IMPROVING WATER QUALITY BY DESIGN

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Abstract

The quality of water in a rainwater tank is a matter of much speculation, however several techniques can be used to protect and enhance the quality. If these procedures are followed, tank water should conform to the World Health Organisation's "Low Risk" category.

The primary contamination pathways are via vectors (such as lizards or frogs) directly entering the tank and via inlet water.

This first of these is easily blocked for larger animals by screening all inlets and overflows.

A more important path is via the water entering from the roof. As water passes through the air, onto the roof and flows to the tank, it picks up contamination and carries it into the tank. The contaminants tend to adhere to solid matter that is washed along with the water flow and can be filtered using simple techniques. There is also substantial evidence that water quality improves with time, therefore any system that prevents contaminated water from interacting with "aged" water in the tank will also enhance water quality.

This paper discusses inlet and outlet arrangements for water tanks that can easily be incorporated in low-income countries, yet will substantially enhance water quality both by preventing contaminants from entering the tank and by aiding natural water purification occurring in the tank. A brief discussion is also offered on system maintenance for quality enhancement.

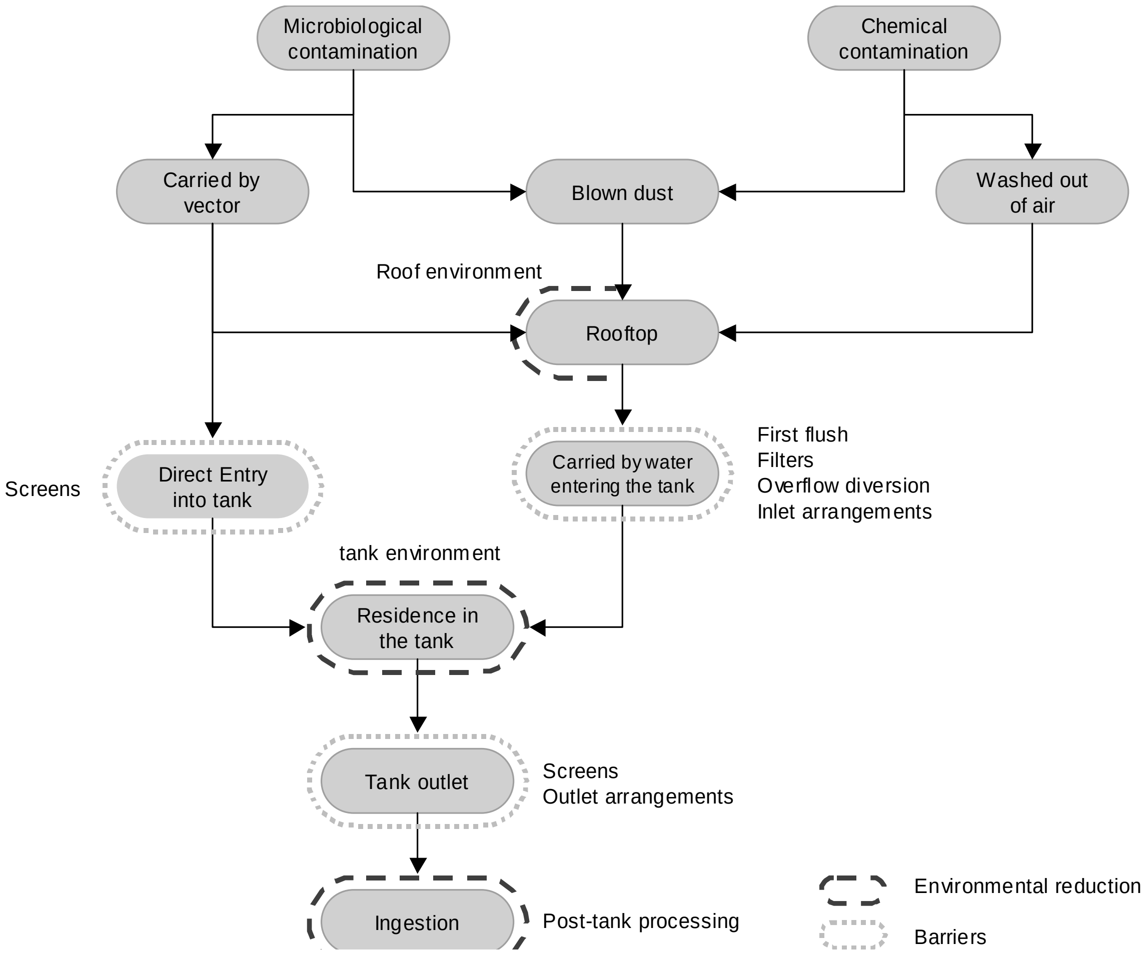
1. Introduction

The water quality of rainwater harvesting (RWH) systems is becoming an issue of increased interest, particularly to water professionals considering adding RWH to their technological mix. A large number of studies (e.g. Ariyananda, 1999; Coombes et al., 2000; Vasudevan et al., 2001; Wirojanagud, 1990) have shown that well kept rainwater is a good quality source, usually within the WHO “low risk” category (WHO, 1997). Poor practice will however reduce the quality considerably. Conversely there are a number of simple techniques that can be used to *improve* the quality of water in the system. Such techniques draw particularly on German, Japanese and Australian best practice.

2. The path of contamination

To decide on the best strategy to reduce contamination in roofwater systems, it is useful to observe the path a contaminant must follow in order to enter a potential host. The usual paths available are shown diagrammatically in Figure 1.

Figure 1: Contamination paths for roofwater harvesting



Of the available paths, the direct entry of contamination is seemingly the simplest route to block, indeed many of the usual pieces of advice (tight fitting lid, screens on all outlets) are directed toward this. However it can prove very difficult in the field to totally eradicate all possible disease vectors, since the smallest of creatures such as insects will find *any* hole in the tank's defences. Larger animals, particularly mammals and birds who represent the highest disease risk to humans, can, however be excluded by ensuring all inlets and outlets are screened.

The remaining paths rely on the contaminants being washed in from the roof. It is reassuring to note that an impermeable roof (particularly one made from steel) is an extremely hostile environment for human pathogens, which have evolved to live in a warm, wet, low-oxygen environment. The dry heat typical of a metal roof under bright sunlight will effectively kill many of these pathogens. This effect is borne out by the usually lower microbiological indicator levels from metal roofs as compared to other roof types (Yaziz et al., 1989).

3. Inlet screens

As the water must pass from the roof to the tank inlet, the conveyance is a prime candidate for placing a filter to block any contamination from entering the tank. The vast majority of contaminates will be stuck to debris from the roof so removing the debris will also remove

Table 1: Pros and cons of various filter positions

Type	Pros	Cons
In-Gutter	• Prevents leaf build-up in gutter thus; – removes fire hazard – reduces mosquito breeding – avoids cleaning chore	• Can be expensive due to large areas to be covered • Poor installation can; – increase leaf build-up due to leaves catching on filter – make cleaning what isn't filtered more difficult
At downpipe	• Central location minimises filter area • Can be combined with a drop to increase efficiency • Can replace downpipe connection as gutter box • Can be self cleaning (to an extent)	• Difficult to clean due to height • If simply placed into gutter-level downpipe connection can block entire gutter
In Downpipe	• Increase in filter area due to length of downpipe available • Low space use • Wetting requirement means first flush is dumped	• Uses more than 10% of water for self cleaning action • Requires more complex design • Poor design can lead to excessive water loss • Difficult to access for cleaning • Blockages not obvious
In-line (underground)	• Removes mounting problems • Easily accessed for cleaning	• Only useful for underground tanks • Poor design can lead to ingress of stormwater into the tank
At tank entrance	• Simple and inexpensive installation • Can be as simple as a cloth over the tank inlet • Very visible	• Entrance to tank is available to accidental (or deliberate) contamination • Reduces possibility of any further filtration

the contaminant. Removing debris also reduces the level of nutrient reaching the tank and thereby impedes mosquito larvae development and long-term survival of bacteria.

The filter can be anywhere along the conveyance path from the gutter entrance to the tank inlet. Table 1 shows the pros and cons of various positions on the conveyance path.

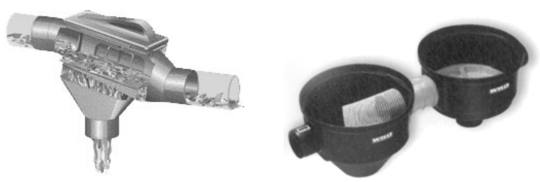
A key constraint to any filter in a rainwater harvesting system is that it should be capable of dealing with the high flows associated with high rainfall intensities. A 2mm/min peak intensity translates into a 1.7 l/s flow on a $50m^2$ roof or a flow of 85l/h through a Ø30cm filter. A more typical flow for a “rapid” water treatment filter is 8-40 l/h (Droste, 1997).

Criteria that should be met for inlet filters are set out below:

- The filter should be easy to clean or largely self-cleaning
- It should not block easily (if at all) and blockages should be obvious and easy to rectify
- It should not provide an entrance for additional contamination
- The total cost should not be out of proportion with the rest of the system (5-10% of the tank cost should be considered a maximum in all but the most fastidious of households)

An answer to the problems of blocking and self-cleaning being applied in several countries is to split the inlet filter into two; a course leaf filter and a fine filter. As shown below in Figure 2

Figure 2: Two examples of staged filters



Source: 3P Technik　　Source: WILO

Similar solutions can easily be applied to low-cost devices

Rott and Mayer examined a number of filter designs available in Germany and reported the results according to hydraulic efficiency and efficiency in material removal (Rott & Meyer, 2001). Similar experiments are underway at the DTU for low-cost filters suitable for use in developing countries and results will be available as a supplement to this paper by conference time.

3.1. Coarse Leaf filters

The first line of defence is a coarse leaf filter. The filter can be installed anywhere from the gutter to the entrance to the tank. It need not be especially fine (a 5mm grid is sufficient) and so no problems should be encountered with flow rate through the filter and the filter itself can be removable for cleaning.

3.2. Fine filters

Most fine filters used in developing countries are based on sand or gravel. These filters can be used for roofwater harvesting systems, however there can be problems with upkeep as householders often dispose of the filter media when it blocks, replacing it with courser media or nothing at all (Ranatunga, 1999). In developed countries, self-cleaning filters are available with a fine mesh screen (typically 0.4mm). These screens use the first flow of water from a storm to flush the filter of debris (3P Technik, 2001)or have a continual washing action using about 10% of the water (WISY). In smaller, low-cost roofwater systems there is usually significantly more water available from the roof than the tank can contain, so self-washing filters can be viable using cloth as a filter.

3.3. First flush

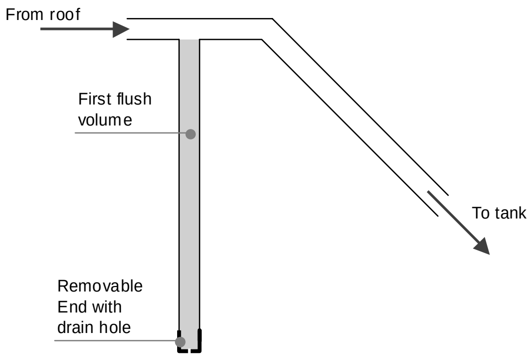
First flush systems are becoming more common. Contaminants from a roof are usually concentrated in the first run off from the roof. After this runoff has passed and washed the roof the water is considerably safer so a useful alternative to fine filtering is to remove the first part of the rainfall. At the most extreme case all water from the first storm of the new wet season should be thrown away, as the roof will be very dirty after the dry season. After that throwing away the first millimetre of rainfall of each storm is usually sufficient.

Several arrangements have been used for first flush diversion of which the simplest is to move the downpipe to one side at the start of the rains. This does, however rely on the user both being at home and prepared to go out into the rain to do this.

A simple automatic method is to add an extra closed off section of down pipe before the tank inlet as shown in Figure 3. It has been shown (Michaelides, 1987) that placement of the pipe is critical to the efficiency of the mechanism. The pipe should be from a horizontally flowing section of downpipe. This will reduce mixing in the first-flush system itself and greatly improve its performance.

The amount of water flushed will be the capacity of the pipe divided by the roof area. The cap at the end of the pipe must be removable to facilitate cleaning. A small hole in the cap will allow the pipe to empty over a period of hours, resetting the system for the next rainfall. If this hole is not added, the system must be drained down manually. Failure to do this will result in a pipe full of contaminated water that will not only fail to work for the next storm, but can cause additional pollutants to be washed in to the tank from the first flush device itself.

Figure 3: Pipe first flush arrangement



4. Inlet and outlet arrangements

As water is resident in the tank its quality improves with time. (Droste, 1997) Small particles sediment out and bacteria die off. Water entering the tank tends to be of a lower quality than the stored water in the tank and it is desirable that the new water should not mix with the older water. Current German best practice (Deltau, 2001) is to arrange the inlet so that it goes all the way to the bottom of the tank as shown in Figure 4. A ring of material surrounding the inlet will break the downward flow and prevent it from disturbing any settled material. With this arrangement, the incoming water will remain in a zone on the bottom of the tank and will not disturb the aged water above it.

Figure 4: Ideal inlet arrangement

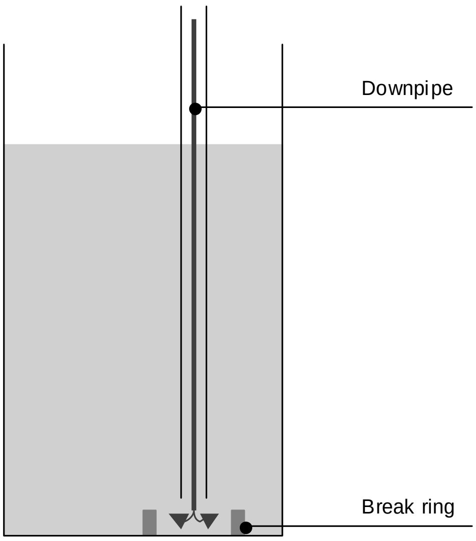


Figure 5: Examples of downward facing inlets with break ring

a. Commercial example from Germany

b. Mortar ring in Sri Lanka

Source: WILO

The outlet to the tank is similarly important. As the dirtiest water is at the bottom of the tank, it is best to take the water from the top. To do this the outlet must be on a flexible hose with a float at the top as shown in Figure 6.

The float can be anything that floats; successful examples have been made from discarded mineral water bottles. To prevent entry of floating matter, the entrance to the hose should be about 2" below the surface of the water.

Figure 6: Ideal Outlet arrangement

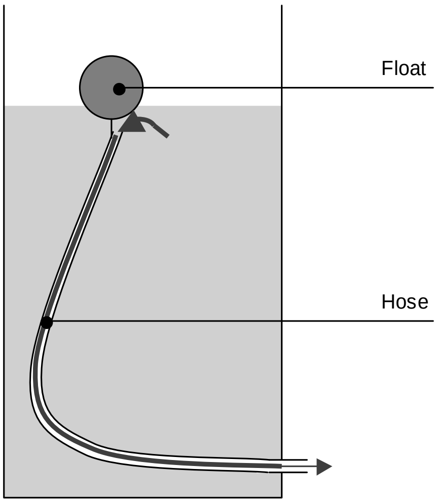


Figure 7:Examples of Floating off takes

a. Commercial example from Germany

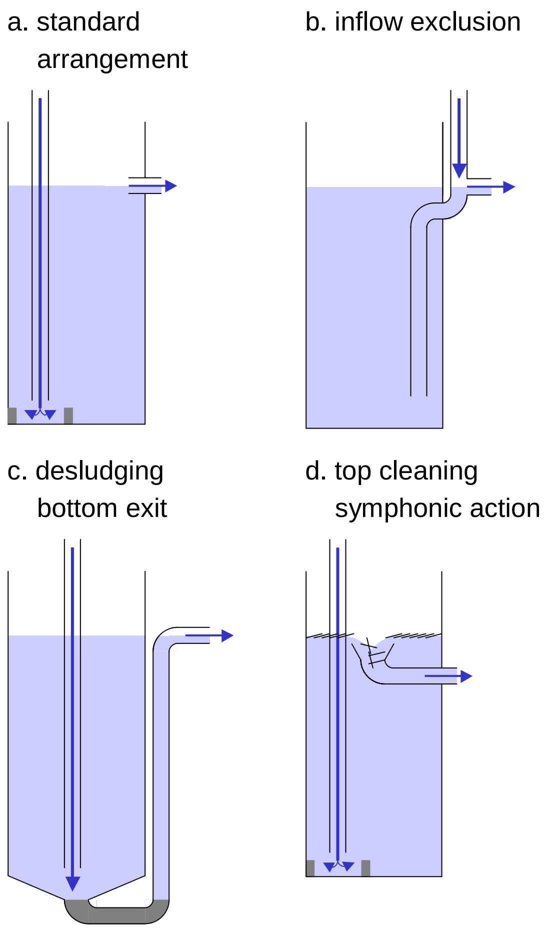
Source: WILO

b. Floating off-take in Uganda

5. Overflow arrangements

The overflow from the tank can improve or protect water quality. The standard overflow shown in Figure 8a simply throws water from the top of the tank. If the bottom-in top-out arrangement is used, this will be the cleanest water, which will be thrown away replacing it with dirty water from the roof. A better arrangement is shown in Figure 8b where the overflow water bocks any incoming water, preventing it from mixing with the water stored in the tank. This is probably the best arrangement for tanks of less than $2m^3$.

Figure 8:Overflow arrangements



For larger tanks with well-designed inlets, the mix water will have a lower impact and can therefore be used to perform cleaning tasks to actually improve the quality of water in the tank. Figure 8c shows an arrangement where the overflow water is taken from the bottom of the tank. This means that the overflow water will be the dirtiest water and will also carry any settled matter with it. A tank with an overflow of this design will never need desludgeing but will need to have any floating matter skimmed from the water surface periodically. In an area where most material entering the tank floats to the top, the arrangement shown in Figure 8d may be preferable. In this configuration the overflow acts as a suction pump as the water must accelerate to fall into the overflow pipe. This tends to suck any floating matter into the overflow, cleaning the top of the tank.

6. Conclusions

The state-of the art for water quality enhancement has improved greatly in recent years, thanks mainly to the adoption of RWH for service water in several quality-conscious highincome countries, with a subsequent increase in research and product development. Many of these new ideas can easily be incorporated into designs used in low-cost systems with subsequent improvements in water quality.

7. References

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