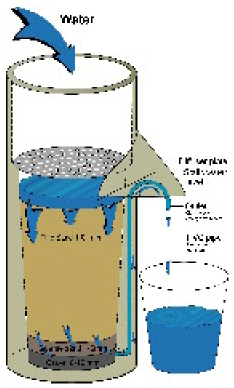
Medair Kenya - Bio sand filter project evaluation report[1]

Interpretation of results



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Abstract

This document interprets the results of an evaluation carried out by Medair in May 2003, in Machakos District, Kenya. Purpose of the exercise was to measure the success and sustainability of a project implemented in between July 1999 and June 2000. During this period, more than 200 concrete Bio-Sand Filters were built and sold to individual households who depended on contaminated surface water for drinking. The results show that the filters are still performing very well, producing drinking water of acceptable purity to the majority of households that bought one 4 years ago.

Dates of evaluation: 14 – 30 May 2003

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Testing methodology

Sample size: 57 households. For bacteria and turbidity counts, the filters in use was the sample size = 51 households.

- The spout was never disinfected in order to get the real situation for the people who collect the water and drink it.
- Water was running for a minute before a sample was taken, but never longer. All samples were taken from running filters except one household.
- The raw water was taken out of the storage container by decanting it straight into the sample bottle rather than dipping the bottle into the container.
- Care was taken by the sampler not to touch the edge of the glass bottles with fingers.
- The samples were taken in sterile glass bottles. When each water sample was taken, the bottle was filled and emptied twice before the final and third sample was kept. 100ml was always collected.
- The filled bottle went back into the cooling box straight away and was left there until I tested it back in the base.
- Samples were taken back to the base the same day and the tests were done between 5 and 10 hours later, since they were collected from 10 am to 3 pm.
- Glass bottles were used which had been boiled for at least 20 minutes in water one day before testing. The samples were carried in a cool box together with ice packs. The glass bottles were kept in the cool box (empty and full) during the whole day in the field.
- Before testing the sample was shaken gently again, especially since some samples contained visible particles. Those that were physically heavily contaminated were tested using less than 100 ml (50 ml or 20 ml measured with a syringe) and calculated later for 100 ml.

Filters in use

Number of households using filters during survey: 51/57 = 89.47%
Number of households NOT using filters during survey: 6/57 = 10.52%

Of those not using filter, reasons for disuse:

- Rainwater as seasonal alternative source: 2/6 = 33.3%
- Blockage: 3/6 = 50%
- No time to use due to family circumstances: 1/6 = 16.6%

It seems that only 1 household had completely stopped using the filter, as opposed to temporary stoppage (since 2 months or less).

Number/% of households with used OR unused filters doing the following:

- Never hibernated filter – has always been in use: 47/57 = 82.5%
- Hibernated it once: 9/57 = 15.8%
- Hibernated more than 2 times: 1/57 = 1.8%

Out of those households that hibernated the filter, number/% doing the following:

- Water drained: 0/10 = 0%
- Water left standing inside: 10/10 = 100%

Additional comments about hibernation:

- It seems there was no knowledge about the need to drain filters during hibernation.

Turbidity removal

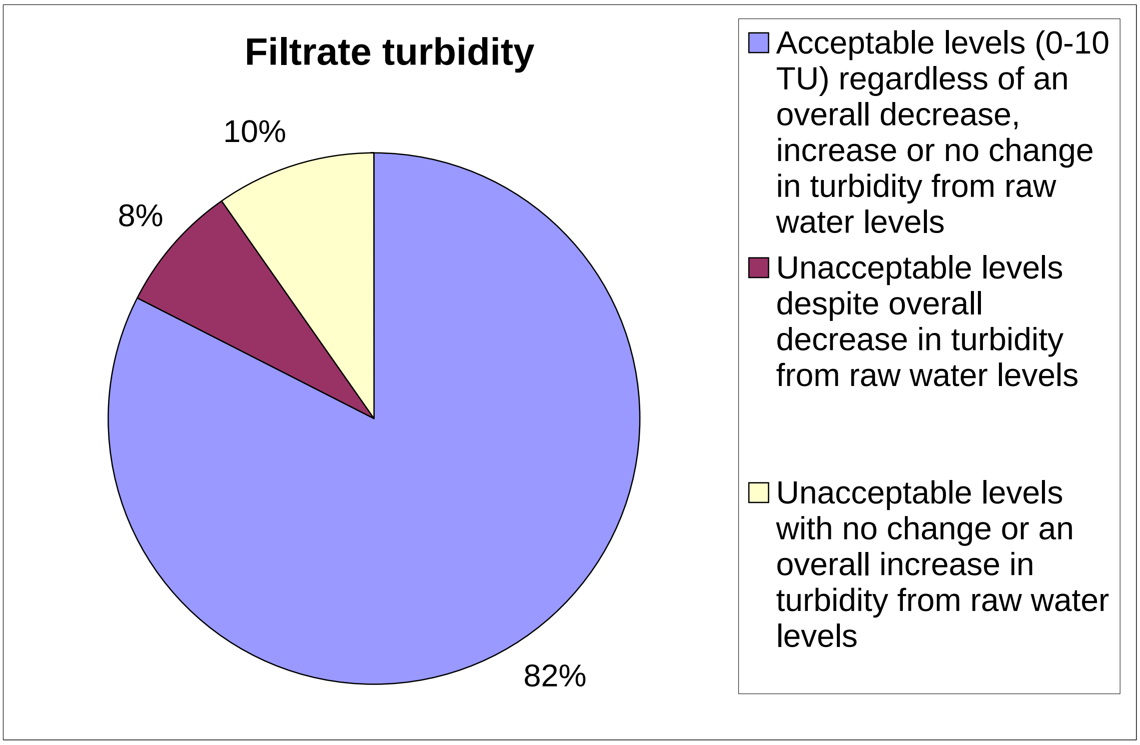
Documenting only % of households showing a decrease, no change or increase in turbidity did not accurately reflect filtrate water with acceptable levels. Many households had no discernable change in turbidity because raw water turbidity was also low and to document these households as having no change in turbidity would make it appear that the filters were not functioning correctly (e.g. – House 14 which showed <5 TU in both raw water and filtrate). Similarly, documenting that a certain % of households showed a decrease in turbidity would not reveal that some of those still had unacceptably high filtrate turbidities (e.g. – House 35 with a reduction from 300 TU to 75 TU). Therefore the analysis looks rather at the following:

Out of those USING filters during survey (51 households), number/% of households that showed:

(a) Acceptable turbidity levels (0-10 TU) regardless of an overall decrease, increase or no change in turbidity from raw water levels: 42/51 = 82.4%

(b) Unacceptable turbidity levels despite overall decrease in turbidity from raw water levels: 4/51 = 7.8%

(c) Unacceptable levels with no change or an overall increase in turbidity from raw water levels: 5/51 = 9.8%



Comments:

- Out of the households showing no change or decrease but which still had unacceptable turbidity levels, 3 out of the 5 had filtrate levels of 12 TU, very near the maximum of 10 TU.
- Out of all 4 households showing an increase in turbidity above acceptable levels, interestingly all of these had acceptable levels of coliforms. 3 out of 5 households showing turbidity decrease also had acceptable levels of coliforms, whereas 13 out of the 42 households that showed acceptable turbidity levels had unacceptable coliforms levels. It is therefore inconclusive to look at turbidity levels and assume proper bacteriological filtration in this study.
- Note that in the Delagua kit, the testing tube measures turbidity units (TU), not Nephelometric Turbidity Units (NTU) which is measured differently. The TU measured in this evaluation more accurately can be referred to as Jackson Turbidity Units (JTU) although this will have to be confirmed by Roben's Institute, the manufacturer of the Delagua kit.

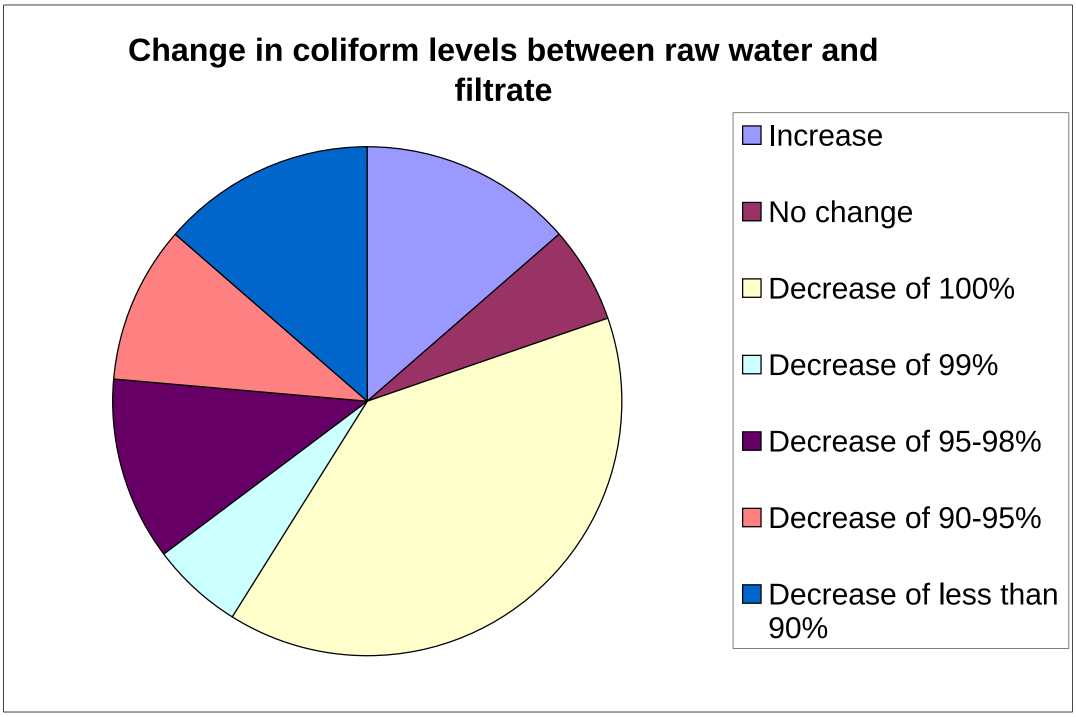
Bacterial increase or decrease

Average CFU in RW for all filters being used: 462
Average CFU in filtered water for all filters being used: 66

Percentage change in coliform levels

Out of those USING filters during survey (51 households), number/% of households that showed change in coliform levels between raw water and filtrate:

- Increase: 7/51 = 13.7%
- No change: 3/51 = 5.9%
- Decrease of 100%: 20/51 = 39.2%
- Decrease of 99%: 3/51 = 5.9%
- Decrease of 95-98%: 6/51 = 11.8%
- Decrease of 90-95%: 5/51 = 9.8%
- Decrease of less than 90%: 7/51 = 13.7%



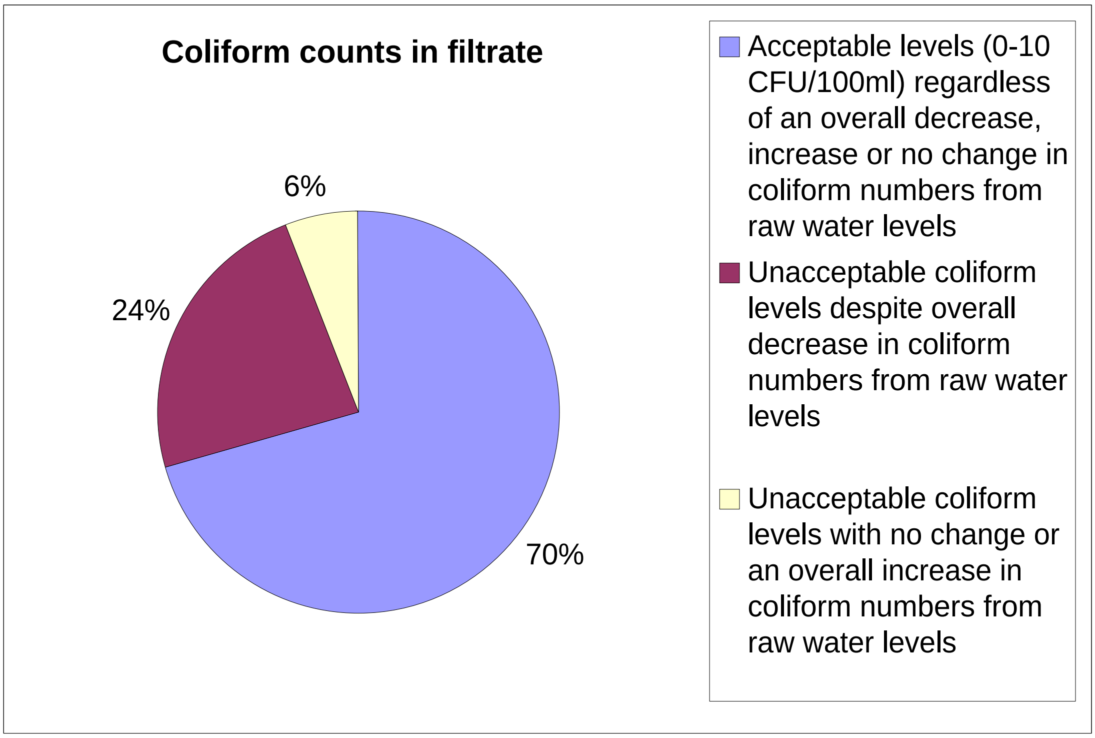
In the same way as analysing turbidity, the % decrease or increase shown should only act as a rough indicator, because the figures may not accurately reflect whether the filtrate had an acceptable level of coliforms. In fact, all the households that showed no change in coliform levels actually had no initial levels (Houses 22, 28 and 34). Alternatively, households showing high percentage reductions in coliforms could still end up having unacceptable levels of coliforms in the filtrate (e.g. – House 29 which had a 96% reduction and yet a filtrate level of

20 coliforms). Similarly, it would not be immediately apparent that households showing a lower percentage overall reduction may have acceptable coliform levels (e.g. – House 56 which had only 33% reduction but where the filtrate had just 4 coliforms). Therefore, as with turbidity, the analysis needs to focus rather on the following:

Percentage with acceptable/unacceptable coliform levels

Out of those USING filters during survey (51 households), number/% of households that showed

(a) Acceptable coliform levels (0-10 CFU/100ml) regardless of an overall decrease, increase or no change in coliform numbers from raw water levels: 36/51 = 70.6%
(b) Unacceptable coliform levels despite overall decrease in coliform numbers from raw water levels: 12/51 = 23.5%
(c) Unacceptable coliform levels with no change or an overall increase in coliform numbers from raw water levels: 3/51 = 5.9%



CFU = Colony Forming Units. The level of 0-10 is based on Sphere Standards for undisinfected supplies.

Analysis of risks causing poor filter performance:

For those households that showed unacceptable levels of coliforms, 4 had filtrate coliform levels near the acceptable mark, with levels ranging from 12 to 22 coliforms per 100ml (Houses 10, 17, 29 and 37). For most, however, further investigation was required to determine the likely causes of the raised levels. To do this, various factors were analysed alongside each category above, which could have affected the results:

(a) *Proportion of filters in each category correlated to individual risks*

For the 70% that had acceptable coliform levels:

- Filter had been cleaned within 1 month of the test: 7/36 = 19.4%
- Filter had been brought out of hibernation within 1 month of the test and had not been drained during hibernation: 1/36 = 2.8%
- Children had access to filter: 2/36 = 5.6%
- Contaminated water used (dam/well/spring water only, not rainwater) AND had a depth of fine sand below 46cm: 9/36 = 25%
- Other possible reasons for contamination present – e.g. cleaning spout with toothbrush, general bad hygiene state of house: 1/36 = 2.8%
- Animals had access to filter: 0/36 = 0%
- Filter had been moved within 1 month of the test: 1/36 = 2.8%

For the 30% that had unacceptable coliform levels:

- Filter had been cleaned within 1 month of the test: 6/15 = 40%
- Filter had been brought out of hibernation within 1 month of the test and had not been drained during hibernation: 1/15 = 6.7%
- Children had access to filter: 4/15 = 26.7%
- Contaminated water used (dam/well/spring water only, not rainwater) AND had a depth of fine sand below 46cm: 9/15 = 60%
- Other possible reasons for contamination present – e.g. cleaning spout with toothbrush, general bad hygiene state of house: 2/15 = 13.3%
- Animals had access to filter: 0/15 = 0%
- Filter had been moved within 1 month of the test: 0/15 = 0%

The above list outlines risks and potential contamination. In some cases by looking at the data, it appears very likely that one particular thing caused the unacceptable levels – for example, a sand height of 36cm in House 45 logically could be seen to cause the recorded result. However, it is not that simple to draw such a conclusion unless consistency is seen for ALL or most of the filters with shallow sand. Thus by looking at the above data, it can only be said that a particular reason would appear likely to be a cause for unacceptable coliform levels in filtrate water. This is by virtue of an increased percentage of filters with unacceptable filtrate water when considering a particular factor - for example the proportion of filters that were cleaned within a month of the test doubled when considering acceptable filtrate and unacceptable filtrate levels. It could be construed that this indicates that cleaning could be a factor in the unacceptable coliform levels.

However, because various factors may interact, and filtrate quality may not be the result of only one factor, an attempt was made to analyse this further using a risk scoring system.

(b) *Proportion of filters in each category correlated to a risk scoring system*

Some of the above risks were applied to all filters to try to find out a more general view for in-house contamination. Risks that had no impact on coliform levels were excluded. The risks included were:

1. Filter cleaned within 1 month of the test
2. Filter brought out of hibernation within 1 month of the test and had not drained it during hibernation
3. Children had access to filter
4. Dam/well/spring water used only (ie – not rainwater) AND where filter had a depth of fine sand below 46cm
5. Other possible reasons for contamination – e.g. cleaning spout with toothbrush, general bad hygiene state of house

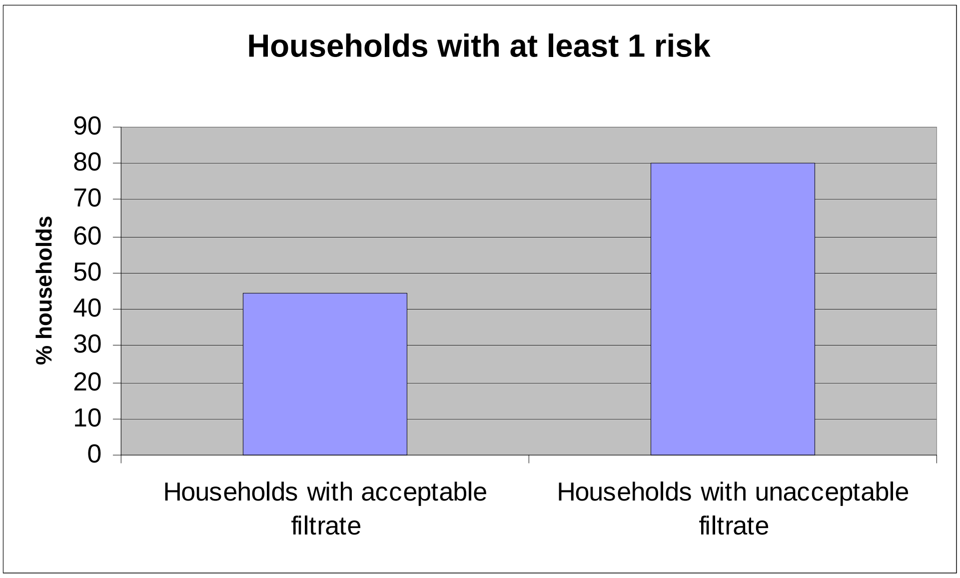
The percentage of acceptable or unacceptable filtrate results could then be viewed in relation to a sum of risks:

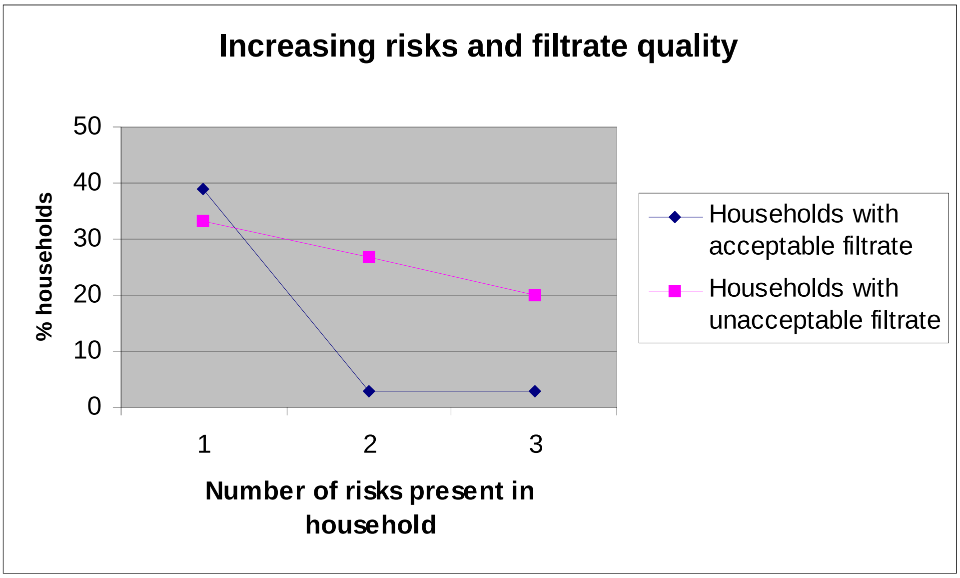
For the 70% that had acceptable coliform levels:

- Total households that showed a one or more risks: 16/36 = 44.4%
- Total households that had a risk score of 0: 20/36 = 55.6%
- Total households that had a risk score of 1: 14/36 = 38.9%
- Total households that had a risk score of 2: 1/36 = 2.8%
- Total households that had a risk score of 3: 1/36 = 2.8%
- Total households that had a risk score of 4: 0/36 = 0%
- Total households that had a risk score of 5: 0/36 = 0%

For the 30% that had unacceptable coliform levels:

- Total households that showed a one or more risks: 12/15 = 80%
- Total households that had a risk score of 0: 3/15 = 20%
- Total households that had a risk score of 1: 5/15 = 33.3%
- Total households that had a risk score of 2: 4/15 = 26.7%
- Total households that had a risk score of 3: 3/15 = 20%
- Total households that had a risk score of 4: 0/15 = 0%
- Total households that had a risk score of 5: 0/15 = 0%





It is likely that cleaning or hibernating of the filters within a month prior to the test, access to children and depths of fine sand that had fallen lower than 46cm all contribute at times to filtrate water of unacceptable quality. This likelihood is based on an increased proportion of filters with unacceptable filtrate given these factors, in contrast to filters with acceptable filtrate.

In addition it would also seem likely that the cumulative effect of risks also contributes at times to filtrate water of unacceptable quality. This seems likely as the risk scoring revealed that 80% of affected filters had some kind of risk, in contrast to 44% for those with acceptable filtrate. In addition, 46.7% of filters with unacceptable filtrate had between 2 and 3 risks present in the household, as opposed to only 5.6% for those with acceptable filtrate – a markedly higher figure.

How these risks might affect the filtrate are as follows:

- Cleaning a filter disturbs the biological layer and this can take up to several weeks to redevelop to full capacity (NB: need to find a reference here…)
- Hibernating a filter without draining the water creates a stagnant section of water where the biological layer dies off for lack of food. It can take several weeks to redevelop the biological layer. There may be other effects on future filtrate quality based on the total die-off of the biological layer (NB: need to find a reference here…)
- Children playing with the filter can affect results. One household admitted that the children do play with the spout (House 27) – contamination is therefore possible. If the filter is knocked or rocked, this can disturb the biological layer (NB: need to find a reference here…)
- Decreased sand levels may affect filtrate quality, especially when the water is contaminated. There is a general consensus that slow sand filters need to have a minimum depth of 50 – 60 cm to be totally effective, due to migration of bacteria to various levels within the sand up to between 40 and 50 cm depth (Huisman and Wood, 1974) and to allow some extra for sand lost during cleaning (Visscher, *et al*, 1985). The depth of the biological layer is a function of sand size, flow rate and raw water quality, meaning that in some filters with a different combination of these factors, increasing the sand bed depth will not automatically mean it will positively affect filtrate quality if most of the biological activity is in the top layer (Buzunis, 1995). However, since the sand was presumably sieved for all the evaluated filters, for some filters it is quite possible that the missing part of the equation is not having enough sand depth for their particular raw water quality, meaning that a fully active biological layer could not develop and filtrate quality was compromised. It is therefore quite conceivable that in the case of filters in this evaluation, since the maximum level of sand found during the evaluation was 48 cm (excluding the extra 5 cm of coarse sand in the base of the filter that sometimes ends up being closer to the grade of gravel than sand), many filters may not be functioning at full capacity. In the same way, it would explain why some filters with less than ideal depths of sand had acceptable filtrate.

Constraints of interpretation:
One or two households had not specified which month they had last cleaned it but said, for example, 'every 3 months'. These households were not counted. Most households just stated which month, but a lack of an exact date makes it hard to know if cleaning took place exactly, less or more than 1 month before the test – for example, a filter tested on 20th May could be affected if the cleaning had taken place at the end of April, but perhaps not if it had been the beginning of April.

<u>Proportion of filters in each category correlated to testing methodology</u>

Testing methodology was also called into question as it was revealed that only about one-fifth of samples had been tested within the 4-6 hour time limit that was initially discussed when the

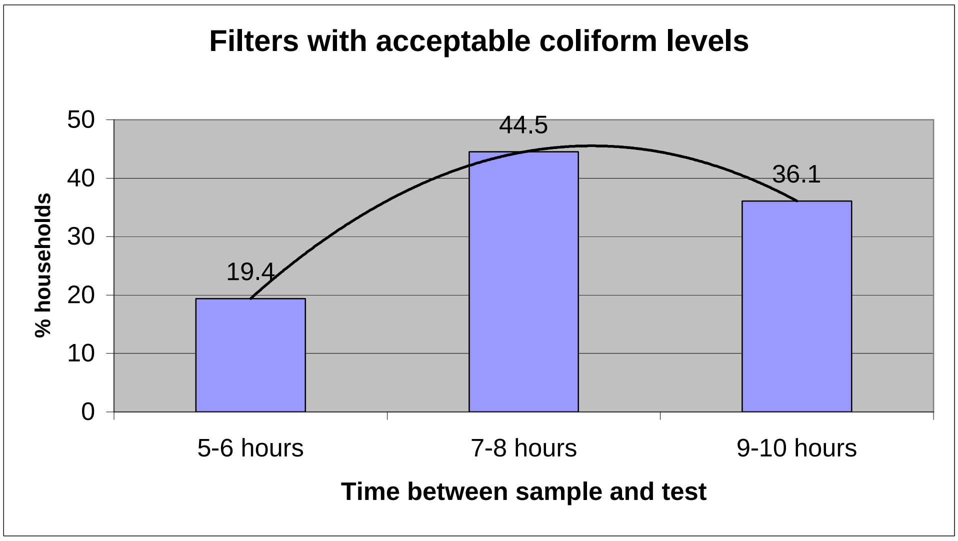
ToR was issued. Although the sample jars were sterilised and samples had been transported in an icebox, it could still be possible that bacteria counts increased past this time limit. To find out, the proportion of filters with acceptable filtrate that had been tested in 3 time brackets was compared to that with unacceptable filtrate. The results are below:

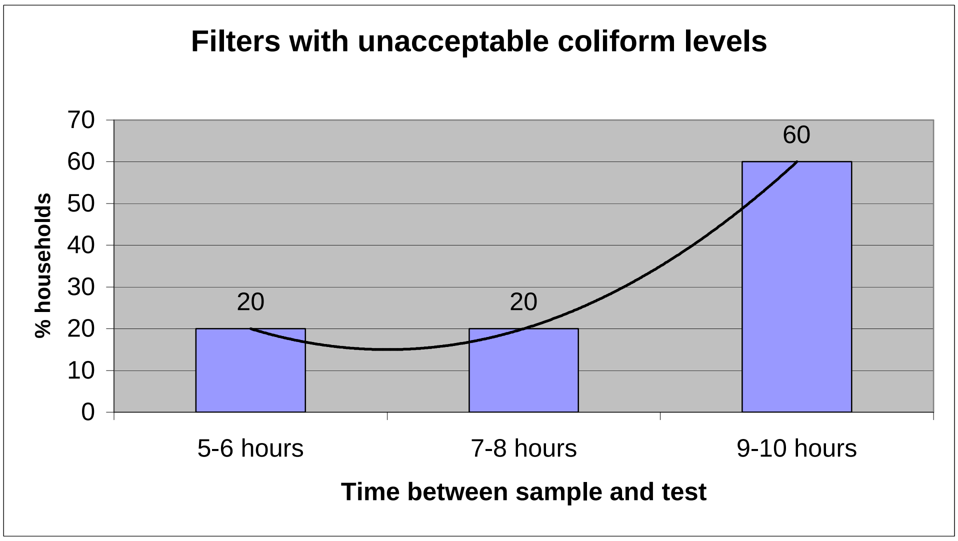
For the 70% that had acceptable coliform levels:

- Filters that were tested 5-6 hours after sampling: 7/36 = 19.4%
- Filters that were tested 7-8 hours after sampling: 16/36 = 44.5%
- Filters that were tested 9-10 hours after sampling: 13/36 = 36.1%

For the 30% that had unacceptable coliform levels:

- Filters that were tested 5-6 hours after sampling: 3/15 = 20%
- Filters that were tested 7-8 hours after sampling: 3/15 = 20%
- Filters that were tested 9-10 hours after sampling: 9/15 = 60%





It is difficult to draw conclusions from this data because there were quite a few filters that had few coliforms in the filtrate but that had been tested 9-10 hours after sampling, and also some that showed many coliforms in the filtrate but that had been tested between 5-6 hours after sampling. If the time factor was an issue, then these filters should also be showing higher and lower counts respectively, especially those with counts above zero, as the few bacteria would have had a chance to multiply. However it is also clear that almost two-thirds of those filters showing unacceptable filtrate quality had been tested 9-10 hours after sampling, an increase of about double that of those with acceptable filtrate. Also 6 out of the 15 households with unacceptable quality filtrate had the lowest coliform counts of that category (63CFU/100ml and less) – out of these, 3 of the 6 had been tested within 5-6 hours, 2 within 7-8 hours and only 1 within 9-10 hours. All the other tests showing unacceptable filtrate quality (9 households) were done between 7 and 10 hours. Sampling/testing methodology could have been a factor in the strange results seen, but it cannot be proved for certain.

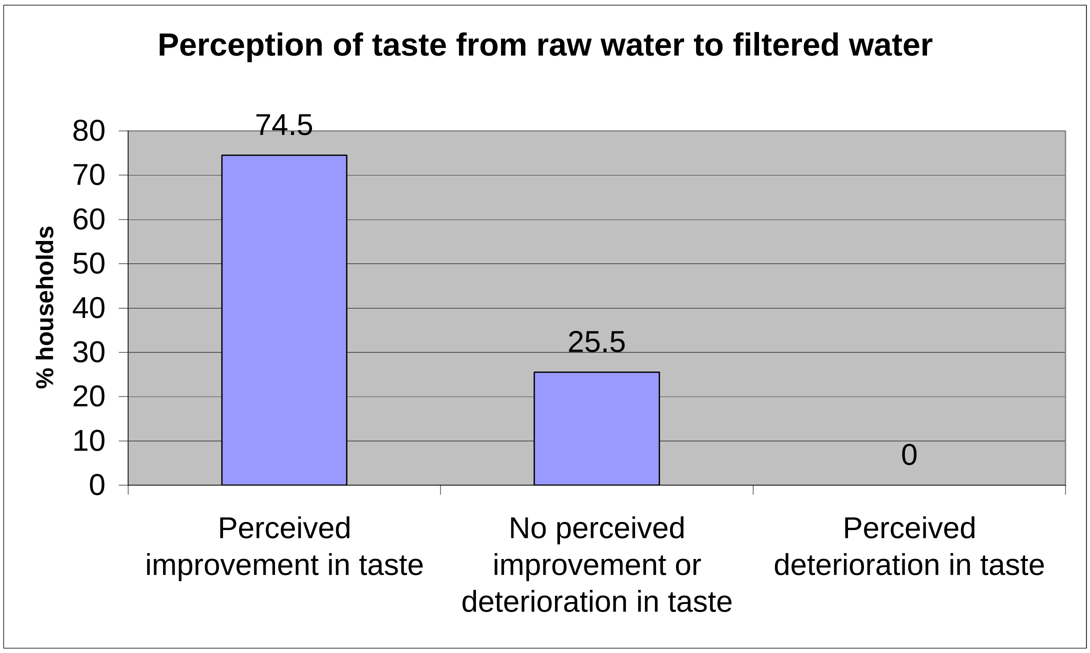
Perception of water to householder

Out of households using filters, number/% of those that showed improvement from RW to filtered water of the following parameters:

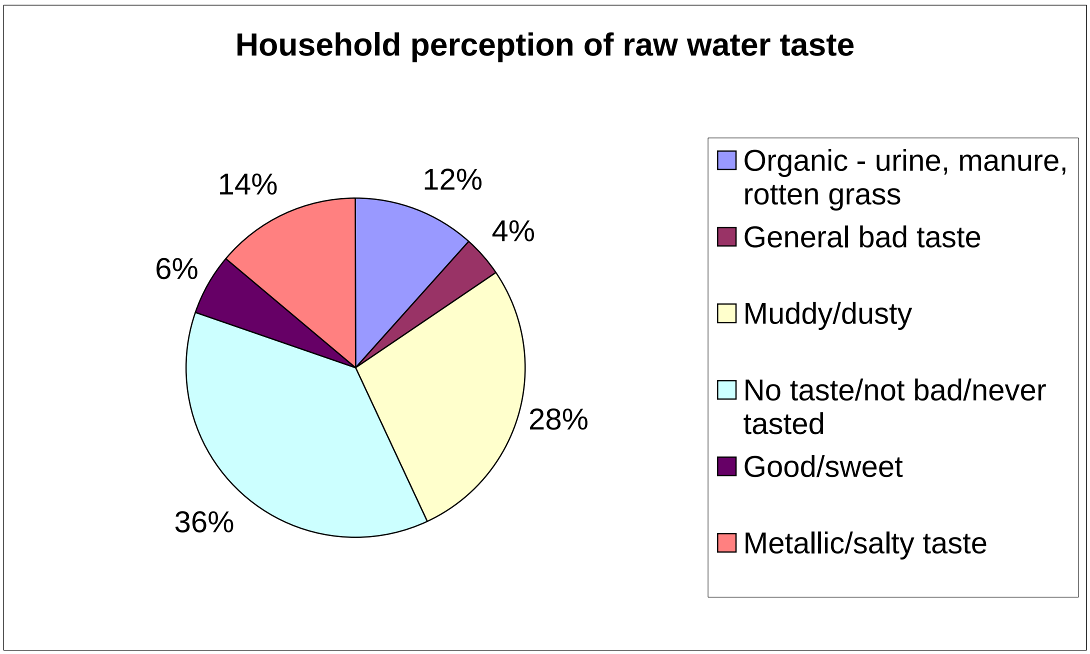
Taste:

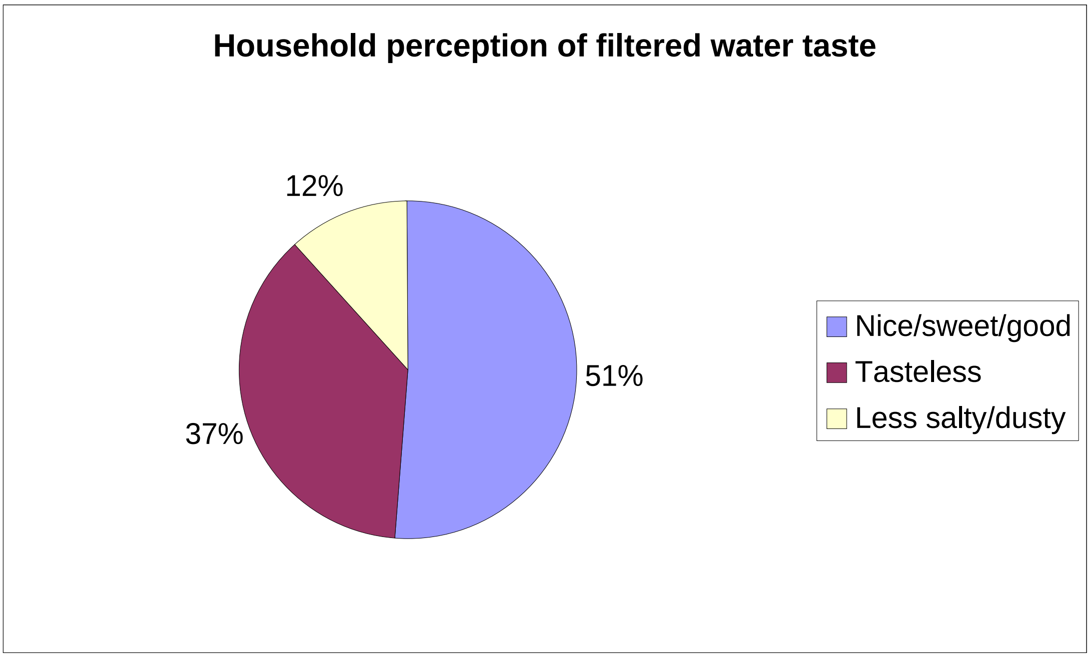
Out of households using filters, number/% of those that showed:

- Perceived improvement in taste from RW to filtered water: 38/51 = 74.5%
- No perceived improvement or deterioration in taste from RW to filtered water: 13/51 = 25.5%
- Perceived deterioration in taste from RW to filtered water: 0/51 = 0%



Perceptions of water definitely tasting good increased from 6% for raw water to 51% for filtered. There were no bad perceptions of filtered water, only one case of rainwater becoming tasteless where it had been sweet before (House 19). Note that taste of filtered water was independent of high or low coliform counts – high CFU counts were recorded even where taste was good.





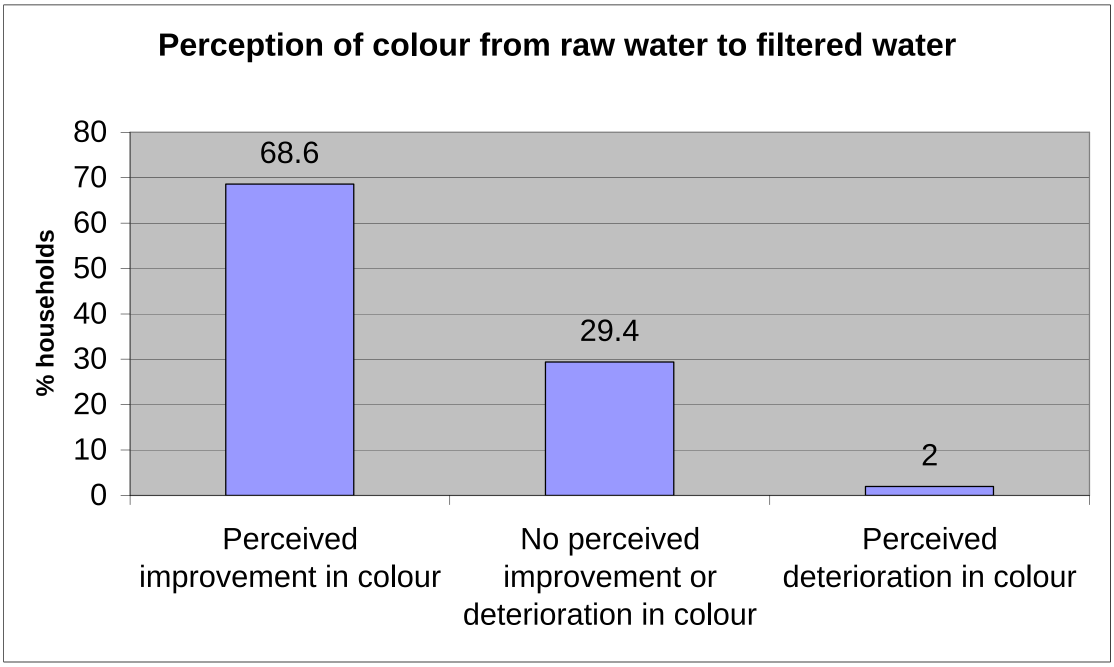
Colour:

Out of households using filters, number/% of those that showed:

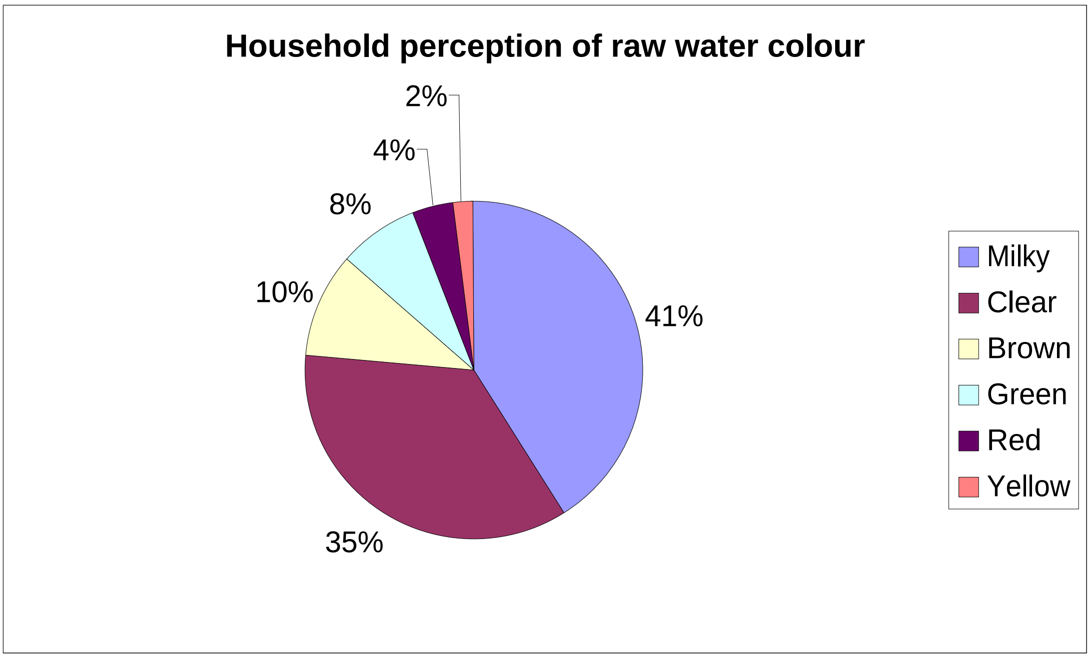
- Perceived improvement in colour from RW to filtered water: 35/51 = 68.6%
- No perceived improvement or deterioration in colour from RW to filtered water: 15/51 = 29.4%

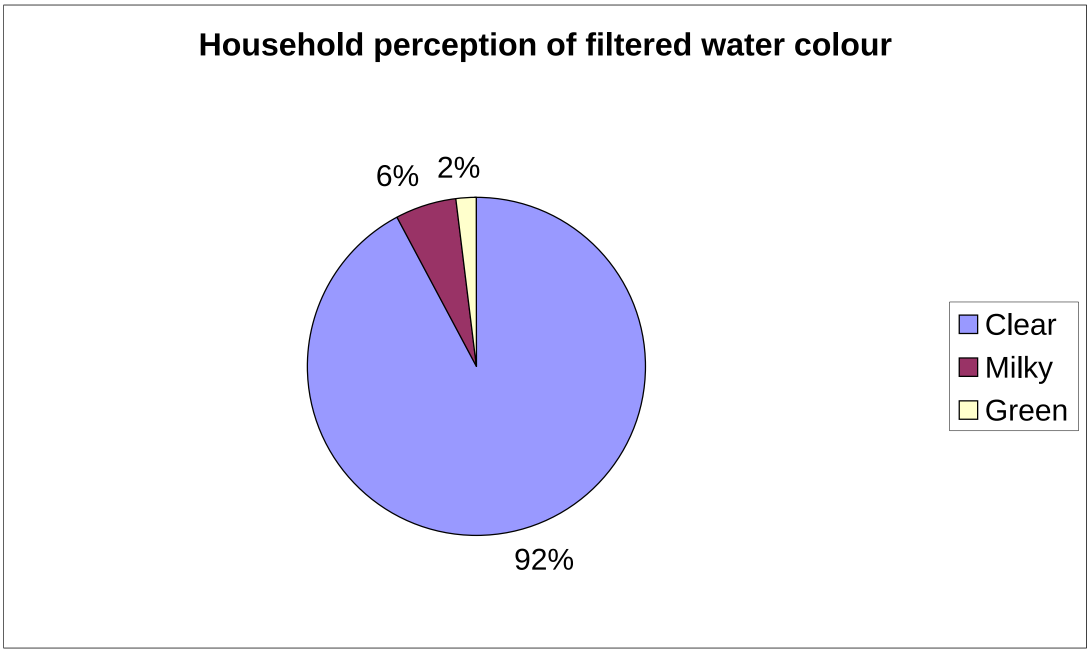
- Perceived deterioration in colour from RW to filtered water: 1/51 = 2%

Note that those households whose filters showed no difference in colour all collected raw water from rainwater, springs or a well.



Perceptions of colour changed dramatically. 35% of raw water was considered clear, compared to 92% of filtered water. Likewise, 41% of households perceived raw water as milky in contrast to only 6% for filtered water. Note that colour of filtered water was independent of high or low coliform counts – high CFU counts occurred even where water was perceived as clear or not.

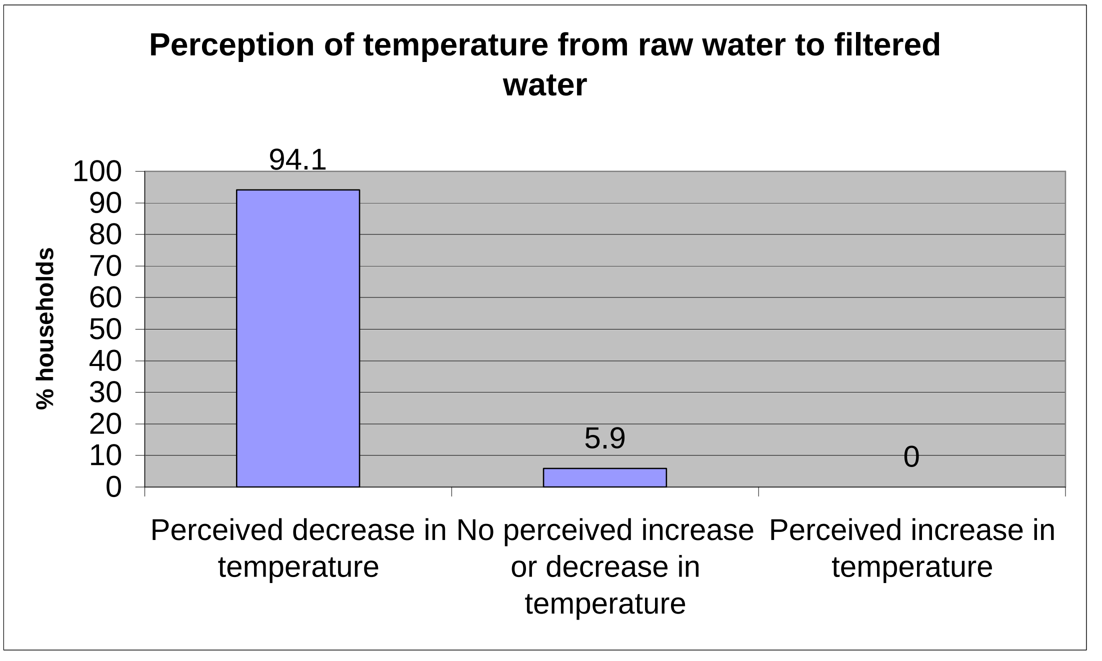




Temperature:

Out of households using filters, number/% of those that showed:

- Perceived decrease in temperature from RW to filtered water: 48/51 = 94.1%
- No perceived increase or decrease in temperature from RW to filtered water: 3/51 = 5.9%
- Perceived increase in temperature from RW to filtered water: 0/51 = 0%

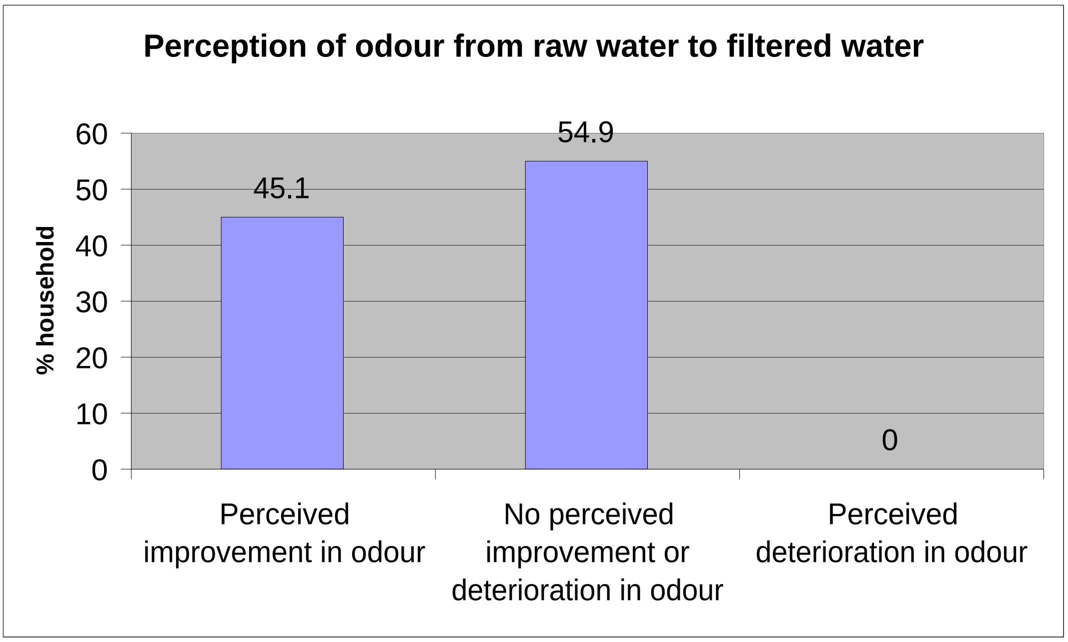


Households generally perceive cold filter water as an advantage.

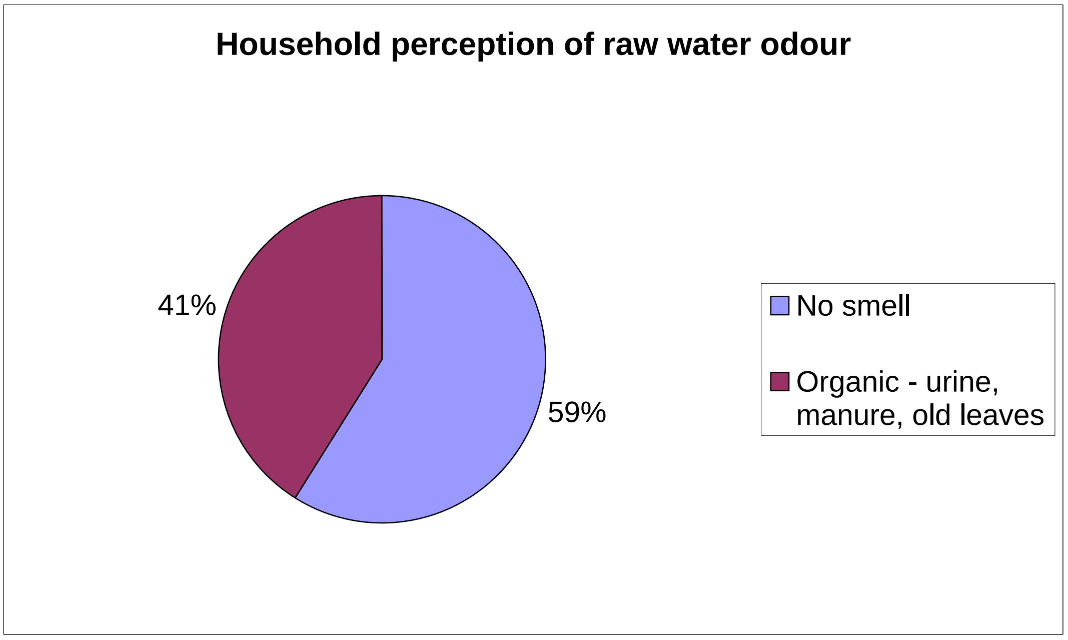
<u>Odour:</u>

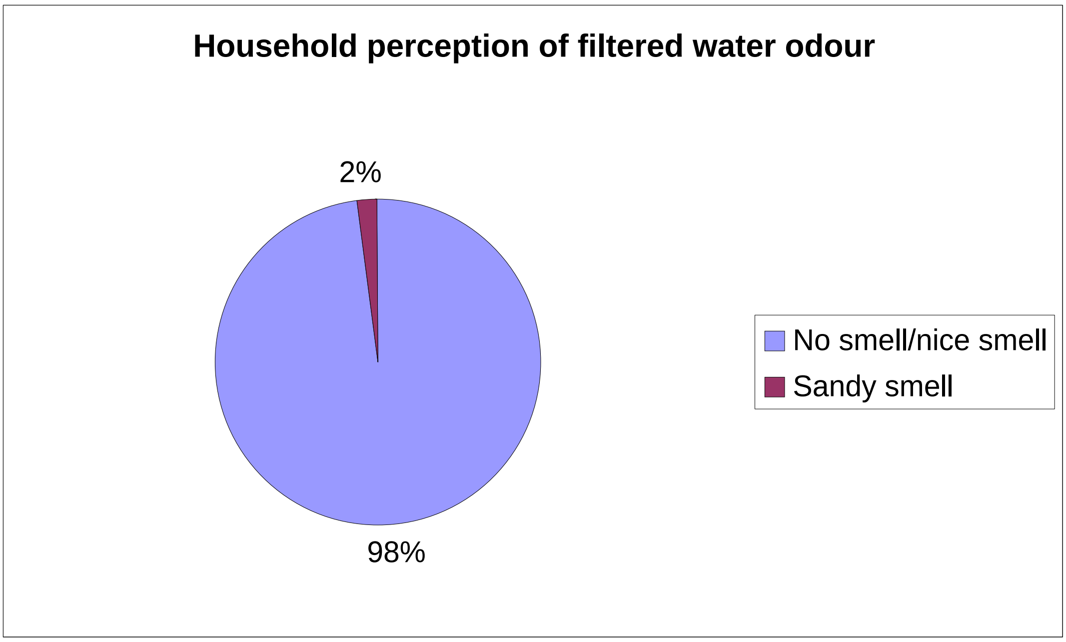
Out of households using filters, number/% of those that showed:

- Perceived improvement in odour from RW to filtered water: 23/51 = 45.1%
- No perceived improvement or deterioration in odour from RW to filtered water: 28/51 = 54.9%
- Perceived deterioration in odour from RW to filtered water: 0/51 = 0%



There was a vast improvement in smell, with 59% of households perceiving raw water as odourless, to 98% perceiving filter ed water as odourless.



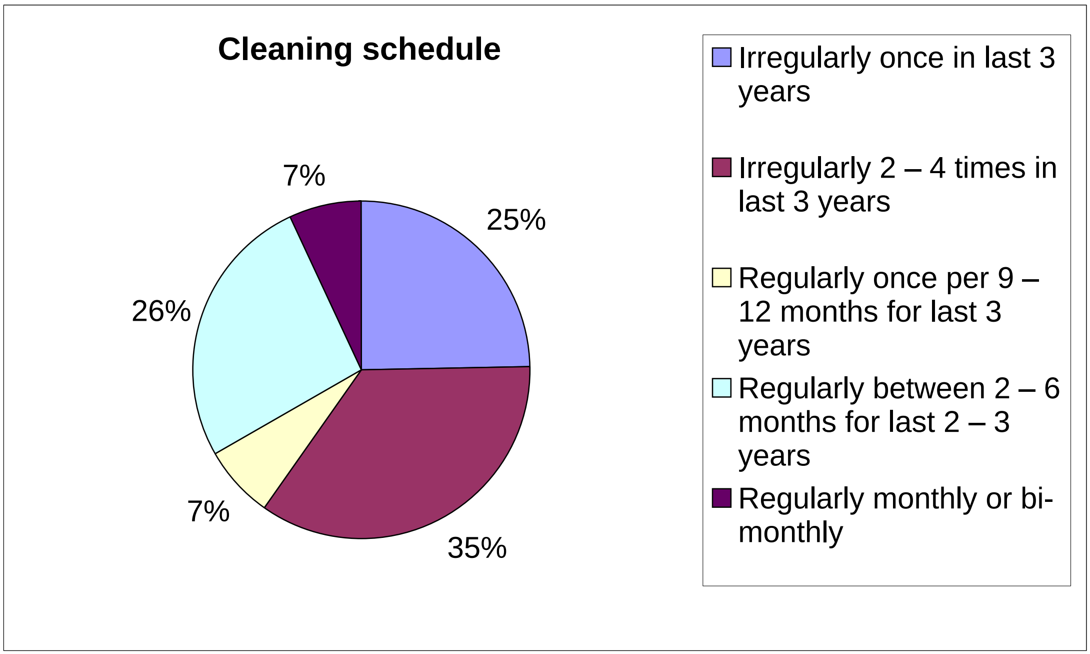

Household perception of filtered water odour
2%
98%
No smell/nice smell
Sandy smell

Cleaning methods and implications

Cleaning schedule

Number/% of ALL filters (used and unused) that were cleaned:

- Irregularly once in last 3 years: 14/57 = 24.6%
- Irregularly 2 – 4 times in last 3 years: 20/57 = 35.1%
- Regularly once per 9 – 12 months for last 3 years: 4/57 = 7%
- Regularly between 2 – 6 months for last 2 – 3 years: 15/57 = 26.3%
- Regularly monthly or bi-monthly: 4/57 = 7%



Cleaning appeared to be either irregular or regular. This depended either on (a) actual blockages or (b) a cleaning routine regardless of whether cleaning was needed or not. About 72% of households had experienced one or more occasions where they had experienced problems in flow (see below for statistics). For those households where cleaning was done regularly because of blockages rather than routine, the intervals between cleanings were less predictable – in these cases, the average time between cleanings was taken.

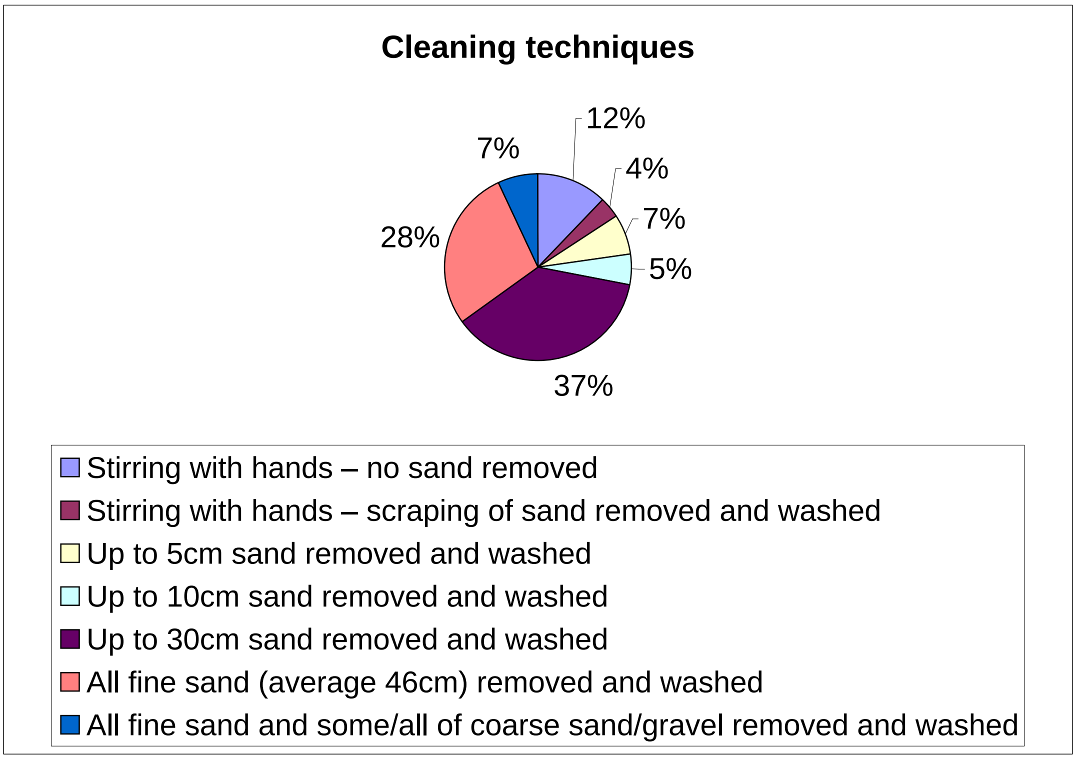
One third of households cleaned their filters anywhere between twice a month and 6 months. 79% of these households did so because of flow problems (4/19 = 21% with no flow problems), meaning only 21% did it out of routine than out of necessity. This can be compared to 28.1% of all households that cleaned at least once or more out of routine rather than necessity (16/57 households – based on the fact of no flow problems). However this fact is skewed by the fact that Samaritan's Purse had done a house-to-house training in August 2001 where filters were shown how to be cleaned. Taking these households out of the equation (ones that only had August 2001 as a cleaning date), we can see that only 15.8% of households clean out of routine rather than necessity (9/57 households – based on the fact of no flow problems). This is backed up by the interviewer's comment that some of the people interviewed cleaned their filter out of routine or because it had been a long time since the last cleaning, rather than because of blockage, although some did their routine pre-emptively to prevent an inevitable blockage later. The sand filter producers explained that when the filters were installed, everyone was explained when and how to clean the filter. Despite this and the Samaritan's Purse training, people can still end up over-cleaning their filter.

Techniques for cleaning

Number/% of ALL filters (used and unused) that were cleaned by:

- Stirring with hands and collecting dirty water – no sand removed: 7/57 = 12.3%
- Stirring with hands and collecting dirty water – scraping of sand removed and washed: 2/57 = 3.5%
- Up to 5cm sand removed and washed: 4/57 = 7%
- Up to 10cm sand removed and washed: 3/57 = 5.3%
- Up to 30cm sand removed and washed: 21/57 = 36.8%
- All fine sand (average 46cm) removed and washed: 16/57 = 28.1%
- All fine sand and some/all of coarse sand/gravel removed and washed: 4/57 = 4%

Interestingly, 12% had figured out that wet harrowing (disturbing the surface) worked very well. This technique seems to work well and has the advantage of needing less work and disturbing the biological layer less. 72% of households washed large amounts of sand per cleaning (more than 10cm) and this was not dependent on whether rainwater or dam water was used as the raw water source.



Out of those that only removed a portion of the sand, number/% that had removed all the sand for cleaning at least once: 27/57 = 47.4%. This shows that about half of the households cleaned the filter sand entirely at least once – this figure includes the 28% that usually removed all the sand for cleaning every time.

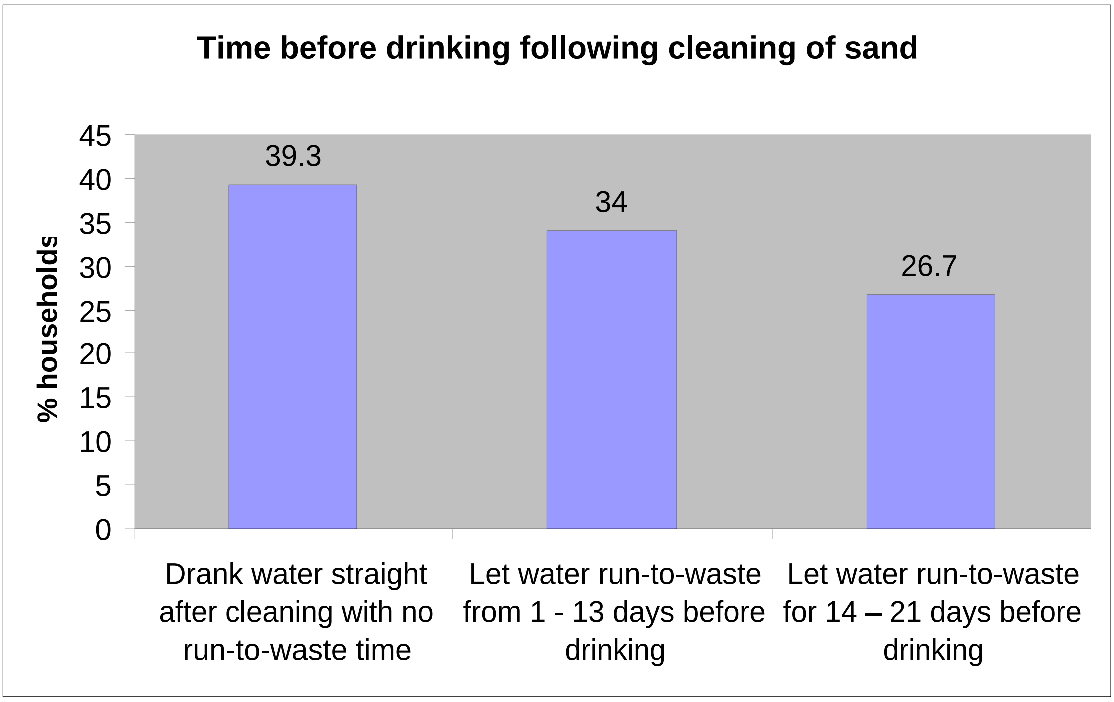
Number/% cleaning filter sand with soap/chlorine/other chemicals: 0/57 = 0%

Number/% cleaning spout or diffuser plate with soap and/or cloth/brush: 3/57 = 5.3%

Number/% of ALL filters (used and unused) where people:

- Drank water straight after cleaning with no run-to-waste time: 22/56 = 39.3%
- Let water run to waste from 1 - 13 days before drinking: 19/56 = 34%
- Let water run to waste for 14 – 21 days before drinking: 15/56 = 26.7%

One household did not remember how long they had waited before drinking, hence the total of 56 instead of 57 households sampled. A large number of households drank water without waiting after cleaning (39.3%) and three-quarters drank water within 2 weeks after cleaning.



Out of those that let water run to waste from 1 - 13 days before drinking, number/% that based readiness for consumption on:

- Sight/taste – clear water: 10/19 = 52.6%
- Technician's advice: 3/19 = 15.8%
- When flow slowed down: 1/19 = 5.3%
- Guessing: 4/19 = 21%
- Pressure from children: 1/19 = 5.3%

Out of those that let water run to waste from 14 – 21 days before drinking, number/% that based readiness for consumption on:

- Sight/taste – clear water: 1/15 = 6.7%
- Technician's advice: 14/15 = 93.3%

From this we can see that those who waited between 2 and 3 weeks before drinking did so almost entirely because of what they were taught by the technicians rather than by sight or other factors. For the three-quarters of households that did not wait more than 13 days before drinking, 84.2% of them did not base their decision on what they had been taught by technicians, and over half of them based this decision on sight/taste alone.

This has implications for the implementation of slow sand filters – if three-quarters of households will either forget or ignore cleaning advice, the filters cannot be viewed as a 100% failsafe method of water purification but rather as a 'better-than-nothing' interim method of water treatment. It could be that information and follow-up about cleaning methods could be done differently and more frequently, but in all probability, there will always be some households who do not get it right. This has to be viewed as a disadvantage of household point-of-use water treatment and weighed up against the many advantages.

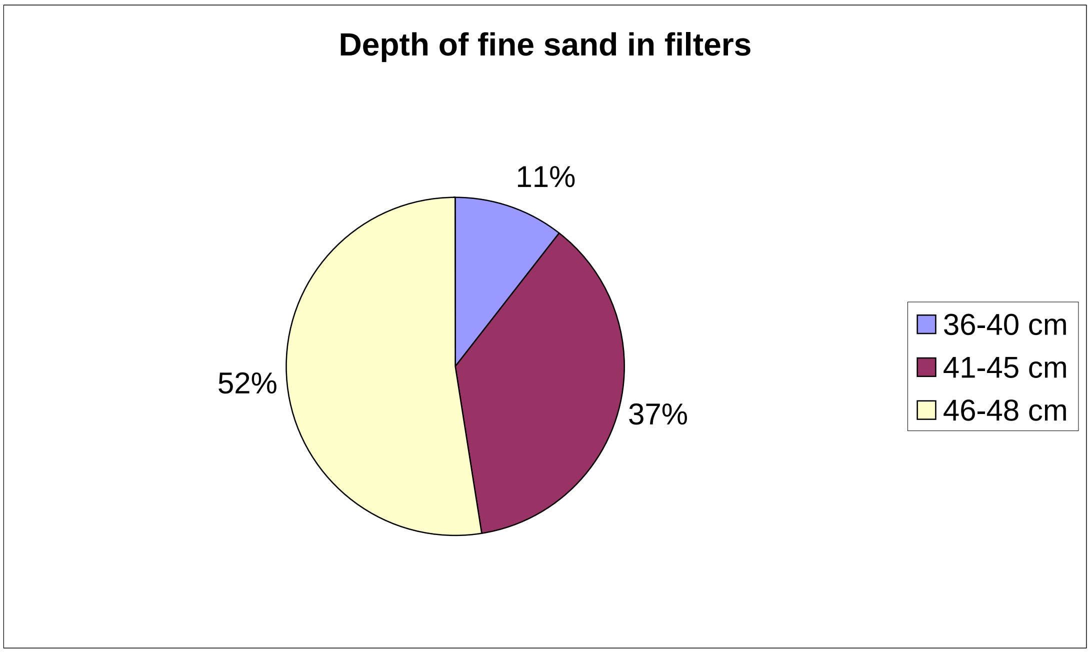
Out of those that let water run to waste (34 households), number/% of ALL filters (used and unused) that ran the following number of litres to waste per day during the run-to-waste period:

- 10 litres: 8/34 = 23.5%
- 20 litres: 11/34 = 32.4%
- 30 litres: 10/34 = 29.4%
- 40 – 60 litres: 3/34 = 8.8%
- Does not remember 2/34 = 5.9%

Number/% of ALL filters (used and unused) that had the following depths of sand remaining (fine sand excluding 10cm gravels):

- 36-40cm: 6/57 = 10.5%
- 41-45cm: 21/57 = 36.9%
- 46-48cm: 30/57 = 52.6%

The sand measured was the fine sand and did not include the coarse sand or gravel. Just over half of all filters had the recommended level of sand for this type of filter. A conclusion here would be to make future filters with a higher initial level of sand (e.g. – 60cm) to allow for an inevitable maximum decrease in sand level of 10 cm that happens due to cleaning and behaviour/knowledge of the householder to replace the sand to a certain level. The advice from Visscher, *et al* (1985) to increase sand depth an extra 10 cm past the biologically active layer, would correlate well with the experience from this evaluation.



Number/% of ALL filters (used and unused) that considered the rate of flow to be:
- Not a problem: 16/56 = 28.5%
- Yes, flow rate a problem one time: 9/56 = 16.1%
- Yes, flow rate a problem sometimes/more than once: 31/56 = 55.4%

There was no data for one household, hence why figures are taken out of 56 instead of 57 households. More than half of all households experienced difficulties with flow rate, where flow rate was slower than what was perceived as convenient. However, the timing of the evaluation coincided with the rainy season, and consequently the quality of the raw water for many households (dam water) was considerably more turbid than normal due to run-off. Some households specifically mentioned that the flow rate problem was seasonal. It seems that during this time, blockages can occur in the filters every few months. A conclusion of this can be that pre-filtration settlement can be encouraged during promotion and sales of the filters. Allowing water to settle prior to filtration would most likely reduce the blockages, as influent for slow sand filters should not exceed 50 NTU on a regular basis (Schulz and Okun, 1984), while the best filtration occurs with water below 10 NTU (Huisman and Wood, 1974).

Other comments that householders had about cleaning/maintenance:
- One household explained that they stored up enough filtered water in advance of a cleaning session, so as to have enough while the filter runs to waste.

Procurement

Number/% of ALL households (used and unused filters) that purchased a filter because of the following reasons (multiple reasons so not adding to 100%):

- Health reasons/awareness: 38/57 = 66.7%
- To save firewood used to boil water = 23/57 = 40.4%
- Wanted clean/clear water: 12/57 = 21.1%
- Heard about it: 2/57 = 3.5%
- Attended seminar: 1/57 = 1.8%
- Heard that the water coming out is cold: 1/57 = 1.8%
- To save time (don't have to boil): 1/57 = 1.8%
- Nice taste: 1/57 = 1.8%
- Safer water for children than boiling water (too hot): 1/57 = 1.8%
- Can use water for washing: 1/57 = 1.8%

In Machakos, it seems that there is a high level of awareness of health benefits associated with the filter. Another clearly important point is that of firewood. It seems that sand filters can be promoted as an environmentally friendly technology.

Number/% of households with used and unused filters that have a painted filter: 10/57 = 17.5%.

All interviewed customers bought the filter for KSh 450. The current price is approximately KSh 1,000[5].

[5] Exchange rate at the time of the evaluation was about 75 KSh to 1 USD.

Filter receptacle

Number/% of ALL households (used and unused filters) that felt that the concrete structure was:

- Good: 54/57 = 94.7%
- Not good: 3/57 = 5.3%

Number/% of ALL households (used and unused filters) that felt that the outlet pipe was:

- Good: 44/57 = 77.2%
- Not good: 13/57 = 22.8%

It seems that structurally the concrete filters are very sound, but there are significant numbers that identified some kind of problem with the outlet pipe. It is not known what the problems were – possibly the dribble factor, or the fact that the outlet can be damaged due to protruding from the concrete. Generally, the interviewer felt that the filters were still in very good condition, probably a result of being stored inside the house (all the filters were inside a building). A few people that said that the structure was good also mentioned that there were one or two cracks appearing, or that they had to do repair work in the past.

Number/% of ALL households (used and unused filters) that:

- Still used the diffuser plate: 51/51 = 100%
- Did not use the diffuser plate anymore: 0/51 = 0%

Number/% of ALL households (used and unused filters) that had modified the filter in the following ways (multiple reasons so not adding to 100%):

- No changes made: 6/56 = 10.7%
- Changed the diffuser plate (due to rusting): 45/56 = 80.4%
- Changed lid: 1/56 = 1.8%
- Hosepipe attached to outlet: 1/56 = 1.8%
- Plastic elbow attached to outlet: 1/56 = 1.8%
- Filter put on raised place and hosepipe attached to outlet that feeds to 10 litre jerry can with tap: 3/56 = 5.4%

One household did not give any information about modifications, so that’s why 56 households are used not 57.

Location of filter in the house

Number/% of ALL households (used and unused filters) that had moved the location of the filter:

- Never moved it: 45/57 = 82.5%
- Moved it once: 9/57 = 15.8%
- Moved it more than once: 1/57 = 1.8%

The conclusion here is that any filter has to be fairly robust as it is likely that some of them will be moved during the course of their lives.

Number/% of ALL households (used and unused filters) where the filter was located:

- Inside the house: 57/57 = 100%
- Outside the house: 0/57 = 0%

Number/% of ALL households (used and unused filters) where the filter was located:

- In direct sunlight: 3/57 = 5.3%
- Out of direct sunlight 54/57 = 94.7%

Number/% of ALL households (used and unused filters) that had a lid:

- No lid: 1/57 = 1.8%
- Lid: 56/57 = 98.2%

Number/% of ALL households (used and unused filters) where the filter/spout was accessible to contamination from:

- Children: 6/57 = 10.5%
- Animals: 0/57 = 0%
- General hygiene state of house: 2/57 = 3.5%

General remarks

Number/% of ALL households (used and unused filters) that were generally satisfied with the filter:

- Satisfied: 55/57 = 96.5%
- No answer: 2/57 = 3.5%

Number/% of ALL households (used and unused filters) that felt the filter was worthwhile purchase:

- Worthwhile/cheap: 57/57 = 100%
- Not worthwhile: 0/57 = 0%

General remarks from owners:

- Price limit would be 1,000 KSh for one householder to buy it – that's the value they put on it knowing its benefit.
- Some householders were unsure about if their cleaning procedures were correct or not and wanted more information
- One said that some other people they knew were mistrusting the filter.
- One said that she was being told by some people that she still had to boil the water after filtering
- One lady wanted to know if she could use chemicals to treat the water before filtration
- One family said it reduced their hospital costs!
- One said that she now felt insecure about drinking unfiltered water from neighbour's homes
- Since using the filter, two families said they never had diarrhoea again since they started!
- One wanted to know why the new filters were more expensive now.
- One lady said other people were asking her where to get the filter from.
- One quote: "Money is powerless compared to the filter"
- One said that it saved her time and now instead of boiling she can now work on the shamba.

References

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