CASE STUDY

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Quality Testing of Raw and Filtered Grey-water Emerging from Kitchen Sink: A Case Study

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Abstract

The limited freshwater supplies in arid regions have created alternative water management strategies. Data indicates that grey-water generation varies from 39-85% in various countries. Grey-water treatment and reuse can be a helpful non-potable water source for toilet draining, watering gardens, car and floor washing, etc. Treated grey-water should be clean, hygienic, environment-friendly and cost-effective. The goal of this research is (i) to test the parameters of raw grey-water (ii) create a filter bed (iii) test parameters of treated grey-water (iv) Compare the parameters of raw and treated grey-water (v) describe the area of use.

Keywords: BOD_5, COD, Grey-water, Nutrients, pH, TOC, TSS, Turbidity.

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Introduction

Nearly 97 percent of the entire water supplies on Earth are found in the oceans, although only 3 percent are eligible for direct use.Of this 3 percent, the volume of water used by mankind is calculated to be one part of hundred.[1] The limited freshwater supplies in arid regions have created alternative water management strategies. Attempts are being made worldwide to enable use of treated grey-water collected by gravity-enabled filtration technology and disinfection techniques for domestic use and to overcome the increasing challenges of water shortage. The waste-water usually produced from the kitchen drains, bath-showers, cloth washing or washing machine, AC duct, etc., is grey-water, sent out as a waste. Data indicates that grey-water generation varies from 39 to 85% in various countries. This data demonstrates that domestic water use varies from country to country.[2]

There are high concentrations of fecal indicator species in domestic waste-water, ranging from 10^6 to 10^8 CFU/100 mL. Suppose the organic and inorganic constituents present in grey-water are released directly into natural bodies of water. In that case, they could contribute to an increase in BOD_5 concentration, thereby leading to the reduction of O_2 levels needed for different types of habitats supported by the natural bodies. The elimination of organic products and nutritional contents from grey-water is an effective way of avoiding eutrophication and algal blooms. Therefore, prior to discharge into water bodies, grey-water should be given adequate treatment.[3]

Grey-water treatment and reuse can be a helpful non-potable water source for toilet draining, watering gardens, automotive and floor washing, etc.[4,5] Many nations have specific rules for the control of grey-water and direct human interaction is prohibited.[6] Treated grey-water should be clean, hygienic, environment friendly, cost-effective and aesthetic.[7] Physical treatment systems cannot decrease the desired microbial concentration, they are used along with certain disinfection measures such as chlorination or activated charcoal or in conjunction with chemical or biological processes.[8] Due to their high porous nature and high carbon concentration, bark and charcoal are attracting attention as filtering mediumin addition to soil and sand.[9,10] The goal of this research is (i) to test the parameters of raw grey-water (ii) create a filter bed (iii) test parameters of treated grey-water (iv) Compare the parameters of raw and treated grey-water (v) describe the area of use.

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Waste-water Quality

Since the early 1970s, when the Clean Water Act was enacted and the USEPA was founded, waste-water quality has been determined using a series of laboratory tests based on four primary areas:[11]

- *Physical Properties:* These tests are carried out to determine the physical properties related with grey-water, such as temperature, color, smell, turbidity etc.
- *Solids:* Using TS, TSS, TDS, TVS and TFS tests, the concentration of suspended or dissolved solids in grey-water can be determined.
- *Organics:* These tests aim to determine the concentration of organic-carbon-based compounds in waste-water, which may include BOD, COD, TOC, and O and G tests.
- *Nutrients:* The nitrogen and phosphorus concentration present in grey-water can be determined using nutrient analysis. Nutrient concentration plays an important role in the natural aging of water bodies.

pH Value

pH scale ranges from 0-14. Fresh (Drinking) water has a pH of 7 (neutral). pH of less than 7.0meanssolution has acidic pH, while pH value above 7.0 indicates the solution is a base. Acidic water with pH of less than 6.5 may have high concentrations of metals such as manganese and iron.[12] On the other hand, a basic or alkaline water can cause corrosion of metals such as copper, aluminium, zinc, iron, and brass. Strips of "*Litmus paper"* can be used to test the pH value of water. The strip turns blue if the solution is a base or red if the solution has acidic pH. If the solution is neutral, the color of litmus paper remains unchanged. *Litmus paper* test only indicates the nature of the solution (alkaline or acidic). However, it does not indicate the exact pH value of the solution. Another effective way to perform the pH test is to use "pH testing strips" that accurately determine the pH value of water by comparing the color of the testing strips against a known standard pH chart indicator. Testing with a digital pH meter can be a more precise way to test water pH as it reduces the chances of parallax errors due to human intervention.

Some ways to neutralize pH condition of water are listed below:

- Use of neutralizing filters.
- Use neutralizing solutions such as Calcium carbonate, synthetic magnesium oxide, Soda ash, vinegar, citric acid or alum.
- Electrolysis.

Treated alkaline part of the water with safe pH values can be used for drinking, while treated water with acidic pH can be utilized for other uses such as washing and cleaning. As neutralizing filters and solutions are cost-effective techniques, they are preferred over ionizers.

Turbidity

Turbidity can affect everything, including the state of our lakes, oceans, and rivers, and is the most common quality of water. It is an indicator of water's cloudiness, which typically comes from particulates that are dissolved in water, including fungi, bacteria, dust, protein, minerals, or even oil appearing in the household waste-water emerging from kitchens, baths and laundries. Cloudy water could be a sign of contamination. If raw grey-water is allowed to flow into streams and lakes without treatment, it can harm aquatic species that live at the bottom of the water.[13]

Although turbidity and suspended solids are related, measuring turbidity is not the same as measuring total suspended solids (TSS). Apart from drinking water, measuring the turbidity of waste-water is useful in many industries including; wine, beverage and food industries. Turbidity is an optical measurement done by passing light through a sample and calculating suspended particle concentration. The more the particle concentration, the higher will be the turbidity. Some methods to measure turbidity:

- *Use of Secchi disk:* This entails lowering a disc into water till it becomes invisible. The Secchi depth is the depth at which the disc is invisible. This method is subjective, and it works better in slow-moving natural waterways with little turbidity.
- A turbidity metre, also known as a nephelometer, is the ideal tool for turbidity measurement in case of large sample size.

Regulations are in place to ensure the safety of drinking water and the efficiency of the manufacturing process. Raw water is treated at potable and waste-water treatment plants to decrease turbidity. Using "flocculation," one can remove particles suspended in water which is the first phase in the water treatment process. Water is mixed with a coagulant, such as alum, to achieve clarity. The addition of alum neutralizes the suspended impurities, causing particles to enlarge and form bigger particles called as 'floc.' The water is then passed through a sedimentation basin, where the floc is removed using filter media. After most of the dissolved impurities removal, the water is filtered again, removing up to 99.5% of the remaining suspended solids.[14]

As per USEPA standards, turbidity of drinking water should be 0.5 NTU and it should not exceed 5 NTU for any sample.

TSS (Total Suspended solids)

TSS is made up of particles larger than 2 microns present in water. A dissolved solid is anything smaller than this. Although algii and bacterium can increase total solid levels, the majority of suspended solids are made up of inorganic elements. TSS is the dry weight of suspended particles in a water sample that does not dissolve. It's calculated by putting a specific amount of water through a pre-weighed filter. When the drying process is completed, the filter can no longer contain any water. TSS is determined by weighing the filter once more. The difference between the filter's starting and end weight determines the TSS value, expressed in milligrams per litre.[15]

Table 1 shows the CPCB and USEPA quality standards for treated waste-water.[4]

Biochemical Oxygen Demand (BOD)

The BOD test is the most extensively used method for estimating the amount of organic content in waste-water samples. It's based on the idea that if there is enough

oxygen, aerobic biological breakdown by microorganisms will continue until all garbage has been consumed. Because it is based on a precise estimate of DO, the BOD test is sometimes known as "BOD_5" (dissolved oxygen). The DO test determines the amount of O_2 dissolved in a sample of water or waste-water. An electronic metre with a specific DO probe is frequently used to measure. The level of DO in a water sample is shown to be mostly influenced by other research:[16,17]

- *Water Temperature:* DO reduces as water temperature rises (i.e., hot water holds less O_2)
- *Salinity:* DO reduces with increased water salinity (i.e., salty water holds less O_2).
- *Atmospheric Pressure:* DO increases with atmospheric pressure (i.e., increasing altitude reduces water O_2 level).

A waste-water sample must be devoid of chlorine to ensure optimal biological activity during the BOD test.

- The pH level should be between 6.5 and 7.5.
- There should be a sufficient microbial population in place.

We utilize specialized 300 mL bottles that allow for full filling and an airtight seal with no air space. The initial dissolved O_2 level (mg/L) in each bottle is measured using a DO metre, at least 8 mg/L. After that, each bottle is kept in the dark 20°C incubator for 5 days. The DO metre is used after 5 days (± three hours) which measures the finally dissolved O_2 level (mg/L), which gets reduced by at least 4 mg/L. The BOD value (mg/L) is then calculated by subtracting the final DO reading from the initial DO reading.[17,18]

Chemical Oxygen Demand (COD)

The COD test is not a replacement for the BOD test; it is an independent assessment of the organic compounds in a waste-water sample. The COD test takes just a few hours to complete, which gives it a significant benefit over the BOD_5 test. COD can be used by waste-water treatment system operators as a near-real-time operational adjustment parameter. COD can be used to test waste-water that is too dangerous to be tested with BOD. The most common current COD testing method includes utilizing sealed and heated (i.e., closed reflux) pre-prepared low-range (3-150 ppm) or high-range (20-1500 ppm) vials that change color from orange to green depending on the quantity of oxidation and are read using a lab colorimeter.[19]

Total Organic Carbon (TOC)

The TOC test is becoming more popular because it only takes 5–10 minutes to complete. Once a consistent TOC to BOD ratio is obtained for a given waste-water stream, the TOC test, like the COD test, can be used to quickly determine BOD level. A carbon analysis equipment, which analyses total organic carbon in a waste-water sample, is at the heart of the TOC test. To measure TOC, various heat and oxygen, UV light, and chemical oxidant-based methods are available, each tailored to the carbon analyzing device in use. Organic carbon is transformed into carbon dioxide (CO_2) and quantified using an infra-red analyzer in the TOC test.[20,21]

Oil and grease (O and G)

Although O and G, FOG both acronyms that relate to the identical waste-water elements, the term O&G (oil and grease) has gained popularity. Plants and animals (e.g., butter, lard, fats and vegetable oils) and petroleum sources can all contribute to O&G constituents in waste-water (e.g., lubricating oils, grease, kerosene,). Because O and G are poorly soluble in waste-water, bacteria have difficulty degrading them. At high temperatures, O and G becomes more soluble in waste-water and create emulsions (oil-water mixes) that separate out of waste-water when temperatures cool; as a result, O and G are renowned for clogging sewers and causing pump failures.[11,22]

Nutrients

Plant growth requires proper nutrient management. For success, the appropriate balance of macronutrients and

Table 1: Quality standards of treated grey-water[4]

Standards	*Use*	*pH*	*Turbidity*	*TSS*	*Referene*
CPCB (India)	Irrigation	5.5-9	-	200	CPCB (2008)
	Inland surface water	5.5-9	-	100	
	Public sewer	5.5-9	-	600	
USEPA	Toilet flushing, Irrigation of lawns, home gardens.	6-9	2	-	USEPA (2012)
	Agricultural use, Industrial cooling, Construction.	6-9	-	30	

Table 2: Typical organic concentrations in untreated residential waste-water[21]

		Typical Concentration		
Constituents	*Unit*	*Low*	*Medium*	*High*
BOD (biochemical oxygen demand)	mg/L	110	190	350
COD (chemical oxygen demand)	mg/L	250	430	800
TOC (total organic carbon)	mg/L	80	140	260
O&G (oil and grease)	mg/L	50	90	100

micronutrients is critical, but excess can be just as harmful as a deficit. Inadequate plant nutrition can harm plant development as well as taint groundwater and pollute surface streams. Nitrogen is necessary for healthy, high-yielding plants. Due to the high expense of nitrogen fertilisers, producers must be well-informed and make precise judgments about when and how much nitrogen is required.[23]

Table 2 represents the typical concentration of organics (BOD, COD, TOC, O&G) in raw domestic grey-water.

Quality Testing

To construct the filter media, a transparent plastic container measuring 30cm x 20cm x 15cm was purchased from the market for Rs. 400. A hole was drilled at the container's bottom so that treated grey-water could flow out through this point. An outlet pipe was glued into the hole, and precaution was taken that the outlet does not produce leakage. The glue was allowed to dry for some time and the container was tested for leakages if any, through drilled hole. The container did not leak, the testing water was thrown out and the container was clean wiped using a dry cloth, taking care that no fine particles of the cloth stick to the container as it could alter the readings for the treated grey-water. Forming a filter bed in this container was then carried out. The container was initially filled with stones of larger size at the bottom to cover a height of nearly 4 cm. Care was taken that the stones are evenly placed inside the container. The layer of stones was then covered with a layer of grit uniformly spread over the larger stones to reach a height of 06 cm. The grit layer was covered with a layer of fine sand up to a height of 8 cm. Finally, a layer of red soil was deposited as the top layer up to 10 cm. The filtration bed was ready, as shown in Figure 1.

To test the quality of grey-water following procedure was adopted:

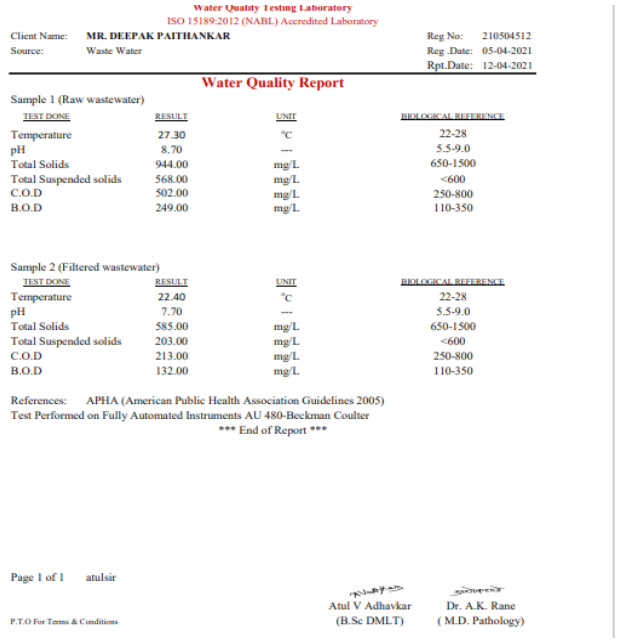
- It was decided to conduct the quality test by collecting the kitchen waste-water.
- A circular filter mesh with small pore size was placed at the mouth of the sink to avoid the flow of food particles through the outlet of the sink.
- The drainage pipe connected to the sink was removed and a bucket was placed underneath to collect the outlet water.
- As an extra precaution, a cloth was tied to the outlet of the sink to collect any food particle that escaped the filter mesh.
- Utensils were washed and water emerging from washing was collected in the underneath bucket.
- Water collected in the bucket was allowed to settle for 2 hours to settle down the sediments.
- After 2 hours, approximately 1 L of the sample was transferred to a container and preserved to measure grey-water parameters such as pH, Turbidity, TSS, BOD_5, COD etc.
- The raw water was poured over the filtration bed using a plastic mug.
- The water dripped vertically through the filter bed and appeared through the outlet pipe.
- The treated water sample was collected in another container to estimate parameters similar to the raw grey-water.

Figure 1: Filtration bed

Results and Discussions

After collecting the samples, the two containers were marked as "Raw" and "Filtered" and the samples were sent to Water quality Testing Laboratory, Vashi, Mumbai, India for testing. The test results were obtained after 07 days. Figure 2 shows the parameters derived from the test.

It is found that simple filtration technique helps to achieve an improvement in parameters of the raw waste-water. pH



Water Quality Testing Laboratory
ISO 15189:2012 (NABL) Accredited Laboratory

Client Name: MR. DEEPAK PAITHANKAR
Source: Waste Water
Reg No: 210504512
Reg .Date: 05-04-2021
Rpt.Date: 12-04-2021

Water Quality Report

Sample 1 (Raw wastewater)

TEST DONE	RESULT	UNIT	BIOLOGICAL REFERENCE
Temperature	27.30	°C	22-28
pH	8.70	---	5.5-9.0
Total Solids	944.00	mg/L	650-1500
Total Suspended solids	568.00	mg/L	<600
C.O.D	502.00	mg/L	250-800
B.O.D	249.00	mg/L	110-350

Sample 2 (Filtered wastewater)

TEST DONE	RESULT	UNIT	BIOLOGICAL REFERENCE
Temperature	22.40	°C	22-28
pH	7.70	---	5.5-9.0
Total Solids	585.00	mg/L	650-1500
Total Suspended solids	203.00	mg/L	<600
C.O.D	213.00	mg/L	250-800
B.O.D	132.00	mg/L	110-350

References: APHA (American Public Health Association Guidelines 2005)
Test Performed on Fully Automated Instruments AU 480-Beckman Coulter
*** End of Report ***

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Figure 2: Water Quality Report

level, TS, TSS, BOD and COD values of filtered waste-water improved by 11.5%, 38.03%, 64.26%, 57.57 and 46.98%, respectively. Filtered waste-water was more clear and contained lesser impurities than the raw waste-water. Filtered waste-water can be used for watering household plants as the BOD and COD levels are better than raw grey-water.

Conclusion

The limited freshwater supplies in arid regions have created alternative water management strategies. Nearly 97 percent of the total water supplies on Earth are found in the oceans, although only 3 percent are eligible for direct use. There are high concentrations of fecal indicator species in domestic waste-water, ranging from 10^6 to 10^8 CFU/100 mL. Grey-water treatment and reuse can be a helpful non-potable water source for toilet draining, watering garden, car and floor washing, etc. It is found that a simple filtration technique helps improve BOD and COD rate by 57.57 and 46.98%, respectively. Filtered waste-water can be used for watering household plants as the BOD and COD levels are better than raw grey-water.

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