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DETERMINATION OF GREYWATER REUSE POTENTIAL IN DAMATURU YOBE STATE, NIGERIA

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ABSTRACT

Greywater reuse is an untapped available water resource for many rural areas in developing countries. Meanwhile, it is one of the alternative ways to overcome water scarcity in many parts of the world. This study was carried out to investigate the potential of Greywater reuse as a means to overcome the problem of water scarcity and environmental pollution among restaurants and hotel owners within Damaturu metropolis in Yobe State of Nigeria. A field survey was conducted from 25 restaurants/hotels operating within Damaturu and Greywater samples were collected for reclamation using rice husk as a filter. The results of the survey indicated that the majority of the respondents expressed the problem of water scarcity and about 99% mentioned that they rely on buying multiple water trucks for their daily needs. The survey further revealed that 76% of the respondents fully agreed with greywater reuse, while 12% disagreed, and the rest of the respondents (10%) remain undecided. Physical parameters including; Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, and Turbidity as well as general coliforms were determined before and after treatment with normal and chemically modified rice husk. However, an insignificant treatment efficiency was observed in the laboratory scale experiment with the normal rice husk which indicates the requirement for further modification. However, modification of the rice husk filter with an acidic reagent was confirmed to increase pH and electrical conductivity of the filter media, and determination of the retention time is always important in developing a greywater system.

Keywords: Greywater; Water scarcity; reclamation; reuse

INTRODUCTION

Water is always an indispensable natural resource, which is critical to human existence, socio-economic activities and development. However, despite this importance of water to mankind, rural and even some urban areas in developing countries of Africa often suffer the most of water scarcities due to various dispositions. The United Nations 2020 report on the Sustainable Development Goals (SDGs) highlighted that approximately 785 million people remain without access to basic drinking water service, and about 700 million could be displaced by intense water scarcity by 2030 (Baba-Adamu and Jajere, 2020). Furthermore, FAO data on African water index reported that by 2025 there would be more than 10 African countries that would suffer from fresh water scarcity unless an alternative water conservation and reuse strategy has been put in place (Oyebande, 2001). Therefore, it is essential to reduce the current freshwater consumption rates by exploring efficient methods and conservation techniques. Meanwhile, large amounts of domestic wastewater (greywater) is produced in Damaturu were not disposed properly and polluting the environment including rivers where locals sometimes acquire water for their daily use. (Adelekan 2010). James *et al*. (2017) reported that Greywater reuse is effective and alternative means to reduce problems of freshwater scarcity. Hence, this study investigates the potential of greywater water reuse for non-potable purpose in some selected restaurant/hotels within Damaturu metropolis in Yobe State of Nigeria.

Greywater reuse

Greywater reuse is an effective and promising alternate to cope with the challenges of scarcity and high rate of freshwater consumption. According to, Greywater can be defined as the domestic wastewater originating from baths, showers, wash basins, kitchen sinks and laundry facilities excluding water from washing closet (James *et al*. (2017). Muthukumaran, Baskaran and Sexton (2011) stated that Greywater reuse for non-potable purposes such as toilet flushing, landscape and irrigation can save up to 50% level of domestic freshwater water consumption. Greywater reuse for non-potable purposes agriculture is among the options to promote reduction in consumption of potable freshwater and control problems of environmental pollution (Lawan and Surendran, 2021). Barker *et al.* (2011) reported that, Melbourne city in Australia is currently one of the most active cities with respect to wastewater irrigation and Greywater reclamation is a common practice at the household level. Other communities have also been reported in countries like Jordan and Tunisia where wastewater reuse management has reduced water budgets and improved environmental sanitation (Othman, *et al.* 2012). Therefore, the implementation of Greywater reclamation systems with low cost and maintenance might assist rural and urban areas of developing countries such as Nigeria to minimize water scarcity and improve their environmental sanitation.
Different types of Greywater reclamation systems have been developed and installed over the years in different areas including sand filtration, activated sludge and other bio filters (Allen, *et al.* 2010).

Challenges with Greywater reclamation

Almost all wastewater treatment systems have peculiar challenges and the same applies to Greywater reclamation. As a result of variability in quantity and quality of Greywater, efficiency of treatment systems is usually affected by the dynamic the nature of the quantity and quality of Greywater (Lawan and Surendran, 2021). For example, biological treatment technologies are usually affected with chemical quality of Greywater containing toxic chemicals such as Boron (Clark and Stephenson 1998; Grady *et al*. 2011). High level of suspended solids can also result in problem of clogging of filters especially in physical technology systems. Hence, understanding the greywater characterization would always assist in the appropriate selection and design of the most effective reclamation system. Soaps, detergents and other strong cleaning agents usually constitute the composition of domestic greywater and too much number of chemical elements such as Boron and Sodium or Potassium salts of Carboxylic acids have been reported to affect treatment systems such as biological process in greywater reclamation (Rosen and Kunjappu 2012; Boyjoo *et al.* 2013).

Greywater Adsorbents

Different filter media (both from natural and artificial material) was reported in literature for the treatment of wastewater. Some notable plants and geo materials **(*Table 1)*** which have been tested and employed as filters for wastewater treatment includes; orange peel, Sawdust, cocoa shell, sugar-cane bagasse, rice hull, barley straw, oil palm waste, silk and wool fibers among others (Kurniawan *et. al* (2006); Bhatnagar and Sillanpää (2010); Ifelebuegu and Johnson (2017)). These plant materials were employed in various physical, biological and or chemical wastewater treatment processes. For example, rice husk (by-product from rice production) was reported for good adsorption capacity due its high percentage composition of silicon (Kumar *et al*. 2013).

Table 1: Some notable plants and geo materials used for greywater reclamation.

Material	Description	Property	Reference
Zeolites.	Can be used in cationic surfactants removal	Negative charge ions (Anionic property)	Widiastuti *et al.* (2008) & Li *et al* (2007)
Black and brown coal activated carbon, Peat, coconut shell and wood.	Large surface area with a good absorption due to Vander Waals force.	Hexagonal Carbon atoms covalent bonding arrangement.	Marsh and Reinoso (2006)
Rice husk	Efficient in dies, heavy metals and some organic compounds removal.	Composed of about 87-97% silica.	Ahmaruzzaman and Gupta (2011) and Kumar *et al*. (2013).
Smectite – Bentonite	Efficient for surfactants removal of as a result of cationic structure.	Octahedral arrangement of Alumina (AlO_3) and Silicate (SiO_2).	Bentaleb *et al*. (2017)
Mussel shell.	used for Phosphates removal through adsorption mechanism after formation of lime.	Composed of Calcium Carbonate ($CaCO_3$) in the form of aragonites.	(Jones *et al* 2011).
Feldspar.	Effective Phosphates and Sulphate removal as well as colored pollutants. Efficiency was reported as 42%, 52% and 73% respectively.	Composed of Aluminosilicate compound containing Potassium, Calcium or Sodium in the form of; $CaAl_2Si_2O$ $KAlSi_3O_8$ – $NaAlSi_3O_{8-8}$ respectively.	Priyantha and Perera, (2000)
Quartz.	Quartz were reported as efficient adsorbent minerals due to their Silicate contents.	Made up of Silicate group (SiO3).	Arias *et al.* (2001)

In Greywater treatment, an adsorbent material is usually a solid material functioning as a filter which can allow liquids or gaseous molecules to physical or chemically bind to its surface (Ip *et al.*, 2009; Babel and Kurniawan, 2003). Hence, the performance of an adsorbent depends on the chemical and physical properties of the adsorbent surface, as well as that of the soluble substances. Other characteristics of a good adsorbent material includes; large surface area with minimum volume, high mechanical strength and chemical stability, as well as high porosity (Adeyemo et al., 2017).

Agricultural bye-products/waste

Generally activated carbon is the most commonly used adsorbent for the removal of organic and inorganic pollutants from wastewater. Meanwhile, Agricultural wastes and by-products are also used as they are mostly cheap and eco-friendly as well as provide high porosity and large surface area required for adsorption in wastewater treatment (Anastopoulos *et al*., 2017; Saxena *et al*., 2019). In recent times, various agricultural bye-products have been tested for the removal of pollutants from greywater. The most commonly reported includes; maize husk. Wheat waste, rice husk, onion skins etc. (Olasehinde and Abegunde, 2020).

Rice husk as an adsorbent for Greywater reclamation.

Most natural plants and geo materials used for adsorption in wastewater treatment usually contain similar chemical properties. Research has shown that silicon is one of the major composition common in many natural adsorption filters used in wastewater treatment. Rice production represents the second largest product of cereal crop in the world. In areas and communities were rice production is abundant there is usually abundant rice husk as an agricultural by-product. By its chemical composition, rice husk is insoluble in water and has a granular physical structure. Furthermore, it also has a remarkable high mechanical strength and chemical stability as well as local availability at almost no cost (El - Azab, 1992). It is also rich in silica – cellulose structural arrangement, which makes it as a very good adsorbent compared to other agricultural by-product. Ahmaruzzaman and Gupta (2011) and Kumar *et al*. (2013), all reported the use of rice husk material as an efficient absorbent in the adsorption of greywater pollutants**.** Hence, rice husk material was used as a filter in this study as a surplus agricultural by-product in Damaturu. According to Kumar (2013:126) rice husk which is 70-80% organic matter is a cheap material and has relative low bulk density with 87-97% composition of silicon (Figure 2). Studies reported by (Mahvi *et al.* (2004); Aliyah *et al.* 2012; Kumar *et al.* (2013); Sethi *et al.* (2014) and Syarif *et al.* 2016) indicated that rice husk material has high removal efficiency for turbidity and TSS in greywater reclamation. Therefore, it can be optimized as a filter media to treat Greywater pollutants. The Chemical properties of rice husk as reported by Rahman *et al.* (1997) is given in table 2 below.

Table 2: Chemical Properties of Rice Husk

Composition	**Percent**
Cellulose	32.24
Hemicellulose	21.34
Lignin	21.44
Extractives	1.82
Water	8.11
Mineral ash	15.05

Adopted from Rahman *et al.* (1997)

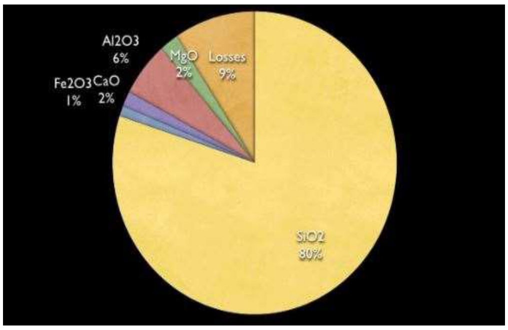

Figure 1: The physical structure and chemical contents of a rice husk (Rahman et al. 1997).

Chemical Modification of rice husk

Adsorption as a surface phenomenon is usually dependent on the surface chemistry and the natural structure of the adsorbent material. Hence, modification of the surface nature of the adsorbent material has a significant impact on its treatment functionalities (Abegunde *et al*. 2020). Thus, according Sadon *et al*. (2012:18), rice husk modification can reduce cellulose crystallinity as well as increase adsorbent porosity. For example, the experimentation by Hsu and Pan in (2007) revealed that, adsorption capacity of methacrylic acid with a modified rice husk is 14 times higher than that of unmodified rice husk. Therefore, it is equally expected that, the modification of the rice husk can increase adsorption capacity of the pollutants from Greywater.

MATERIALS AND METHODS

A multi-dimensional study approach was used to obtain quantitative data through field survey and laboratory experiment. Hence, the study was carried out in three different phases viz; firstly, field survey data collection to obtain the real situation of the study area. Secondly, characterization and analysis of the Greywater sample collected from the study area. The last phase is laboratory scale experimentation for the Greywater sample reclamation using rice husk agricultural by-product as a filter media. The quantitate data obtained were statistically analyzed using an excel spread sheet software to draw the conclusions and possible recommendations.

The Questionnaire surveys

Questionnaire surveys are traditional means of conducting research particularly intended to describe a reality of a given situation in which convenient approaches can be used to collect information on behavior and attitudes by means of a sample to represent a particular population under study (Thomas, Silverman and Nelson 2015). As noted from the literature many research studies have similarly used household surveys on different issues related to grey water reclamation and reuse. A total of 20 restaurants/hotels operating in Damaturu were randomly selected to participate in the survey. The questionnaire survey used for this study were developed by the research team based on the review of similar questionnaire surveys on grey water from the literature and insights obtained during the preliminary visits to the study area.

The survey questionnaire comprised of 18 questions, which were divided into three sections. The first group is about the general information of the building. The second section focused on the information on the Greywater including water sources and uses. The third section is on the assessment of the level of social acceptability for the reuse of Greywater. The respondents were asked about their knowledge on grey water and acceptance for reclaimed Grey water reuse.

The laboratory experiments

Laboratory experiments and analysis was conducted in the water analysis laboratory of the Desert Research Centre, Yobe State University to determine the treatment efficiencies of the normal and modified rice husk material as a filter to treat the Greywater samples. However, due to limited time and resources only the total suspended solids (mg/L), total dissolved solids (mg/L), turbidity (NTU) and pH were determined as physical parameters before and after the treatment. The level of total coliforms as a biological parameter for water quality were also determined. A prototype treatment facility (Figure 3) was designed to treat the Greywater with a rice husk material which has a pore spaces of 20 BSS. Rice husk was used as a filter because of the relative abundance of the material as an agricultural by-product from the study area.

Figure 2: Sieving the rice husk.

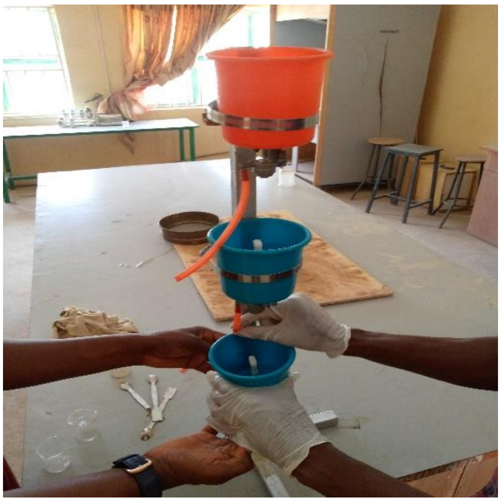

Figure 3: Setting up the Greywater reclamation system.

Laboratory items/materials used in this study includes;

1. Conical flask.
2. Beakers.
3. Measuring cylinders.
4. Electrical sieving machine.
5. Vacuum Flask.
6. Filter Papers
7. pH Metre.
8. Rice husk
9. A prototype treatment system.
10. Concentrated HCl acid with 98% purity.
11. Hand gloves
12. Water sample collection bottles.

RESULTS AND DISCUSSION

The outcome of the filed survey shows that there is a similar social status among the restaurants/hotel's owners based on their gender orientation. The gender of the respondents was 52% males and 48% females with 64% having received formal education while 36% without formal education. Approximately 99% of survey respondents mentioned that their main source of water supply is the public water network but which is often not functional. Hence, they simply rely on commercial water trucks supply on weekly or daily bases. Only 2 out of the 25 respondents (0.08%) expressed that they have their own private water borehole system which is apparently very expensive and unaffordable by many restaurant owners. Hence, most of the restaurants and restaurants directly depends on the underground freshwater resource without wastewater treatment and reuse.

Water Scarcity

Majority of the survey respondents, regardless of their social status expressed that they experience water scarcity. About 99% mentioned that they use the public water supply or rely on buying water trucks to cover their different water uses. This result is in harmony with the study reported by Babagana *et al.* (2017) which discovered an inadequate freshwater supply to the people of Damaturu metropolis. Therefore, it is evidently proven that water scarcity problem and environmental pollution are common geographical issues noticeable in most urban and rural communities of the developing countries (Lawan and Surendran 2021). Therefore, in water scarce community such as Damaturu it can be expressed that the adoption of Greywater reuse practice can help to reduce the use the fresh water for non-potable purposes and reduce the impacts of environmental pollution due to greywater disposal.

Greywater Disposal Practices in Damaturu

Based on the research findings and the data generated, most of the hotels and restaurants in Damaturu do not have a centralised Greywater network system to collect their Greywater waste. The common tradition obtained is that every individual restaurants and hotels store their Greywater in a specialized pits and tanks for further disposal. Moreover, about (46%) of the survey respondents discharge all their grey water generated from kitchen, washing, hand washing and shower to the open environment. Only about 54% reported that they store their Greywater in a special tank for further disposal at the town's open waste disposal area (*see figure 1*). This habit of open Greywater disposal contributes a lot to a poor environmental sanitation. Furthermore, none of the restaurants and hotels have their own Greywater reclamation system to treat their Greywater waste. This indicates a situation of poor sanitation due to Greywater disposal. The consequences of this environmental pollution is always on the restaurants/ hotels clients and the general public. However, if this Greywater can be collected in a reclamation system and treated for reuse can control the poor sanitation practice and also reduce the level of fresh water consumption for non-potable purposes.

Figure 4: The Open Greywater and Solid waste disposal area in Damaturu.

Thus, policy statement about Greywater reuse and disposal needs to be implemented by the government in order to reduce the menace and proliferation of diseases from within and outside the community.

Acceptance for Grey Water reuse

Finding a new and sustainable water resources for daily use is an important aspect to every community where water scarcity is a major challenge. Most of the restaurant and hotels owners visited during the survey process have indicated limited knowledge for Greywater reuse. Hence, it is completely a new concept to many of the respondents. However, according to Othman et al. (2012), the relationship between socio-economic variables (especially; gender and education) and the likelihood of Greywater reuse still remains unclear in the literature. Meanwhile, the responses obtained from the survey provides an evidence that the restaurants/hotels owners surveyed are willing to accept the reuse of treated Greywater for non-potable purposes.

Based on the research findings and the data generated, it was revealed that 78% of the respondents fully agreed with grey water re-use, while 12% disagreed, and the rest of the respondent (10 %) were unable to decide whether to accept or reject. A similar finding reported in the literature by Lawan and Surendran (2021), who investigated the level of social acceptability for Greywater reuse in a local community of Gujba in Yobe State indicated that, about 95% of the people also indicated social acceptance for reclaimed Greywater reuse for non-potable purpose.

However, the percentage of the respondents indicating willingness for reuse in this study is slightly higher than those from Gujba local community. A possible reason for this may be due to the difference in socio-economic characteristics of the two study areas. This suggests that water scarcity in rural areas is the main determinant of willingness to accept reuse the grey water compared with socio-economic variables such as income and level of formal education.

Furthermore, the survey also revealed that about 65% of the respondents were not aware of the concept of Greywater reuse and its potential to reduce water scarcity. Hence, this suggest that there is a need for appropriate educational program in order to encourage and spread the implementation of Greywater reuse especially in communities were water scarcity is their major challenge.

The Greywater Sample

The results of the laboratory experiment (Table 3) shows that the average pH value of the Greywater samples is **5.85** slightly less than the usual value reported for Greywater from kitchen sinks. Eriksson *et al.* (2002) reported a pH of 5-8.0 while Bakare *et al.* (2017) reported a pH value of 6.25. A relatively higher pH value of about 9.4 was also reported for the Greywater from laundry and bath. Hence, the use of chemical products such as the soaps and detergents for washing may be the contributing factor for the high pH value of the Greywater from laundries and baths. The average values of the TDS TSS were 786.45 and 10.63 mg/L respectively. The measurements for total solids have been reported with varied range in publications with the highest value ranged between 113 and 2410 mg/L. The Greywater from Kitchen sinks usually has the highest total solids for the fact that it may contain sands and other debris from washing vegetables sand other food items. The average electrical conductivity of the samples 1574.5 µS/cm with the lowest value at 384 µs/cm. Albalawneh and Chang (2015**),** reported the ranges of electrical conductivity of 190-1,830 µS/cm for dark Greywater samples and 14-921 µS/cm for light Greywater samples. Hence, the Greywater of the study area comprises of the both light and dark categories and this is another dynamic feature of Greywater characterization as earlier indicated.

Table 3: Some physicochemical qualities of the Greywater from the study area.

Sample ID	*pH*	*TDS (mg/L)*	*Conductivity (µs/cm)*	*Turbidity (NTU)*	*TSS (mg/L)*
1	5.61	673	1347	32	3.37
2	4.57	270	541	16	2.70
3	5.24	229	458	14	0.92
4	6.71	827	1656	38	8.27
5	4.69	608	1217	29	7.60
6	4.88	1082	2166	49	16.23

7	5.22	1047	2096	77	15.71
8	6.16	442	885	23	6.63
9	5.23	643	1287	31	9.65
10	5.59	289	579	17	3.61
11	5.61	1529	3061	80	24.46
12	6.8	228	456	34	1.07
13	9.25	870	1742	81	34.80
14	7.17	1495	2993	65	29.90
15	4.49	1495	2993	65	20.93
16	5.23	908	1818	42	9.08
17	4.65	766	1534	36	5.75
18	9.23	1270	2543	80	6.35
19	4.63	866	1734	40	4.33
20	6.04	192	384	13	1.15
Average	**5.85**	**786.45**	**1574.5**	**43.1**	**10.63**

Treatment with the Rice husk filter

The Greywater samples obtained from the study area were treated with a rice husk filter. Meanwhile, the results of the effluents show a reverse outcome as a result of some established facts during the treatment processes. In the first place, a raw rice husk material was used without any modification and laboratory scale testing of the treatment system was operated manually without any external gravity. This is to ascertain the applicability and use of the reclamation system as well as the efficiency of the agricultural by product at a low-cost implication. Furthermore, it is for the fact that the target beneficiaries in the development of the treatment system were local individuals who cannot afford complex and advanced Greywater treatment systems which are mostly associated with high cost and maintenance. The manual operation of the laboratory scale test of the treatment system caused a high retention time of the Greywater sample which leads to dissolve more rice husk material. This further increase the level of the TDS and subsequent value of the TSS. Hence, as matter of fact this would in turn raise the value of the turbidity which is the determinant for water clarity. Therefore, when developing a Greywater reclamation, a consideration for the determination of the retention time is always important. Additionally, modification of the rice with HCl as an acid reagent increases the electrical conductivity as a result of more hydrogen atoms were added to the Greywater. Hence, acid-based reagents tend to increase acidity and electrical conductivity as opposed to non-acidic reagents.

CONCLUSION & RECOMMENDATIONS

Meanwhile, the restaurants/hotels owners in Damaturu have indicated acceptance to use treated Greywater for non-potable purposes, a question mark over the safety of the Greywater after treatment with the rice husk filter for non-potable use requires further research to ascertain the reuse standard by determining the remaining physicochemical and biological parameters. However, the survey responses provide an evidence that restaurants/hotels owners in Damaturu metropolis are willing to accept the reuse of treated grey water for irrigation. Furthermore, some of them are willing to learn more about grey water treatment and reuse in order to operate grey water systems for other non-potable uses. Hence, there is need for further research to determine the opportunities of this untapped resource in other to address the challenges associated with water scarcity and poor environmental sanitation in most other local communities within Yobe State and beyond. Some of the physicochemical characteristics of the Greywater sample analyzed also prove similar qualities with the qualities of Greywater established in the literature. Therefore, already established low cost Greywater reclamation systems can be adopted for the treatment of the Greywater generated from restaurants/hotels in Damaturu metropolis.

REFERENCES

Adeyemo, A.A., Adeoye, I.O., Bello, O.S., (2017). Adsorption of dyes using different types of clay: A review. Appl. Water Sci. 7 (2), 543–568.

Adelekan, I. O. (2010). 'Vulnerability of Poor Urban Coastal Communities to Flooding in Lagos, Nigeria'. Environment and Urbanization 22 (2), 433-450

Aliyah, N. A. (2012). Adsorption of Lead using Rice Husk

Allen, L.; Christian-Smith, J.; Palaniappan, M. *Overview of Greywater Reuse: The Potential of Greywater Systems to Aid Sustainable Water Management*; Pacific Institute Report, Oakland, CA, USA, 2010. Available online: http://www.pacinst.org/reports/Greywater_overview/Greywater_overview.pdf (accessed on 31 July 2012).

Anastopoulos, I., Bhatnagar, A., Hameed, B.H., Yong, S.O., Omirou, M., (2017). A review on waste-derived adsorbents from sugar industry for pollutant removal in water and wastewater. J. Mol. Liq. 240, 179–188.

Baba-Adamu, M. & Jajere, I.A. (2020). Water scarcity measurement in the Yobe region of Nigeria. *KIU Interdisciplinary Journal of Humanities and Social Sciences, 1*(2), 265-280.

Babagana, M., Abubabkar, A., Muhammad, A., and Ado, G., (2017). Assessment of the Current Status and Problems of Potable Water Supply in Damaturu Metropolis. *International Journal for Research in Health Sciences and Nursing*, *3*(12), 01–18. https://doi.org/10.53555/hsn.v3i12.265

Babel, S., Kurniawan, T.A., (2003). Low-cost adsorbents for heavy metals uptake from contaminated water: A review. J. Hazard. Mater. 97 (1–3), 219–243.

Bhatnagar, A. and Sillanpää, M. (2010). 'Utilization of Agro-Industrial and Municipal Waste Materials as Potential Adsorbents for Water treatment—a Review'. *Chemical Engineering Journal* 157 (2), 277-296

Boyjoo, Y., Pareek, V. K., and Ang, M. (2013). 'A Review of Greywater Characteristics and Treatment Processes'. Water Science and Technology 67 (7), 1403-1424

Clark, T. and Stephenson, T. (1998). 'Effects of Chemical Addition on Aerobic Biological Treatment of Municipal Wastewater'. Environmental Technology 19 (6), 579-590

Emeka, D. O. and Weltime, O. M. (2012). 'Trace Elements Determination in Municipal Water Supply in Damaturu Metropolis, Yobe State, Nigeria'. *Bayero Journal of Pure and Applied Sciences, 1(1):58 – 61.*

El – Azab, A. M. M. (1992). PhD thesis, Cairo University, Gong, R., Zhu, S., Zhang, D., Chen, J.,

Grady Jr, C. L., Daigger, G. T., Love, N. G., and Filipe, C. D. (2011). Biological Wastewater Treatment: CRC press

Hsu, S., and Pan, T. (2007). 'Adsorption of paraquat using methacrylic acid-modified rice husk', *Bioresource Technology*, vol. 98, pp. 3617 – 3621.

Ifelebuegu, A. O. and Johnson, A. (2017). 'Nonconventional Low-Cost Cellulose-and Keratin-Based Biopolymeric Sorbents for oil/water Separation and Spill Cleanup: A Review'. *Critical Reviews in Environmental Science and Technology*, 1-38

Ip, A.W.M., Barford, J.P., McKay, G., (2009). Reactive black dye adsorption/desorption onto different adsorbents: Effect of salt, surface chemistry, pore size and surfacearea. J. Colloid In terface Sci. 337 (1), 32–38.

James, D., Surendran, S., Ifelebuegu, A., Ganjian, E., and Kinuthia, J. (2017). 'Grey Water Reclamation for Urban Non-Potable Reuse-Challenges and Solutions: A Review'

Kurniawan, T. A., Chan, G. Y., Lo, W., and Babel, S. (2006). 'Comparisons of Low-Cost Adsorbents for Treating Wastewaters Laden with Heavy Metals'. *Science of the Total Environment* 366 (2), 409-426

Kumar, S., Sangwan, P., Dhankhar, R. M. V., and Bidra, S. (2013). 'Utilization of Rice Husk and their Ash: A Review'. Res.J. Chem.Env.Sci 1 (5), 126-129

Lawan, M.S. and Surendran, S.S. (2021). 'Development of a community system for water reclamation from grey water in Gujba: a conceptual method', *Int. J. Environment and Waste Management*, Vol. 27, No. 2, pp.211–223.

Mahvi, A., Maleki, A., and Eslami, A. (2004). 'Potential of Rice Husk and Rice Husk Ash for Phenol Removal in Aqueous Systems'

M. Anjum, R. Miandad, M. Waqas, F. Gehany, M.A. Barakat, (2016). Remediation of wastewater using various nano-materials, Arabian Journal of Chemistry (2016), doi: http://dx.doi.org/10.1016/j.arabjc. 2016.10.004

Muthukumaran, S., Baskaran, K., and Sexton, N. (2011). 'Quantification of Potable Water Savings by Residential Water Conservation and reuse–A Case Study'. Resources, Conservation and Recycling 55 (11), 945-952

Ni, S., and Guan, R. (2009). 'Adsorption behaviour of cationic dyes on citric acid esterifying wheat straw: Kinetic and thermodynamic profile', *Desalination*, vol. 230, pp. 220 – 228.

Othman A. Al-Mashaqbeh, Ayoup M. Ghrair and Sharon B. Megdal (2012). 'Grey Water Reuse for Agricultural Purposes in the Jordan Valley: Household Survey Results in Deir Alla' *Water **2012**, 4, 580-596; doi:10.3390/w4030580.*

Olasehinde, E.F., Abegunde, S.M., (2020). Adsorption of methylene blue onto acid modified raphia taedigera seed activated carbon. Adv. J. Chem. A 3 (5), 663–679.

Oyebande, L. (2001). 'Water Problems in Africa—how can the Sciences Help?'. Hydrological Sciences Journal 46 (6), 947-962

Rahman, I. A., Ismail, J., and Osman, H. (1997). 'Effect of nitric acid digestion on organic materials and silica in rice husk', *J. Mater. Chem.*, vol. 7, pp. 1505 – 1509.

Rosen, M. J. and Kunjappu, J. T. (2012). Surfactants and Interfacial Phenomena. John Wiley & Sons

Sadon, F. N., Ahmmed Saadi Ibrahem, Kamariah Nor Ismail (2012). An overview of rice husk applications and modification techniques in wastewater treatment. *Journal of Purity, Utility Reaction and Environment Vol.1 No.6, August 2012, 308-334*

S.M. Abegunde, K.S. Idowu, O.M. Adejuwon et al. (2020). A review on the influence of chemical modification on the performance of adsorbents. *Resources, Environment and Sustainability 1 (2020) 100001*

Saxena, Bhardwaj, M., Allen, T., Kumar, S., Sahney, R., (2019). Adsorption of heavy metals from wastewater using agricultural-industrial wastes as biosorbents. Water Sci. 31, 189–197.

Sethi, T. (2014). Characterization and Application of Rice Husk for Removal of Heavy Metals from Laboratory Prepared Waste Water

Syarif, H., Suriamihardja, D., Selintung, M., and Wahab, A. W. (2016). 'Analysis SEM the Chemical and Physics Composition of used Rice Husks as an Absorber Plate'.International Journal of Engineering and Science Applications 2 (1), 25-30

Albalawneh, A. and Chang, T.K., 2015. Review of the greywater and proposed greywater recycling scheme for agricultural irrigation reuses. *International Journal of Research–Granthaalayah*, *3*(12), pp.16-35.

Bakare, B.F., Mtsweni, S. and Rathilal, S., 2017. Characteristics of greywater from different sources within households in a community in Durban, South Africa. *Journal of Water Reuse and Desalination*, *7*(4), pp.520-528.

Barker, F., Faggian, R. and Hamilton, A.J., 2011. A history of wastewater irrigation in Melbourne, Australia. *Journal of Water Sustainability*, *1*(2), pp.31-50.

Eriksson, E., Auffarth, K., Henze, M. and Ledin, A., 2002. Characteristics of grey wastewater. *Urban water*, *4*(1), pp.85-104.