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EVALUATION OF WATER QUALITY INDEX USING PHYSICOCHEMICAL PARAMETERS OF TREATED DOMESTIC SEWAGE WATER

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ABSTRACT: Rice husk, an agricultural waste, its by-product rice husk ash and activated rice husk were investigated for its efficacy in domestic sewage water treatment. The main indicators of water quality namely physical, chemical and biological characteristics determine the level of treatment required for its consumption in many intended purposes according to local and international water standards. Different methods of water quality assessment were used to assure the permissible limits of physicochemical parameters of water before its use for appropriate purposes. It is reported that the main source of water pollution is caused by domestic sewage. The present study was performed to determine the various physicochemical parameters of domestic sewage water after its treatment with rice husk, rice husk ash and activated rice husk. Weighed water quality index (WQI) was also calculated to assess the quality of water for its re-usability of treated water. The results showed that rice husk, rice husk ash and activated rice husk were found to be efficient in decreasing the levels of all the examined parameters, except dissolved oxygen which was found to be slightly elevated. The results of WQI findings revealed that activated rice husk treated domestic sewage water with fair water quality index could be used for irrigation, recreation and other convenient purposes. The optimized use of these adsorbents will surely reduce the problem of huge agricultural waste disposal besides mitigating the challenges of domestic waste water treatment before its use or discharge into the water bodies.

KEYWORDS: Rice Husk, Rice Husk Ash, Activated Rice Husk, Domestic Sewage Water, Physicochemical Properties, Water Quality Index

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1. INTRODUCTION

Water, a renewable natural resource is an indispensable resource required for socio-economic development of any nation [1]. The availability and quality of reliable water resource determines human's choice of siting residential areas. The adequate water management is the right key to unlock economic development and social wellbeing [2]. Globally, 1.1 billion people do not have access to safe water and 2.4 billion people are without adequate sanitation [3]. Water can be used for different utilities based on its quality parameters. pH, turbidity, dissolved oxygen, electrical conductivity, total hardness, total dissolved solids and other parameters are examined to assay the suitability of water for drinking, industrial, aquatic organisms and agricultural purposes. Water quality parameters need to satisfy certain index so as to become fit for these purposes [4]. Many freshwater bodies are prone to be contaminated because of human activities, industrialization, poor sanitation facilities, sewage and waste disposal. Sewage is the main source of fresh water pollution [5]. Indiscriminate discharge of untreated domestic waste water and solid particulates that are dumped into the sewer system makes the task of treating domestic sewage, very complex and expensive. To exterminate any undesired health problems, the waste water from various sources must be treated before its outlet into natural environment. Developing countries has pivoted on reaping the importance of using the sewage effluent as fertilizer and treated sewage water for irrigation purposes as it is considered a source of organic matter and plant nutrients and serves as a good manure [6]. When irrigation water mixed with industrial effluents are used, plants will accumulate the heavy metals in their tissues above the permissible limits. It is certainly a threat to humans and animals that consume these crops which prolong the link of contamination through food chain [7]. Agricultural waste materials such as rice husk, coconut coir, groundnut shell, coconut shell, wood, corn cob, etc., are used to produce activated carbon and can be used for water treatment processes. Agricultural waste peels have been recognized as an ecological burden to the society. These waste peels stimulated the new gateways for the development of renewable, low-cost and sustainable adsorbents for water treatment applications [8]. Rice husk or peel that is generally regraded as waste [9] is now used as a precursor for producing activated carbon [10], Zeo-lite [11], Silica [12], Concrete [13], etc. Various pollutants such as dyes, phenols, organic compounds, pesticides, inorganic anions, and heavy metals are very effectively removed with rice husk as adsorbents [14]. Studies showed rice husk ash and rice husk-based activated carbon has profound effects on removal of contaminants from aqueous phase adsorption process. Being composed of organic matter and silica, the carbonaceous rice husk could be effective in eliminating the color, odour, turbidity and reduce COD, TSS, and TDS by removing the dissolved organic substances, thereby improving the water quality [15]. Rice husk and activated carbon could be successfully used for the removal of metals. It provides an excellent water treatment which proves cost effective and environmental friendly [16]. Studies on the application of rice husk in removal of basic, direct and acid dyes were carried out. Evidences showed that lignin, cellulose and hemicellulose were the principal components involved in dye adsorption. Adsorption of basic dyes onto rice husk involves electrostatic interactions. Alterations in active functional groups on heating decreases the ability to adsorb acidic and direct dyes. Decolorization of sugar syrup and vegetable oil by these agricultural wastes was also studied. Production of activated carbon from rice husk was characterized and used for decolorization of vegetable oils such as rice bran oil [17]. Rice husks and its activated form were intended to use as adsorbents to dispose oil spills [18]. Water quality index provides information about water quality in a single value and is commonly used for detection and evaluation of water pollution. Water quality assessment involves analysis of physicochemical, biological and microbiological parameters that reflects the biotic and abiotic status of ecosystem [19]. Water quality index implies a nominal number that denotes the overall water quality at a certain location and time. It promotes to turn complex water quality data into a detailed information useful for public [20]. All there exists is a lack of awareness and responsibility equally among the uneducated and educated people in avoiding indiscriminate discharge of untreated domestic and industrial effluents directly into natural water bodies. The execution of proper waste water treatment through better and cheap methods is the ever need of the hour. Researchers are in the thirst of searching many novel adsorbents that would rectify the existing problem of waste water disposal and provide a good means to the society to maintain the sustainability of water resources. It is well known that a large amount of re-usable water exists in these waste water. The present investigation aims to determine the water quality index (WQI) of domestic sewage water before and after treatment with rice husk, rice husk ash and activated rice husk in water purification process on the basis of various physicochemical parameters of raw sewage and treated water samples. Besides combating the disposal issues of agricultural residues, the results of these findings could not only fetch an admissible quality to the domestic sewage water before its discharge into natural water sources but also intended the re-use of these treated water for irrigation purposes.

2. MATERIALS AND METHODS

2.1. Collection of Domestic Sewage Water

The domestic sewage water samples were collected from household areas and pooled to obtain collective samples. These samples are the representatives of the sewage water before the waste water gets mixed with the common drainage. Samples for analysis were collected in sterilized bottles.

2.2. Collection of Adsorbent Materials for Water Treatment

The rice husk and rice husk ash were collected from the local mills of Erode District, Tamilnadu, India. These rice husk were then processed, dried and ground into a fine powder. The dried rice husk was kept in oven and dried at 200° C for an hour to obtain the activated rice husk. The rice husk (RH) powder, fine rice husk ash (RHA) and activated rice husk (ARH) were used for water treatment process.

2.3. Treatment of Domestic Sewage Water using Selected Adsorbents

In batch adsorption studies, a known amount of adsorbents (5 g/ 100 ml) were individually added to the pooled domestic sewage water samples. The contents were agitated in a rotary shaker at 150 rpm for one hour. The filtrate obtained after adsorption treatment process with adsorbents was then assayed for its physicochemical properties.

2.4. Physicochemical Analysis of Domestic Sewage Water and Treated Water Samples

The physicochemical analysis of the water samples was performed with raw domestic sewage water and also rice husk (RH), rice husk ash (RHA) and activated rice husk (ARH) treated water samples. The samples were named as follows: Untreated domestic sewage water sample as S1, sewage water treated with RH, RHA and ARH as T1, T2 and T3 respectively. The physicochemical parameters analyzed in the study namely pH, electrical conductivity (EC), total alkalinity (TA), total hardness (TH), calcium, magnesium, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) and total suspended solids (TSS) were determined using standard methods of analysis of water and waste water as prescribed by [21], [22], [23], [24], [25]. All the chemicals and reagents used were of analytical grade.

2.5. Water Quality Index Determination of Domestic Sewage Water and Treated Water Samples

Water quality index (WQI) is defined as the reflection of composite influence of different quality parameters on the overall quality of water. The water quality parameters are selected based on its direct involvement in deteriorating effect in water quality for human consumption. For WQI calculation, above mentioned twelve hydro physical and chemical quality parameters have been selected. The values of these parameters will proportionally increase WQI value. The weighed arithmetic WQI method [26] was used for the calculation of water quality index of the untreated and treated water [27]. Let there be n water quality parameters and quality rating or sub index (Q_n) is a number that reflects the relative value of n^{th} water quality parameter in polluted water with respect to its standard permissible value. Quality rating was calculated as follows:

$$Q_n = 100 * (V_n - V_{10}) / (S_n - V_{10})$$

Where,

Q_n = Quality Rating for the n^{th} water quality parameter

V_n = Estimated value of n^{th} water quality parameters of collected samples

S_n = Standard permissible value of n^{th} water quality parameter

V_{10} = Ideal value of nth water quality parameter in pure water (V_{10} value is 0 for all other parameters except pH and dissolved oxygen which are 7 and 14.6 respectively).

Unit weight (W_n) for n^{th} water quality parameter is a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$$W_n = K/S_n$$

Where,

W_n = Unit weight for n^{th} water quality parameter

S_n = Standard permissible value of nth water quality parameter

K = Constant of Proportionality

The standards recommended by the Indian Council of Medical research (ICMR) and Indian Standards Institution (ISI) are considered for quality rating (Q_n) and Unit Weight (W_n) computation were used in this study [28].

The overall WQI was calculated by aggregating the quality rating with the unit weight linearly and can be given by the following expression.

$$WQI = \Sigma\, Q_nW_n/\Sigma\, W_n$$

Where,

Q_n = Quality Rating for the nth water quality parameter

W_n = Unit weight for n^{th} water quality parameter

The ranges of WQI, the corresponding status of water quality and their possible use are summarized [29], [30].

Table 1: Summary of Water Quality Index (WQI)and Corresponding Water Quality Status (WQS)

S.No	WQI	WQS	Possible Uses
1	0 - 25	Excellent	Drinking, Irrigation and Industrial
2	26 - 50	Good	Domestic, irrigation and Industrial
3	51 - 75	Fair	Irrigation and Industrial
4	76 - 100	Poor	Irrigation
5	101 -150	Very Poor	Restricted use for Irrigation
6	> 150	Unfit for consumption	Proper Treatment Essential before use

3. RESULTS AND DISCUSSION

WQI indicates the water quality in terms of index number and presents useful information of overall quality of water for public or for any other utilities as well as in the pollution abatement programme and in water quality management. The prime prerequisite for WQI calculation is the result of various water quality parameters.

3.1 Physicochemical Parameter Analysis of Water Samples

The evaluation of the physicochemical features of the domestic sewage water before and after treatment with rice husk, rice husk ash and activated rice husk was made using various parameters. The results of the findings showed that the levels of all the examined parameters except dissolved oxygen were found to be decreased after treatment with the adsorbents. Activated rice husk treated water samples were found to have comparatively decreased values except pH and total alkalinity. Dissolved oxygen of activated rice husk treated sample was found to be increased. The statistical summary of the selected parameters of untreated and treated samples were presented with the mean value of the data along with standard error were presented in the Table 2. From the observed physicochemical parameter values, it was noted that all the analyzed values of the three different treated sewage water samples namely pH, electrical conductivity, total alkalinity, total hardness, calcium, magnesium, chloride, dissolved oxygen, total dissolved solids and total suspended solids, were found to be within the standard desired limit as cited by BIS/ICMR i.e., 7.5, 300 μS/cm, 120 mg/l, 300 mg/l, 75 mg/l, 30 mg/l, 250 mg/l, 5 mg/l, 500 mg/l and 500 mg/l respectively. The recorded values of biochemical oxygen demand and chemical oxygen demand exceed the BIS/ICMR standard limit of 5 mg/l and 20 mg/l respectively.

Table 2: Physicochemical Parameters for water quality of Domestic Sewage Water Before and After Treatment with RH, RHA and ARH

S. No	Physicochemical Parameter	Before Treatment	After Treatment with		
			Rice Husk (RH)	Rice Husk Ash (RHA)	Activated Rice Husk (ARH)
1	pH	7.5 ± 0.08	6.4 ± 0.08	7.0 ± 0.08	6.8 ± 0.06
2	Electrical Conductivity (EC) (μS/cm)	482.24 ± 17.06	205.76 ± 7.43	245.01 ± 4.51	151.15 ± 5.91
3	Total Alkalinity (TA) (mg/l)	149.33 ± 2.66	76.00 ±2.30	82.60 ± 1.33	90.00 ± 1.15
4	Total Hardness (TH) (mg/l)	68.23 ± 1.07	58.10 ±1.00	53.41 ± 0.73	52.00 ± 0.64
5	Calcium (Ca) (mg/l)	49.40 ± 0.66	40.60 ± 0.72	38.20 ± 0.52	37.50 ± 0.60
6	Magnesium (Mg) (mg/l)	18.83 ± 0.44	17.50 ± 0.28	15.16 ± 0.44	14.50 ± 0.28
7	Chlorine (Cl) (mg/l)	156.56 ± 0.56	149.50 ± 1.20	139.40 ± 0.60	141.20 ± 1.20
8	Dissolved Oxygen (DO) (mg/l)	6.96 ± 0.10	7.95 ± 0.08	8.24 ± 0.08	11.11 ± 0.30
9	Biochemical Oxygen Demand (BOD) (mg/l)	42.56 ± 1.26	35.83 ± 0.72	29.40 ± 0.55	6.30 ± 0.65
10	Chemical Oxygen Demand (COD) (mg/l)	90.06 ± 0.85	80.40 ± 0.83	66.23 ± 0.50	10.13 ± 1.08

11	Total Dissolved Solids (TDS) (mg/l)	306.66 ± 13.33	90.66 ± 5.81	121.33 ± 3.52	48.00 ± 4.61
12	Total Suspended Solids (TSS) (mg/l)	28.00 ± 2.30	0.66 ± 0.13	0.53 ± 0.13	0.53 ± 0.13

3.2 Water Quality Index (WQI) Analysis of Untreated and Treated Water Samples

The initial step in WQI calculation using "Weighed Arithmetic Index" method involves the estimation of 'Unit Weight' assigned to each physicochemical parameter considered for calculation. By this, all the parameters concerned with different units and dimensions tend to converted to a common scale. The relative standard values (S_n) and unit weight (W_n) of the parameters in WQI assessment are given in Table 3. Maximum weight i.e., 0.3723 is assigned to both DO and BOD, thus suggesting the key significance of these two parameters in water quality assessment and their considerable impact on the index.

Table 3: Relative Standard values (S_n) and Unit Weight (W_n) of the parameters in WQI assessment

S.No	Parameter	ICMR/BIS Standard Value (S_n)	Unit Weight (W_n)
1	pH	7.5	0.219
2	Electrical Conductivity (μS/cm)	300	0.0061
3	Total Alkalinity (mg/l)	120	0.0155
4	Total Hardness (mg/l)	300	0.0062
5	Calcium (mg/l)	75	0.025
6	Magnesium (mg/l)	30	0.061
7	Chlorine (mg/l)	250	0.0074
8	Dissolved Oxygen (mg/l)	5	0.3723
9	Biochemical Oxygen Demand (mg/l)	5	0.3723
10	Chemical Oxygen Demand (mg/l)	20	0.02507
11	Total Dissolved Solids (mg/l)	500	0.0037
12	Total Suspended Solids (mg/l)	500	0.0037
			ΣW_n = 1.11727

The observed values of the selected twelve physicochemical parameters in all the samples and their corresponding WQI values are presented in tabular form. Among all parameters, DO and BOD were found to be the highest influencing parameters in WQI scores (Table - 4, 5, 6, 7). It was noted from Table - 4,5,6 & 7 that DO and BOD were the two predominately pivotal parameters exhibiting maximum prominence in WQI calculation. The summary of WQI values of the untreated and treated domestic sewage water samples are presented in Table - 8 and Chart - 1.

Table 4: Calculation of WQI for Untreated Domestic Sewage Water Sample

S.No	Physico chemical Parameter	Observed Value (V_n)	Standard Value (S_n)	Ideal Value (V_{10})	Unit Weight (W_n)	Quality Rating (Q_n)	W_nQ_n
1	pH	7.5	7.5	7	0.219	100	21.90
2	Electrical Conductivity (μS/cm)	482.24	300	0	0.0061	160.74	0.98
3	Total Alkalinity (mg/l)	149.33	120	0	0.0155	124.44	1.93
4	Total Hardness (mg/l)	68.23	300	0	0.0062	22.74	0.14
5	Calcium (mg/l)	49.4	75	0	0.025	65.87	1.65
6	Magnesium (mg/l)	18.83	30	0	0.061	62.77	3.83
7	Chloride (mg/l)	156.56	250	0	0.0074	62.62	0.46
8	Dissolved Oxygen (mg/l)	6.96	5	14.6	0.3723	79.58	29.63
9	Biochemical Oxygen Demand (mg/l)	42.56	5	0	0.3723	851.2	316.9
10	Chemical Oxygen Demand (mg/l)	90.06	20	0	0.02507	450.3	11.29
11	Total Dissolved Solids (mg/l)	306.66	500	0	0.0037	61.33	0.23
12	Total Suspended Solids (mg/l)	28	500	0	0.0037	5.6	0.02
					ΣW_n = 1.11727	ΣW_nQ_n= 388.96	
							WQI = 348.134

Table 5: Calculation of WQI for Rice Husk Treated Domestic Sewage Water Sample

S.No	Physico chemical Parameter	Observed Value (V_n)	Standard Value (S_n)	Ideal Value (V_{10})	Unit Weight (W_n)	Quality Rating (Q_n)	W_nQ_n
1	pH	6.4	7.5	7	0.219	-120	-26.28
2	Electrical Conductivity (µS/cm)	205.76	300	0	0.0061	68.58	0.418
3	Alkalinity (mg/l)	76	120	0	0.0155	63.33	0.980
4	Total Hardness (mg/l)	58.1	300	0	0.0062	19.37	0.120
5	Calcium (mg/l)	40.6	75	0	0.025	54.13	1.350
6	Magnesium (mg/l)	17.5	30	0	0.061	58.33	3.550
7	Chloride (mg/l)	149.5	250	0	0.0074	59.80	0.440
8	Dissolved Oxygen (mg/l)	7.95	5	14.6	0.3723	69.27	25.780
9	Biochemical Oxygen Demand (mg/l)	35.83	5	0	0.3723	716.6	266.79
10	Chemical Oxygen Demand (mg/l)	80.4	20	0	0.02507	402.00	10.070
11	Total Dissolved Solids (mg/l)	90.66	500	0	0.0037	18.13	0.060
12	Total Suspended Solids (mg/l)	0.66	500	0	0.0037	0.132	0.0004
					$\Sigma W_n = 1.11727$	$\Sigma W_nQ_n = 283.2784$	
							WQI = 253.545

Table 6: Calculation of WQI for Rice Husk Ash Treated Domestic Sewage Water Sample

S.No	Physico chemical Parameter	Observed Value (V_n)	Standard Value (S_n)	Ideal Value (V_{10})	Unit Weight (W_n)	Quality Rating (Q_n)	W_nQ_n
1	pH	7.0	7.5	7	0.219	0	0
2	Electrical Conductivity (µS/cm)	245.01	300	0	0.0061	81.67	0.498
3	Alkalinity (mg/l)	82.6	120	0	0.0155	68.83	1.06
4	Total Hardness (mg/l)	53.41	300	0	0.0062	17.8	0.11
5	Calcium (mg/l)	38.2	75	0	0.025	50.93	1.27
6	Magnesium (mg/l)	15.16	30	0	0.061	50.53	3.08
7	Chloride (mg/l)	139.4	250	0	0.0074	55.76	0.41
8	Dissolved Oxygen (mg/l)	8.24	5	14.6	0.3723	66.25	24.66
9	Biochemical Oxygen Demand (mg/l)	29.4	5	0	0.3723	588	218.91
10	Chemical Oxygen Demand (mg/l)	66.23	20	0	0.02507	331.15	8.30
11	Total Dissolved Solids (mg/l)	121.33	500	0	0.0037	24.26	0.08
12	Total Suspended Solids (mg/l)	0.53	500	0	0.0037	0.106	0.0003
					ΣW_n = 1 .11727	ΣW_nQ_n = 258.3783	
						WQI = 231.259	

Table 7: Calculation of WQI for Activated Rice Husk Treated Domestic Sewage Water Sample

S.No	**Physico chemical Parameter**	**Observed Value (V_n)**	**Standard Value (S_n)**	**Ideal Value (V_{10})**	**Unit Weight (W_n)**	**Quality Rating (Q_n)**	**W_nQ_n**
1	pH	6.8	7.5	7	0.219	-40	-8.760
2	Electrical Conductivity (µS/cm)	151.15	300	0	0.0061	50.38	0.307
3	Alkalinity (mg/l)	90	120	0	0.0155	75	1.162
4	Total Hardness (mg/l)	52	300	0	0.0062	17.33	0.107
5	Calcium (mg/l)	37.5	75	0	0.025	50	1.250
6	Magnesium (mg/l)	14.5	30	0	0.061	48.33	2.948
7	Chloride (mg/l)	141.2	250	0	0.0074	56.48	0.417
8	Dissolved Oxygen (mg/l)	11.11	5	14.6	0.3723	36.35	13.53
9	Biochemical Oxygen Demand (BOD) (mg/l)	6.3	5	0	0.3723	126	46.90
10	Chemical Oxygen Demand (mg/l)	10.13	20	0	0.0250 7	50.65	1.269
11	Total Dissolved Solids (mg/l)	48	500	0	0.0037	9.6	0.035
12	Total Suspended Solids (mg/l)	0.53	500	0	0.0037	0.106	0.0003
					ΣW_n = 1.11727		ΣW_nQ_n = 59.1653
WQI = 52.955							

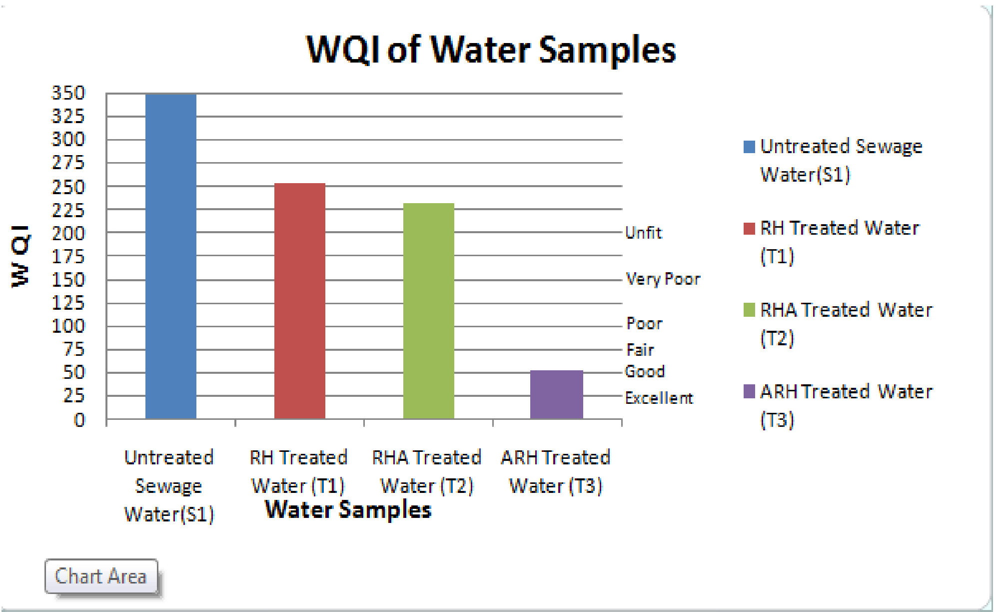
Table 8: Summary of WQI and WQS of Water Samples

S. No	Water Samples	Water Quality Index (WQI)	Water Quality Status (WQS)
1	Untreated Domestic Sewage Water (S1)	348.134	Unfit for consumption*
2	Rice Husk Treated Sewage Water (T1)	253.545	Unfit for consumption*
3	Rice Husk Ash Treated Sewage Water (T2)	231.259	Unfit for consumption*
4	Activated Rice Husk Treated Sewage Water (T3)	52.955	Fair**

** - Utilized for Irrigation; and Industries (if favorable)

* - Proper treatment essential before use or discharge

Chart - 1: WQI Rating of Water Samples Before and After Sewage Water Treatment



From the calculation of WQI for treated water samples, it was noticed that the WQI value of activated rice husk treated domestic sewage water sample was found to have "Fair" water quality status and could be possibly used for irrigation, recreation and other convenient purposes. Though, the WQI value of rice husk and rice husk ash treated domestic sewage water samples were lower than WQI of untreated raw domestic sewage, it was found unfit for consumption. Either those treatments need more adsorbent concentration and adsorption time to ensure proper treatment before its use or discharge.

4. CONCLUSION

Water quality index assessment helps in water quality management. The discharge of untreated sewage into fresh water is highly wretched, unhealthy and depraves water quality for drinking water and domestic uses. Activated carbon from agricultural waste residues prove to be eco-friendly and a renewable resource for water purification. Based on observed WQI results, it can be concluded that, though the domestic sewage water treated with activated rice husk falls under "fair" quality water, it could be reused for irrigation and recreation purposes. Effective sewage water treatment should be enforced to bring up the water quality in water bodies. This requires appropriate water quality management system for sustainable water restoration. With strict restrictions, the inflow of raw sewage from residential/commercial establishments and unabated dumping of solid waste into water sources must be ceased, thereby the natural environment including water, soil and air resources could be rehabilitated.

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CONFLICT OF INTEREST

Authors have no conflict of interest.

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