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A Preliminary Study on the Capability of Burned Rice Hulls to Reduce *Escherichia coli* in Drinking Water

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One out of six or 1.1 billion people do not have access to improved water supply and most of them are poverty-stricken. In order to free these people from disease, the need for a secure access to adequate supply of water and proper sanitation has been strongly recognized. There are several modern water purification methods that have come up in the past years; but the high financial burden make them almost impossible for most of the world's population to gain access especially in rural areas. As such, the concern of people is on how to have access to safe drinking water without the high financial requirement. This study aims at looking into the use of burned rice hulls which are readily available in the Philippines and other agricultural countries as alternative means of purifying water. The rice hulls were burned at 300, 600 and 900^{0}C using a furnace for 5 hours. Aside from this, backyard burned rice hulls were also prepared. The properties of the burned rice hulls such as bulk density, pore volume, porosity and weight of volatiles removed were taken. The burned hulls were placed in a column; and the autoclaved distilled water was spiked with a known amount of E. coli before letting the water pass through the column. The spiked water that passed through the column was collected and analyzed for microbial quality using the Most Probable Number (MPN) Method to determine if there is a significant reduction in the cell density of E. coli. The results showed that the different *types of burned rice hulls used in the study have the capability to reduce E. coli but then the resulting effluent still did not meet the accepted value set by 1993 Philippine National Standards for Drinking Water.*

Keywords: *water treatment, burned rice hulls, Escherichia coli, MPN Method*

1.0 INTRODUCTION

Water is vital to all life forms, but reality strikes us that it is not an unlimited luxury. It is estimated that in the Philippines, only 1,907 m^3 of fresh water is available to each person per year; while in other countries, they have an estimated 3,300 cubic meters of fresh water available per person. This ratio ranks the Philippines as second to the lowest among Southeast Asian countries in fresh water availability [1].

In 1999, the United Nations Environment Programme (UNEP) reported that 200 scientists in 50 countries had identified water shortage as one of the two most worrying problems for the new millennium (the other was global warming) [2]. Water scarcity was identified as a major problem at the Johannesburg Summit in 2002. An area will experience water scarcity when the annual water supplies drop below 1,000m^3 per person [5]. Moreover, one of the priority program areas for urgent action in Chapter 18 of Agenda 21 of the Earth Summit is water resources assessment.

Currently, a third of the world's countries are water stressed. An area will experience water stress when the annual water supplies drop below 1,700m^3 per person and results from an imbalance between water use and water resources [5]. This indicates that around 1.1 billion people or one out of six people globally do not have access to improved water supply sources whereas 2.4 billion people or two out of six people do not have access to any type of improved sanitation facility. About 2 million people die every year either by hunger, diarrhea or easily preventable disease [3], and most of them are children less than 5 years of age [7]. The most affected are the populations in developing countries such as the Philippines.

There are several reasons for the water crisis. One is the simple rise in population and the desire for better living standards. Another is the inefficiency of the way we use much of our water. Irrigation allows wastage, with the water trickling away or simply evaporating before it can do any good; and pollution is making more of the water that is available to us unfit for use [3]. It is all the more critical that increased water use by humans does not only reduce the amount of water available for industrial and agricultural development but has a profound effect on aquatic ecosystems and their dependent species. Environmental balances are disturbed and cannot play their regulating role anymore [6]. In fact, the United Nations Educational, Scientific and Cultural Organization (UNESCO) officials expect the world's clean water resource to drop by a third within 20 years as the world population booms. The World Bank even predicts that war might arise over clean water supply. This may seem to be an exaggeration at this point but this possibility exists.

Increasingly, governments are seeking to solve their water problems by turning away from reliance on rainfall and surface water, and using subterranean supplies of groundwater instead. Using up this irreplaceable groundwater means that the depletion of available resources, such as rivers, wetlands and lakes that depend on it can dry out. Saline seawater can flow in to replace the fresh water that has been pumped out. And the emptied underground aquifers can be compressed, causing surface subsidence – a problem familiar in Bangkok, Mexico City and Venice [2].

Scientists, in response to this, continuously develop water treatment processes for adequate water supply and improved sanitation. The results are abundant but it made water an expensive commodity for everyone. In response to this problem, cheaper water treatment methods have to be explored.

One possible material that can be looked into is the use of burned rice hulls as filter media. Marshall stated that burned rice hulls were as effective as the commercial carbon [4]. The Philippines, as an agricultural country, has a steady source of rice hulls especially in the rural areas. According to the NSO Philippine Yearbook of 2001, agricultural land planted to palay in 1999 had a total area of 4.00 million hectares, about 26.2 percent more from the 3.17 million hectares recorded in 1998. If this study on rice hull utilization produces satisfactory results, it will be helpful in reducing the cost of water purifiers. This in turn will be of great help especially to those who live in the remote areas in the Philippines. This study aims to determine whether burned rice hulls have the capability to reduce *Escherichia coli* (*E. coli)* in drinking water and to compare whether the microbial quality of the drinking water produced using the designed water treatment to that of the Philippine National Standard for Drinking Water.

To determine the capability of burned rice hulls to reduce *E. coli* in drinking water, it was decided to simulate contaminated drinking water by initially spiking the water to be tested with *E. coli* (DH5α strain); for the reason that coliforms, typified by *E. coli,* act as indicators of possible contamination. Their presence also indicates that other pathogenic microbes may also be present. It was also decided that distilled water, in this case distilled drinking water, will be autoclaved first to make certain that the sample does not contain microorganisms and chlorine for they could affect the results of the analyses.

2.0 METHODOLOGY

2.1 MATERIALS, SPECIMEN, AND EQUIPMENT

The different types of burned rice hulls that were used as filter media in this study were the following: rice hulls burned at 300, 600, and 900^{o}C using a Redstar Furnace, and by burning on a bonfire (referred throughout this paper as backyard burned rice hulls). The rice hulls came from International Rice Research Institute (IRRI), Los Baños, Laguna.

The water that was used in the study does not contain chlorine and other minerals for these might affect the reduction of bacteria. This was achieved by using distilled drinking water. Coliform bacteria, typified by *E. coli* (DH5α strain), was the specimen spiked to the drinking water.

2.2 EXPERIMENTAL SET-UP

As shown in Figure 1, the design of the column was made simple because it is intended for use in the province where rice hulls are abundant and cheap filter media are unavailable.

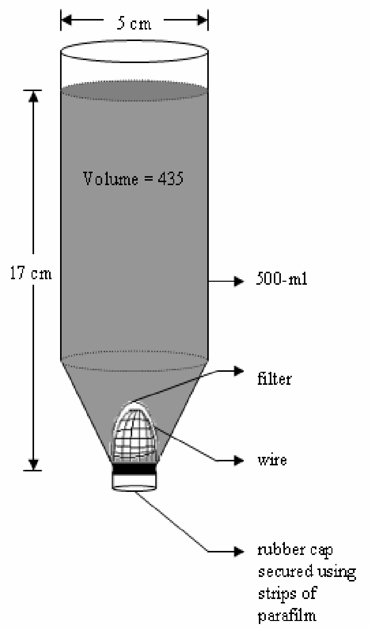


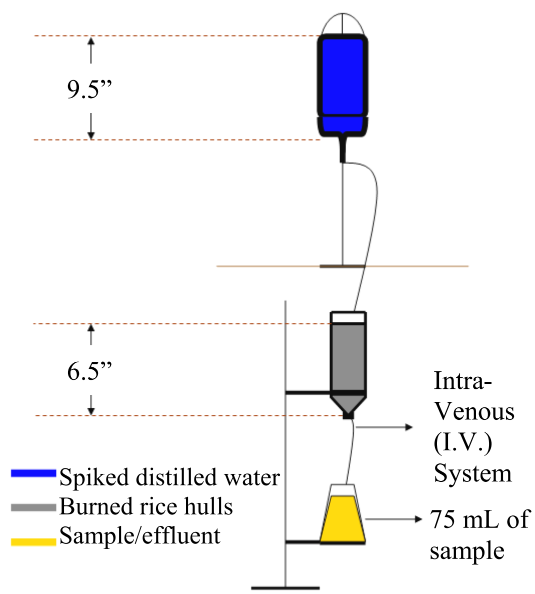
Figure 1: Dimensions of the plastic column used in the study

An inverted 500 ml plastic bottle cut at the bottom was used to contain the burned rice hulls to form the column. It was prepared by emptying the plastic bottle of its contents and washing it with antibacterial dishwashing liquid. After which, autoclaved distilled water was passed through inside the bottle.

An autoclaved wire screen was fitted at the mouth of the bottle together with a piece of filter paper. A rubber cap of the dextrose bottle was utilized to secure the wire screen and the filter paper in place, and to provide an opening for the I.V. System. To prevent leaks during the run, strips of parafilm were placed around the rubber cap and the neck of the bottle.

The bottom of the bottle was cut aseptically by using a flamed knife. Then the bottle was inverted and the burned rice hulls were placed inside until it fills the height of 6.5 inches forming the column.

The complete setup is composed of the bottle, the burned rice hulls column, and the sterile 125-ml Erlenmeyer flask for the collection of samples. Note that the I.V. System attached at the bottom of the column (i.e. the inverted plastic bottle with the burned rice hulls) and the dextrose bottle was only used to control the flow of the water passing through it. Figure 2 shows the experimental set-up.



(a) (b)

Figure 2: Experimental set-up: (a) schematic diagram; (b) actual setup

2.3 Experimental Procedures

The variations of the degree and mode of burning of the rice hulls would result to variations in their bulk density, pore volume, porosity, and weight of volatiles removed that may have an effect on the microbial quality and appearance of the water sample.

Bulk density is determined by water displacement method. Three trials were performed for each types of burned rice hulls so that ANOVA: Single Factor (a feature of MS-Excel) can be applied. After knowing that the null hypothesis can be accepted (i.e. the P-value is greater than the □-value), the bulk densities in each trial can be averaged to get a single value for reporting.

The volume absorbed by the rice hulls during the runs determined the pore volume for each type of burned rice hulls. With this, the porosity can be determined by the equation shown.

$$Porosity = \frac{pore\ volume}{total\ volume}$$

Since the weight of the burned rice hulls placed inside the column was noted and the bulk density has been determined by water displacement method, thus the total volume would equal to the weight of burned rice hulls inside the column divided by the bulk density. In symbols,

$$V_{TOTAL} = \frac{wt.of\ burned\ rice\ hulls\ in\ the\ column}{\rho_{bulk}}$$

Percent volatiles for each type of burned rice hulls were determined by noting the weight of the rice hulls before and after burning. The change in weight equals the weight of the volatiles removed during the burning process. This can be represented as

$$\%Volatiles = \frac{wt_{BEFORE\ BURNING} - wt_{AFTER\ BURNING}}{wt_{BEFORE\ BURNING}}$$

For the microbiological part of the study, in order to avoid getting contaminated prior to spiking the distilled water was first sterilized. The cell density of the *E. coli* spiked to the autoclaved distilled water is 20 cell/ml (or 2000 cells/100 ml) that corresponds to the maximum combination in the MPN Table (i.e. 5-5-5). The spiked distilled water was then allowed to pass through the designed burned rice hull column. Samples of the effluent water were then analyzed for *E. coli* reduction using the MPN Method. Detailed procedure used for the MPN Method can be found in the 1993 Philippine National Standards for Drinking Water.

3.0 Discussion of Results

The properties such as bulk density, pore volume, porosity, and percent volatiles were determined for each type of burned rice hulls used in the experiment. These parameters were taken for they might have something to do with the reduction of *E. coli*. Table 1 below shows the results.

Table 1: Properties of each type of burned rice hulls used in the study

TYPE OF BURNED RICE HULLS	ρ_{BULK} (g/ml)	*PORE VOLUME (ml)	POROSITY	WT. OF VOLATILES REMOVED (g)	PERCENT VOLATILES
Backyard (approx. 195°C)	0.1869	351.7	1.2655	90.00	36.00
300°C	0.3471	351.5	1.7957	118.30	59.15
600°C	0.2903	364.8	1.7094	137.48	68.74
900°C	0.2635	368.2	2.1228	150.08	75.04

*Pore volume is equal to the volume absorbed recorded during the runs

Backyard burned rice hulls are burned in an uncontrolled environment (i.e. the temperature is difficult to note) unlike those rice hulls burned using the furnace where the desired burning temperature can be easily set. The data collected from this particular burned rice hull caused inconsistency with the observations seen with those rice hulls burned using the furnace. Though this is the case, it was included in the analyses to see the effect of burned rice hulls that have no or negligible amount of ash in it. Referring to the data collected as shown in Table 1, it can be said that as the burning temperature increases: the bulk density decreases while the pore volume increases for the rice hulls burned using the furnace; significant increase in porosity for the rice hulls burned at 600°C to 900°C was observed; and weight of volatiles removed increases for all types of rice hulls.

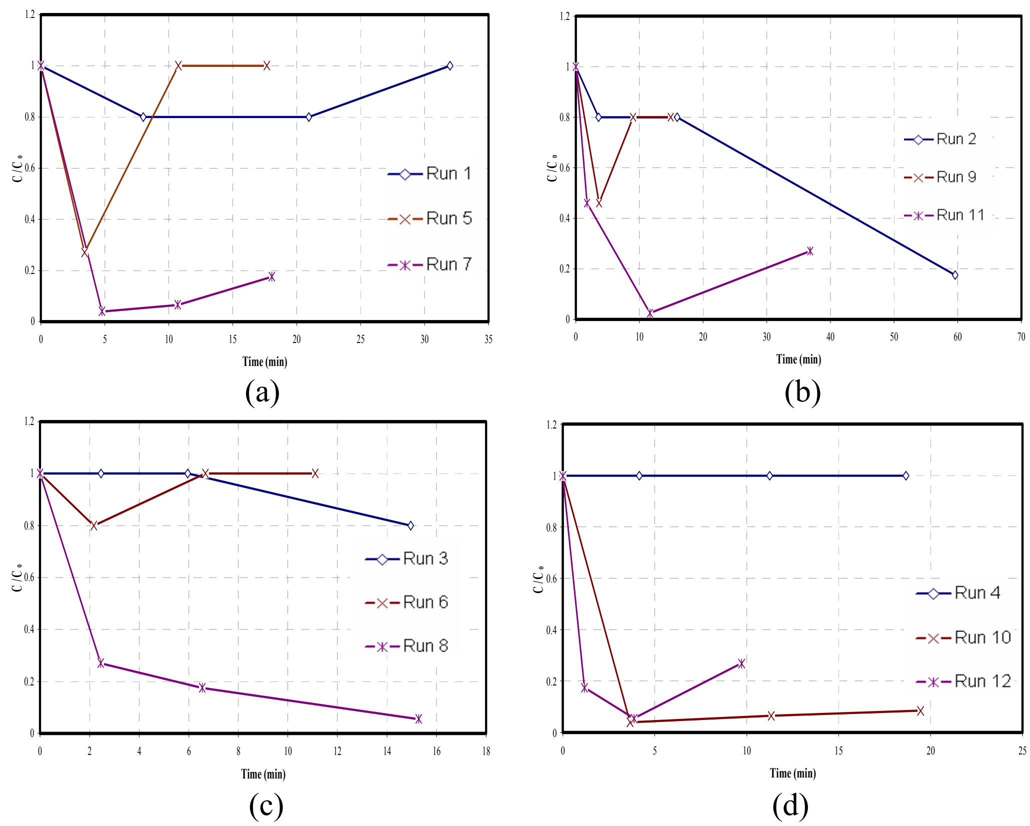


Figure 3: C/C_o vs. time plot for rice hulls burned at: (a) 900°C; (b) 600°C; (c) 300°C; and (d) backyard (approx. 195°C)

Single Factor ANOVA was applied to confirm if the values can be averaged or not (i.e. values are found in one range) as what is done in the computation for the bulk density and pore volume. All the P-values for the trials performed in determining the bulk density and pore volume are greater than the α-value. These confirmed that the results of the trials performed are within the range for a specific burning temperature. Thus, the values can be averaged to get a single value for reporting.

The plots C/C_o versus time (as shown in Figure 3) exhibit the trend of the adsorption of *E. coli* to the burned rice hulls at 900 °C, 600 °C, 300°C, and backyard burned rice hulls. The first points in the plots represent the positive, i.e. the spiked *E. coli* in the autoclaved distilled water. It was tested and always resulted to 5-5-5 combination in the MPN table. The 2nd, 3rd, and 4th points represent samples 1, 3, and 5 respectively. Most of the plots show that at sample 1, there is sudden reduction in the amount of *E. coli*. This could be accounted to the free surface of the burned rice hulls ready to adsorb the bacteria. Then, as time progresses, the surface gets saturated with the bacteria resulting to weak adsorption. Thus, the plot for samples 3 and 5 are usually higher than the plot of sample 1.

The water treatment column designed utilizing rice hulls burned at 300°C, 600°C, 900°C, and backyard burned did not significantly lower the amount of *E. coli*. The lowest MPN index/100ml obtained is 49, which is approximately 49 times greater than the accepted value for drinking water (<2 as found in the 1993 Philippine National Standard for Drinking Water).

The appearance of the effluent after passing through the furnace-burned (300, 600, and 900°C) and backyard-burned rice hulls was also observed. Only the backyard burned rice hulls did not affect the appearance of the water. As for the rice hulls burned at 900°C, the water became a bit cloudy, but after collecting 2 to 3 more samples the water samples collected were as clear as those collected using the backyard burned rice hulls. While for the 2 other types of burned rice hulls (burned at 300°C and 600°C), dark yellow to a tinge of yellow was seen; with the earlier samples (samples 1 to 2) collected quite turbid. The cloudiness of the samples collected could be accounted to the ash present in the burned rice hulls. It has been observed that rice hulls burned at high temperatures produce more ash as compared to those burned at lower temperatures.

The ANOVA: Single Factor was initially done for the 3 trials of each type of burned rice hulls. Results show that only for the trials with rice hulls burned at 600°C was consistent with each other. This led to the comparison of each of the first, second and third trials for each type of burned rice hulls. This was done because the first 4 runs were immediately tested after passing through the column while the other 8 were refrigerated for almost 4 days. Only the second trial showed inconsistency with its values. Looking at the result generated for the first and third trials using ANOVA: Single Factor, trial 1 for 600°C (run 2) and trial 3 of 900°C (run 7) got the lowest average MPN indices respectively. Although 49 is the lowest MPN index obtained (sample 3 of run 11 – rice hulls burned at 600°C), the rice hulls burned at 900°C column was chosen to be the most effective not only for getting one of the lowest MPN index but also because clear effluents for samples 3 to 5 were obtained. These could be accounted to the properties of this particular type of burned rice hulls such as pore volume and porosity. As presented in Table 1, the pore volume of the rice hulls burned at 900°C is 368.2 ml and the porosity is 2.1228. Both of these values are the largest among the types of burned rice tested in this study.

4.0 CONCLUSIONS AND RECOMMENDATIONS

For the properties of burned rice hulls, it was clearly shown in Table 1 that as the burning temperature increases: (a) the bulk density decreases for the rice hulls burned in the furnace; (b) the pore volume increases (except for the backyard burned rice hulls which is burned in an uncontrolled condition); (c) significant increase in porosity from the burning temperature of 600°C to 900°C; and (d) the weight of volatiles removed increases.

As far as the designed column for burned and backyard burned rice hull is concerned, none is recommended for use as filter medium for drinking water. The different types of burned rice hulls tested in this study have the capability to reduce *E. coli* but did not meet the accepted value (<2 cells/ml -- MPN Index) given in the 1993 Philippine National Standard for Drinking Water.

Since the experimental setup used was not well established, it is recommended to explore further modifications of the setup especially increasing its packed height to provide more adsorbing capacity. In doing this, the occurrence of possible errors in the performance of each run can be minimized. Thus, more accurate result may be achieved.

It is also recommended to perform more trials for each type of burned rice hulls (300°C, 600°C, 900°C, and backyard burned). In line with this, the use of other temperatures in burning the rice hulls should also be tried.

With regards to the number of pass that can be employed, making use of more than one pass is highly recommended for this can give more significant findings on the utilization of burned/carbonized rice hulls as filter medium for drinking water. Comparing results of multiple passes with a single pass may give vital information on whether the burned rice hulls can increase or decrease *E. coli*, or may have no effect at all.

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