# New housing unit designed for ceramic water filters in rural and peri-urban communities in South Africa

Report to the

**WATER RESEARCH COMMISSION**

by

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# EXECUTIVE SUMMARY

## BACKGROUND AND RATIONALE OF THE STUDY

The lack of access to safe, reliable water sources remains a problem for many people in developing countries. According the World Health Organisation (WHO) and the United Nations (UN), roughly 11% of the world's population does not have access to an improved water supply as of 2012 (UNAIDS global report, 2013). The people most vulnerable to waterborne diseases such as diarrhoea, cholera, enteric fever and hepatitis are the children under the age of five years old (WHO/UNICEF, 2006). A meta-analyses study by Clasen et al. (2007) found that water interventions at the point-of-use (POU) or household level are more effective in improving the water quality and reducing diarrhoeal disease. The Potters-for-peace ceramic water filter (PFPCWF) has been successfully distributed as a POU water treatment device and tested in various countries around the world to convert unsafe environmental water into potable water. A previous Water Research Commission study (WRC Report No. 1653/1/11) was carried out in the Limpopo Province of South Africa by the University of Venda and the University of Johannesburg and the results showed that the Potters for Peace ceramic filter (sourced from Ghana) is a viable option. Part of the study was looking how the rural communities accepted these filters and what possible changes could be made to increase the efficiency of the filters. It was found that if certain design aspects could be addressed, the water filter would be better accepted. The main design aspects that were identified were as follow:

- A stand for the container since most of the households had to construct a makeshift stand to place the filter on.
- A better design to combat the cracking of the housing bucket if the spigot was tightened too much.
- A method to wash the ceramic filter without placing it onto the floor, etc.
- A way of sealing of the filtered water from the environment since it was found that the plastic ring into which the fitted didn't seal properly, allowing insects and dust to enter the bucket and possibly recontamination the water. This was indeed also the situation found with the biological tests performed on the filtered water.
- A problem encountered in other studies where more contaminated river water was used was the influence of debris in the filter that would collect, and block, the ceramic filter. In these cases there would be an increased need to wash the ceramic filter which could lead to an increased risk of the actual ceramic filter breaking.

In an attempt to address these needs the Water and Health Research Unit (University of Johannesburg) employed an industrial designer to assist with the redesign of the ceramic filter housing unit so that:

- The current problems could be addressed.
- To design a filter that would possibly be functional and cost effective for implementation in rural areas.
- To design a filter that could also be attractive to people going camping in remote areas as a method to purify water.

Thus, the objectives of this study were to:

- Design and produce a new housing unit.
- Test the new designed housing unit for the potters-for-peace ceramic pot filter as a point-of-use treatment system in rural and peri-urban communities of South Africa.
- Ascertain user acceptance of new housing unit.
- Ascertain user friendliness of new housing unit.

The project methodology was structured so that the project team could test the possible improvement in water quality, compared to the original Potters-for-Peace ceramic filter as well as to get feedback from the community on the new housing unit design. The following steps were used:

*Step 1: Design, development and production of the new housing unit*

The new housing unit design was first designed and then produced by DUYS rotor-moulding for the pilot study. After the pilot study as performed in steps 2-4, the last changes (if any) were to be made. This should decrease the price of the unit drastically.

*Step 2: Field testing of the new housing design:*

The new housing design was then tested in a comparative study with the normal Potter-for-peace ceramic filter housing unit, so that the ceramic pot filter was purchased from the same distributor. The baseline water quality assessment for the area was completed and met the requirements for having *Escherichia coli* counts of more than 10 colony forming units (CFU) per 100 ml. The study was carried out in a peri-urban community in Gauteng with households who was using the original Potters for Peace ceramic filter from Ghana (Potpaz ceramic filter with the Potters for peace housing unit) and a rural community in the Limpopo Province who has not been using any POU water treatment device. All study households were provided with a new housing unit and the peri-urban households continued using the Potpaz ceramic filter with the new housing unit while the rural households were provided with a new ceramic filter (Potpaz) to use with the new housing unit. Samples were collected once from each filter, household storage container and water source every second week over a period of 3 months in sterile one litre plastic containers and transported to the research laboratory for the microbiological and physico-chemical analysis. Samples were kept at

4°C during transport and processed immediately when delivered to the laboratory on the day they are collected (Standard Methods, 2005).

*Step 3: Assessment of the housing unit design using a questionnaire*

All the households participating in the study were asked to complete a questionnaire to assess their perception of the new filter design.

**RESULTS AND DISCUSSION**

The housing unit was successfully designed and developed and a total of 90 housing units were produced by rotor-moulding. These were assessed for user friendliness and acceptability in a peri-urban and a rural community using the silver impregnated ceramic POTPAC pot filter. The results for total coliforms and *E. coli* counts indicated that water deteriorated when stored in household storage containers in the households. Focussing on the *E. coli* bacterial counts as an indication of the successful improvement of the housing unit-ceramic pot filter as a POU device, the results showed an improvement in the water quality in both communities. However more studies need to be performed on the ceramic pot filter which was not part of the scope of this study. Pathogenic strains isolated from the different samples included commensal *E. coli*, *E. coli* toxin, EHEC, ETEC, EPEC, EAEC and EIAC. The main problem were the fact that the filtered water had similar counts and pathogenic *E. coli* strains as the household storage water which showed that it could either be unhygienic practices from the households or the material used in the production of the new housing unit that needed to be refined in the manufacturing process. Dishcloths used by the peri-urban households had shown contamination with pathogenic *E. coli* strains which could have played a role in the contamination of the filtered water.

In the assessment of user friendliness and overall acceptance of the new housing unit by the peri-urban and rural households, the feedback showed an overall satisfaction with the new design especially with the stability of the unit, the taste of the filtered water, the easy cleaning process of the unit and the fact that the design provides enough water for the family.

**KEY FINDINGS OF THE STUDY AND CONCLUSIONS**

Using the colour coding grading of the WRC, the results indicates that the concept *did* work and the water quality *did* improve in comparison to the water quality in the household water storage containers. It was a concern that the results still showed high counts of total coliform bacteria which could be responsible for several opportunistic diseases in vulnerable people. The assessment of the dishcloths used by the households to clean the inside of the housing unit showed clearly that specific unhygienic practices in the households need to be addressed. More studies need to be done on the manufacturing process of the water bucket in the new design to make sure that good grade materials are used where biofilms cannot form and microorganisms cannot adhere to the inside of the bucket and re-contaminate the filtered water. Ceramic filter pots need to be obtained from factories who has proper quality assurance procedures in place to make sure that the ceramic pots do not allow bacteria to filter through. A training manual needs to be developed to indicate proper cleaning procedures to the household members to avoid recontamination of filtered water.

Generally the results from the questionnaire indicated that households from both peri-urban and rural households liked the new design of the housing unit and the next step should include studies to find a ceramic pot filter produced in South Africa to use with this housing unit to produce safe water for drinking.

## ACKNOWLEDGEMENTS

The authors would like to thank the WRC for the financial assistance and support during the duration of the project

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius |
| cfu | colony forming units |
| *E. coli* | *Esherichia coli* |
| EAEC | Entero-aggregative *Escherichia coli* |
| EHEC | Entero-hemorrhagic *Escherichia coli* |
| EIEC | Entero-invasive *Escherichia coli* |
| EPEC | Entero-pathogenic *Escherichia coli* |
| ETEC | Entero-toxigenic *Escherichia coli* |
| ml | millilitre |
| n | number |
| PFPCWF | Potters-for-peace ceramic water filter |
| POU | point-of-use |
| UN | United Nations |
| WHO | World Health Organisation |
| WRC | Water Research Commission |

# 1 INTRODUCTION AND OBJECTIVES

The lack of access to safe, reliable water sources remains a serious problem for millions of people in the developing world. It is estimated by the United Nations and the World Health Organization (WHO) that roughly 11% of the world's population or 780 million people did not have access to an improved water supply in 2012 (Joint UN Program on HIV/AIDS (UNAIDS) Global Aids Response Progress report, 2013). Due to this, waterborne diseases such as diarrhoea, cholera, enteric fever, and hepatitis is responsible for 1.6 million deaths annually, and children under five years old are especially vulnerable (WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme, 2006). Consequently providing clean drinking water requires specific technology and infrastructure. Point-of-use (POU) water treatment devices are one attractive option for expanding access to clean water in developing countries where households treat their own drinking water before consuming it. One particularly promising type of POU water treatment technology is the silver-impregnated ceramic water pot filters which has been shown to effectively remove microorganisms such as *Escherichia coli*, total coliforms, protozoan oocysts and turbidity from water (Lantagne, 2001; Campbell, 2005; Oyanedel-Craver and Smith, 2008; Kallman et al., 2011; Simonis and Basson, 2012). Recent work has concentrated on assessing the cultural acceptability of this treatment, understanding the impacts of raw water quality on disinfection performance, and varying materials composition and/or manufacturing techniques to optimize disinfection (Kallman et al., 2011; Zhang et al., 2012). Most of these studies were on the silver impregnated ceramic pot-filter and little studies have focus on the housing unit and the potential role this part of the device plays in re-contamination of filtered water, user friendliness and acceptance. A more acceptable housing unit will assist in the ceramic water filtration system to be accepted as a point-of-use treatment system in households where safe water is a serious problem. Currently no ceramic water filters are available commercially in South Africa. The potential for commercialization and job creation is enormous. In addition the production of the housing unit locally would make the product more affordable for the market for which it is intended. The design will also improve the industrial competitiveness of South Africa in the household treatment devices. An affordable point-of-use treatment system for drinking water would also improve the potential health risks for vulnerable populations such as people suffering from immune-compromised diseases, old people and children under the age of 5 years.

The Water Research Commission study (WRC Report No. 1653/1/11 and 1653/2/11) which was carried out in the Limpopo Province of South Africa by the University of Venda and the University of Johannesburg showed that the Potters for Peace ceramic filter (sourced from Ghana) is a viable option for the point-of-use treatment of water. However, the assessment on user acceptability (sustainability and acceptability), user friendliness of the filter, effectiveness of the educational component of implementation, and post implementation problems has shown that the housing design used by Potters for Peace could be improved for households here in South Africa. The suggested improvements included adaptations to the housing unit (plastic components) that held the ceramic filter and stored the water. The suggestions formed the basis for the re-design of the housing unit to make it more acceptable and user-friendly in South African rural and peri-urban settings.

The objectives of the study were therefore as follow:

a) Design and produce new housing unit for field testing with the current Potters-for-peace ceramic filter
b) Test the new housing unit for the Potters-for-peace ceramic filter as a point-of-use treatment system in rural and peri-urban communities of South Africa
c) Ascertain user acceptance of new housing unit
d) Ascertain user friendliness of new housing unit

## 2 DESIGN, DEVELOPMENT AND PRODUCTION OF NEW HOUSING UNIT

### 2.1 INTRODUCTION

Point-of-use water treatment is a well-studied area of home water treatment, especially related to rural settings. In all these settings the home owners were either supplied with a type of filter, such as slow sand filtration, ceramic water filters, etc., or with chemicals that can be added to the water to treat the water. Examples of these types of treatment options typically include flocculants, coagulants and chlorine in the form of a detergent. In a previous study performed by the research team in the Vhembe region of the Limpopo Province, the Potpaz Potters-for-Peace ceramic water filter (Figure 2.1) was introduced into households and followed for a period of three months looking at the typical water treatment efficiency of the well accepted treatment option (Ref).

**Figure 2.1** Potpaz Potters-for-Peace ceramic water filter implemented in the Vhembe region of the Limpopo province

One difference of this study with other reported studies was the inclusions of an industrial designer in the project team to not only investigate the effectiveness of the design of the unit but also the typical use and user experience during the project. A variety of observations was observed including possible areas of improvement for the design of the housing unit for the ceramic water filter that could increase the user acceptability of the filter in the South African setting. User acceptability of a product is not always one of the main design criteria when treatment technologies are packaged, not the cultural beliefs of the community or the environment in which the filter would be stored and operated in the households. This information formed the basis for this study and the design and production process will be highlighted in the sections below.

## 2.2 EXPERIMENTAL PROCEDURES

### 2.2.1 DESIGN AND DEVELOPMENT OF THE NEW HOUSING UNIT

The design of the housing unit was initiated by extracting the identified problem areas related to the original housing unit in the context of the South African settings. Alternatives to the identified problem areas were sketched by hand and discussed with the research team to obtain the best perceived solutions or alternatives to address these areas. Once a consensus was reached for the proposed changes the hand drawings were redone using the Solid Works 2012 software to get the necessary sketches and information for the production of the plastic components.

### 2.2.2 PRODUCTION OF NEW HOUSING UNITS

Following the design of the new housing units moulds used for the production of the plastic parts were produced by DUYS rotor-moulding. The plastic components were all made by rotor moulding using polypropylene (PP) resin. A total of 90 housing units were produced to be tested with during this study. The ceramic filter support and seal was made from nitrile butadiene rubber (NBR) by pressed die cutting. The plastic taps fitted to the collection unit were purchased from Trim Plastics Products.

## 2.3 RESULTS AND DISCUSSION

### 2.3.1 DESIGN AND DEVELOPMENT OF THE NEW HOUSING UNIT

The main design changes considered were focused on making the housing unit more acceptable for the South African market and possibly give more protection for to the treated water. These included the addition of a stand, changing aspects of the main water container, adding a type of seal to protect the ceramic filter, possibly add a second filtration stage and adapting the lid to make it more versatile. Some of the hand drawings made (with typical comments) is shown in Figure 2.2 below and shows the options and process followed. A rendering showing the new housing unit with the changes made to the original housing unit can be seen in Figure 2.3.

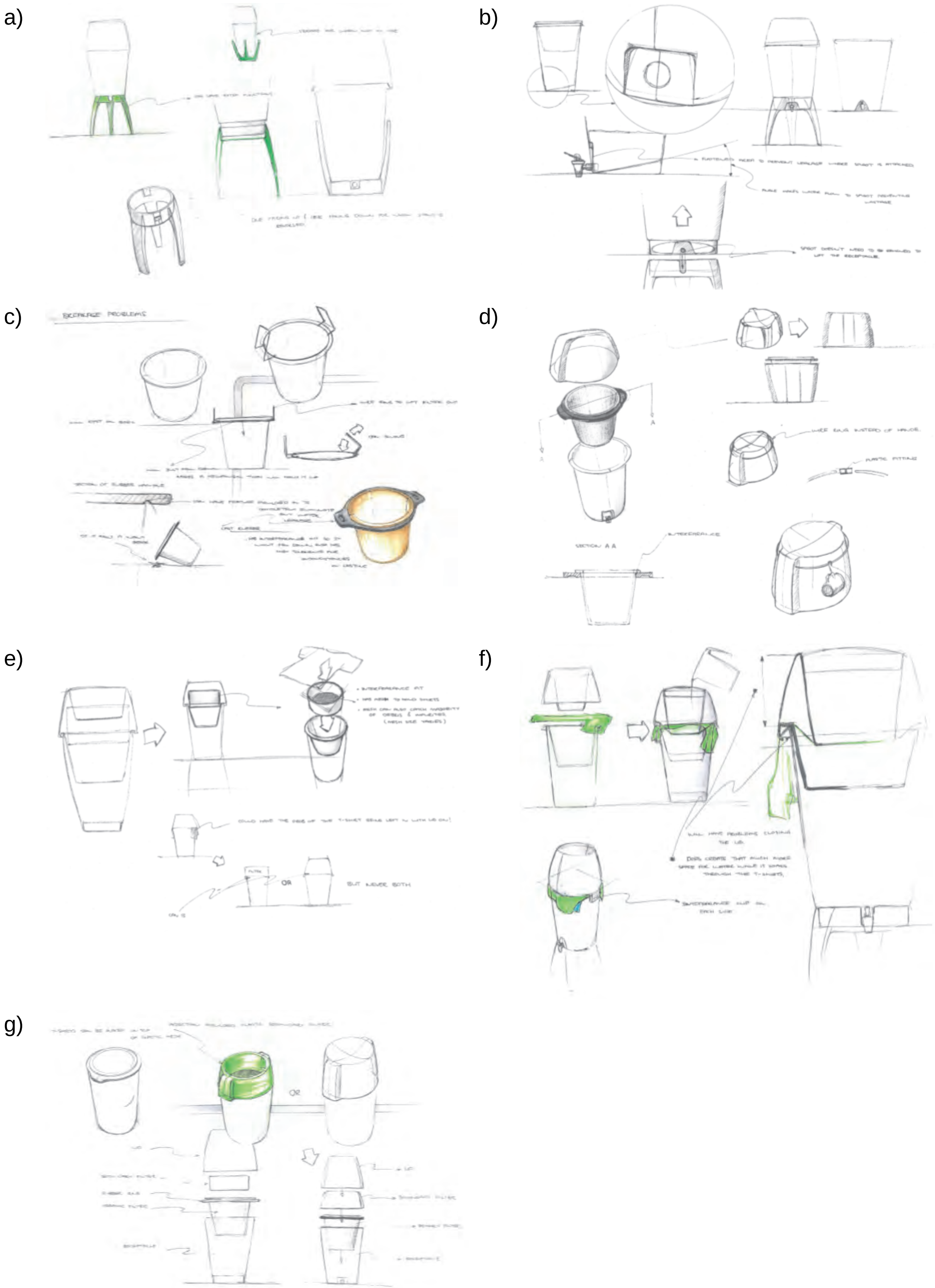


**Figure 2.2** Hand drawings showing the typical planning or the design of the new housing units

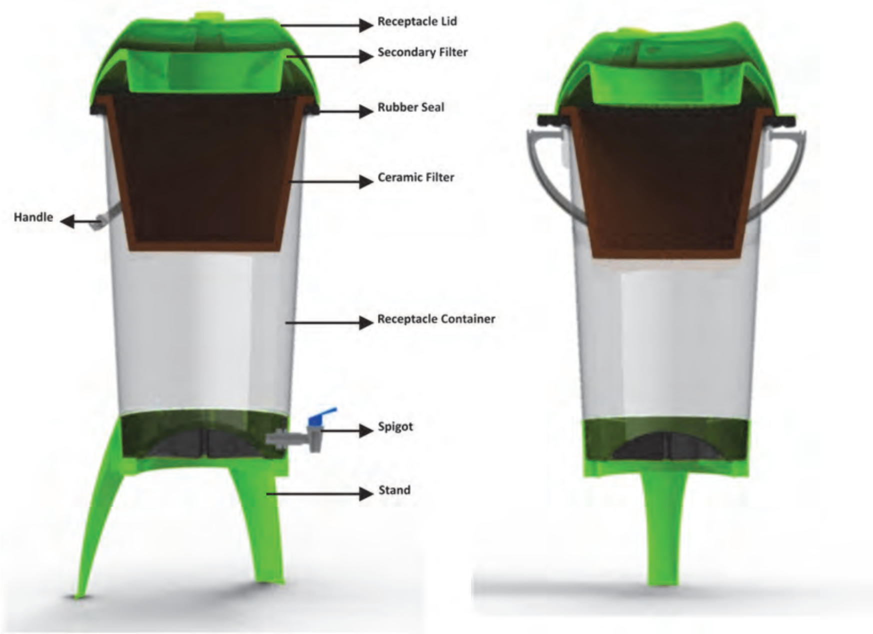


**Figure 2.3** Rendering of the new housing unit with the selected changes incorporated into the old housing unit design

Observations from previous work showed that in rural areas in South Africa there is a real possibility that the water filter will either be placed on the floor on or make shift stands since there is no furniture available in the household. This typically leads to problems such as the tap being close to the floor giving small children and animals access to the tap. It also means that the filter has to either be lifted or tipped before water can be collected form the water. It was decided to add a stand to the water filter that will lift the filter housing unit high enough that a small container or cup can be used to collect the water. Although it might still not keep the filter, especially the tap, away from children and animals it does lift it off the ground reducing the possibility for contamination of the water.

The stand was placed on top of a three legged (tripod) stand since this is a sturdy design especially when downward pressure is applied to it (Figure 2.2a). If the stand is placed on unstable ground the unit will still be sturdy and stable and should not rock around on the tripod stand. If a four legged stand were used the ground would have to be 100% flat to prevent falling over and to ensure the unit is stable. In most cases the ground or surface that the water filter is placed on is not 100% flat so the tripod stand will better suit the environment the unit were tested in.

The main water container was the second part that the team made changes to. It was noticed in the previous study that there would always be water left below the tap which could not be accessed without tipping the container over. This increases the risk of the filter falling over and needed to be addressed. A half dome was included in the bottom of the container so that the maximum amount of water can be expelled from the spigot leaving very little water behind in the water container (Figure 2.2b). The introduction of the dome also ensures that the water is evenly distributed in the container so that the downward pressure is equal distributing when placed on the tripod stand.

The second problem with the water container was that the spigot or tap was fastened is curved and lead to some of the containers cracking when the spigot was fastened to tightly. The new design ensured that the area were the spigot is screwed onto is flat. When the spigot is screwed on with the nut and washer it makes 100% contacted with the surface making in 100% leak proof. It also reduces the risk that the container cracks if the spigot is tightened to tight. The container now also has a big lip on the container so that the rubber seal can fit perfectly and seal of the water inside the container from the outside environment.

The rubber seal was designed to fit tightly around the edge of the ceramic filter and contains handles that makes it easier to lift from the plastic container (Figure 2.2c and d). Since the rubber seal goes around the ceramic pot it protects the round edge of the pot where it is was found the most damage occurs when the ceramic filter is removed. All of this decreases the probability that the pot might be damaged when it is handled or bumped into other surfaces. As mentioned above the rubber seal closes of the water from the surroundings to ensure that no insects or dust can enter the container when assembled.

The decision was taken to include an optional secondary filter that can be used to remove small sticks, stones, leaves or foreign object from the water before it flows into the ceramic filter (Figure 2.2 e and f). This not only reduces the stress on the ceramic filter and reduces the accumulation of material that can reduce the flow of water or lead to further contamination of the water. The plastic part for the secondary filter can house a wide variety of material that can be used if needed or if the user decided to use it.

The lid was designed not just to be a lid for the water container but also a container that can be used to clean the ceramic pot. The lid is a dome shape lid with three feet extrudes on the outside making a tripod stand when turned around. This makes the lid very sturdy so that the ceramic pot can be cleaned in it safely without it toppling over. This feature was included since it was noted that when the plastic parts were cleaned the users did not always know where to place the ceramic filter. This can not only lead to the filter accidentally breaking but also that the filter can be contaminated on the outside thus contaminating the filtered water as it enters the water container.
With all the changes highlighted, the design completed and the fit of all the parts shown theoretically with the technical drawings it was decided to start the production of the housing unit parts.

### 2.3.2 PRODUCTION OF THE NEW HOUSING UNITS

The moulds to be used for the production of the various parts via rotor-moulding were produced and tested to ensure that everything was produced as planned. Table 2.1 shows the different parts from the first test run of the housing unit which were produced and highlights some of the functions discussed above as well.

**Table 2.1** Pictures and descriptions of the new housing unit parts produced from the first test run of the moulds

| Part | Picture | Comments |
|---|---|---|
| **Separate parts** | | |
| Stand alone |  | The stand alone with the opening for the spigot in the front. The bottom of the receptacle container has a flat area that corresponds with this opening. The flat area is designed to better support the spigot. |
| Bucket |  | The receptacle container includes a rounded elevated area in the middle to ensure that all the water is guided towards the spigot. This will decrease the volume of wasted water. The container will have indicators for the maximum and minimum levels of water for the optimal use of the filter. |
| Primary filter assembled |  | This shows the assembled primary filter. To reduce costs this was not moulded as one part but as too. This design is however more versatile and robust for use in the field. |
| Primary filter separate |  | The primary filter with the sieve part removed from the actual filter. |
| Lid |  | The lid for the housing unit that can be turned upside down for the washing of the ceramic filter. |

When the parts were assembled in the lab to test the fit a good idea was obtained for how the final product would look. Table 2.2 shows the assembled parts in the sequence that it would be assembled but did not yet include the rubber seal of the spigot.

**Table 2.2** New housing unit assembled parts

| Assembled parts | | |
|---|---|---|
| Assemble 1 |  | This shows the stand, receptacle container and the actual ceramic filter assembled. The only part missing is the rubber seal but will be included in the final product. The rubber seal will be made after we sign of on these parts to ensure a perfect fit. |
| Assemble 2 |  | Same as above with the primary filter added. |
| Assemble 3 |  | Same as above with the lid added. |
| Assemble 4 |  | The lid turned upside down showing how the ceramic filter will fit into it when the filter is washed. |

As discussed above one of design aspects that were included was the tripod stand that can be used in most settings and that lends to the strength of the housing unit. To show this the flexibility of the tripod stand alone is shown In Table 2.3. When all the parts were assembled the strength of the housing unit can be seen. In Table 2.3 the industrial designer is sitting on top of the assembled filter housing unit and the tripod is not giving way showing that the decision to include this feature was a good decision.

**Table 2.3** New housing unit durability

| Housing unit durability | | |
|---|---|---|
| Stand alone |  | This section shows the durability of the assembled housing unit. The base alone is very sturdy although it is flexible. The flexibility is due to the opening included for the spigot. |
| Assembled |  | Despite the flexibility of the stand alone, once assembled the whole structure can take the weight of a full grown man (~75 kg). |

## 2.4 KEY FINDINGS IN THE DESIGN, DEVELOPMENT AND PRODUCTION OF THE NEW HOUSING UNIT

For the final product the colour decided on for some of the plastic parts was green but can be changed to any colour decided on (Figure 2.4). Due to the material used for the production, the colour of the receptacle units was opaque and not clear. This can be altered if a different material or production manner (rotor vs. injection moulding) is used. Despite the fact the fact that that the colour is opaque, it should be noted that this method of production contributes to the strength of the assembled housing unit. The unit can also be coloured which would theoretically reduce the changes of algal growth within the receptacle container.

**Figure 2.4** Final produced housing unit assembled in the laboratory

It was noted that the product delivered were not completely polished, buffed and completed but due to time constraints the product was used in the field. The commercial partner acknowledged this fact and also indicated that due to the strict timeframes this was not done but will be done when larger orders are placed. It is not expected that this should however have an impact when the filter is used and since this was only a project to proof that the concept could work the filter housing unit was used in the field.

The objective of this section of the study was successfully completed despite some problems with the final polishing of the product. The production approach for this study was rotor-moulding but can be adapted to injection moulding in the future to increase the number of parts produced per day.

# 3. FIELD TESTING OF NEW HOUSING UNITS

## 3.1 INTRODUCTION

The next step of the study was to test the new housing design for the Potters-for-peace ceramic filter as a point-of-use treatment system in rural and peri-urban communities with field studies. The filters was tested in a comparative study with the normal Potter-for-peace ceramic filter housing unit, so that the ceramic filter was purchased from the same distributor.

## 3.2 EXPERIMENTAL PROCEDURES

### 3.2.1 SELECTION OF STUDY HOUSEHOLDS

A total of 57 households were finally integrated as study households in this project. The study team selected 29 households in a peri-urban cohort in the Gauteng (Heidelberg/Nigel area) who were all participants in a previous study in the past 12 months using the Potters-for-Peace ceramic filter (Figure 2.1) as treatment device. Using these settings the team had a group of participants that could compare the use of the housing unit alone since the ceramic filters stayed the same (Figure 2.4). These households all had yard taps connected to a borehole. The second study cohort of about 28 households was selected from a rural area (Basani/Tshikonelo/Muraga villages) in the Limpopo Province who was never exposed to any point-of-use water treatment device and was given the new housing design together with new Ghana Potpaz ceramic filters. These households were getting drinking water from communal taps which was not always delivering water and the households had to wait on a water truck to get their drinking water.

### 3.2.2 WATER SAMPLE COLLECTION AND ANALYSIS

Water samples (150 ml) used for household purposes was collected at the source [river, tap inside yard or communal tap shared], from the household storage containers (to determine the storage conditions on the quality of water) and from the housing unit spigot using protocols published by the Water Research Commission (WRC, 1998). Water samples were collected every second week over a period of 3 months in sterile one litre plastic containers and transported to the research laboratory for the microbiological and physico-chemical analysis. Samples were kept at 4-10°C during transport and analysed on the day they were collected (Standard Methods, 2005). Total coliforms and *E. coli* in all collected water samples were enumerated in accordance with the Colilert® Quanti-Tray®/2000 method (IDEXX, Westbrook, ME, USA). Total coliform bacteria produced a yellow colour while *E. coli* produced a fluorescent signal under a 6-W UV light after incubation at 35$^{o}$C for 24 hours (IDEXX, 2002). The temperature of the samples were measured in the field using the GTH175/Pt digital thermometer (Greisingereletronincs, Germany). The pH (Cyberscan PC510 benchtop meter), conductivity (Cyberscan PC510 benchtop meter) and turbidity (Eutech TN 100 turbidity meter) measurements were done in the laboratory.

All results obtained were discussed in terms of guidelines sourced from SANS 241, the World Health Organisation (WHO) and the State of Connecticut Department of Environmental Protection (SCDEP) (Table 3.1).

**Table 3.1** Heath-related Water Quality Guidelines used as guide for this study

| **Parameter used** | **Drinking water guideline** |
|---|---|
| *Escherichia coli* (cfu/100 mℓ) | ≤ 1[1,3] |
| pH | 6.5-8.5[1] |
| Temperature (°C) | ≤ 25[1] |
| Turbidity (NTU) | ≤ 5[1,2] |
| Conductivity (mS/m) | ≤ 150[1] |

[1]South African National Standard (SANS) code 241. (2005) Drinking Water. Edition 6.Standards South Africa (SABS). Pretoria. ISBN 0-626-17752-9.[2]State of Connecticut Department of Environmental Protection (SCDEP). (2002). Water Quality Standards. Rocque AJ; Commissioner JR. Hartford, USA. [3]WHO. (2004). Guidelines for Drinking-Water Quality. First addendum to third edition. Volume 1, Recommendations. World Health Organization. Geneva, Switzerland.

All the results for total coliform counts and E. coli counts were shown as the real counts and highlighted in the different classification classes as shown in the WRC Volume 1 report (Water research commission (WRC), the Department of Water Afairs (DWA) and the Department of Health, 1999) and shown in Table 3.2.

**Table 3.2** Heath-related Water Quality classification guide ((Water research commission (WRC), the Department of Water Afairs (DWA) and the Department of Health, 1999)

| **Classification** | | **Water quality** | ***E. coli* count/100 ml** | **Total Coliform count/100 ml** |
|---|---|---|---|---|
| Class 0 | Blue | Ideal | 0 | 0 |
| Class 1 | Green | Good | 0-1 | 0-10 |
| Class 2 | Yellow | Marginal | 1-10 | 10-100 |
| Class 3 | Red | Poor | 10-100 | 100-1000 |
| Class 4 | Purple | unacceptable | >100 | >1000 |

### 3.2.3 IDENTIFICATION OF PATHOGENIC E. coli STRAINS IN WATER SAMPLES

Two millilitre of media was removed from up to 10 positive *E. coli* wells of the Collilert® Quanti-Tray®/2000 with sterile 1 ml disposable syringes with mounted needles and aliquoted into 2 ml sterile eppendorf tubes. The tubes were centrifuged for 5 minutes each at 13,000 x g to pellet the cells and the supernatant was discarded. DNA was extracted from the collected bacterial cells using an adapted version of the guanidium thiocyanate/silica method reported by Boom et al. (1990) using homemade spin columns prepared as reported by Borodina et al., (2003). The changes to the DNA extraction method included the addition of 250 µl 100% ethanol to lysis the buffer to enhance the binding of DNA to the celite. The celite containing the bound DNA was loaded into the spin columns before doing the washing steps. DNA was eluted from the celite with

100 µl Qiagen elution buffer. The extracted DNA was used as template in all PCR reactions (Omar et al., 2010). All multiplex Polymerase Chain Reaction (m-PCR), were performed in a Biorad Mycycler Thermal cycler in a total volume of 20 µl. A multiplex PCR kit (Qiagen) was used for the m- PCR procedure. Each reaction consisted of 1X Qiagen PCR multiplex mix (containing HotstartTaq DNA polymerase, multiplex PCR buffer and dNTP mix). The reactions were subjected to an initial activation step at 95ºC for 15 minutes, followed by 35 cycles consisting of denaturing at 94ºC for 45 seconds, annealing at 55ºC for 45s, extension at 68ºC for 2 minutes and final elongation at 72ºC for 5 minutes (Omar et al., 2010). The DNA was analyzed using a 2.5% (w/v) agarose gel in TAE (Tris-acetate-EDTA) buffer (40 mml/l Tris acetate 2 mmol/l EDTA, PH 8.3) with 0.5 µg ml/l ethidium bromide. Electrophoresis was conducted for aperiod of 1-2 hours in electric field strength of 8 V /cm gel and the DNA visualized with Ultra Violet light. Examination or photography took place shortly after cessation of electrophoresis. This procedure was applied for all experiments. The relative sizes of the DNA fragments were estimated by comparing their electrophoretic mobility with that of the standards run with the sample in each gel, either 1kB or 100 bp markers (Omar et al., 2010).

## 3.3 RESULTS AND DISCUSSION

### 3.3.1 PERI-URBAN HOUSEHOLDS IN GAUTENG PROVINCE:

In the peri-urban area 30 households were identified but only 29 households using borehole yard tap water in the Gauteng province participated in the study – one household moved when the study started. All of these households had been exposed to the POTPAZ ceramic Potters for Peace POU device in a study done in the same households one year previously. Therefore these households were each giving a new housing unit to use with the ceramic pot filter (used in their households in the previous study) in order to compare the Potters for Peace POU device with the new design housing unit.

Tables 3.3 and 3.4 is showing the counts/100 ml for total coliform bacteria and *E. coli* bacteria respectively which was obtained from the sources, household water storage containers and the new housing unit containing the ceramic pot filter. All the data is shown in order for the reader to observe the microbial quality of the water samples tested. From the data it was clear that the water did deteriorate after storing in the household containers – this could be seen for both the total coliform and *E. coli* counts. Consequently by just focussing on the *E. coli* counts in Table 3.7, the new housing unit – ceramic pot filter POU device did improve the water quality (blue, green and yellow highlighted colour coding). The pH, temp and Turbidity were well within guidelines sourced from SANS 241, the World Health Organisation (WHO) and the State of Connecticut Department of Environmental Protection (SCDEP) (Table 3.4).

**Table 3.3** Total coliform counts detected and colour coded to show water quality for peri-urban households

| Sample point | Source (Borehole) | | | | | Household Storage Container | | | | | Filtered water | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 |
| J1 | 21 | 8 | 2420 | ND | 2420 | 152 | 308 | ND | ND | 2420 | ND | 2420 | ND | ND | 517 |
| J2 | 16 | 3 | 9 | 2420 | 2420 | 10 | 2420 | 2420 | 2420 | 2420 | ND | ND | 47 | 75 | 196 |
| J3 | 68 | 12 | 10 | ND | 2420 | 261 | 79 | 137 | ND | 116 | ND | 31 | 2420 | ND | 28 |
| J5 | 6 | 4 | 22 | 410 | 2420 | 2420 | 3 | 7 | 3 | 0 | ND | 1 | 2 | 0 | 0 |
| J6 | 2 | 10 | 19 | 2420 | 19 | 9 | 2420 | 2420 | 130 | 2420 | ND | 2420 | 2420 | 0 | 2420 |
| J9 | 16 | 13 | 8 | 57 | 2420 | 48 | 435 | 2420 | 2420 | 2420 | ND | 2420 | 2420 | 291 | 980 |
| J12 A | 12 | 86 | 25 | 81 | 25 | 10 | 1414 | 2420 | 248 | 2420 | ND | 2420 | 2420 | 2420 | 2420 |
| J12 B | 12 | 86 | 25 | 81 | 25 | 157 | 2420 | 2420 | 2420 | 2420 | ND | 2420 | 2420 | 179 | 2420 |
| J13 | 12 | ND | 11 | ND | ND | 21 | ND | 7 | ND | ND | ND | ND | 2420 | ND | ND |
| J15 | 12 | 3 | 25 | ND | 2420 | 6 | 2 | 1 | ND | 2 | ND | 6 | 0 | ND | 0 |
| J16 | 10 | ND | 24 | 66 | ND | 14 | ND | 147 | 47 | ND | ND | ND | 2420 | 2420 | ND |
| J17 | 10 | 4 | 10 | 27 | 2420 | 1986 | 2420 | 2420 | 921 | 2420 | ND | ND | 2420 | 2420 | 770 |
| J19 | 25 | 3 | 1 | 0 | 0 | 2420 | 2420 | 2420 | 2420 | 2420 | ND | 2420 | 2420 | 1300 | 2420 |
| J20 | 25 | 2420 | 1 | 0 | 0 | 2420 | 1120 | 2420 | 2420 | 2420 | ND | ND | 1011 | ND | ND |
| J21 | 30 | 2420 | 2 | 28 | 1 | 86 | 687 | 15 | 1414 | 2420 | ND | ND | ND | 2420 | 0 |
| J22 | 30 | 2 | 27 | 1 | 9 | 2420 | 1733 | 613 | 687 | 517 | ND | 2420 | 129 | 2420 | 2420 |
| J23 | 1046 | 2420 | ND | 1 | 2420 | 79 | 1120 | ND | 2420 | 2420 | ND | ND | ND | 135 | 5 |
| J24 | 29 | 3 | 0 | ND | ND | 2420 | 2420 | 58 | 1 | 23 | ND | 0 | 0 | 12 | 12 |
| DB1 | 73 | 2420 | 68 | 111 | 54 | 2420 | 687 | 88 | 75 | 111 | ND | 2420 | 49 | 157 | ND |
| DB2 | 79 | ND | 1733 | 119 | ND | 84 | 2420 | 51 | 2420 | ND | ND | ND | 2420 | 1011 | ND |
| DB3 | 79 | 1120 | 91 | 261 | 59.1 | 1553 | 2420 | 649 | 2420 | 2420 | ND | ND | 125 | 980 | 435 |
| DB5 | 118 | 2420 | 110 | 121 | 61 | 2420 | 411 | 2420 | 2420 | 2420 | ND | 2420 | 2420 | 2420 | 2420 |
| DB6 | 2420 | 2420 | 73 | 20 | 74 | 86 | 1986 | 2420 | 308 | 344 | ND | 1986 | 236 | 461 | 816 |
| DB7 | 127 | ND | 120 | 461 | 261 | 115 | ND | 2420 | ND | ND | ND | ND | 1986 | 44 | ND |
| DB8 | 125 | 1733 | 110 | 365 | 461 | 96 | 263 | 1414 | 166 | 2420 | ND | ND | ND | 1414 | 1735 |
| DB9 | 18 | 2 | 8 | 1414 | 2420 | 24 | 0 | 2420 | 2420 | ND | ND | 765 | 2420 | 1733 | ND |
| DB10 | 36 | 2 | ND | 1414 | 2420 | ND | 2420 | ND | 12 | 1553 | ND | ND | ND | 26 | 52 |
| DB11 | ND | 2 | 8 | 1414 | 2420 | 6 | 4 | 12 | 1986 | 2420 | ND | 2420 | 2420 | 479 | 22 |
| DB12 | ND | 2 | 8 | ND | ND | 2420 | 8 | 147 | ND | ND | ND | 72 | 43 | ND | ND |

*Week 1 in filter samples were when the housing units were installed in the households and water samples were only taken from source and storage container

**Table 3.4** *E. coli* counts detected and colour coded to show water quality for peri-urban households

| Sample point | Source (Borehole) | | | | | Household Storage Container | | | | | Filtered water | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1* | Week 3 | Week 5 | Week 7 | Week 9 |
| J1 | 0 | 1 | 0 | ND | 0 | 0 | 0 | ND | ND | 0 | ND | 0 | ND | ND | 0 |
| J2 | 0 | 0 | 0 | 1 | 1 | 0 | 649 | 1 | 7 | 140 | ND | ND | 0 | 1 | 0 |
| J3 | 41 | 2 | 0 | ND | 0 | 29 | 1 | 0 | ND | 0 | ND | 0 | 1 | ND | 0 |
| J5 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | ND | 0 | 0 | 0 | 0 |
| J6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | ND | 0 | 0 | 0 | 0 |
| J9 | 0 | 0 | 1 | 6 | 1 | 1 | 6 | 2 | 13 | 1 | ND | 1300 | 4 | 1 | 1 |
| J12 A | 0 | 6 | 1 | 6 | 1 | 0 | 1 | 16 | 8 | 16 | ND | 1 | 4 | 196 | 4 |
| J12 B | 0 | 6 | 1 | 6 | 1 | 0 | 0 | 23 | 365 | 23 | ND | 1 | 0 | 0 | 0 |
| J13 | 0 | ND | 0 | ND | ND | 0 | ND | 2420 | ND | ND | ND | ND | 0 | ND | ND |
| J15 | 0 | 0 | 2 | ND | 0 | 0 | 0 | 1 | ND | 0 | ND | 0 | 0 | ND | 0 |
| J16 | 0 | ND | 4.1 | 6 | ND | 0 | ND | 1 | 7 | ND | ND | ND | 1 | 0 | ND |
| J17 | 0 | 0 | 0 | 7 | 0 | 0 | 45 | 2 | 0 | 20 | ND | ND | 2420 | 10 | 7 |
| J19 | 0 | 0 | 0 | 0 | 0 | 816 | 2420 | 2 | 11 | 82 | ND | 35 | 11 | 7 | 99 |
| J20 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 411 | 37 | 1413 | ND | ND | 961 | ND | ND |
| J21 | 0 | 4 | 0 | 26 | 0 | 0 | 3 | 0 | 61 | 4 | ND | ND | ND | 1 | 0 |
| J22 | 0 | 0 | 0 | 0 | 0 | 1120 | 16 | 1 | 0 | 0 | ND | 1 | 0 | 28 | 0 |
| J23 | 0 | 166 | ND | 0 | 8 | 0 | 1 | ND | 67 | 13 | ND | ND | ND | 3 | 0 |
| J24 | 0 | 3 | 0 | ND | ND | 8 | 45 | 1 | 0 | 4 | ND | 0 | 0 | 0 | 0 |
| DB1 | 0 | 6 | 0 | 0 | 0 | 15 | 3 | 0 | 0 | 1 | ND | 4 | 0 | 2 | ND |
| DB2 | 0 | ND | 0 | 0 | ND | 0 | 166 | 0 | 16 | ND | ND | ND | 4 | 0 | ND |
| DB3 | 0 | 16 | 0 | 0 | 0 | 23 | 2420 | 47 | 16 | 2420 | ND | ND | 0 | 1 | 0 |
| DB5 | 0 | 10 | 0 | 0 | 0 | 921 | 261 | 2420 | 60 | 2420 | ND | 2420 | 2420 | 0 | 2420 |
| DB6 | 0 | 3 | 0 | 0 | 0 | 0 | 26 | 2 | 0 | 0 | ND | 0 | 0 | 0 | 0 |
| DB7 | 0 | ND | 0 | 0 | 0 | 0 | ND | 548 | ND | ND | ND | ND | 0 | 0 | ND |
| DB8 | 0 | 4 | 0 | 0 | 0 | 8 | 263 | 50 | 0 | 2 | ND | ND | ND | 5 | 0 |
| DB9 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | ND | ND | 0 | 11 | 0 | ND |
| DB10 | 1 | 1 | ND | 0 | 0 | ND | 19 | ND | 0 | 0 | ND | ND | ND | 0 | 0 |
| DB11 | ND | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 11 | ND | 24 | 1 | 0 | 0 |
| DB12 | ND | 1 | 2 | ND | ND | 1 | 1 | 6 | ND | ND | ND | 0 | 0 | ND | ND |

*Week 1 in filter samples were when the housing units were installed in the households and water samples were only taken from source and storage container

Identification of diarrhoegenic *E. coli* strains identified all the pathogenic strains such as EHEC, EPEC, ETEC, EAEC and EIEC as well as commensal *E. coli* and E. *coli* toxin. The results are shown in Table 3.5. Getting *E. coli* in the filtered water samples was not what we wanted to see because these households were using the Potters-for Peace unit before this study and the filtered water were very clean and had little *E. coli* bacteria compared to what we are seeing in these new housing designs. It was therefore decided to take swab samples from the spigot and inside of the container after the water was filtered to test for *E. coli* presence and determine potential recontamination.

**Table 3.5** *E. coli* bacteria identified in sources, household storage containers and new housing unit

| Week | Water source | Household storage containers | New housing unit/filter |
|---|---|---|---|
| 1 | EHEC. EPEC, ETEC | EHEC. EPEC, ETEC, *E. coli* toxin, EAEC | ND |
| 3 | EHEC, *E. coli* toxin, Commensal *E. coli* | EPEC, EIEC, EAEC, EHEC, *E. coli* toxin, Commensal *E. coli* | EIEC. EAEC, EPEC, *E. coli* toxin, Commensal *E. coli* |
| 5 | EPEC, ETEC, EHEC, *E. coli* toxin | EPEC, EHEC,EIEC, *E. coli* toxin, Commensal *E. coli* | EPEC, ETEC, EHEC, *E. coli* toxin, Commensal *E. coli* |
| 7 | EPEC, EHEC,EAEC | EPEC, EHEC,EAEC, ETEC | EPEC, ETEC, EHEC,EIEC, EAEC |
| 9 | EPEC, ETEC, EHEC, EIEC, *E. coli* toxin | EPEC, EAEC, EHEC, ETEC, *E. coli* toxin | EHEC, EAEC, EIEC, ETEC, EPEC, *E. coli* toxin |

Eight households from the peri urban household study group were randomly selected to test whether the spigot was the problem. Table 3.6 showed that only 1 house had Total coliform bacteria and no *E. coli* bacteria on the spigot while 3 households had both Total coliform bacteria and *E. coli* bacteria inside the bucket where the filtered water was stored. The fact that pathogenic *E. coli* was also detected in the water bucket could possibly contribute to that fact that the inside of the water bucket was not properly polished. This creates a rough surface where the bacteria can attach and multiply in the form of biofilms. Another option can be that the manufacturer did not use proper food grade polypropylene although this would not contribute to the bacterial growth. Even if the bacteria were growing on the inside there would still need to be a seeding event to introduce the bacteria into the bucket. This could potentially be attributed to poor hygiene practises in the household.

**Table 3.6** Total coliform and *E. coli* bacteria on spigot and inside of new housing unit

| Household number | Spigot SWAB | Housing water bucket inside | Total Coliform count/100 ml | *E. coli* count/100 ml | *E. coli* strain isolated |
|---|---|---|---|---|---|
| 1 | X | | 62.4 | 0 | |
| 2 | | X | 2420 | 59.4 | EPEC, EAEC |
| 3 | | X | 2420 | 4.1 | EAEC |
| 4 | X | | 0 | 0 | |
| 5 | X | | 0 | 0 | |
| 6 | | X | 2420 | 1 | EHEC |
| 7 | X | | 0 | 0 | |
| 8 | X | | 0 | 0 | |

nd = not detected

To investigate the effect of hygiene practices it was decided to look at the cleaning method used for cleaning the buckets and what was used. It was found that the majority of households used the same dishcloth that they used to clean everything in the household to wipe clean the bucket inside before use. The dishcloths of 15 of the study households were tested and high numbers of *E. coli* strains were seen on these dishcloths (Table 3.7).

**Table 3.7** *E. coli* strains isolated from the dishcloths used in cleaning the inside of the new housing unit

| Dishcloth number | ***E. coli* strain isolated** |
|---|---|
| 1 | Commensal *E. coli* |
| 2 | EIEC |
| 3 | *E. coli* toxin |
| 4 | EAEC |
| 5 | EPEC, EHEC |
| 6 | *E. coli* toxin |
| 7 | EPEC, EAEC, EHEC |
| 8 | EHEC, EAEC, *E. coli* toxin |
| 9 | *E. coli* |
| 10 | EHEC, EAEC, EPEC, EIEC, *E. coli* toxin |
| 11 | EPEC, EAEC, *E. coli* toxin |
| 12 | EPEC, ETEC and EHEC |
| 13 | EPEC, EHEC, ETEC, *E. coli* toxin |
| 14 | *E. coli* toxin |
| 15 | EHEC, EPEC |

It was then decided to also dig deeper into why the same household had clean water in the old Potters-for-Peace bucket and not in the newly designed bucket. So far the only reasonable explanation is that the new bucket is not made from plastic like the Potters-for-Peace but from Polypropylene which have grooves in which the microorganisms can hide and then when water is filling the bucket, these microorganisms comes loose and contaminate the water.

The only way to test this theory is to do the second part of the study in another area in households which have not yet used these filters or buckets and train them the same way as the previous group who has used both the Potters for Peace filter unit and the new housing unit and see if there is a difference. If the water still contains *E. coli* bacteria, we have to look into the product used to make the bucket and change it to a plastic.

### 3.3.2 RURAL HOUSEHOLD STUDY IN THE LIMPOPO PROVINCE

A total of 30 rural households were identified and a final total of 28 households using communal tap water and water trucks in the Limpopo province were included in this study. All of these households had never been exposed to a POU device before and therefore the training and subsequent follow-up visits were used to assess the POU new housing design and user acceptance by the study households.

Tables 3.8 and 3.9 is showing the counts/100 ml for total coliform bacteria and *E. coli* bacteria respectively which was obtained from the sources, household water storage containers and the new housing unit containing the ceramic pot filter. All the data is shown in order for the reader to observe the microbial quality of the water samples tested. From the data it was clear that the water did deteriorate after storing in the household containers – this could be seen for both the total coliform and *E. coli* counts. Consequently by just focussing on the *E. coli* counts in Table 3.12, the new housing unit – ceramic pot filter POU device did improve the water quality (blue, green and yellow highlighted colour coding). The pH, temp and Turbidity were well within guidelines sourced from SANS 241, the World Health Organisation (WHO) and the State of Connecticut Department of Environmental Protection (SCDEP) (Table 3.1).

Similarly to the peri-urban households, the identification of diarrhoegenic *E. coli* strains in the rural household water samples indicated the prevalence of all the pathogenic strains such as EHEC, EPEC, ETEC, EAEC and EIEC as well as commensal *E. coli* and E. *coli* toxin. The results are shown in Table 3.10.

**Table 3.8** Total coliform counts detected and colour coded to show water quality for rural households

| Sample point | Source | | | | | Household Storage Container | | | | | Filtered water | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 |
| Basani 190 | 0 | 0 | 19 | 0 | 0 | 207 | ND | ND | 579 | 770 | ND | ND | ND | 770 | 1553 |
| Basani 543 | 0 | 0 | 2 | 0 | 0 | 0 | ND | 55 | 124 | 2420 | ND | ND | 6 | 5 | 0 |
| Basani 164 | 0 | 0 | 2 | 0 | 0 | 770 | ND | ND | 517 | ND | ND | 1300 | ND | ND | ND |
| Basani 222 | 0 | 0 | 0 | 0 | 0 | 1203 | ND | 1414 | 96 | 99 | ND | 2420 | 16 | 179 | 2420 |
| Tshikonelo k103 | 2 | 6 | 5 | 2 | 0 | 2420 | ND | ND | 2420 | 6 | ND | 0 | ND | 45 | 0 |
| Tshikonelo k304 | 0 | 0 | | 0 | 0 | 57 | ND | 10 | 388 | 81 | ND | 2 | 225 | 5 | 0 |
| Tshikonelo k44 | | | | | | 2420 | ND | 34 | 8 | 2420 | ND | ND | 43 | 29 | 488 |
| Tshikonelo k509 | 1 | 1 | 0 | 1 | 0 | 770 | ND | 48 | 1733 | 2420 | ND | ND | 2420 | 2420 | 1011 |
| Tshikonelo k6011 | 1 | 1 | 0 | 0 | 3 | 81 | ND | 25 | 248 | 4 | ND | ND | 205 | 225 | 2 |
| Tshikonelo k813 | | | | | | 0 | ND | 6 | 1 | ND | ND | ND | 9 | 50 | ND |
| Tshikonelo j1101 | | | | | | 1 | ND | ND | 436 | 411 | ND | ND | ND | 2420 | 2420 |
| Tshikonelo j1001 | | | | | | 548 | ND | 2420 | 2420 | 2420 | ND | ND | 2420 | 0 | 3 |
| Tshikonelo j1102 | | | | | | 0 | ND | 119 | 2420 | 8 | ND | ND | 0 | 0 | 0 |
| Tshikonelo j1204 | | | | | | 548 | ND | 2420 | 141 | 365 | ND | 5 | 3 | 128 | 79 |
| Tshikonelo j1806 | | | | | | 2420 | ND | 12 | 2420 | ND | ND | 5 | 387 | 326 | ND |
| Tshikonelo j1207 | | | | | | 133 | ND | 2420 | 17 | ND | ND | 2420 | 0 | 29 | ND |
| Tshikonelo j1902 | | | | | | 248 | ND | 308 | 403 | 205 | ND | 2420 | 2420 | 2420 | 345 |
| Tshikonelo j1704 | | | | | | 109 | ND | 2420 | 461 | 166 | ND | 179 | 770 | 549 | 2420 |
| Tshikonelo j2008 | 19 | 5 | 0 | 0 | 0 | 2420 | ND | 16 | 9 | 0 | ND | ND | 17 | 16 | 214 |
| Muraga 249 | | | | | | 2420 | ND | 2420 | 1011 | 0 | ND | ND | 1046 | 13 | 0 |
| Muraga 235 | | | | | | 201 | ND | 291 | ND | ND | ND | 2 | 112 | ND | ND |
| Muraga 267 | | | | | | 770 | ND | 2420 | 2420 | 14 | ND | 66 | 4 | 82 | 5 |
| Muraga 200 | | | | | | 2420 | ND | 3 | ND | 0 | ND | 0 | 613 | ND | 1 |
| Muraga 294 | | | | | | 0 | ND | 0 | ND | ND | ND | 2420 | 71 | ND | ND |
| Muraga 304 | | | | | | 2420 | ND | ND | ND | ND | ND | 2420 | ND | ND | ND |
| Muraga 227 | | | | | | 2420 | ND | 0 | 2420 | ND | ND | 15 | 88 | 36 | ND |
| Muraga 000 | | | | | | 2420 | ND | 16 | ND | ND | ND | 3 | 395 | ND | ND |
| Muraga 434 | | | | | | 179 | ND | 649 | ND | ND | ND | 0 | 1011 | ND | ND |

*Week 1 in filter samples were when the housing units were installed in the households and water samples were only taken from source and storage container

**Table 3.9** *E. coli* counts detected and colour coded to show water quality for rural households

| Sample point | Source | | | | | Household Storage Container | | | | | Filtered water | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 | Week 1 | Week 3 | Week 5 | Week 7 | Week 9 |
| Basani 190 | 0 | 0 | 0 | 0 | 0 | 0 | ND | ND | 161 | 0 | ND | ND | ND | 131 | 0 |
| Basani 543 | 0 | 0 | 0 | 0 | 0 | 0 | ND | 0 | 0 | 26 | ND | ND | 0 | 0 | 0 |
| Basani 164 | 0 | 0 | 0 | 0 | 0 | 0 | ND | ND | 0 | ND | ND | 0 | ND | ND | ND |
| Basani 222 | 0 | 0 | 0 | 0 | 0 | 1 | ND | 0 | 0 | 0 | ND | 37 | 0 | 0 | 0 |
| Tshikonelo k103 | 2 | 0 | 0 | 0 | 0 | 214 | ND | ND | 0 | 0 | ND | 0 | ND | 0 | 0 |
| Tshikonelo k304 | 0 | 0 | 0 | 0 | 0 | 0 | ND | 0 | 0 | 0 | ND | 0 | 0 | 0 | 0 |
| Tshikonelo k44 | | | | | | 0 | ND | 0 | 0 | 6 | ND | ND | 1 | 9 | 0 |
| Tshikonelo k509 | 1 | 0 | 0 | 0 | 0 | 0 | ND | 0 | 0 | 2420 | ND | ND | 0 | 0 | 2420 |
| Tshikonelo k6011 | 1 | 0 | 0 | 0 | 0 | 0 | ND | 0 | 0 | 0 | ND | ND | 0 | 0 | 0 |
| Tshikonelo k813 | | | | | | 0 | ND | 0 | 0 | ND | ND | ND | 0 | 0 | ND |
| Tshikonelo j1101 | | | | | | 0 | ND | ND | 0 | 1 | ND | ND | ND | 11 | 2 |
| Tshikonelo j1001 | | | | | | 2 | ND | 0 | 4 | 0 | ND | ND | 0 | 0 | 0 |
| Tshikonelo j1102 | | | | | | 0 | ND | 0 | 16 | 0 | ND | ND | 0 | 0 | 0 |
| Tshikonelo j1204 | | | | | | 0 | ND | 0 | 0 | 10 | ND | 0 | 0 | 0 | 0 |
| Tshikonelo j1806 | | | | | | 0 | ND | 0 | 0 | ND | ND | 0 | 0 | 0 | ND |
| Tshikonelo j1207 | | | | | | 0 | ND | 0 | 0 | ND | ND | 65 | 0 | 0 | ND |
| Tshikonelo j1902 | | | | | | 0 | ND | 1 | 2 | 3 | ND | 0 | 345 | 1 | 0 |
| Tshikonelo j1704 | | | | | | 5 | ND | 8 | 1 | 0 | ND | 0 | 5 | 0 | 0 |
| Tshikonelo j2008 | 19 | 3 | 0 | 1 | 0 | 68 | ND | 0 | 2 | 0 | ND | ND | 0 | 3 | 0 |
| Muraga 249 | | | | | | 3 | ND | 2 | 5 | 0 | ND | ND | 0 | 0 | 0 |
| Muraga 235 | | | | | | 0 | ND | 0 | ND | ND | ND | 0 | 0 | ND | ND |
| Muraga 267 | | | | | | 0 | ND | 236 | 0 | 0 | ND | 0 | 0 | 0 | 0 |
| Muraga 200 | | | | | | 3 | ND | 0 | ND | 0 | ND | 0 | 0 | ND | 0 |
| Muraga 294 | | | | | | 0 | ND | 0 | ND | ND | ND | 0 | 0 | ND | ND |
| Muraga 304 | | | | | | 5 | ND | ND | ND | ND | ND | 0 | ND | ND | ND |
| Muraga 227 | | | | | | 6 | ND | 0 | 0 | ND | ND | 0 | 0 | 0 | ND |
| Muraga 000 | | | | | | 649 | ND | 0 | ND | ND | ND | 0 | 4 | ND | ND |
| Muraga 434 | | | | | | 0 | ND | 0 | ND | ND | ND | 0 | 0 | ND | ND |

*Week 1 in filter samples were when the housing units were installed in the households and water samples were only taken from source and storage container

**Table 3.10** *E. coli* bacteria identified

| Week | Water source | Household storage containers | New housing unit/filter |
|---|---|---|---|
| 1 | EAEC, EPEC, ETEC, EHEC | EPEC, EAEC, Commensal *E. coli* | ND |
| 3 | | ND | ETEC, EPEC, EAEC, EHEC, *E. coli* toxin |
| 5 | | EAEC, EHEC,ETEC | EPEC, ETEC |
| 7 | | EPEC, EAEC,ETEC, Commensal *E. coli, E. coli* toxin | EAEC, EHEC, ETEC, EPEC |
| 9 | EAEC, EPEC | EPEC, EAEC, EIEC, ETEC, *E. coli* toxin | EPEC, EAEC, *E. coli* toxin |

## 3.4 KEY FINDINGS OF THE FIELD TESTING OF THE NEW HOUSING UNITS

The *E. coli* and total coliform counts obtained for all the water samples posed a risk to human health but to varying degrees with *E. coli* detected in all the samples. The guideline published by the WRC and DWAF (1998) made the recommendation that total coliform levels of 10-100 cfu/100 ml could lead to clinical infections in sensitive groups and that with values above 100 cfu/100 ml for the total coliforms there would be an increased risk of clinical infections that become more common. The *E. coli* counts in the Limpopo Province households were lower than the counts seen in the study households in Gauteng. This could be due to the fact that the households in the Limpopo Province is still new to the use of the filter and are more inclined to be careful in their hygiene and sanitation practices.

Different pathogenic strains of *E. coli* were isolated from the source, storage container and filter samples and included commensal *E. coli*, *E. coli* toxin, EHEC, ETEC, EPEC, EAEC and EIAC. It was important to note that the filtered water had similar pathogenic *E. coli* strains as the household storage water. This could which showed that it could either be unhygienic practices from the households or the material used in the production of the new housing unit that needed to be refined in the manufacturing process. Dishcloths used by the peri-urban households had shown contamination with pathogenic *E. coli* strains which could have played a role in the contamination of the filtered water.

More studies need to be done to determine the reasons for the presence of *E. coli* in the water and the impact of hygiene and sanitation aspects surrounding the placement, cleaning and use of the ceramic filter pot unit. The conclusion thus-far on the prevalence of *E. coli* in water samples could be due to the Ghana Potpaz filter and the manufacturing process (quality aspects of the production which falls outside the scope of this study).

# 4. ASSESSMENT OF USER ACCEPTANCE AND USER FRIENDLINESS OF NEW HOUSING UNIT

## 4.1 INTRODUCTION

The last step in this study was to assess the new housing design unit in the field and see what the households thoughts were on the design. Assessing the user perception and acceptance of the new housing unit design was an important part of the work since this was the basis for the whole project. Public acceptance will always guide the uptake and long term use of any product, which is the ultimate aim of the any project. From personal experience study participants are usually more positive and honest about the usability and acceptance of any product. Although the proof of acceptance can only be investigated and proven with the continued use of the product after a project team has left the area for a period of time, the aim of this section was to acquire a feeling for the acceptability of the new housing unit. To achieve this, the participants were first given the original housing unit to use so that they have a basis for comparison when the new housing unit was introduced. With this in mind the study participants were asked questions that would give the research team an idea of the ease of use and functionality of the newly introduced design changes. The aim of this section of the work was thus to evaluate the effectiveness of the new housing unit introduced into two different housing settings in South Africa as discussed in the previous chapter.

## 4.2 EXPERIMENTAL PROCEDURES

### 4.2.1 HOUSEHOLD QUESTIONNAIRE

The questionnaire was designed, tested and validated in the original study using the Potpaz Potters-for-Peace ceramic water filter. The questionnaire (Appendix 1) was a structured questionnaire with some open-ended questions to give the participants the opportunity to give their perception on certain aspects. The questionnaire questions focused on the placement of the filter, filling and emptying of the filter and housing unit, perceived water quality, cleaning of the ceramic filter and housing unit as well as general remarks regarding the new design. The questionnaire was available in English and Venda but can be adapted and translated as needed. In all cases the person responsible for the water filter was interviewed except in cases where this person was not available. The questionnaire was completed by one of the research team who asked the questions and completed the questionnaire on the participant's behalf.

## 4.3 RESULTS AND DISCUSSION

### 4.3.1 PLACEMENT OF THE FILTER

Placement of the water filter is an important consideration since it will influence the use of the water filter but also access of children and animals to the filter. From the answers received it can be seen in Figure 4.1 that 71% of the filters in the Gauteng study site kept the filter in the kitchen. Only 8 of the households kept the filters in the living area or dining area.

In the Limpopo study site all the participants kept the water filter in the kitchen which could be attributed to the smaller houses associated with rural areas. When asked about the stability of the filter, in all the households from both the study areas it was indicated that the filter was very stable and was never knocked over during the study period. Since this was the idea with the decision of the tripod stand it shows that this was the correct choice.

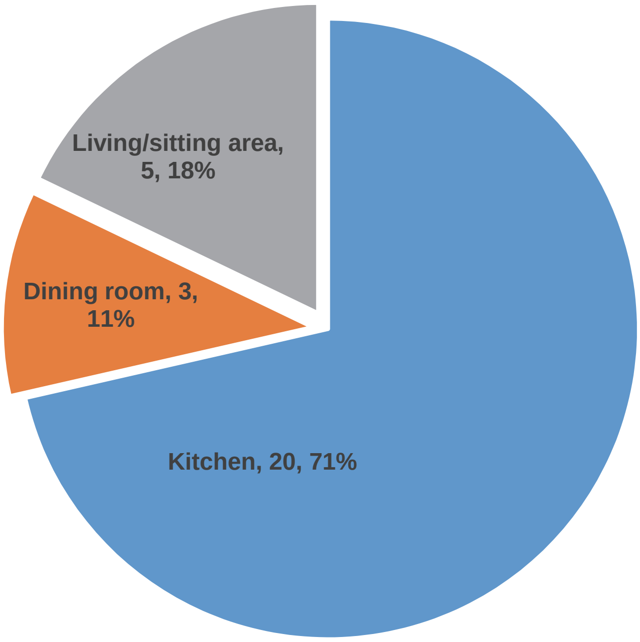


**Figure 4.1** Typical placements of the filter units in the Gauteng study site

### 4.3.2 FILLING OF THE CERAMIC FILTER

The duty of filling the ceramic filter was mostly done by a female figure in the household in the Gauteng study area (Figure 4.2) although 11% of the households did indicate that the father or husband filled the water filter. Contrary to this all the households in the Limpopo study area indicated that a female figure, usually the mother or grandmother, was responsible for the filling of the ceramic filter.

The households reported using a wide variety of jugs, buckets and containers of varying volumes to fill the ceramic filter. Despite this none of the participants indicated any problems with the filling of the filter indicating that the height of the filter was still a comfortable height, despite the fact that the tripod stand was added.

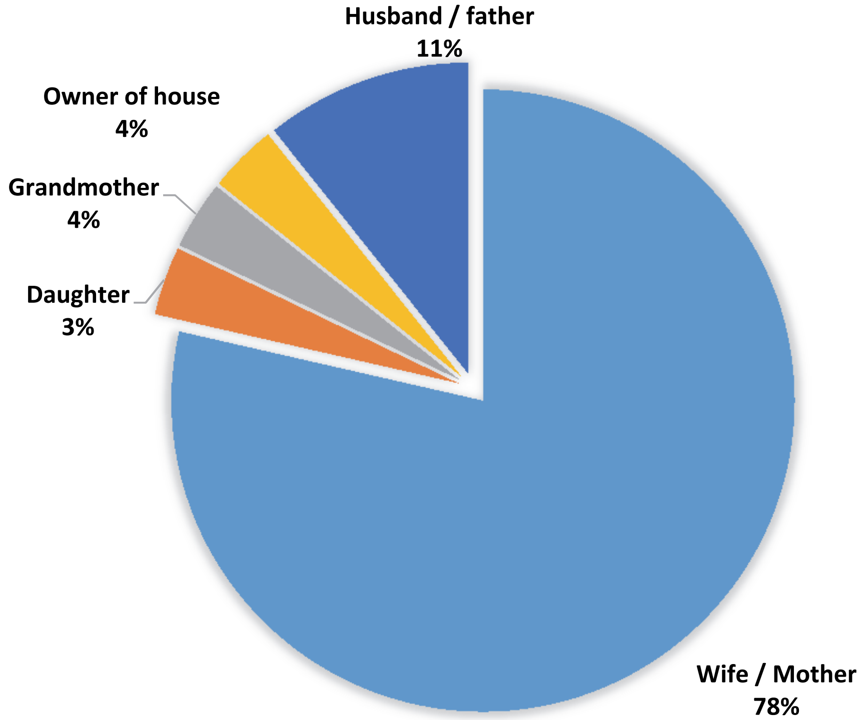


**Figure 4.2** People responsible for the filling of the ceramic filter in the Gauteng study area

### 4.3.3 COLLECTING WATER FROM THE CONTAINER

Collecting water from the container is done via the spigot and this was one of the main design adaptations that were implemented to reduce the cracking of the water container and leaking from the tap. It was found that 4 of the taps from the Gauteng study area (Figure 4.3) leaked compared to 1 from the Limpopo study area. It was however found that the spigot was not correctly tightened and once this was corrected there were no more leaking from the tap.

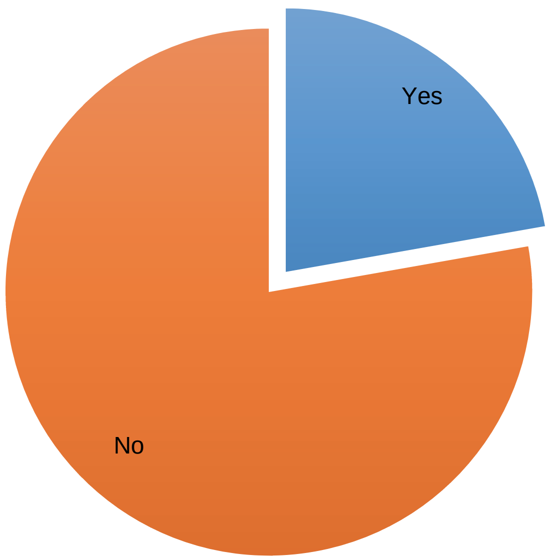


**Figure 4.3** Percentage of leaking taps in the Gauteng study area

In all cases the residents reported that they used a specific type of container, such as glass, jug or beaker to collect water from the tap. The type of container used varied more in the Gauteng study area compared to the Limpopo study area that all reported using a 250 ml glass or jug. In the Gauteng are some of the residents even reported using 5 l buckets to collect water from the spigot (Figure 4.4).

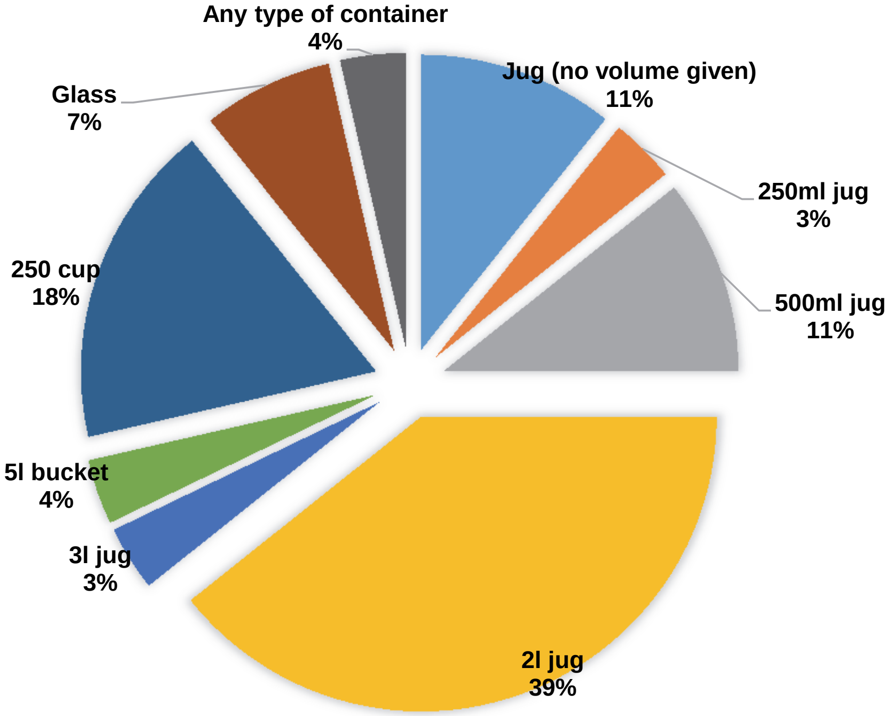


**Figure 4.4** Typical containers used to collect water from the spigot in the Gauteng study area

All the respondents, except one household in the Limpopo study area, reported that they used different containers for filling and collecting water which will reduce the possibility of contaminating the water once collected form the tap. All the users in the Limpopo province felt that the housing units give water fast enough. This was not the case in the Gauteng study area were only 36% of the people felt that the housing unit gave water fast enough. This is one of the aspects that will have to be further investigated to get better data on how fast water is given form the housing unit.

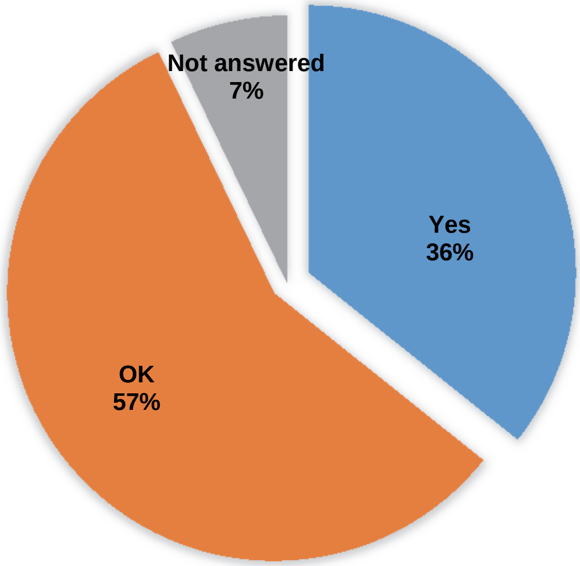


**Figure 4.5** Responses from the Gauteng study area when asked if the filter is giving water fast enough

### 4.3.4 PERCEIVED WATER QUALITY

One of the best indicators of any intervention is the public perception about the water quality. Although the new housing unit cannot directly influence the water quality which is more associated with the ceramic filter that was sourced elsewhere. The housing unite designs incorporated is directed to ensuring that the water do not get contaminated by dust and insects that can enter the water again. All the users in the Limpopo study area liked the taste of the water. This was however not the case in the Gauteng study area where only 82% of the users liked the water (Figure 4.6). This might however be influenced by the fact that they have been using the ceramic filter for more than a year with the old housing unit which could have influenced the affectivity of the filter.

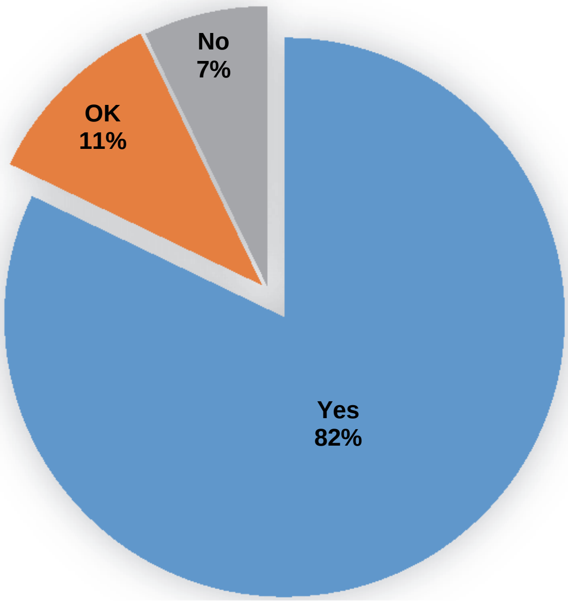


**Figure 4.6** Responses from the Gauteng study area when asked if they liked the taste of the water

Despite this all the participants in the Gauteng study area did like the taste of the filtered water better than the unfiltered water. Only on participant in the Limpopo study area preferred the taste of the unfiltered water. When asked what specific is different in the water the users in the Limpopo study area all reported that the water tasted better and smelled nicer than the unfiltered water. It is unclear why the one responded still preferred the unfiltered water and still indicated that the water tasted better in a separate question. The users in the Gauteng study area were more responsive in their feedback and indicated that the water was cooler, tasted better with some of the users even comparing the taste to that of mineral water (Figure 4.7). Although not all the users gave this type of feedback it is encouraging that all of them still liked the filtered water better.

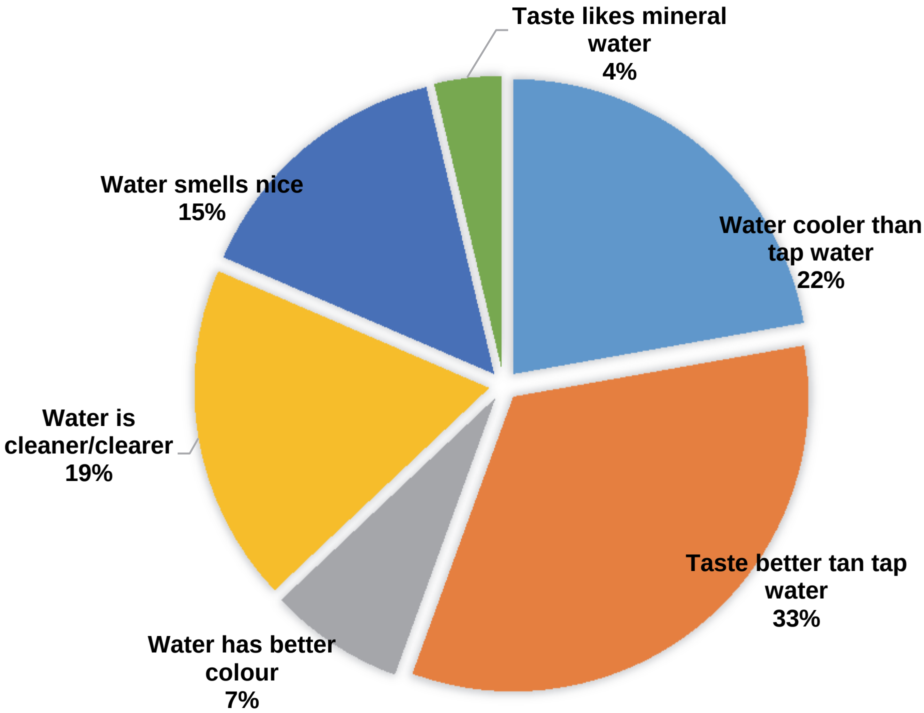


**Figure 4.7** Responses from the Gauteng study area when asked what they liked about the filtered water

### 4.3.5 CLEANING OF THE FILTER AND HOUSING UNIT

Probably the most important role of the participants in the study is during the cleaning of the filter and housing unit since this can influence the water quality during and after the filtration step. One of the design changes that were introduced was the lid that can be used as a wash basin to assist with maintaining the ceramic filter. All the participants in both the study areas indicated that they used the lid as a wash basin for washing the filters. Neither did any of the participants have any problems lifting the ceramic filter out of the filter housing unit, indicating the rubber seal does help with the handling of the ceramic filter. The way the water is handled during the cleaning process can give an important glimpse into the cleaning practises of the households. As seen from Figure 4.8 the majority of the people in both the study areas let the water filter on its own before cleaning the filter.

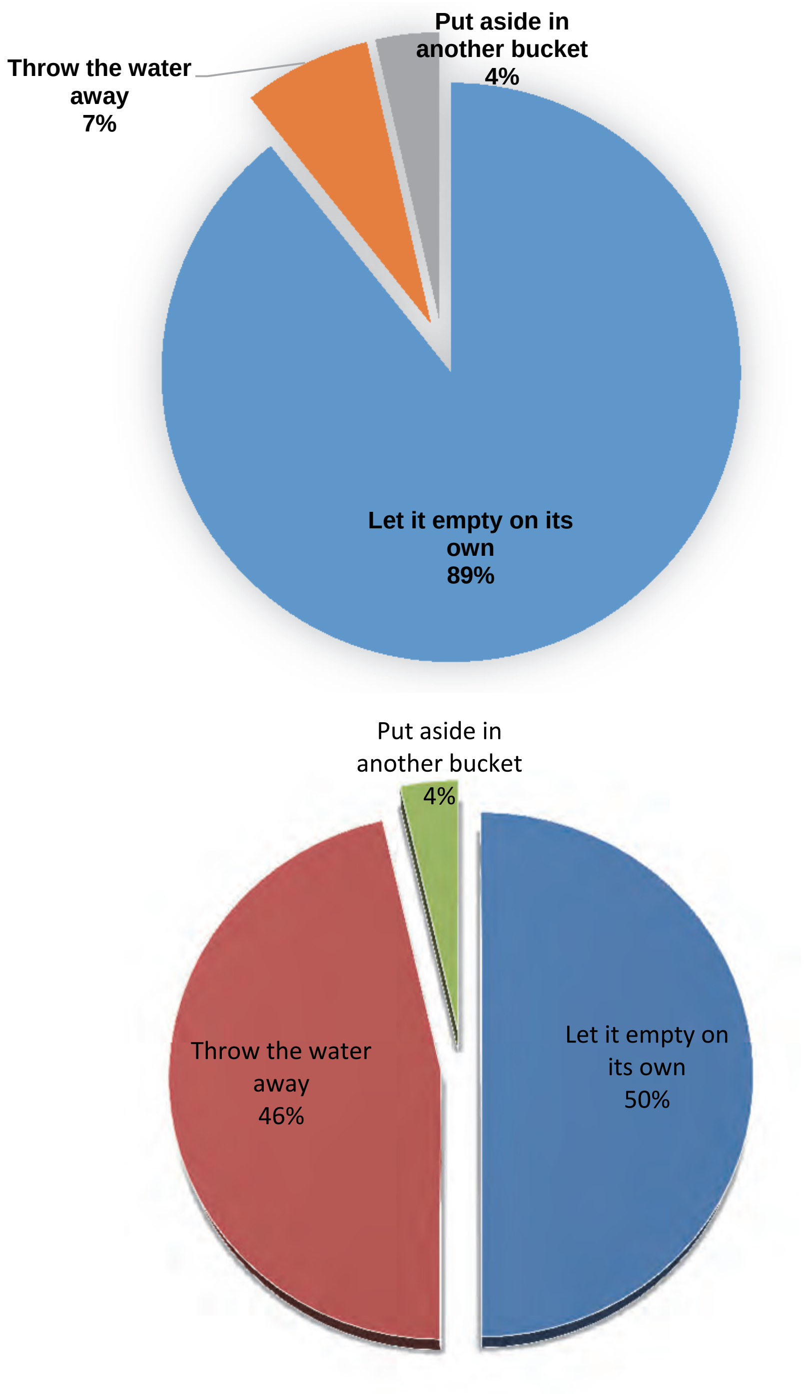


**Figure 4.8** Responses from the Gauteng (top) and Limpopo (bottom) study area when asked what they did with the water in the ceramic filter before cleaning it

The rest of the participants indicated that they either throw the unfiltered water away or put it aside to filter at a later stage. When asked the same question about the water left within the housing unit all the participants from the Limpopo study area indicated that they threw the water away. Only in the Gauteng study area did 46% of the participants indicate that they placed the water in another container (Figure 4.9). The fact that people throw the water away is worrying since this water should be used for the washing of the filter and housing unit components. It is however unclear whether the water was thrown away before or after the rest of the components was cleaned. This could have a serious impact on the water quality if the dirty unfiltered water is used to clean the housing unit.

This fear is supported when the question was of how the container was cleaned was asked. All the participants in the Limpopo study area indicated that they only use water to clean the housing unit. Since all the participants indicated that they throw the filtered water away before the container is cleaned, it can be assumed that they are using unfiltered water to clean the housing unit. In the Gauteng study area it was found that at least 79% of the participants use some type of soap to was the housing unit although 21% still indicated that they only used water, with or without a sponge, to clean the housing unit (Figure 3.9).

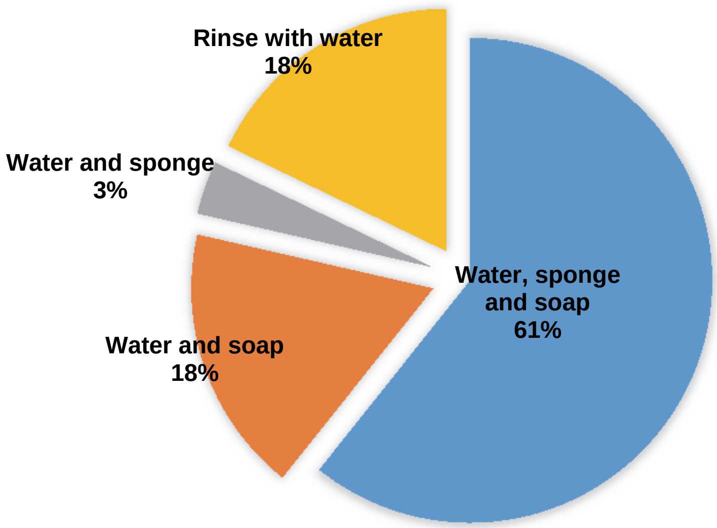


**Figure 4.9** Responses from the Gauteng study area when asked how they cleaned the housing unit

The participants that did use soap reported using Sunlight Liquid (9), Jik (1) and Handy Andy (1) to clean the filter. Ten of the households did not report what type of soap they used but did indicate that they used soap during cleaning. Interestingly none of the participants in either study area reported that they had a problem with cleaning both the ceramic filter and housing unit, indicating that better instructions and training on the proper cleaning of the filter is urgently needed.

### 4.3.6 GENERAL QUESTIONS

When asked if any part of the filter or housing unit had broken during the study all the participants indicated that nothing had broken. The participants were asked if the filter produced enough water for the family and 89% of the participants in the Gauteng study area said that the filter produced enough water versus the 57% of the participants in the Limpopo study area indicating they have enough water. It was not asked if the lack of water was strictly for drinking purposes or for general household activities as well.

The design of the filter housing unit accommodates 16 litres of filtered water and increasing this volume might decrease the stability of the housing unit and filtered when assembled.

The participants asked what problems they had with the new design 53% of the participants in the Gauteng region and 97% of the participants in the Limpopo study would not change anything (Figure 4.10). In both areas one household commented that the lid was to loose and could be made to fit more tightly.

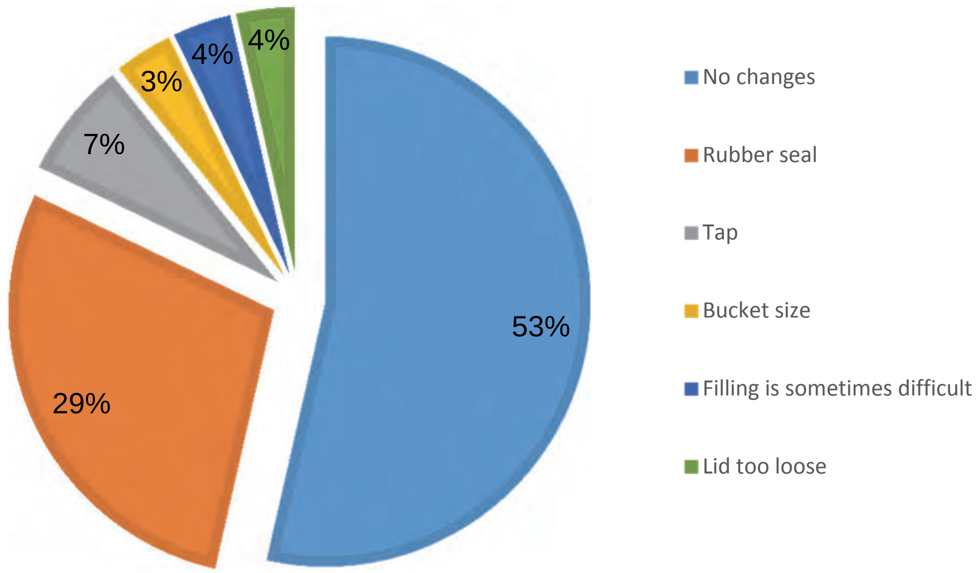


**Figure 4.10** Responses from the Gauteng study area when asked what they would change on the filter

Twenty nine percent of the households in the Gauteng study area mentioned that the rubber seal was too tight and hard but this will change over time. The design was specifically done to accommodate the slight variations in the ceramic pot sizes, hence the tighter fit in some of the households. This should however not harm the actual pot and with continued use the rubber will stretch and become more flexible. Only one household in the Gauteng study area requested a bigger container with 2 households mentioning problems with the opening and closing of the tap. Since the tap is bought commercially not much can be done about this except to check each tap before they are implemented.

## 4.4 KEY FINDINGS OF HOUSEHOLD QUESTIONNAIRE

The general feedback was positive from the households with no request for major changes to the new filter housing unit. It was found that the questionnaire must be expanded to incorporate questions to better answer questions that arose during the study. Probably the most important observation was the need for more continued training on the cleaning of the ceramic filter and housing unit.

## 5. SUMMARY OF KEY FINDINGS AND CONCLUSIONS

It must be kept in mind that the objective of this study was not to assess the Potters-for-Peace ceramic pot filter, but the new housing unit that was designed and developed to determine user acceptance and friendliness.

The new design fulfilled and met all the requirements the previous WRC study pointed out. It proofed to be good to look at, sturdy, stable, providing enough water for drinking and easy to clean. It was found acceptable and user friendly by the majority of the households in the study. The study results indicated that it is important in future studies to include a proper manual on household hygiene practices specifically looking at how the ceramic pot filter and the inside of the housing unit is cleaned.

The prevalence of total coliform bacteria and *E. coli* bacteria could be due either to the ceramic pot filter from Ghana which indicates the importance of obtaining a ceramic pot filter which is produced in a factory with adequate quality measures. However, it could also be due to the inside material of the housing unit which were not smooth (pilot study and first production). Polypropylene is not the wrong material for the new housing design. However the manufacturing process needs to be re-evaluated and the use of the right grade of polypropylene needs to be implemented in the manufacturing. In addition it was also seen that the polypropylene was not polished which needs to be done.

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# APPENDIX:

**Mbudziso: dza Mudini na Gurupu ya vatu.**

**Questionnaire: for Households and Focus Group meetings.**

Martin Bolton, University of Johannesburg, Masters Degree Project.

**Mbudziso dza Mudini:** ☐

**Household questionnaire:** ☐

Dzina:____________________(Otoufuna)

Name:____________________(Optional)

Duvha:_____________________

Date:_______________________

Dzina la muvhudu:____________

Village name:________________

Nomboro ya vhathu mudini:_________________

Number of people in household:______________

**Mbudziso kha Mutangano wa Gurupu:** ☐

**Focus Group Meeting Questionnaire:** ☐

Nomboro ya vhadzheneleli:_________

Number of participants:____________

Dzina la muvhudu:________________

Village name:____________________

Duvha:___________________________

Date:_____________________________

***Kuvhetshele kwa Tshitundo: Placement of filter:***

1) Vho vhea ngayi tshitundo yavho?

1) Where do you place the filter?

2) Itshi tshitundo tshono ndi vhuya tshawa?

2) Has the filter been knocked over?

3) Vhono vhuya vha vhana vhu thanda nga kudzulele kwa tshitudo?

3) Have you found any problems with how stable the filter is?

***U hwala tshitimbo: Lifting the lid:***

4) Vhafarisa hani tshitimbo musi vhatshi tshibvisa kha tshitundo?

4) How do you hold the covering lid when you lift it off of the bucket and filter?

***U ndadzwa tshitundo: Filling the filter:***

5) Vha ndadza hani khali ya usefa nga madi? (nga tshikelelo ubva kha doromu, kana ushela madi ubva kha tshigubu 20/25 tsha madi)

5) How do you fill the ceramic filter with water? (Scooping water from large drum, or pouring water from a 20/25 litre water container)

6) Ndi nnyi ane a thongomela uri tshitundo tshina madi olinganaho?

6) Who makes sure that the filter has enough water?

7) Huna thaidzo musi vha tshishela madi kha khali ya vumba?

7) Are there any problems which you have when filling the ceramic filter?

***U wana madi kha sefo na kushumisele kwa thepe: Getting water from filter & operating the tap:***

8) Vha shumisa tsha ukelela tshokhetheaho uka madi avhudi ubva kha thepe, kana vha shumisa zwa ukelela zwofhambanaho?

8) Do you use a specific container to take clean water from the filter's tap, or do you use different containers?

9) Vha shumisa tshaukelela tshifhiho?

9) What container do you use?

10) Vhono di tangana na thaidzo thepe musi vha tsh khou kelela madi?

10) Have you found any problems with filling your container from the filter's tap?

11) Thepe yavho ibvidisa madi?

11) Does the filter's tap leak water?

12) Vha farisa hani tshikelelo na ubvulela thepe? (Vhashumisa tshanda tshithihi kana zwivhili?)

12) How do you hold the container and open the filter's tap? (Do you use one or two hands?)

13) Thepe i bvisa madi olinganaho nga utavhanya?

13) Does the filter's tap give water fast enough?

***Vhuvhudi ha madi. Water quality.***

14) Vha au takalela mutshelo wa madi o sefiwaho?

14) Do you like the taste of the filtered water?

15) Huna phambano vhukati ha osefiwaho na a songo sefiwaho?

15) Is there a difference between the filtered water's taste compared to unfiltered water?

16) Phambani ya hone ndi ifhio?

16) What is the difference?

***Ukunakisa sefo/liravha(Bakete), na zwinwevho.* Cleaning the filter/ bucket, etc.**

17) Vha shululisa hani madi kha sefo phanda ha musi vha tshitshitakula kha liravha(Bakete)?

17) How do you empty the ceramic filter before you lift it out of the bucket?

18) Vhana na thaidzo kha u wala sefo ubva kha liravha(bakete)?

18) Do you have any problems with lifting the ceramic filter out of the bucket?

19) Phanda ha musi vhasaathu ukunakisa bakete ngomu, vha itamini nga madi osalaho ngomu halo?

19) Before you clean the inside of the plastic bucket, what do you do with all the water that is left inside?

20) Vha tanzwa hani liravha(Bakete) ngomu hayo?

20) How do you clean the inside of the plastic bucket?

21) Vhana thaidzo kana usafarea zwavhudi nga u tanzwa sefo?

21) Do you have any problems or irritations with cleaning the ceramic filter?

22) Vhana thaidzo kana usafarea zwavhudi nga u tanzwa liravha(Bakete)?

22) Do you have any problems or irritations with cleaning the plastic bucket?

***Dzinwe mbudziso.* Other questions.**

23) Ndi zwini zwithu zwine zwinga shandukisiwa kha tshitudo uita uri tshileluwe u shuma?

23) What things do you think can be changed on the filter to make the filter easier to use?

24) Huna tshinwe tshithu tshe tsha kwashea kha tshitudo zwezwi vha tshi khou tshishumisa?

24) Has anything been broken on the filter while you were using it?

25) Itshi tshitundo tshi sefa madi alinganaho vhathu vhothe nga hayani?

25) Does the filter provide enough water for everyone in your family?