International Conference of Sciences, Engineering & Environmental Technology (ICONSEET), 2(47): 361-366, 2017
ISSN 0794-9650
www.repcomseet.com

Construction of Charcoal Filter for Rainwater Treatment

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Abstract – The aim of this study is to construct charcoal filter for rainwater treatment with simple low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. Model filter and prototype filter were constructed, the model filter consisted of 48cm layer of 12mm granite spread at the bottom of the plastic bucket, followed by a 24cm layer of 10mm granite, and 48cm layer of Activated Carbon which was later followed by a layer of beach sand whose thickness is a function of infiltration rate and the thickness of each layer in model filter was multiplied by 3.5 to get their respective thickness in prototype filter. Tests conducted on the filtrate of model and prototype filter revealed that the model filtrate satisfied all physiochemical and bacteriological parameters except turbidity which is more than 5 NTU and the most probable number (MPN) of coliform count which is 5 while that of prototype satisfied all physiochemical and bacteriological parameters except the most probable number of coliform. Charcoal filters remove MPN by 97% and 98% in model and prototype filters respectively which shows that the filters are effective. According to WHO, the filtrate from both model and prototype filters can still be considered fit for drinking since the MPN value is less than 10 in 100ml and rain water is not susceptible to faecal contamination.

Keywords: Charcoal filter, Coliform, Model, Most Probable Number, Rainwater, Treatment.

1. Introduction

Water is the most common or major substance on earth, covering more than 70% of the planet's surface. All living things consist mostly of water. The never-ending exchange of water from the atmosphere to the oceans and back is known as the hydrologic cycle. This cycle is the source of all forms of precipitation (hail, rain, sleet, and snow), and thus of all the water. Precipitation stored in streams, lakes and soil evaporates while water stored in plants transpires to form clouds which store the water in the atmosphere. Currently, about 75% to 80% of conventional water supply is from lakes, rivers and wells. Making the most efficient use of these limited and precious resources is essential. Otherwise, scarcity of water will be faced by our future generations. This includes using appliances and plumbing fixtures that conserve water, not wasting water, and taking advantage of alternative water sources such as grey water reuse and rain water harvesting (IRICEN, 2006). If we do not wake up even now, then we will not have enough good water to go round, and our future generations will be faced with severe crisis of water.

The solution to all these problems is to replenish ground water bodies with rain water by man-made means. Rain Water Harvesting (RWH) as defined by Eldho (n.d.) and IRICEN (2006) is the process or technique of collecting, conveying & storing water (at surface or in sub-surface aquifer) from rainfall in an area for beneficial use. The rain water as posited by IRICEN (2006) is one of purest form of water and does not contain suspended/dissolved impurities. However, when this water is collected through rain water harvesting, it gets contaminated because of contact with roof surface/ground and some of the impurities get mixed in it.

These impurities are required to be removed before collecting the harvested rain water in storage tank or diverting it or recharging of ground water aquifers. Chukwuma *et al* (2012) in their study assess the physico-chemical and microbiological parameters of rainwater collected in the open in Oko, Orumba North L.G.A. of Anambra State Nigeria. Some water quality parameters were considered and analyzed in the laboratory. The laboratory results were compared to permissible water quality level as recommended by National Agency for Food and Drugs Administration and Control (NAFDAC). The comparative parameters analysis shows that the rainwater sample collected were within the permissible limit except for the pH which was slightly acidic. Granular activated carbon (GAC) is commonly used for removing organic constituents and residual disinfectants in water supplies.

This not only improves taste and minimizes health hazards; it protects other water treatment units such as reverse osmosis membranes and ion exchange resins from possible damage due to oxidation or organic fouling. Activated carbon is a favored water treatment technique because of its multifunctional nature and the fact that it adds nothing detrimental to the treated water (DeSilva, 2000). Eliminating organics in potable water, such as humic and fulvic acid, prevents chlorine in the water from chemically reacting with the acids and forming trihalomethanes, a class of known carcinogens (Waterprofessionals, n.d.). The study aims at constructing charcoal filter for rainwater treatment with simple low-cost technique that requires minimum specific expertise or knowledge and offers many benefits.

2. Materials and Methods

Materials

Materials used for the construction of rainwater filter include: plastic drum, plastic bucket, granite of 12mm and 10mm size, beach sand, activated carbon and tap (plus its accessories).

Sample treatment: Granite was washed thoroughly (to remove some impurities such as dirt, broken glass, wood, etc.), sun-dried and then passed through BS sieve of 14mm, 12mm, and 10mm. Then the ones that pass through 12mm and 10mm were used. Afterward, beach sand was washed thoroughly with tap water (to remove organic and inorganic salt), sun-dried and sieved with 0.8mm and 0.6mm sieves.

Methods

Sieving of the granite: The samples of the granite were made to pass through the sieves of 14mm, 12mm and 10mm. The sample that passed through 14mm sieve but was retained on 12mm sieve, and the one that passed through 10mm were obtained and tagged as sample 1 and sample 2 respectively.

Sieving of beach sand: In order to obtain 0.8mm and 0.6mm sand size, the sample of the sand were made to pass through 0.8mm and 0.6mm IS sieves, the samples that were retained on 0.8mm sieve and the sample that passed through 0.6mm sieve were obtained and used.

Arrangement of model filter: The filter apparatus which was locally manufactured, consists of a plastic bucket, pipe, fine and coarse aggregates, and activated carbon. Before placing them in the filter set-up, both sand and gravel were washed again thoroughly with hot water. Graded granite was laid as support for the sand filter. Sample 1 (that is, granite of 12mm size) was laid at the bottom of the bucket to a depth of 4.8cm and Sample 2 (granite passing through sieve 10mm) was placed immediately on top of Sample 1 to a depth of 2.4cm, followed by 4.8cm layer of activated carbon. In other words, the total layer of granite is 7.2cm. The filter sand has no specific depth but can only be achieved by flow test. A layer of beach sand was placed immediately after the activated carbon leaving about 7.2cm clearance above the sand in the bucket as shown in Figure 1. Water was then poured into it and allows it to run for 60 seconds.

Flow rate test: The apparatus used are graduated container and stop watch. Water was poured into the filter arrangement with the tap closed and graduated container placed below tap. Adequate time was considered for the water particles to travel through the bed, and then the tap was open and at the same time the stop watches started reading. The quantiity of water in the graduated container after 1minute was recorded and that gave flow rate of 1.8L/minutes, 2.0L/minutes and 2.0L/minutes respectively.

Arrangement of prototype filter: The filter apparatus which was locally manufactured, consists of a plastic bucket, pipe, activated carbon, fine and coarse aggregates. Before placing them in the filter set-up, both sand and gravel were washed again thoroughly with hot water. Graded granite was laid as support for the sand filter. Sample 1 (that is, granite of 12mm size) was laid at the bottom of the bucket to a depth of 0.2m and Sample 2 (granite passing through sieve 10mm) was placed immediately on top of Sample 1 to a depth of 0.08m, followed by 0.2m layer of activated carbon. In other words, the total layer of granite is 0.28m. The value of 3.5 was obtained from the comparison between the ratio of the volume of the model to that of prototype and the thickness of each layer in model filter was multiplied by 3.5 to get their respective thickness in prototype filter. See Figure 2.

Tests

Raw and filtered rainwater samples were carried to the laboratory and the following tests were carried out: physical tests, biological tests and chemical tests. The physiochemical and bacteriological tests were carried out at Osun State Water Corporation Central Laboratory, Ede, Osun State.

Fig. 1: The Model Charcoal Filter

Fig. 2: The Setup of Prototype Filter

3. Results and Discussion

The physiochemical and bacteriological test results for both model and prototype charcoal filters and their effectiveness are shown below in Tables 1 and 2.

Table 1: Water Quality Indices of Filtrate from Model Filter

PARAMETERS	MODEL FILTER			
	RAW RAINWATER	FILTERED RAINWATER	Percentage Reduction (%)	Remarks According to WHO Standard
Colour (H.U.)	25.00	15.00	56	Safe
pH at Laboratory	7.70	7.60	4	Safe
Turbidity (FTU)	9.39	6.46	58	Unsafe
Temperature ºC	30.00	30.00	0.00	Safe
Total Hardness (mg/l)	32.00	22.00	37.5	Safe
Magnessium Hardness (mg/l)	26.00	12.00	57.7	Safe
Magnessium ions (mg/l)	6.50	3.00	54	Safe
Chloride ions (mg/l)	11.00	7.50	31.8	Safe
Iron (mg/l)	0.084	0.064	42	Safe
Silica (mg/l)	4.399	0.006	99.8	Safe
Nitrate Nitrogen (NO_3^{2-}) (mg/l)	0.049	0.05	90	Safe
Nitrite Nitrogen (NO_2^{2-}) (mg/l)	0.642	Less than	_	Safe
Copper (mg/l)	0.620	0.20	67.7	Safe
Manganese (mg/l)	0.002	0.002	100	Safe

Aluminium (mg/l)	0.04	Less than	_	Safe
Chromium (mg/l)	0.09	0.03	67	Safe
Conductivity	154.8	22.20	86.1	Safe
Sulphate (mg/l)	25.0	5.00	84	Safe
Zinc (mg/l)	0.45	0.19	57.8	Safe
Bicarbonate (mg/l)	475.80	83.00	82.5	Safe
Flocculation (PPM)	15.00	15.00	0	Safe
Total Dissolved Solids (mg/l)	77.4	54.0	30	Safe
MPN of Bacteria Coliform per 100ml of Water Sample	180	5.00	97	Unsafe

Table 2: Water Quality Indices of Filtrate from Prototype Filter

PARAMETERS	PROTOTYPE FILTER			
	RAW RAINWATER	FILTERED RAINWATER	Percentage Reduction (%)	Remarks According to WHO Standard
Colour (H.U.)	25.00	11.00	40	Safe
pH at Laboratory	7.70	7.40	1.3	Safe
Turbidity (FTU)	9.39	3.90	15	Safe
Temperature (°C)	30.00	30.00	0	Safe
Total Hardness (mg/l)	32.00	20.00	31	Safe
Magnessium Hardness (mg/l)	26.00	11.00	54	Safe
Magnessium ions (mg/l)	6.50	7.50	54	Safe
Chloride ions (mg/l)	11.00	0.064	27	Safe
Iron (mg/l)	0.084	0.064	42	Safe
Silica (mg/l)	4.399	0.05	99.8	Safe
Nitrate Nitrogen (NO_3^{2-}) (mg/l)	0.049	0.005	90	Safe
Nitrite Nitrogen (NO_2^{2-}) (mg/l)	0.642	Less than	_	Safe
Copper (mg/l)	0.620	0.24	61.3	Safe

Manganese (mg/l)	0.002	0.00	100	Safe
Aluminium (mg/l)	0.04	Less than	_	Safe
Chromium (mg/l)	0.09	0.03	67	Safe
Conductivity	154.8	26.70	83	Safe
Sulphate (mg/l)	25.0	5.00	80	Safe
Zinc (mg/l)	0.45	0.21	53	Safe
Bicarbonate (mg/l)	475.80	85.30	82	Safe
Flocculation (PPM)	15.00	15.00	0	Safe
Total Dissolved Solids (mg/l)	77.4	49.50	36	Safe
MPN of Bacteria Coliform per 100ml of Water Sample	180	3	98.3	Unsafe

According to USEPA standards, water samples in which coliforms are detected should be considered unacceptable for drinking water as they are regarded as the principal indicators of water pollution. The WHO standards for total and faecal coliforms are 1 to 10/100ml and 0/100ml respectively (USEPA, 2001 & WHO, 2003). From table 1 above it can be clearly seen that unfiltered water has 180 most probable number (MPN) and filtered rainwater have 5 MPN for model filter and 3 MPN for prototype filter which means the model and prototype filters reduce the number of coliform present in rainwater by 97 and 98% respectively. The Most Probable Number (MPN) falls within the permissible limit for World Health Organization standard (WHO, 2003) but does not fall within the permissible limit for United States Environmental Protection Agency standard (USEPA, 2001).

4. Conclusion and Recommendations

Conclusion

Based on the results obtained in this research, the following conclusions were drawn:

i. The filtrate of the model filter satisfied all the physiochemical parameters except turbidity and bacteriological parameters except most probable number of coliform count while the filtrate of prototype filter satisfied all the physiochemical parameters and bacteriological parameters except most probable number of coliform count.

ii. The charcoal filters are effective because it removes most probable number of coliform by 97% and 98% in the model and prototype filters respectively.

iii. According to WHO (2004), the filtrates from both model and prototype filters can still be considered fit for drinking since MPN value is less than 10 in 100ml and raw rainwater collected is not susceptible to faecal contamination.

Recommendations

i. Raw water tanks must be washed annually prior to rainy season.

ii. The height at which rainwater will be collected should not be less than 3m because at higher height, the level of contamination (dust, debris, etc.) will reduce in rainwater.

Acknowledgements

The authors are indeed grateful to Technical Staff at Osun State Water Corporation, Ede and Civil Engineering Students, Federal Polytechnic Ede, Nigeria for their assistance during the laboratory works.

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