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Determination of A Rice Husk Efficiency as A Filter for Greywater Reclamation

Muhammad Lawan Shettima[1], G. Suleiman[1], and S. S. Surendran[2]

1. Desert Research and Monitoring Control Centre, Yobe State University, Damaturu, Nigeria

2. School of Energy, Construction and Environment, Coventry University, United Kingdom

Abstract: The study shows an effective and sustainable alternative method of managing the growing greywater problems in Nigeria. Environmental pollution and health related problems as a result of poor greywater management have been a reality in many African countries. Greywater reclamation for non-potable reuse such as toilet flushing, dust control around the house, cattle drinking and watering the home gardens are among the options to reduce the consumption of potable water and control environmental pollution. The aim of this paper is to demonstrate the treatment capability and performance of rice husk as an abundant agricultural by-product to develop greywater reclamation system in Gujba local area in Yobe state of Nigeria. The performance of this unconventional reclamation system shows that rice husk material is efficient to treat greywater to non-portable quality for domestic agriculture use in farming and livestock feeding. Results of the questionnaire survey conducted shows that maximum greywater generation in Gujba was 720 l/day per household. Furthermore, about 95% of the people participated in the survey have indicated social acceptability on reclaimed greywater for non-potable use. Turbidity and total suspended solids of the greywater were 427.6 NTU and 5.84 Mg/l respectively. Rice husk was examined for the treatment at rapid flow of 3.207 L/h and slow flow of 0.534 L/h. The average removal efficiencies for turbidity and total suspended solids were 81.81% and 86.47% respectively.

Key words: greywater, rice husk, suspended solids, turbidity, Gujba, treatment systems

1. Introduction

Almost all human activities that use water generates wastewater and vast majority is directly released to the environment without proper treatment. This is a common practice of the developing countries because of low environmental regulations. The impacts are always on human health, economy and ambient quality of the ecosystem. It was reported that about 32 out 48 Sub- Saharan African countries do not have data on wastewater generation and percentage of wastewater treatment is 38%, 28% and 8% for high-income, middle-income and low income countries respectively [1]. The continual failure of the effort to address the problems of wastewater and its implications on humans and the environment may affect other efforts to achieve the 2030 Agenda for sustainable goals [2]. Thus, there is need for sustainable integrated water resource management (IWRM) to explore alternative water resources such as developing a system to recycle wastewater. Rural communities of developing countries such as Nigeria are often neglected with provision of social amenities (such as pipe borne water). Meanwhile if such facilities were available, they are often not operational due to lack of proper maintenance [3]. Hence, planned GW reclamation system from low-cost agricultural by-product can be a sustainable option to solve future water and wastewater problems [4].

1.1 Global Average Water Consumption

The global record on freshwater consumption stood at 32,928 km^3/year with agricultural production

Corresponding author: Muhammad Lawan Shettima, M.Sc; research areas/interests: petroleum & environmental technology. E-mail: lawanm3@uni.coventry.ac.uk.

contributing to about 70% of the total consumption and up to 90% in developing countries [2]. Approximately 38% of global agricultural irrigation (Fig. 1) and half of the world's population depends on groundwater. The impact of this affects the level of available freshwater and consequently leading to problems of water scarcity.

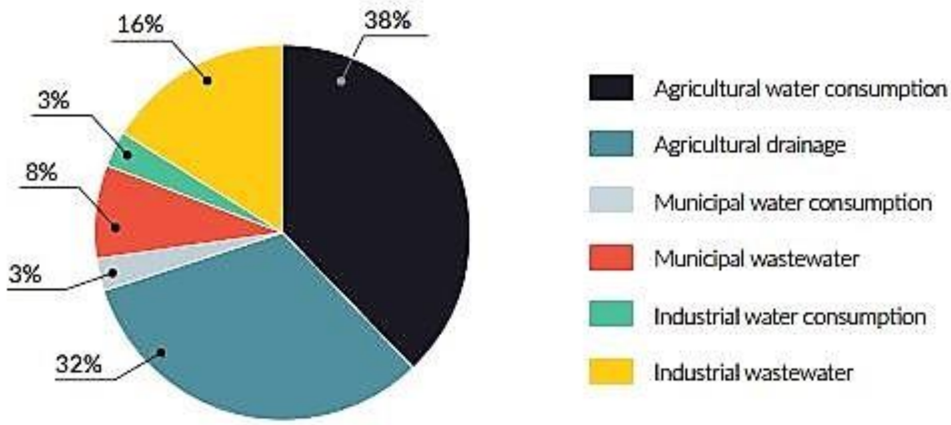

Fig. 1 Global freshwater consumption by areas of application [2].

1.2 Greywater Generation from Developing Countries

GW is defined as the domestic wastewater originating from baths, showers, wash basins, laundry facilities and excluding water closet flushing, kitchen sinks and other non-domestic sources [5]. The Level of water consumption preferentially depends on domestic lifestyle and availability of water resources obtainable from individual houses [6]. It was recorded from an estimate that GW generated from households accounts for about 75% by volume of domestic water consumption [7]. Morel (2006) [8] stated that volume of GW typically ranges from 90-120 L/day for high income countries without water challenges. However in low income countries (such as Nigeria, Niger, India, Jordan, and Oman etc.) experiencing water scarcity, volume of GW generation can be up to 20-30 L/day.

1.3 Background of the Research

The research was conducted to provide evidence and reliable innovation that could solve greywater problems in the local area of Gujba in Yobe State, North eastern Nigeria. Rural communities require innovative technology to develop systems which are reliable and cost effective to manage their wastewater. A study conducted by Surendran and Wheatley (1998) [4] shows that GW and runoff from farms/agricultural communities can be treated according to the intended use through coagulation and flocculation, adsorption, disinfection and among others.

2. Materials and Methods

The research was carried out in three stages. Firstly gathering information (water use studies and greywater characterisation); and secondly field questionnaire survey (e.g., social acceptability survey, quality and quantity of the greywater production). The third stage was laboratory scale analysis with the use of the rice husk for the greywater reclamation. Disproportionate sampling method was used purposely to select a sample of individuals to respond to the questionnaire. The final stage of data collection was through laboratory experiments and analysis to determine the GW qualities and treatment processes. Six different sets of laboratory experiments were conducted to treat the simulated GW and to determine the removal efficiencies of Turbidity and TSS. A list of the experiments conducted are presented in Table 1. Treatment efficiencies of three filter media at high (3.0 l/h) and slow (0.5 l/h) flow rates were determined. The

Table 1 Laboratory experiments conducted.

Experiment	Combination of filter media	Flow rate (L/h)
Experiment 1	**RH-RH**	Rapid
Experiment 2	**RH-RH**	Slow
Experiment 3	**RH-RHC**	Rapid
Experiment 4	**RH-RHC**	Slow
Experiment 5	**GAC-RHC**	Rapid
Experiment 6	**GAC-RHC**	Slow

materials combination used as filter media includes; RH-RH, RH-RHC and GAC-RHC (See the list of abbreviations above).

2.1 Simulated Greywater Qualities

It is important to study the GW characterization of a given community prior to development of GW systems [9]. Simulated GW (Fig. 2c) was prepared based on the outcome of the survey and established values from the literature. This is because, on a relative scale the significant compositions of GW cheaply depends on household activities and domestic lifestyle [10, 11]. Furthermore, specific GW qualities can be estimated based on the statement of contents which can be obtained from packages of domestic chemical products established on statistics of industrial production [12].

Maximum and minimum quantities of GW generation obtained from the filed survey indicated 720 L/day and 120 L/day respectively. These were used to evaluate the rapid and slow rates used in the laboratory experiment (Table 2).

Prior to the experiment, two simulated GWs of different concentrations (low and high concentrations) were synthesised. Average turbidity values were

Table 2 Calculating the rapid and slow flowrates.

Rapid flowrate	Slow flowrate
$Q = \frac{\text{Max. Quantity of GW}}{\text{Time of day (24 hrs)}}$	$Q = \frac{\text{Min. Quantity of GW}}{\text{Time of day (24 hrs)}}$
$= \frac{720.0\text{ L}}{24\text{ hrs}}$	$= \frac{120.0\text{ L}}{24\text{ hrs}}$
30.0 L/hr	**5.0L/hr**

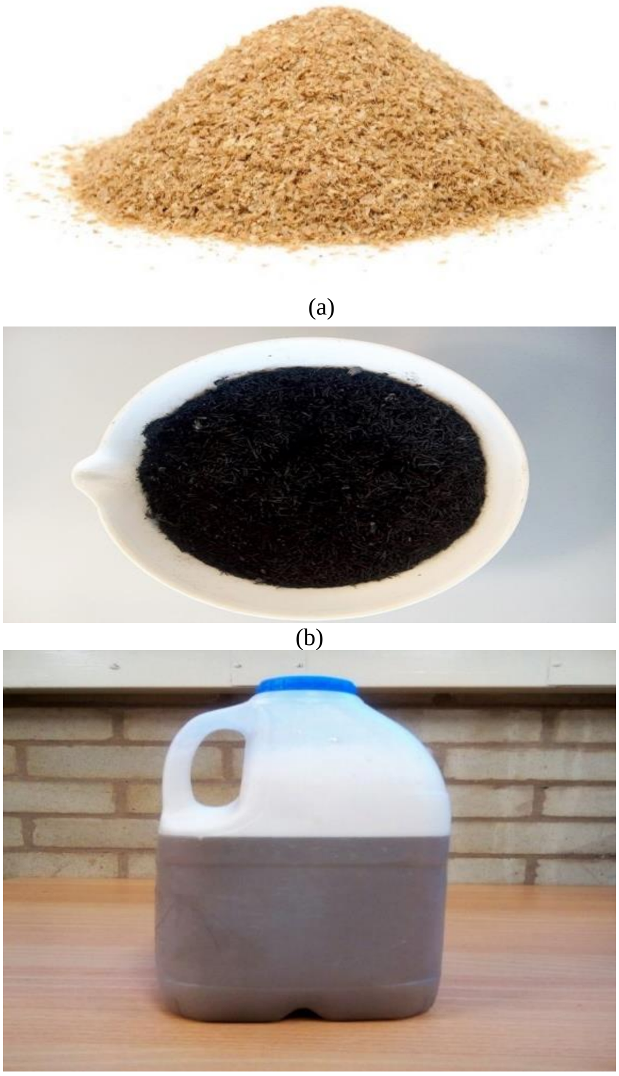

Fig. 2 (a) Rice husk, (b) rice husk charcoal, (c) simulated greywater.

468.5 NTU and 386.7 NTU for agitated and non-agitated samples of the low concentrated GW respectively. For the higher concentrated sample, turbidity was recorded as 538.5 NTU. TSS were 10.14 mg/l (agitated sample) and 5.84 mg/l for the high and low GW concentrations respectively. The use of these two different concentrations is as a result of the dynamic nature of the GW concentration. Using the CE 583 adsorption rig, reduction in turbidity and TSS were observed with the filter materials and the results are presented in Tables 3-5. Furthermore, agitated samples were used for the laboratory experiment in order to reflect the turbulent flow nature of the GW in real life scenarios.

It is important to recall and note that the respective initial Turbidity and TSS of the influent GW used before the treatment are; 427.60 NTU and 5.84 mg/l for RH-RH and RH-RHC media while 538.5 NTU and 10.4 mg/l for the GAC-RHC.

Fig. 3 Laboratory Scale testing of the rice husk charcoal filter on the CE absorption rig.

Table 3 Average qualities of the treated GW effluent.

Parameter	**Raw GW influent**	**Treatment**					
		RH-RH		**RH-RHC**		**GAC-RHC**	
Flow rates (L/h)		**3.207**	**0.534**	**3.207**	**0.534**	**3.207**	**0.534**
Turbidity (NTU)	427.60	105.96	49.46	124.66	135.00	78.90	73.60
TSS (mg/l)	5.84	0.11	1.47	0.05	0.05	0.02	0.71

Table 4 Turbidity removal efficiency.

		Material media					
		RH-RH		**RH-RHC**		**GAC-RHC**	
Influent	**Time (Hours)**	**Treatment efficiencies (%)**					
(NTU)		Rapid Flow	Slow Flow	Rapid Flow	Slow Flow	Rapid Flow	Slow Flow
427.6	**T1**	68.40	88.00	80.50	78.60	95.20	78.70
427.6	**T2**	78.25	88.40	77.10	71.20	80.00	83.50
427.6	**T3**	78.90	88.80	72.80	74.90	69.30	86.00
	Average	75.18	88.40	76.80	74.90	81.50	82.73

Table 5 TSS removal efficiency.

		Material media					
		RH-RH		**RH-RHC**		**GAC-RHC**	
Influent	**Time (Hours)**	**Treatment efficiencies (%)**					
(mg/l)		Rapid Flow	Slow Flow	Rapid Flow	Slow Flow	Rapid Flow	Slow Flow
5.84	**T1**	99.90	99.80	90.10	99.70	99.60	99.90
5.84	**T2**	99.80	99.80	99.70	99.40	99.60	64.00
5.84	**T3**	94.80	99.92	98.90	99.40	99.80	99.50
	Average	98.17	99.84	96.23	99.50	99.67	87.80

The removal efficiency was determined from the table of experimental data using the relationship in Eq. (1).

$$\text{Removal efficiency} = \frac{\text{(Influent Quality - Effluent Quality)}}{\text{Influent Quality}} \times 100 \quad (1)$$

The results of similar study conducted by Adams and Mulaba-Bafubiandi (2014) [13] reported that turbidity removal efficiency of RH can be up to 96% efficient. Based on this results of efficiency and the effluent quality of the reclaimed GW, it can be maintained that RH material can be optimised and used as a filter to remove turbidity from GW concentrations. Furthermore, the effluent quality is high enough to satisfy non-potable use reference to the reuse standards set by the UN and adopted by other countries such as Jordan [1].

An average TSS removal efficiency for the rapid and slow flow rates were obtained as 98.1 % and 74.7% (RH-RH), 96.2% & 99.5% (RH-RHC), and 99.6% & 87.8% (GAC-RHC) respectively. Indeed the TSS removal was excellent using all the materials. Results of the study by Zahid et al. (2016) [14] indicated that rice husk charcoal has 80% TSS removal efficiency. Furthermore, comparing the removal efficiencies of RH and saw dust, Waghmare (2013) [15] indicated that RH has about 80.88% and 80% removal efficiency for TSS and Turbidity respectively.

2.2 Social Acceptability and Willingness to Pay Survey

The successful outcome in the development of a water reclamation system cheaply depends on the level of social acceptability, affordability and willingness to pay [16]. About 75% of the peoples' responses have indicated social acceptability and willingness to pay for the system. The survey covered a total number of 20 residents from the community over a period of two weeks from 1st to 14th November, 2017. Nominal data was assigned from 1-20 for all the residents for coding purpose. Average number of people per household is 5 from a total number of 85 individuals. As a low income and high temperature zone, about 90% of the individuals have indicated problems of water scarcity and much dependency on public water supply. Thus, the high level of acceptability may be due to the problem of water scarcity [17]. The remaining 25% of the respondent expressed unacceptability because of health and religious grounds. Similar study conducted by Surendran (2001) [9] indicated that about 22% of individuals usually oppose greywater reuse due to fear of diseases and about 70% are willing to accept and invest.

3. Conclusion

Non-portable greywater reuse has substantial contribution to the reduction of water demand up to 56.2% in high temperature areas [18]. Greywater reuse practice was reported to reduce discharges of wastewater and minimise pollution and flooding [9]. Reclaimed greywater and run off can be used for several purposes from potable to non-potable reuse (Fig. 4) such as toilet flushing, irrigation, landscaping, groundwater recharge among others [10].

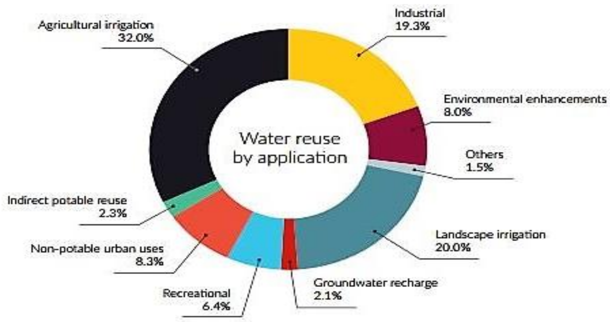

Fig. 4 Water reuse purposes [2].

Hence;

- Results of the laboratory experiment conducted on the three filter media indicated that GW can be treated for non-potable use quality with RH material.
- The removal efficiency for turbidity and TSS using the RH filter 81.81% and 86.47% respectively.

- The qualities of the final effluent based on turbidity and TSS can cope with permissible level for irrigation according reuse guidelines adopted from Jordan.
- Advantages of the GW system include; cost effectiveness, simple operation and maintenance as well as being environmentally friendly.

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