Exploring the potential greywater use in a typical microcosmic commercial area of South Africa

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Abstract. With water scarcity looming, South Africa needs to be mindful of the way water is used, conserved, or disposed of. By investigating the biological and physical characteristics of grey water, this paper attempted to explore the potential use of grey water within a microcosmic commercial area. Through different methods, samples were tested for Conductivity, Temperature, pH, and Turbidity. Using IDEXX 2000 method, biological characteristics of the grey water (Total Coliform (TC) and E-coli) were tested. At a pH range of 5.8 to 9, Turbidity in the grey water was found to be between 20.1 and 814. The count for TC ranged between $6.83 \times 10^5 - 3.255 \times 10^9$ MPN/100 ml, and that for E-coli ranged between $0.1046 \times 10^4$ and $0.7701 \times 10^8$ MPN/100 ml. The study found that high turbidity values may have serious implications on the perception of people on grey water use as a potential substitute for potable water. However, the low number of E-coli counts suggests that greywater in commercial areas of South Africa may not pose a major health risk to people compared to black water. This paper will contribute to the knowledge about grey water characteristics expected to be encountered when contemplating exploiting grey water in commercial areas around South Africa.

1. Introduction

The potential use of grey water is seen as an alternative solution to the looming water scarcity not only in South Africa but also in the continent of Africa and beyond. According to the World Meteorological Organization [25], South Africa is posed to have water shortages mainly due to the deficient and erratic rainfall in the country. This has already been observed in 2015 in cape town, where the shortage of rain resulted in drought which subsequently affected the water supply. Moreover, activities deriving from industries such as agriculture and mining, amongst many, have been found to induce pollution which threatens water resources [19]. This is because these activities release harmful chemicals in rivers and subsurface water sources hence constitute a threat to the already scarce available clean water. All these are evidence that clean water is threatened. Yet, wastage of domestic water is on the rise [2],[6]. Hence a call to explore alternative sources of water to preserve freshwater is required. Amongst these alternative sources is grey water (GW). Grey water is the wastewater produced from activities such as cooking, bathing, washing hands, clothes, and dishes [1].

This water can be used as a substitute for clean water, which, is used in activities such as toilet flushing and irrigation [20]. Thus, instead of being wasted because these activities consume much of the municipal fresh water supplies, GW can be used in the place of clean water. GW has many advantages, the most prominent of which, is when it is used for toilet flushing and irrigation in
household and commercial areas. This has been found to have great economic benefits such as reduction in water bills [[20],[11]] since it is known that grey water use can conserve between 30 to 50% of municipal water supplies [21]. Furthermore, from a perspective of environmental sustainability, the reusing of greywater presents a great potential source for saving water [[11],[21]].

In South Africa, only a small body of research on grey water exists. For instance, Jackson et al [13] performed microbiological analysis of domestic grey water for use to irrigate crops, Carden et al [5] investigated the use and disposal of GW in non-sewer-reticulated areas. Zuma et al [26] used a mulch tower system to treat with grey water. Rodda et al [23] applied untreated GW from informal settlement to irrigate crops, Ilemobade et al [12] explored potential use of GW in universities and non-commercial areas, Lubbe et al [17] explored the effect of grey water for irrigation use purposes, Bolton & Randall [3] developed a microbial fuel cell and a sand filtration system for the treatment of grey water, Radingoana et al [22] assessed the suitability of rural GW in home gardens while, Matebese & Moutloali [18] used membrane filtration methods as alternatives to treating grey water. As it can be seen, many of these scholars have focused mainly on the use of grey water for irrigation of food purposes in informal settlements. However, to truly combat the water scarcity in South Africa, research on greywater should not only be limited to informal settlements but urban settlements as well. Thus, although a considerable body of knowledge exists on the properties of grey water, the most fitting for this study was found to be the summary (table 1) given by [7]. This is because this gave a general picture of greywater characteristics from all the sources. Similarly, concerning grey water standards, there are not that many standards that stipulate the required quality for GW reuse. For this reason, this research adopted the standard that focused on the health and environmental aspect of grey water reuse [16], since these form the most critical aspect to be observed when contemplating grey water reuse. Therefore, by investigating the biological and physical characteristics of grey water in a typical microcosmic commercial urban area, this study attempted to explore the potential greywater use in an urban area of South Africa. This investigation used the University of Johannesburg student mall at the Doornfontein campus as a microcosmic representation of a larger reality of commercial places.

### Table 1. Grey water properties as per the generation sources [7]

| Parameter       | Unit   | Kitchen | Bathroom | Laundry | Dish-washer | Mixed       |
|-----------------|--------|---------|----------|---------|-------------|-------------|
| pH              |        | 5.9 - 7.4 | 6.4 – 8.1 | 7.1 – 10 | 8.2         | 6.3 – 8.1   |
| TSS mg/L        | 134 - 1300 | 7 - 505  | 68 - 465 | 100 - 440 | 25 - 183    |             |
| Turbidity NTU   | 0 - 298 | 44 - 275 | 50 - 444 | -       | 29 - 375    |             |
| COD mg/L        | 26 - 2050 | 100 - 633 | 231 - 2950 | 1300   | 100 - 700   |             |
| BOD mg/L        | 536 - 1460 | 50 - 300  | 48 - 472 | -       | 47 - 466    |             |
| TN mg/L         | 11.4 - 74 | 3.6 – 19.4 | 1.1 – 40.3 | -     | 1.7 – 34.3  |             |
| TP mg/L         | 2.9 - 74 | 0.11 – 48.8 | -     | 0.11 – 22.8 | -             |
| Total Coliform CFU / 100 ml | > 2.4 × 10⁸ | 10 – 2.4 × 10⁷ | 200.5 – 7 × 10⁵ | - | 56 – 8.03 × 10⁷ |
| Fecal coliform CFU/ 100 ml | - | 0 – 3.4 × 10⁵ | 50 – 1.4 × 10⁵ | - | 0.1 – 1.5 × 10⁸ |

### 2. Methods and Data

#### 2.1. Research Locality

The study was conducted at the University of Johannesburg’s Doornfontein campus (DFC) as indicated in figure 1, which can be found in the Doornfontein area of the City of Johannesburg’s Metropolitan Municipality in South Africa. The study area can be located on coordinates (26.1949° S, 28.0552° E), approximately 64 kilometres south of Pretoria, the Capital City. Hydrologically, DFC is situated in the Jukskei River Catchment of the upper Crocodile River sub-catchment, which itself, is
within the Limpopo River Basin. This university campus is immediately north of the sub-continental surface water divide between the orange River basin to the south and the Limpopo River basin to the north [10]. The orange river drains into the Atlantic Ocean while the Limpopo River drains into the Indian Ocean. Johannesburg is within the Gauteng Province, which is the biggest water user in South Africa [14]. Therefore, this particular study was found to be important in as far as exploring alternative sources of water in South Africa is concerned.

![Figure 1. University of Johannesburg Doornfontein Campus](image)

2.2. Data and Sampling

Research methodology is about how a researcher plans to acquire information concerning the research [15]. For this research, field and lab tests were required to investigate the physical and biological characteristics of grey water in a typical microcosmic commercial area in South Africa, bearing in mind that grey water characteristics have an implication on the kind of treatment that is required when contemplating exploring grey water [8]. Thus, this research adopted an applied research methodology, which is carried out practically, with an aim of either understanding the problem, address the problem, answer multiple questions or discover the implication of an effect [9].

Therefore, with this in mind, the research followed the workflow process as outlined in Figure 2.
As mentioned earlier, the University of Johannesburg’s student mall at DFC was identified as a suitable sampling site for this study. It can be delineated as a small commercial area where commercial activities occur. Bearing these in mind, water quality tests were performed. Performing water quality sampling (WQS) requires that samples be collected from a representative source of the water which is intended to be investigated [24]. The typical commercial activities found in DFC’s student mall that aided the investigation included restaurants, gyms, and retailer stores. Furthermore, this specific site was found convenient because of its minimised traveling costs to and from the UJ Water and Health Research Laboratory where laboratory tests were performed. Grey water samples were collected from the Gully that drained a majority of the students’ mall shops wastewaters. This is because usually, a gully is designed to carry grey wastewaters from the kitchen, bathroom (mainly bath and shower tub), and laundry, then drain it into the municipal sewer pipe. Water flowing into the gullies is not as toxic as black water (wastewater from toilet) flowing in the sewer pipes. Because of this, GW can restrain pollutants. The water from the gullies usually acts a sealant that prevent harmful gases and disease carrying pathogen from leaving the main sewer [4].

2.3. Method
The samples were collected daily over two weeks. This was done using 100 ml plastic bottles and a standard beaker. The samples were first tested for Conductivity, Temperature, and pH (CTp), using Hanna HI 98129 Waterproof PH, EC/TDS & Temperature meter respectively. The samples were then tested for Turbidity using portable waterproof turbidity meter TN 100. These tests were performed immediately at the point of extraction because these properties may change during storage and transportation [24]. However, the wastewater microbiology of the grey water was carried out in the lab.
The GW samples were put in the 100ml plastic bottle and then transferred immediately to a light-proof insulated box containing ice as recommended by the WHO [24]. The samples were then carried to the lab for analysis within less than 6 hours [24]. The biological parameters investigated were mainly the Total Coliform (TC) and E-coli. The sample was diluted with distilled water using serial dilutions of -1, -2, and -3 respectively.

The purpose of dilution was to reduce the concentration of the grey wastewater in order to get a countable number of E. coli. A-1 diluted sample represented the sample with the highest count. Procedures for the analysis of E. coli were carried out according to the IDEXX 2000, using Colilert-18 test Kits, which had a substrate called DST (Defined Substrate Technology) that was metabolized by E. coli when mixed with a sample of grey water. The mixture was placed in a quanti-tray shown in figure 3, then placed in a quanti-tray sealer to seal the quanti-tray. This was then incubated at a temperature of 35 °C for 18 hours as per the instruction of the test toolkit, and the results were observed.

**Figure 3 (a).** Quanti-trays post-incubation.  
**Figure 3 (b).** View of greywater under UV-light post-incubation.

### 3. Results and Discussions

Potential reuse of grey water depends on the physical, chemical, and biological water characteristics [8]. The results of the grey water characteristics for the student mall are given in the table 2. It is also worth noting that grey water harvested from different source points (e.g. kitchen, bathroom, or laundry), have different water characteristics as indicated earlier in table 1. In this research, there was no need to divide different source points, because the grey water was collected from a common gully trap shared by student mall restaurants and gym, where the principal activities occurring which generated greywater were mainly cooking, washing of hands, and cleaning of utensils, and bathwater.
Table 2. Grey water characteristics from student mall

| Sampling days | Temperature °C | pH | Turbidity NTU | Conductivity μs | Total Coliform (MPN/100 ml) | Faecal coliform (MPN/100 ml) |
|---------------|----------------|----|---------------|----------------|-----------------------------|-----------------------------|
| 1             | 19.8           | 7.10 | 119          | 588            | 2046000                    | 579400                     |
| 2             | 27             | 8.50 | 794          | 368            | 2359000                    | 461100                     |
| 3             | 24.3           | 7.67 | 729          | 363            | 2359000                    | 461100                     |
| 4             | 36.2           | 8.38 | 425          | 777            | 2864500                    | 733000                     |
| 5             | 26.5           | 5.98 | 120          | 648            | 960600000                  | 2419600                    |
| 6             | 27.0           | 7.31 | 55.3         | 438            | 14136000                   | 5475000                    |
| 7             | 28.9           | 7.37 | 814          | 2697           | 344800000                  | 6090000                    |
| 8             | 28.2           | 7.43 | 69.5         | 462            | 3255000000                 | 2495000                    |
| 9             | 25.8           | 7.74 | 127          | 272            | 683000                     | 52000                      |
| 10            | 26.2           | 8.01 | 67.0         | 388            | 4884000                    | 2755000                    |
| 11            | 28             | 8.03 | 260          | 923            | 4611000                    | 1106000                    |
| 12            | 23.2           | 7.24 | 20.1         | 205            | 2419600                    | 348400                     |
| 13            | 29             | 7.13 | 79.4         | 522            | 1732900                    | 488400                     |
| 14            | 24.2           | 6.864| 32.8         | 1600           | 5475000                    | 1046                       |
| 15            | 30.6           | 5.658| 282          | 924            | > 2419600000               | 7701000                    |

*Colony Forming Unit (CFU) = 1 Most Probable Number (MPN). CFU and MPN are said to be equivalent because both units estimate the number of bacteria. They only differ by method.*

The findings on the physical characteristics of the GW indicated that temperature of the GW ranged between 19 and 37 °C. Similarly, values for turbidity were found to be between 20.1 and 814. Also, the pH of the grey water was between 5.8 to 9. From the biological characteristics point of view, the IDEXX method used in this study showed similar results. The guidelines for analysis and interpreting the IDEXX method can be found on the IDEXX manual [11]. Using this method, a yellow colour served as an indication for total coliform while a yellow and fluorescence colour indicated that the sample was contaminated by E. coli. The count for the total coliform (TC) ranged between 6.83 × 10^5 – 3.255 × 10^9 MPN/100 ml, and that for faecal coliform (FC) ranged between 0.1046 × 10^4 and 0.7701 × 10^8 MPN/100 ml. Table 3 is a summary of the results obtained from the grey water samples. The range indicates the typical values between which specific parameters will occur for grey water samples collected in commercial areas, especially in a typical shopping mall.

Table 3. Summary of results at student mall in comparison to what has been reported in literature.

| Parameter                  | Unit   | Kitchen | Bathroom | Laundry | Dishwasher | Mixed | Student mall GW characteristics |
|----------------------------|--------|---------|----------|---------|------------|-------|-------------------------------|
| pH                         | 5.9 - 7.4 | 6.4 - 8.1 | 7.1 - 10 | 8.2     | 6.3 – 8.1  | 5.8 - 9 | 19 - 37                       |
| TSS (mg/L)                 | 134-1300 | 7 - 505 | 68 - 465 | 100 - 440| 25 - 183   | -     |                               |
| Turbidity (NTU)            | 0 - 298 | 44 - 375 | 50 - 444 | 29 - 375 | -          | 20.1 - 814 |                               |
| Temperature (°C)           | -      | -       | -        | -       | -          | 19 - 37 |                               |
| Conductivity (μs)          | -      | -       | -        | -       | 205 - 2697 |       |                               |
| COD (mg/L)                 | 26 - 2050 | 100 - 633 | 231 - 2950 | 1300   | 100 - 700   | -     |                               |
| BOD (mg/L)                 | 536 - 1460 | 50 - 300 | 48 - 472 | -       | 47 - 466   | -     |                               |
| TN (mg/L)                  | 11.4 - 74 | 3.6 - 19.4 | 1.1 - 40.3 | -       | 1.7 - 34.3  | -     |                               |
| TP (mg/L)                  | 2.9 - 74 | 0.11 - 48.8 | -        | 0.11 - 22.8 | -          |       |                               |
| Total Coliform (CFU / 100 ml) | > 2.4 × 10^8 | 10 – 2.4 × 10^7 | 200.5 – 7 × 10^9 | - | 56 – 8.03 × 10^7 | 6.38 × 10^3 – 3.255 × 10^9 |
| Fecal Coliform (CFU / 100 ml) | - | 0 – 3.4 × 10^3 | 50 – 1.4 × 10^3 | - | 0.1 – 1.5 × 10^8 | 0.1046 × 10^3 – 0.7701 × 10^8 |
Based on the results that surfaced from this research, it may be inferred that the ranges of greywater identified, are the typical of what can be expected to occur in commercial places such as malls. These results have serious implications, especially when contemplating the reuse of grey water in commercial areas. For example, the high pH and conductivity values (figure 4) observed confirms that greywater generated in South Africa exhibits similar properties to the grey water generated in different countries. This study also suggests that the grey water generated in commercial areas around South Africa has a potential to cause corrosion of equipment. The high turbidity values (figure 4(b)) found in DFC grey water may have serious implications on the perception of people on grey water use, as a potential substitute for potable water. Temperature values (Table 3) observed in this study correlated with the temperature of grey water reported in the literature. However, such temperature ranges render grey water to be a potential vector carrier. This is because it is within these temperature ranges where micro-organisms growth is promoted [8]. The low number of E-coli counts found in grey water at DFC (Figure 4 (d)) suggests that greywater in commercial areas of South Africa may not pose a major health risk to people compared to black water. However, direct use of untreated grey water around commercial areas should be discouraged.

4. Conclusion
As it was pointed out, determining the characteristics of greywater will aid the identification of the correct remedy to be applied to treat it. In instances where GW has a high number of Faecal coliforms, it should not be reused for any purpose unless it is treated as this could have detrimental health consequences. Furthermore, as other scholars have pointed out, we recommend that GW generated in commercial areas in South Africa must not be used directly unless it is treated to the required standards. Treatment methods should be contemplated in line with the strength of the grey water. For low strength greywater, methods such as Filtration (For instance, soil filtration) coupled with
disinfection (Chlorine or UV-disinfection) could be used. For high strength GW, more advanced methods (e.g., Membrane-based technologies, chemical treatment, or biological treatment) could be explored. Globally, more of these treatment technologies are being developed and tested internationally for grey water treatment, there is little that is being done in African countries, South Africa inclusive. A lot of research currently being carried out is international, and the current trend has also focused on new constituents which are emerging that people should look out for when contemplating grey water reuse. Thus, researchers in developed countries are focusing on new methods to keep up with emerging compounds that are being found. However, these emerging new methods may be expensive to be implemented in developing countries like South Africa. The result of this is that developing countries are lagging in combating water scarcity and therefore are unable to explore the potential use of GW as a means to mitigate the scarcity of water.

Nevertheless, the World health organization (WHO) and many other entities, including the Water research committee (in South Africa), support GW reuse and consider it to be within a framework of conservative and sustainable environmental practices. Thus, there is a need to continue exploring the potential use of GW not only in South Africa but in the entire Continent as a whole. However, while doing this, it is imperative to take an excellent standard of care, to avoid the negative impacts of GW. This can be achieved through incorporating and educating people who have interest in grey water harvesting about best management practice, by presenting a framework which balances the social and environmental aspect of grey water use with its effects on people and the environment.

Also, South African decision-makers can look at other developed countries that have been successful in adopting the reuse of GW for both potable and non-potable uses within their environment, and then implement their methods. As indicated, this study focused on the physical and biological characteristics of grey water. The study, therefore, recommends that further analysis is done for a better understanding of the general quality of the grey water generated, and the cost-effective methods of treatments that can be applied and rolled out at a smaller scale in an urban African context.

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