca^{2+}, Mg^{2+}$. Alkaline treatment (0.75 M NaOH) increased the effectiveness of metal removal for the majority of adsorbents. In contrast, acid treatment (0.75M H_2SO_4) either reduced or did not affect the adsorption capacity of the materials tested. It was found that oyster shells, red cedar wood, vermiculite, cocoa shells, and peanut shells, were effective natural adsorbents for the selective removal of lead and trivalent chromium from acidic effluent [27].

A study was undertaken to evaluate the efficacy of *Acacia galpinii* (monkey thorn tree) biomass in removing lead Pb^{2+}, Cd^{2+} calcium, Ca^{2+}, and Mg^{2+} ions from drinking water. *Acacia galpinii* seeds and seed pods are inexpensive, readily available and may serve as a cost effective means for treatment of drinking water for domestic users in low and middle income countries. *A. Galpinii* biomass from seed and seed pods was processed by pulverizing and was Soxhlet oil extracted followed by particle size grading. The material was analyzed by X-ray fluorescence (XRF) and Fourier transform infrared (FTIR) spectrophotometry. Particle size, dose, contact time and pH all played significant roles in the effectiveness of metal removal for both seed and seed pod biomass. At biomass particle size <90 microns, 98% removal rates of Pb (II) ions were achieved for powdered seed pods compared with 65% for powdered seeds. The same trend was observed for Cd, Ca, and Mg. Contact time for effective removal of metal ions by pod powder and seed powder was 90 minutes and 120 minutes, respectively. Maximum adsorption was achieved at solution pH 6-8 for all metals. Lead adsorption followed a Langmuir isotherm model with maximum adsorption capacities of 10.8932 for pod powder and 3.4412 for seed powder. Adsorption of Ca and Mg followed a Freundlich model, with adsorption capacity of 1.1789 for Ca and 1.4521 for Mg [28].

Fungi such as *Agaricus macrosporus* show potential for the removal of heavy metals from aqueous solutions contaminated by zinc, copper, mercury, cadmium or lead. This study investigated biosorption of these metals by living or non-living biomass of *A. macrosporus* from an acid solution, an acid solution supplemented with potassium and phosphorus, and an alkaline solution. Uptake showed a pH-dependent profile. Maximum percentage uptake of all metals was found to occur at alkaline pH (Cu 96%, Pb 89%). With living biomass, metal biosorption was greater and faster in K/P-supplemented acid medium than in non-supplemented acid medium, with equilibrium reached within 15min for all metals, and the highest percentage uptake being of cadmium (96%). In general, the greatest differences in biosorption capacity were seen for living biomass, between supplemented and non-supplemented acid medium; the smallest differences were between living and dead biomass in alkaline medium. These results support the potential utility of *A. macrosporus* for heavy metal removal (Removal of toxic metals from aqueous solutions by fungal biomass of *Agaricus macrosporus* [29].

The removal of Cr (III) and Cu (II) from contaminated wastewaters by the natural adsorbent rice husk, as an organic solid waste, was investigated [30]. Experiments were performed in triplicates to investigate the influence of wastewater initial concentration, pH of solution, and contact time on the efficiency of Cr (III) and Cu (II) removal. The results indicated that the maximum removal of Cr (III) and Cu (II) occurred at pH 5-6 by rice husk and removal rate increased by increased pH from 1 to 6. The metal ion removal efficiency was enhanced by increasing wastewater initial concentration in the first percentage of adsorption and then decreased due to saturation of rice husk particles. Calculated saturation capacity in per gram rice husk for Cr (III) and Cu (II) were 30 and 22.5mg g (-1), respectively. The amounts of Cr (III) and Cu (II) adsorbed increased via increase in their contact time. Kinetically, the rate of reaction was fast. It was observed that 15-20min after the start of the reaction, 50 to 60 % of metal ions were removed. A contact time of 60min was proposed as the optimum contact time [30].

Low-cost adsorbent in Infused tea leaves have been research in the removal of the Pb_{2+}, Fe^{2+} and Cd^{2+} ions from aqueous solution. The adsorption study was carried out in a batch process and the effects of parameters such as initial pH, adsorbent dose, contact time and initial metal ion concentration were investigated. the maximum adsorption of metal ions occurred at pH 5 for Pb^{2+} and Fe^{2+} and at pH 6 for Cd^{2+}. Adsorption of metal ions increased with increasing adsorbent concentration and contact time. The isothermal data for the adsorption of metal ions by infused tea leaves were fit well with the Langmuir equations. The maximum adsorption capacities of the metal ions onto the infused tea leaves were found to follow the sequence: $Pb^{2+} > Cd^{2+} > Fe^{2+}$ [31].

Conclusion

A series of low cost, natural, selective, and environmentally safe adsorbents have been surveyed. All have been reported to show selectivity in the removal of metal ions. Particle size, dose, contact time and pH must be taken into considerations, when using an adsorbent for water treatment and purification. Calculation saturation capacity in per gram of adsorbent must also be taken into consideration. Also, the isothermal data for the adsorption of metal ions must fit well with the Langmuir equations. There is an ongoing search for natural adsorbents because of low cost and environmental safety. It's anticipated that natural abdsorbents will replace synthetic adsorbents in the future.

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