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Status of Surface Water at Three Selected Areas of Coastal Guyana and the treatment of the respective water with a suitable adsorbent

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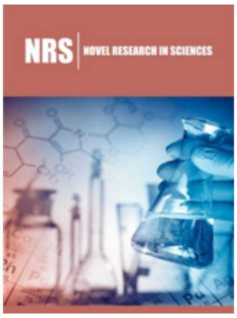

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Abstract

Three surface water: Skeldon, Mahaica Creek and Hope Canal were tested for the presence of heavy metal cations and anions and electrical conductivity, EC. Metal Cation tested for were Al, Zn, Arsenic, Lead (Pb), Cadmium, Mercury and Copper. Anions tested for were: Chlorides, Sulphates, Nitrate and Phosphate. The respective surface water was treated with an adsorbent in ground coconut midrib, which was uncarbonized. The latter prior to be used was ground, extracted with hexane and subjected to drying. The coconut midrib in its uncarbonized state was effective in removing SO_4^{2-} ions for all the treated water at all three surface water and PO_4^{3-} ions at Skeldon Surface Water. This is the first report of the use of uncarbonized or natural coconut midrid as a selective adsorbent.

Keywords: Surface water; Cations; Anions; Adsorbent; Ground coconut midrib

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 [8]. Guyana water need continual monitoring to assess the concentration of toxic elements8. 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 rain water 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 (fertilizers and pesticides) run-off. Excess fertilizers, 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 anthropogenic 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 into the water from 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]. Due to the contamination of these water ways with cations and anions, a proposed adsorbent of coconut fibers was chosen as an adsorbent to selectively removed metal ions from three selected areas surface water. Coconut shell is used as an adsorbent due to its greater micro-pores, low coat and its abundance over other agricultural by-products.

For example, Jagessar et al. [20] reported the removal of metal ions from three selected surface water on Coastal Guyana, using the peanut shell 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 decreased from 346±3.15mg/L to 293±1.77mg/L, 15.31%, whilst that for chloride, Cl-, decreased 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 [20].

Jagessar and Lord reported the status of surface water at five selected areas of Coastal Guyana: Blairmount, Bath, Bush lot, Bella drum and Mahaicony before and after treatment with a suitable coconut fiber adsorbent. 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. The adsorbents (coconut fibers) was selective in its removal of Pb^{2+} at Bush lot, Mahaicony and Bella drum 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 [21]. The suitability of recycled coconut fiber as the filter media for the treatment of waste water has been reported. It has been observed that coconut fiber can be used as an alternative filter media for the removal of pollutants as well as fungus from waste water, as there are large number of micro-pores with standard surface area existing in coconut fibres [22].

The use and efficiency of activated carbon from coconut shells as the potential cost effective absorbent material in drinking water filter has been noted [23]. Activation of the coconut shell carbon was carried out by carbonization in the exposure to nitrogen (N_2) atmosphere followed by heating with the activating agents for a specific retention period. pH test. Testing of filtered water were conducted using the protocol established by ANSI/NSF Standard 53 (Health Effects of Water Treatment System). The pH value was indicated to increase proportionally to the level of filtering, which has achieved a constant value of 6.41 after eight times of filtering. The activated carbon has been found to remove Methyl Tertiary-butyl Ether (MTBE) to non-detectable level, which is less than 1 part per billion (ppb). The non-detectable level has sufficiently reduced the odor and taste problems [23]. The performance of coconut fiber ash as an alternative low-cost adsorbent to the synthetic adsorbents used in wastewater treatment has been observed [24]. The optimum condition for the adsorption process was investigated, considering the effect of particle size, adsorbent dosage, and contact time of adsorbents of coconut fiber ash. It was found to be effective in the removal of Lead (Pb), Copper (Cu), and Zinc (Zn) metal ions from electroplating wastewater. The adsorbents coconut fiber ash was prepared through activation of carbon at 450 °C.

The experiments were conducted at varying adsorbent dosages (0.2g, 0.6g, and 1g), particle size (50 to 200 microns), and contact times (40 minutes, 80 minutes, and 120 minutes). The adsorbents show less efficiency in removing Zn metal ions, which is not more than 34% in the case of 1g adsorbent dosage, particle size ranges 100-200 microns, and 120 minute contact time. The maximum removal efficiency of 95.04% and 80% was obtained at the optimum amount (1g) of adsorbent dosage for Pb and Cu respectively. In the case of contact time, it was identified that the optimum condition for maximum removal efficiency is 120 minutes with a 1g adsorbent dosage both for Pb and Cu ions. (Wastewater treatment using coconut fiber ash as an adsorbent for removal of heavy metals [24]. Coconut shells via the production of activated carbon have been used in the treatment processes of ground water to reduce water hardness via the removal of Calcium, Magnesium and Total hardness. The initial values of Calcium, Magnesium and Total Hardness in the raw water sample were 120.24mg/L, 98.29mg/L and 588.00mg/L, respectively, which are above the World Health Organization (WHO) standard. Calcium, Magnesium and Total Hardness were removed via the adsorbent at a contact time of 60 minutes with removal efficiencies of 80%, 60.44% and 66.71%, respectively. Also, the optimum dosage occurred at 1.2g for Calcium hardness, 1.5g for Magnesium hardness and Total hardness [25].

Coconut midrib as plantation waste can be used as raw material for activated charcoal production. In the initial stage, the coconut midrib was dried and homogenized to 2 mesh. After that the coconut midrib was carbonized at temperatures of 425 °C, 450 °C, and 475 °C and a time of 105 minutes, 135 minutes and 165 minutes. In the next stage, the carbonization results are activated with HCl solution to produce activated charcoal. The highest yield of activated charcoal was obtained at 425 °C for 105 minutes at 30.9%. Increased temperature and carbonization time cause reduced yield of activated charcoal from coconut midribs. The results of the initial analysis of jump tan waste indicate a high COD level of 180mg/L and exceeds the Environmental Quality Standard which is a maximum of 150mg/L. The maximum adsorption performance of activated charcoal was obtained when the carbonization temperature was 425 °C which caused a decrease in COD to 20mg/L (88.89%). A decrease in BOD which was initially 160mg/mL was significantly reduced to 16mg/L (90%) in the same carbonization condition. It shows that the activated carbon from the coconut midrib is able to reduce the levels of COD and BOD of jump tan liquid waste which can be comparable with the Environmental Quality Standards [26].

The use of natural adsorbents to remove heavy metal ions from water, have been finding increasing applications [27,28].

Guyana is a sovereign state on the northern mainland of South America and is also part of the Caribbean region. Guyana (83,000 square miles) is bordered by the Atlantic Ocean to the north, Brazil to the south and southwest, Suriname to the east and Venezuela to the west [29]. Figure 1 is a map of two of the selected areas of coastal Guyana. It's an Amerindian word, meaning land of many waters. Thus, the general objectives of the research were to identify and evaluate the status of surface water from selected areas of coastal Guyana (Skeldon sugar estate canal surface water, Hope canal surface water and Mahaica canal surface water) and to remove toxic contaminants using coconut midrib fibres, Figure 2 as a cheaper ecofriendly adsorbent alternative. Also, to identify the optimal percentage level of heavy metals, cations & anions, along with the turbidity and conductivity within the water samples. To the best of knowledge, the coconut midrib in an uncarbonized state has never been used as an adsorbent (Figure 3).

Figure 1: A coconut branch, showing its distinctive midrib.

Figure 2: Map of Guyana.

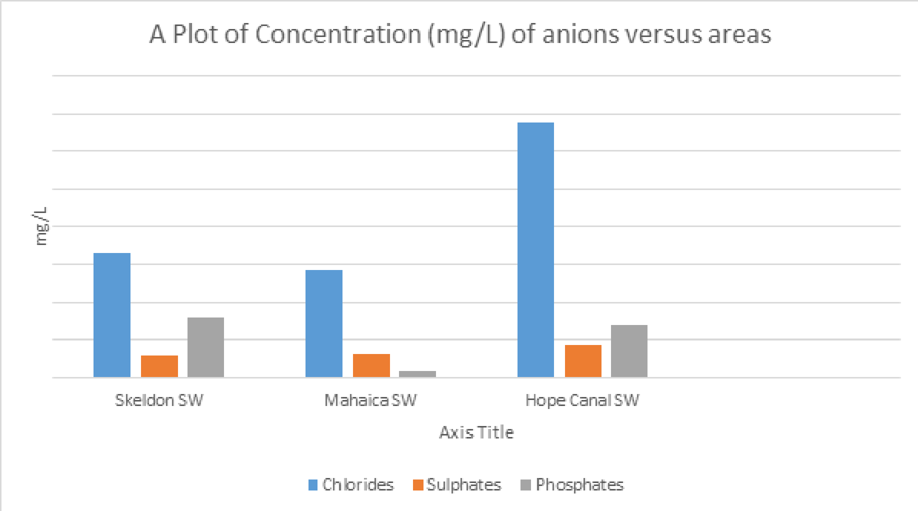

Figure 3: A Plot of Concentration (mg/L) of anions versus selected coastal areas for untreated water.

Procedure

Sampling and collection of surface water

A total of 3(3x3=27) bottles were required for this project. The water samples were collected in triplicates of two (2) from the three selected areas of Guyana's Coastland, six bottles for each site, plus another three bottles for the filtrate of the treated water (3 for treated water and 3 for untreated water and another three to collect the filtrate). The samples were collected randomly, labeled and stored in a cool environment. The samples were then submitted immediately for analyses at GUYSCO. One of the Triplicates set of water was treated with an adsorbent and filtered. For the untreated and treated water, the water samples were filtered, using a pore diameter membrane filter. After filtration, the filtrate was transferred to a beaker. 5ml of Conc. H_2SO_4 and several boiling chips were added. The contents of the beaker were brought to a slow boil and evaporated onto a hot plate to the lowest volume (10ml) to initiate precipitation. Heating continued with concomitant addition of HNO_3 until digestion was completed. Drying of the sample was avoided. The flask was then washed with water and contents filtered. The filtrate was transferred to a 100ml volumetric flask and made up to the mark. Portions of the solution were then taken for metal ion determinations using Flame Atomic Spectroscopy, (FAS). For each metal analyzed, an appropriate standard solution of known metal concentration in the water with a matrix similar to the sample was prepared.

Preparation of adsorbent

A coconut midrib was stripped of its leaves, mechanically chopped and ground into a powder using a grinding mill. About 7.0g of the adsorbent was placed in a small jar and the lipophilic component of the ground coconut midrib was extracted thrice with hexane and filtered, until the filtrate is colorless. The resulting green extract was discarded, whereas the ground extract was placed on a large filter paper to be dried for a day, then the required amount were added to a portion of the surface water, stirred for thirty (30) minutes and then filtered. This constituted the treated water.

Data analysis

From the results collected from each test, comparisons and calculations was done to identify trends and possible patterns. The data was placed into tables and graphs to be represented and analyzed. Recommendations were made based on the data gathered from each of these tests.

Statistical analysis

Analysis of Variance (ANOVA) One way without replication was done. This is a statistical technique used to find out if the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the means of different samples. It splits an observed aggregate variability found inside a data set into two parts: systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use the ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study (Kenton, 2019).

Discussion

The untreated and treated surface water from the three selected areas: Skeldon Surface Water, Mahaica Surface Water and Hope Canal Surface water were analyzed for the presence of cations such as Al, As, Pd, Cd. Hg, Cd and Zn and anions such as Cl^-, NO^{3-}, SO_4^{2-} and PO_4^{3-}. For all of the cations tested for, it was found that the concentration was below the Minimum Detection Level (MDL). Thus, it appears that the surface water from the three selected areas remains uncontaminated with cations. With respect to the anions, it was found that the adsorbent significantly reduce the chloride ion concentration at Mahaica Surface Water. The chloride ion concentration significantly decreased from 14.2mg/L to 3.74mg/L i.e. 73.66% reduction. For the Skeldon and Hope Canal Surface water, the treated water showed a higher chloride ion content than the untreated water, indicating that the adsorbent wasn't effective in removing the Cl^- ions in these areas. For the nitrate anion, there wasn't any detection, amongst all three areas. The concentration of NO^{3-} was below the metal detection limit, MDL. For the SO_4^{2-}, the concentration of the anion in the treated water was lower than in untreated water for all cases. This indicates that the adsorbent was effective in removing sulphate anions in the treated water. The highest concentration of sulphate anions in untreated water was found to be in the Hope Canal Surface water, followed by Mahaica Surface Water i.e. the SO_4^{2-} anion concentration followed the sequence: Hope Canal Surface water > Mahaica Surface water > Skeldon surface water.

The adsorbent was effective in removing phosphate anion, PO43- only at Skeldon Surface water. For the other two surface water, the highest concentration of selected anion for the untreated water was noticeable at Skeldon Surface water. PO_4^{3-} concentration decreases from 8.0mg/L to < MDL, which is below the Metal detection Limit, MDL. For the other two surface water, the anion concentration increased in the treated water. So far PO_4^{3-}, the adsorbent was effective in removing PO_4^{3-}only at Skeldon Surface Water. The electrical conductivity, EC, is a function of the metal ion concentration in water. The greater the metal ion concentration in the water, the greater is the electrical conductivity, EC. There was a slight increase in the metal ion concentration, transitioning from the untreated water to the treated water for all of the selected surface water. It must be mentioned that the concentration of cations is below the internationally accepted threshold value for each metal ion analyzed for as shown in Table 1 vs. Table 2. For the anions, all were below the International accepted values, with the exception for PO_4^{3-} for untreated water at Skeldon (8.0mg/L) and Hope Canal Surface water (6.95mg/L), Table 3. The threshold value for PO_4^{3-} is 5. Result were obtained for the Cl-, SO_4^{2-} and PO_4^{3-}value for Skeldon, Mahaica and Hope Canal untreated water and as such ANOVA analyses were done and are presented in Table 4. Anova analyses were done for some of the anions but not cations, since cations were below the detection limit, MDL. ANOVA analyses reveal that the three areas tested for, there wasn't any significant difference with respect to the anions: Cl^-, SO_4^{2-} and PO_4^{3-} concentration. The P value (0.271206) was found to be greater than 0.05 (Table 5). This is substantiated by the F value=1.840433 < F critical (6.944). It also revealed that there is a significant difference in concentration of the various anions amongst the three selected areas as P value (0.0342) < 0.05. This is further substantiated by the fact that F value (8.8135) > F critical (6.944).

Table 1: Detection of cations.

	Parameters						
Sample Description	Al	As	Pb	Cd	Hg	Cu	Zn
A1 Treated	< MDL	< MDL	< MDL	< MDL	< MDL	<MDL	< MDL
A2 Untreated	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL
B1 Treated	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL
B1 Untreated	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL
C1 Treated	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL
C2 Untreated	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL	< MDL

Table 2: Detection of anions.

	Parameters				
Sample Description	Cl-	NO^{3-}	SO_4^{2-}	PO_4^{3-}	ECW
A1 Treated	18	< MDL	< MDL	<MDL	1.49
A2 Untreated	16.6	< MDL	2.98	8	0.1
B1 Treated	3.74	< MDL	< MDL	5.77	0.09
B1 Untreated	14.2	< MDL	3.19	0.82	0.02
C1 Treated	39	< MDL	<MDL	12.1	0.17
C2 Untreated	33.7	< MDL	4.36	6.95	0.11

MDL: Metal Detection Limit

A = Skeldon Surface Water

B = Mahaica Canal Surface water

C = Hope Canal surface water

Weight of adsorbent used = 0.71g

Color of adsorbent: off white

Table 3: Health based guideline by the World Health Organization, WHO for cations and anions within the three selected surface water.

Cations and Anions	Health Based Guideline by the WHO (mg/l)
Al	0.1-0.2
Fe	3
Pb	1.0×10^{-2}
Cd	3.0×10^{-3}
Zn	3
PO^{3-}_4	5
SO^{2-}_4	250
Cl	250
ECw	256

Table 4: Status of selected anions at three surface waters.

Areas	Cl-	SO_4^{2-}	PO_4^{3-}
Skeldon	16.6	2.98	8
Mahaica Canal	14.2	3.19	0.82
Hope Canal	33.7	4.36	6.95

Table 5: ANOVA analyses for anions: Chlorides, sulphates and phosphates for untreated water.

Source of Variation	F	P-value	F crit
Rows	1.840433	0.271206	6.944272
Columns	8.813502	0.034208	6.944272

Conclusion

The concentration of the various cations: Al, As, Pb, Cd, Hg, Cu and Zn were below Metal Detection Limit (MDL) for untreated and treated water. For anions, NO3- was below the detection limit for untreated and treated water, whereas for the other anions, its only SO42- that was below the metal detection limit for the treated water. The adsorbent, the coconut midrib in its un carbonised state, was effective in removing SO42- ions for all the treated water at all three-surface water and SO42- ions at Skeldon Surface Water. Thus, the coconut midrib has shown selectivity in removing SO42- ions. However, further experiments are needed to justify this.

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