Effective use of rice husk ash to treat highly polluted water: case study in the Dhalassori River, Bangladesh

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Abstract. In Dhaka city the source of surface waters as like as Dhalassori, Sitalakha, Buriganga rivers are frequently deteriorating due to the discharging of heavily toxic wastes into the water by the various industries and factories. The major source of drinking water is the underground which is rapidly decreasing due to the frequent use. If quality of surface water like Dhalassori river is such that it is too difficult to treat the water for the drinking purpose then a catastrophe may happen one time because the people who are wasting this valuable source of water may not know that how much days they can survive without potable water. In this research it is successfully shown by through laboratory and statistical analysis that a bio adsorbent called Rice Husk Ash obtained from the burning of Rice husk has the COD removal efficiency 99.33 .3% ~ 99.99% and color removal efficiency of 99.96% with respect to the raw water of Dhalassori river if the factors influencing adsorption that is investigated for the Rice Husk Ash, can be properly maintained.

Keywords: Wastes, Waste water, River, Pollution, Economical, Biosorbents, Bacteria, Rice husk ash, Biomass

1. INTRODUCTION

The River Dhalassori is the life line of the Dhaka city and flanked in its southern side. Unlike many other rivers in the world, the Dhalassori River is not only important for providing vital ecological function, but also for various other purposes such as drinking water supply, transportation, cleaning, washing, recreation, ground water recharge, flood control and also as a means of disposing wastes within the assimilation capacity of the river. The Dhalassori River receives wastewater and storm water along its course through many point sources such as sluice gates, city drains and effluent outfall of the Pagla Sewage Treatment Plant (PSTP). The study by Kamal (1996) and Magumdar (2005) have identified this particular sluice gate to be the most susceptible to discharge highly polluted wastewater from tanneries in Hazaribagh area along with municipal wastewater from the neighbouring areas of Katasur and Ramchandrapur khal.

These are mostly located within very densely populated areas near the river like Islambagh, Shahidnagar and Kamrangir Char. Because of this scattered and unpredictable drainage pattern, the Dhalassori River basin has been subdivided into a number of wastewater and storm water drainage zones by previous studies in order to compute wastewater flow rates and pollution loadings (JICA 1991; Browder 1992; Kamal 1996; Rahman and Rana 1996).

The major drainage channels (locally known as Khal) in the City are Dholai khal, Gerani khal, Segunbagicha khal and Begunbari khal, which collect catchment's runoff as well as wastewater and drain to the peripheral rivers. According to a recent estimate, about 70,000 tons of raw hides and skins are processed in these tanneries every year polluting the environment and the quantity of untanned solid wastes namely raw trimming, we lime fleshing, pelt trimming generated in these tanneries is estimated to be 28,000 tons. Statistics provided by various sources suggest that a big tannery of the Hazaribagh area releases 2,500 gallons of chemicals wastes each day, polluting the city's air in addition to contaminating the water of the river Dhalassori. (Ahmad et al., 2009)

Therefore, for the necessity of time and to save our future generation from a certain catastrophe, finding a highly sustainable treatment option for the Dhalassori river waste water is obvious. The technology used in this research is bio adsorption and the bio adsorbent used for the treatment is rice husk ash. An integrated approach has been taken in this study to characterize and to evaluate the efficiency of rice husk ash and to give the most cost effective solution for the treatment of Dhalassori river waste water. Treatment of Dhalassori river waste water by RHA under several treatment processes. To select the most effective treatment processes for the treatment of Dhalassori river waste water which is highly sustainable and economical in the context of Bangladesh.

2. BIO ADSORBENTS:

Rapid industrialization and urbanization have resulted in the generation of large quantities of aqueous effluents, many of which contain high levels of toxic pollutants. Various physicochemical and biological processes are usually employed to remove pollutants from industrial wastewaters before discharge into the environment. Since any type of solid material has the capacity to adsorb pollutants to some degree, a number of industrial inorganic wastes, such as ash, or natural inorganic materials like clay, synthetic materials like zeolite, as well as, living or nonliving biomass/biomaterials, have been investigated as cheap adsorbents capable of replacing the well-known, but more expressive ones. The use of biosorbents for the removal of toxic pollutants or for the recovery of valuable resources from aqueous waste water is one of the most recent developments in environmental or bioresource technology. The major advantages of this technology over conventional ones include not only its low cost, but also its high efficiency, the minimization of chemical or biological sludge, the ability to regenerate biosorbents, and the possibility of metal recovery following adsorption. As opposed to a much more complex phenomenon of bioaccumulation based on active metabolic transport, biosorption by dead biomass (or by some molecules and/or their active groups) is passive and occurs primarily due to the 'affinity' between the biosorbent and adsorbate.

2.1 Types of Biomass or Biomaterials

Adsorptive pollutants like metals and dyes can be removed by living microorganisms, but can also be removed by dead biological material. Feasibility studies for large-scale applications have demonstrated that biosorptive processes using non-living biomass are in fact more applicable than the bioaccumulative processes that use living microorganisms, since the latter require a nutrient supply and complicated bioreactor systems. The first major challenge faced by biosorption researchers was to select the most promising types of biomass from an extremely large pool of readily available and inexpensive biomaterials.

Biosorptive capacities of various biomass types have been quantitatively compared in many review papers. In some cases, the uptake of heavy metals by biomass reached as high as 50% of its dry weight. Biosorbents primarily fall into the following categories: bacteria, fungi, algae, industrial wastes, agricultural wastes, natural residues, and other biomaterials. It should be noted that the biosorptive capacity of a certain type of biosorbent depends on its pretreatment methods, as well as, on experimental conditions like pH and temperature. When comparing biosorptive capacities of biosorbents for a target pollutant, therefore, the experimental data of each researcher should be carefully considered in light of these factors. Although simple cutting and/or grinding of dried biomass may yield stable biosorbent particles, some types of biomass have to be either immobilized in a synthetic polymer matrix and/or grafted onto an inorganic support material like silica to yield particles with the required mechanical properties.

3. RICE HUSK ASH

Rice husk is an agricultural residue abundantly available in rice producing countries. The annual rice husk produce in India amounts is generally approximately 12 million tons. Rice husk is generally not recommended as cattle feed since its cellulose and other sugar contents are low. Furfural and rice bran oil are extracted from rice husk. Industries use rice husk as fuel in boilers and for power generation. Rice Husk Ash is a substance which is obtained during the production of Rice Husk activated carbon. The rice husk ash which is used in this study was obtained from the burning of rice husk at a temperature 86^{0}C in a furnace made of 1.00 mm MS steel sheet and has a diameter and height 35.56 cm and 50.8 cm respectively with two 7.62 cm × 15.24 cm openings at the bottom side. (Mahmudur Rahman, 2011).Rice husk ash is an excellent bio adsorbent due to its highly mico-porous structure. Among the different types of biomass used for gasification, rice husk ash has a high ash content varying from 18 – 20 %. Silica is the major constituent of rice husk ash and the following tables gives typical composition of rice husk and rice husk ash. With such a large ash content and silica content in the ash it becomes economical to extract silica from the ash, which has wide market and also takes care of ash disposal.

3.1 Chemical Composition of Rice Husk

The rice husk ash was one of lignocelluloses material which consist of lignin, cellulose and xylon which apart of biomass material with high content of carbon and silica. The conversion of the composition and phase involves of primary decomposition of lignocellulosic matrix that is composed of three interconnected polymeric materials: cellulose, hemicellulose, and lignin. The pyrolysis process will form high carbon content with deformation on the surface condition (surface area). Table-1 shows the theoretical percent of chemical composition compound in virgin rice husk ash.

Table 1. Composition of Rice husk Ash on dry basis (Mahmudur Rahman, 2011).

Element	Mass fraction (%)
Carbon	41.44
Hydrogen	4.94
Oxygen	37.34
Nitrogen	0.57
Silicon	14.56
Potassium	0.59
Sodium	0.035
Sulfur	0.3
Phosphorous	0.07
Calcium	0.06
Iron	0.006
Magnesium	0.003

3.2 Characterization of Rice Husk Ash

Rice husk ash used in this research was obtained from the production of rice husk activated carbon by the controlled heating of rice husk in a furnace in the environmental engineering laboratory (Mahmudur Rahman, 2011). Detailed characterization of rice husk ash was studied. To study the characteristics the following parameter were analyzed. The result of analysis of Table-2 showed the results of proximate analysis.

Table 2. Characterization chart of Rice Husk Ash.

	Sample-1	Sample-2	Sample-3	Average
Moisture Content (%)	5.2	5.57	5.45	5.41
Volatile Solid Content (%)	1.83	0.50	0.44	0.92
Ash Content (%)	99.12	98.89	96.99	98.33

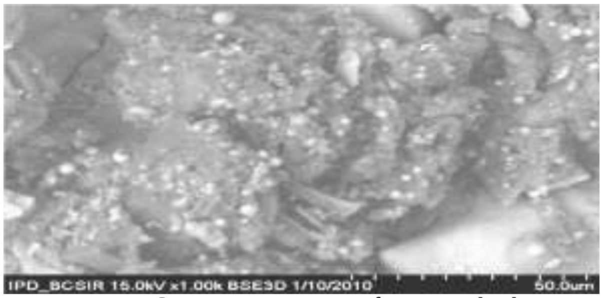


Fig. 1. Cross section images of Raw rice husk.

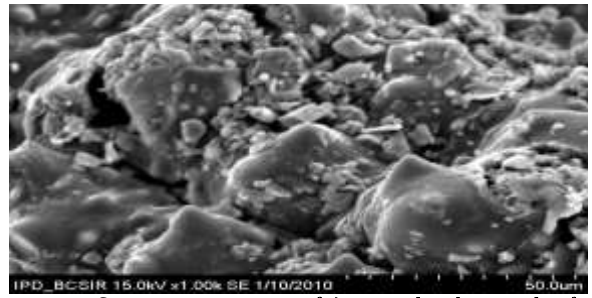


Fig. 2. Cross section images of Activated carbon made of rice husk ash.

4. METHODOLOGY

4.1 Batch Tests to Treat Dhalassori River Waste Water

Series of six batch tests were conducted to evaluate the effective option. Each batch tests consist of several selected unit processes. The treatment options are given in figure 3.

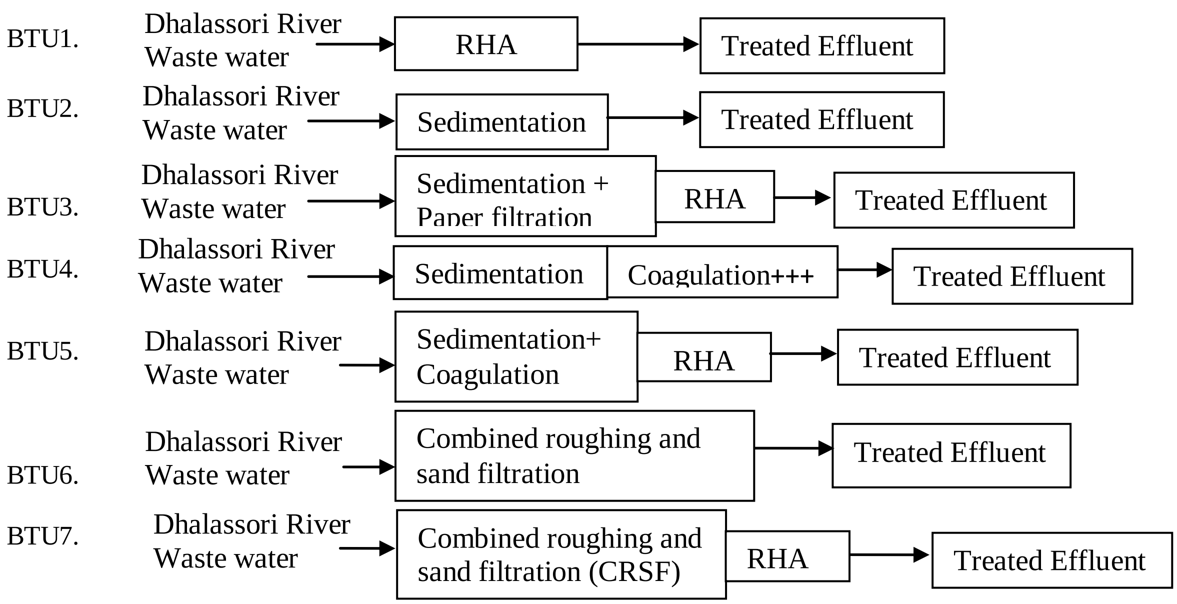


Fig. 3. Batch Tests to Treat Dhalassori River Waste Water.

For sedimentation unit the wastewater was retained for 1 day in a jar. After that the clear effluent from the top of the sedimentation unit was collect for test. For coagulation unit, FeCl3 was used as coagulant. The coagulant dose was started from 150mg/L and with 500 mL wastewater and was carried out until finding an optimum dose. Then the wastewater is subjected to rapid mixing for 1 minute and after that 30 minutes slow mixing. Then the wastewater was retained for 60 minutes. After 60 minutes the clear effluent from sedimentation unit was collected for further test. For filtration unit, combined roughing and sand filter was used. The wastewater passes through the sand filter was collected in separate beaker. For rice husk ash adsorption unit, 25 gm activated carbon was mixed in 100 mL wastewater for 60minutes in 40^{o}C. Then the mixed wastewater was filtered in Whatman filter paper and collected the effluent.

4.1.1 Sample Preparation

The experimental solutions were prepared by dissolving 15mg of methylene blue in 1000mL distilled
water i.e. 15mg/L to produce color of 180-185 Pt-Co.

4.2 Characteristics of Dhalassori River Waste Water Used in this Study

The water used in this research was collected from a sewer flow discharged directly into the Dhalassori river without any treatment or a little treatment. However, according to the WASA 9 different industries are simultaneously discharging the waste water through this pipe into the Dhalassori river. Figure 4 is showing the source of the waste water.

Fig. 4. Dumping of waste in Dhalassori River through concrete pipe.

The raw water was contained high amount of COD, color and total dissolved solids. Table-3 is showing the quality of the raw water tested in the laboratory.

Table 3. Raw water quality of the Dhalassori River.

Water quality parameter	Unit	Amount in waste water
pH		7.43
Color	Pt-CO	3900
TS	mg/L	2277
TDS	mg/L	1846.67
SS	mg/L	296.33
COD	mg O_2/L	27633.3
Chloride	mg/L	1953.33
Hardness	mg/L	2681.57
NO_3^-	mg/L	229

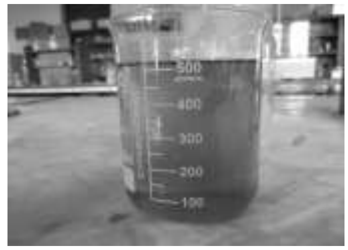
4.3 Batch Treatment of the Dhalassori River Waste Water

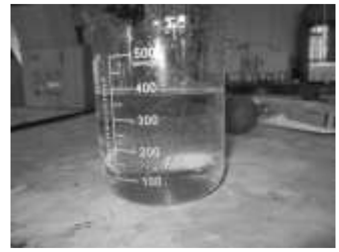
The collected waste water was treated by batch treatment. Seven treatment batches were selected and in each and every case the quality of the treated effluent was investigated. Due to the high concentration of total solid in each and every batch operation primary sedimentation was necessary. The variation of color of the treated effluent and the raw color for various batch operations is given in figure 5. The variation of COD value and color with the batch operation is shown in Table 4 and 5 respectively.

Raw Water

Treated Effluent after sedimentation


Raw Water


Sedimentation+ Filtration


Treated Effluent after RHA


Raw Water


Sedimentation+ Filtration


Sedimentation+ Filtration+ Coagulation


Treatment after RHA

Fig. 5. Treatment of Dhalassori river waste water by different batches.

Table 4. Variation of COD with the variation of treatment unit.

Serial No.	Treatment unit	COD value (mg O_2/L)	Bangladesh standard	Amount in raw water	% Efficiency
BTU 1	Waste water + RHA	186.67	4	27733.3	99.3269102
BTU 2	Waste water + Sedimentation	810.67	4	27733.3	97.0769075
BTU 3	Waste water + Sedimentation + RHA	32	4	27733.3	99.8846152
BTU 4	Waste water + Sedimentation + Coagulation	170.67	4	27733.3	99.3846026
BTU 5	Waste water + Sedimentation + Coagulation + RHA	26.67	4	27733.3	99.903834
BTU 6	Waste water + Sedimentation+ CRSF	533.33	4	27733.3	98.0769328
BTU 7	Waste water + Sedimentation+ CRSF + RHA	37.33	4	27733.3	99.8653965

Table 5. Variation of color with the variation of treatment unit.

Serial No.	Treatment unit	Color (Pt-CO)	Amount in raw water	Bangladesh standard	% Efficiency
BTU1	Waste water + RHA	13.3	3900	15	99.6589744
BTU2	Waste water + Sedimentation	305	3900	15	92.1794872

BTU3	Waste water + Sedimentation + RHA	12.2	3900	15	99.6871795
BTU4	Waste water + Sedimentation + Coagulation	97	3900	15	97.5128205
BTU5	Waste water + Sedimentation + Coagulation + RHA	14.2	3900	15	99.6358974
BTU6	Waste water + Sedimentation+ CRSF	101	3900	15	97.4102564
BTU7	Waste water + Sedimentation+ CRSF + RHA	12	3900	15	99.6923077

Heat is a significant influence on the adsorption and with the gradual increase of temperature adsorption efficiency was increased but after 45^{o}C temperature desorption was started. After that desorption was started. The contact time study the temperature was kept constant to 45^{o}C. Started from five minutes the adsorption was reached in its equilibrium after 50 minutes and after 50 minutes with the increase of time the adsorption efficiency was remain more or less same and it satisfied the adsorption equilibrium condition. Contact time study was carried out for three different doses and in every case the equilibrium time was same. At 50 minutes the adsorption efficiency of RHA for 7gm, 8gm and 9gm dose was 97.95%, 99.24% and 100% respectively which is more than the adsorption efficiency (35%) of available commercial and industrial grade activated carbon (Mahmudur Rahman, 2011) Adsorbent dose had a vital role on the adsorption efficiency. The batch operation 1 where waste water was directly treated with RHA it was observed that almost 25g RHA was needed for 100mL solution to decrease the color into the accepted level where according to table 5.2 the COD value was still high with respect to the normal value. For the treatment unit 2 where the waste water was kept 1 day for sedimentation the color and COD value was not still satisfactory.

Table 6. Effectiveness analysis of different treatment unit

No. of treatment unit	TDS (mg/L)	SS (mg/L)	Percentage of the amount of water available after treatment (%)	Amount of RHA was needed for the treatment (gm/100mL)
1	435	21.67	45	25
3	342.03	13.95	62	16
5	297.307	297.307	87	5
7	330	113.333	80	12

The COD treatment unit 5 was the most effective. Rice husk ash was needed for the treatment unit 1, 3, 5 and 7. The value of TDS, SS, percentage of the amount of water available after treatment and the amount of RHA was needed for the treatment unit 1, 3, 5 and 7 is shown in table. the Dhalassori river waste water treatment unit 5 was the most effective unit that means if the Dhalassori river waste water is primarily kept into sedimentation for one days and then coagulated by ferric chloride of dose 600 mg/L.

5. CONCLUSION

The characteristics of RHA were studied with respect to adsorption kinetic study, contact time study, physical properties and Dhalassori river waste water treatment efficiency. Rice husk ash is a porous bio-adsorbent and for its micro porous structure it acts as an excellent adsorbent. Every adsorption study had fulfilled the equilibrium criteria of adsorption as well as adsorption isotherm that is for contact time study when the temperature was constant to 45^{o}C, after 50 minutes the adsorption had reached to its equilibrium state and with the further increase of time adsorption efficiency did not show a noticeable increase or decrease and adsorption intensity n for Freundlich adsorption isotherm was greater than 1 which indicated an excellent condition for adsorption. Treatment of Dhalassori river waste water was done by seven different treatment batches. The investigated efficiency of rice husk ash for the standard methylene blue solution was nearly 100 percent. For the treatment process 5 the COD removal efficiency of rice husk ash was 99.3% ~ 99.99% and color removal efficiency was 99.96% with respect to the raw water of Dhalassori river and it was ensured the complete and effective reusability of the waste water. By analyzing the five important parameters of the reusability of water in industrial scale it was concluded that the treatment process 5 that means treatment by RHA after one day sedimentation and coagulation by ferric chloride was the most effective treatment for the Dhalassori river waste water.

REFERENCES

Ahmed M.F. & M.M. Rahman(2000), Water Supply and Sanitation, Rural and Low Income Urban
Communities, ITN-Bangladesh, BUET, Dhaka.

Ahmed, M. F. and Mohammed, K.N.,1988. "Pollution effects of effluent discharges from Dhaka City on
the river Dhalassori", in T. Pansward (ed.), Pollution Control in Developing Countries, pp 123-129,
Pergamon Press, Thailand.

DOE (Department of Environment), 1993. "Water Quality Data of Rivers Dhalassori, Meghna, Balu,
Sitalakhya, Jamuna (1981-90)", Government of Bangladesh, Dhaka.

Magumdar, T.K., 2005. "Assessment of water quality of the peripheral river system around Dhaka City".
M. Engg. Thesis, Bangladesh University of Engineering and Technology (BUET), Dhaka.

Mohammed, K.N., 1988. "Characterization, treatment and disposal of sewage of Dhaka City", M.Sc.
Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and
Technology (BUET), Dhaka.

Rahman, M.R. and Rana, M.Y., 1996. "Pollution Assimilation Capacity of Dhalassori River", Journal of
Civil Engineering, The Institution of Engineers, Bangladesh, vol. 24, no. 1, pp.85-95.

Dandia-Unicef (1999), ''Evaluation of the Rural Water Supply and Sanitation Programme Bangladesh''

The Bangladesh Environment Conservation Act (1995)

BKH Consulting Engineers, 1995. "Industrial pollution control management, Bangladesh", ADB TA
1769-BAN, Final Report-Phase 1, The Asian Development Bank and the Government of Bangladesh,
Dhaka.

Browder, G. J., 1992. "Final report for water quality management task", ADB TA 1104-BAN, National
Environmental Monitoring and Pollution Control Project, The Asian Development Bank, Dhaka.

Abdessemed, D. and Nezzal, G. (2002) "Treatment of primary effluent by coagulation adsorption-ultrafiltration for reuse", Desalination, Elsevier, Vol. 152, pp 367-373.

Asfour, H. M., Nasser, M. M., Fadali, O. A. and El-Geundi, M. S. (1985) "Colour removal from textile effluents using hardwood sawdust as an absorbent", Journal of Chemical Technology and Biotechnology, Wiley, Vol. 35, pp 28.

Aksu, Z. (2005). "Application of biosorption for the removal of organic pollutants: a review", Process Biochemistry, Elsevier, Vol. 40, pp 997–1026

Batra, S.H. (1985) "Other long vegetable fibers: abaca, banana, sisal, henequen, flax, ramie, hemp, sunn, and coir", Handbook of fiber science and technology, *In* M. Lewin and E.M. Pearce (ed.). Fiber Chemistry, Vol. IV, pp 15-22, Marcel Dekker, New York.

BKH Consulting Engineers, 1995. "Industrial pollution control management, Bangladesh", ADB TA 1769-BAN, Final Report-Phase 1, The Asian Development Bank and the Government of Bangladesh, Dhaka.

Derbyshire, F., Jagtoyen, M., Andrews, R., Rao, A., Martin-Gullon, I., and Grulke, E. (2001) "Carbon materials in environmental applications", In L. R. Radovic (Ed.), Journal of Chemistry and physics of carbon, Vol 27 pp 1–66, New York: Marcel Dekker.

Dhale A.D and Mahajani, V.V. (2000) "Studies on treatment of disperse dye waste: membrane-wet oxidation process", Journal of Waste Management, Vol. 20, pp 85-92.

Deo, H.T. and Desai, B.K. (1999) "Dyeing of cotton and jute with tea as a natural dye", Coloration Technology, Vol. 115, pp 224-227.

Bortone, G., Cech, J.S., Bianchi, R. and Tilche, A., (1995) "Effects of an anaerobic zone in a textile wastewater treatment plant", Water Science Technology. Vol.32, pp 133-140.

Tilzer, M. M. and Khondker, M. (1993). "Hypertrophic and polluted freshwater ecosystems: Ecological basis for water resource management." Dept. of Botany, Dhaka University, Bangladesh.