A review of water resources management in buildings.

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Abstract— With the ever increasing cost of potable water, building services engineers always strive to reduce water wastage in their designs. They also explore ways of recycling grey water and harvesting and utilizing rain water. The main focus of this paper is to review the latest technologies employed by building services engineers to minimize water wastage, to recycle grey water and to harvest and utilize rain water.

Keywords— Potable water, building services engineers, recycling, grey water.

I. TECHNIQUES USED IN MINIMIZING WATER WASTAGE

Water is often lost because of leakages, excessive use for such activities like flushing, the extra dispersion of water that is lost after hand washing as controlled by infrared sensors, cleaning utensils in high flow taps, leakages etc.

The following practices and techniques have been used to minimize wastage of water.

- Reduction of leakage by installing warning pipes in positions that can be readily seen or employing systems that gives audible alarm in case of overflow. Lining pools and ponds with impervious membranes also minimizes water wastage.
- Use of 6 litre or dual-flush cisterns. [1] Dual-flush cisterns are required to give a maximum full flush of 6 litres and a lesser flush volume of two-thirds that of the full flush i.e. 4 litres. Also permitted are “pressure flushing cisterns” which use incoming water pressure to compress air which in turn is used to increase the pressure of the water available for flushing the WC pan.
- Use of time control to shut off water when not in use.
- Use of low flow (and pressure) showers and taps.
- Use of self closing taps.
- Use of showers in lieu of bath tubs.
- Recycling of grey water.
- Harvesting and utilization of rain water. Where recycled grey water or rain water is used to augment mains water, precautions should be taken to protect the mains water supply from contamination.

II. GREY WATER RECYCLING

With the term ‘’greywater’’ we refer to wastewater originating from showers, washbasins and washing machines, which after appropriate treatment can be used to supply non-potable water uses such as toilet flushing, garden irrigation, car and floor washing [2]. According to Fangyue et al, the combination of aerobic biological process with physical filtration and disinfection is considered to be the most economical and feasible solution for grey water recycling [3]. The simple septic tank is the most familiar biological treatment method for onsite wastewater management [4]. A septic tank is a simple tank made of concrete, fiberglass or polyethylene which must be buried in the yard of the house. A septic system is normally driven by gravity where water runs down from the house to the tank and then down from the tank to the drain field. The tank consists of three layers named Scum Layer, Water Layer and Sludge Layer. Scum is produced in the scum layer whereas water layer consists of partially treated liquid which is free of solids but has bacteria and chemical. In the sludge layer solids are collected and digested by anaerobic bacteria. The elevations of pipe keep the septic tank almost full all the times which practically allows bacteria to absorb all the solids that enter the tank.

III. CHALLENGES ENCOUNTERED IN HARVESTING AND UTILIZATION OF RAIN WATER

The following are some of the challenges encountered in rain water harvesting and their proposed solutions.

- Mosquitoes; mosquitoes require a small body of water for breeding. Sag or any detail in the roof or gutter which can hold water is a good breeding area for mosquitoes. Such sags and details should be avoided to ensure that flat roof, gutters etc stay dry after rainfall. Mosquito screen meshes should also be installed on overflow pipes, inlet pipes or other openings to make sure mosquitoes don't get into rain water collection tanks [1].
- Rodents and vermin; use of screen mesh prevents rodents from occupying rain water pipes.
- Treatment of rain water to make it potable; rain water should be filtered of sediments and treated to kill pathogens. This treatment could be use of chlorination, UV treatment or other appropriate means.
- Augmenting of traditional water sources with collected rain water; this is not straight forward since it would be preferable to utilize rain water as soon as it is available, that means shutting off traditional water sources. For example, as soon as it rains, a user would like to shut off municipal water and utilize the harvested rain water. The electronic control system for this arrangement would have to be custom made (not out of the shelve solution). Contamination due to backflow should also be guarded against. This adds to the complexity of the system. Three possible solutions to this problem are suggested here;

a) **<u>Use of electronic logic control system and a solenoid valve</u>**

In this arrangement, municipal water is shut off by the solenoid valve in the event that rain water is available. A sketch of the arrangement is shown in Fig. 1. A limitation of the use of a solenoid valve is that most manufactures use a weak electrical signal to operate the solenoid valve. This means that a long electrical cable between the rain water tank and the solenoid valve can't be used (longer cable offers more electrical resistance). This limits the distance between the rain water collection tank and roof tank (because too long an electrical signal transmission cable is not allowed). Notice that separate balls valves are used so as contamination protection of the municipal mains can be achieved. Type AA gaps are employed in the ball valves as a means of contamination protection. The control panel is wired such that when water is full in the rain water collection tank, the solenoid valve shuts off the municipal supply mains and depending on the water level in the roof tank, the pump will or will not start. If for example there is water in the rain water collection tank and there is little or no water in the roof tank, the pump conveys water to the roof tank. Remember that as long as there is water in the rain water collection tank, the solenoid valve shuts off municipal water and only rain water can be used. Developing a truth table and logic gates for the control panel for this arrangement is highly customized i.e. the arrangement is not common and therefore not commercially available.

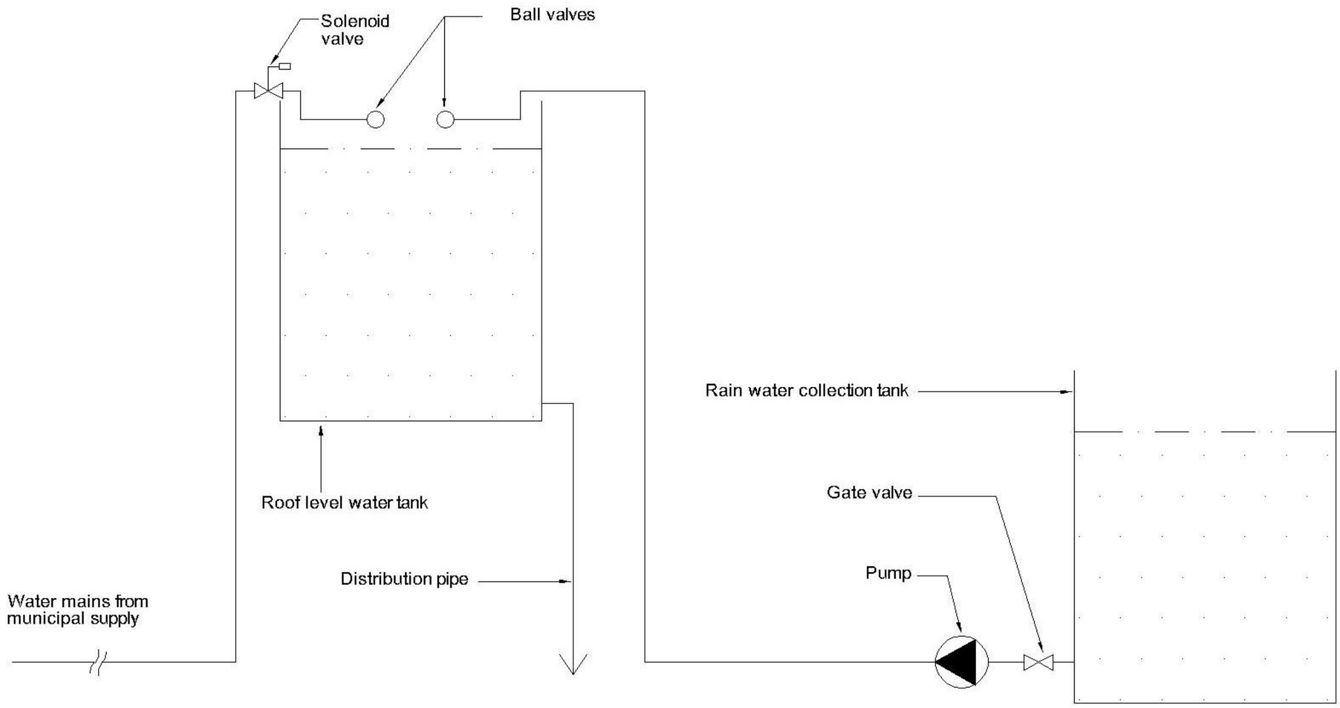

Fig. 1

b) **Use of electronic logic control system to control multiple pumps**

This arrangement is most suitable for elevated level tanks whereby multiple pumps are employed. The arrangement is as shown in Fig. 2. Solenoid valves are not utilized in this arrangement. When the rain water collection tank contains sufficient water, the control panel shuts off the municipal water pump and therefore only the rain water can be utilized (via rain water pump). Notice also that two float valves are used as a means of contamination protection. Use of two float valves is not very desirable because of the cost, multiple puncturing of the tank and servicing requirements. Combined check valve and vacuum breaker could be used to replace one float valve in case where contamination risk is not category 1 [1].

c) Manual closing of gate valve or switching off of pumps

In the situation shown in Fig. 1, the solenoid valve can be replaced by an ordinary gate valve. The gate valve is to be closed by hand to shut off mains water supply in the case where only rain water is to be utilized. In the situation shown in Fig. 2, the municipal water pump set is manually switched off (disconnected from power supply) when it is desirable that rain water in the rainwater harvesting tank is to be utilized. The problem with this manual closing of gate valves and switching off of pumps is the continuous monitoring of availability of rain water. It would be an inconvenience if one was to wake up in the night to shut off a gate valve or switch off pumps because it has just rained.

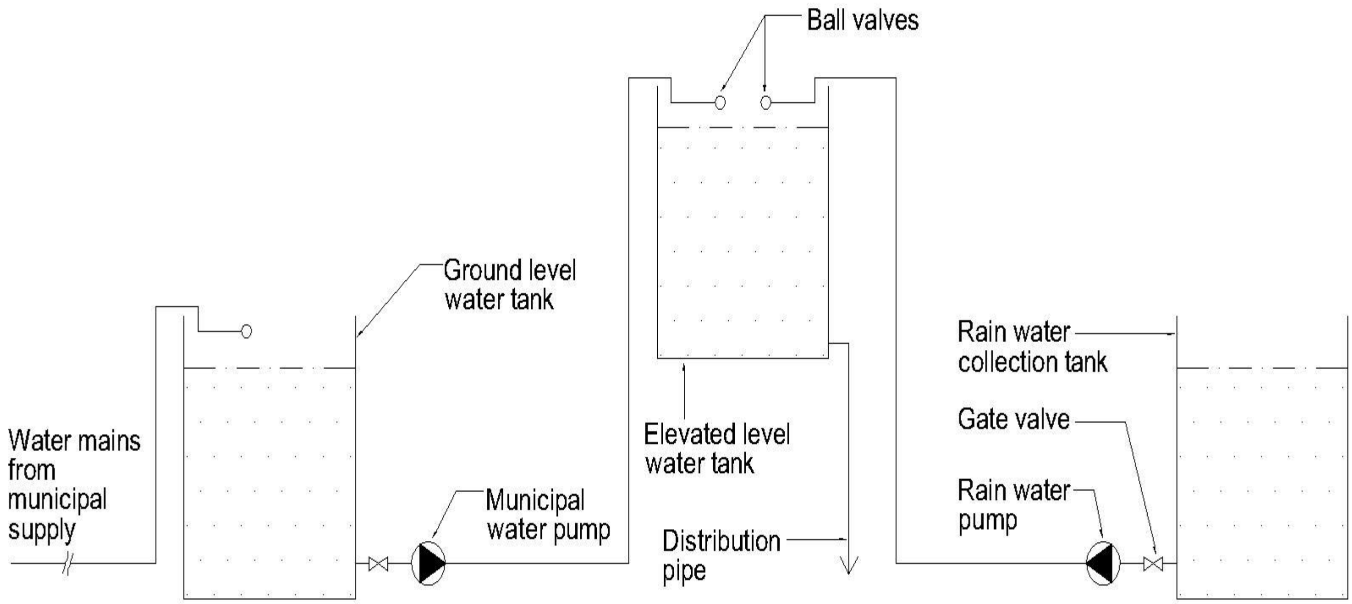

Fig. 2

IV. CASE STUDY

As part of my work, I designed (under the supervision of a licensed Practicing Engineer) rain water harvesting and reticulation system for Proposed Lunga-lunga and Taveta One Stop Boarder Posts. The buildings are roofed with the stone coated steel sheets branded as Decra. This roofing material is suitable for rain water harvesting since it does not contain such toxins as asbestos and lead. I obtained the relevant data e.g. the design rainfall intensity from meteorological data compiled by the Kenya Meteorological Statistics and the effective roof length from architectural elevation drawings. I was then able to calculate the rate of run-off, gutter flow rates and gutter size, vertical rain water pipes sizes and spacing and to determine the capacity of the rain water storage [5]. This part of the design was easy and straight forward because I consulted such elaborately expounded design guides as those of CIBSE and The Institute of Plumbing. I consulted manufactures' catalogues like Terrain and Wavin in selecting appropriate gutters, pipes, fittings and accessories.

The hard part however was the external reticulation of harvested rain water. In one instance I was supposed to convey harvested rain water to a roof level tank as described in Fig. 1. The rain water did not need treating because it was not meant for drinking but for toilet and urinal flushing. The challenge was to design the system so that the utilization of harvested rain water is prioritized over that of water from municipal supply. I consulted water pump and water pump control panel dealers like Davis and Shirtliff and I was given detailed specifications for appropriate pump control panel and solenoid valve.

In another instance of my design, I encountered a challenge whereby harvested rain water had to be treated to make it potable and reticulated to the various end points. Safeguarding water mains from municipal supply against contamination was one of my concerns. I chose to use type-AA air gap between the ball valves outlet (two separate ball valves as shown in Fig. 3) and the highest water surface as a means of contamination protection. As for treatment of the rain water, I chose chlorination over UV-disinfection and ozone treatment. This was because on one hand UV-disinfected water ought to be consumed almost immediately. When stored for a long time, UV-disinfected water can easily get contaminated by pathogens. On the other hand, ozone treatment requires that ozone, unlike chlorine, be generated on site. Ozone has a short half life (about 20miutes) and is therefore difficult to store [6]. Chlorination has the benefit that residual chlorine guards stored water against contamination (an advantage over UV-treatment). It also has the benefit that liquefied chlorine or hypochlorite solutions are stable and can be stored for a long time and hence no need to generate chlorine on site. I consulted water treatment companies to fine-tune my chlorination treatment design and they proposed appropriate filtration equipment, chlorine storage and dosing equipment, circulation pump among others.

In the same instance, my design specification was that the harvested rain water be temporarily stored in a ground level tank before being treated and conveyed to the elevated tank as shown in Fig. 3. The challenge I encountered here was that the elevated water tank and municipal water pump set had already been installed. Synchronizing the already installed municipal water pump set with the yet to be installed treated rain water pump set so that utilization of treated rain water is prioritized was the biggest challenge. My initial idea/suggestion was to wire the pumps and float valves (ball valves) so as to approximately comply with the sketch circuit shown in Fig. 4. S1 is a double throw (2-way) float switch installed in the treated rain water collection tank (refer to Fig. 3). P2 is the treated rain water pump. S3 is the ball valve (float switch) installed at the treated rain water inlet of the elevated level tank. S2 is the ball valve (float switch) installed at the inlet of the ground level tank i.e. connected to the municipal water mains as shown in Fig. 3. P1 is the municipal water pump. S4 is the float switch at the elevated water tank that serves municipal water mains line. The circuit is supposed to operate in such a way that if there is sufficient treated rain water in the treated rain water tank, the two way switch S1 positions itself in the state shown in Fig. 4 i.e. closed state, trying to complete loop S1, P2, S3 and Source. If there is insufficient water at the elevated tank, float switch S3 closes and pump P2 runs, filling the elevated tank with treated rain water. When the elevated tank is full, float switch S3 opens and hence switching off pump P2. At any instance that there is sufficient water in the treated rain water tank, the 2-way float switch S1 is in the position shown in the diagram. This means that only pump P2 can operate and hence prioritizing utilization of rain water over the municipal water. When there is insufficient water in both the treated rain water tank and the elevated tank, while at the same time there is sufficient water in the ground level tank, the circuit loop Source, S1, S2, P1 and S4 will be complete. This means that pump P1 will pump municipal water to the elevated tank.

After a wide consultation about the design problem, it was decided that the existing pump control panel for the municipal water pump set be replaced by a PLC gadget (programmable logic circuit) so that the PLC can control both sets of pumps (municipal water pump set and treated water pump set).

This was because my sketch circuit (Fig. 4) is too basic. It does not show such complex detail as automatic change over between duty and stand-by pumps, 'running' and 'trip' neon lights, overload and power surge protection, does not provide for manual override, and is fixed wired (not reprogrammable).

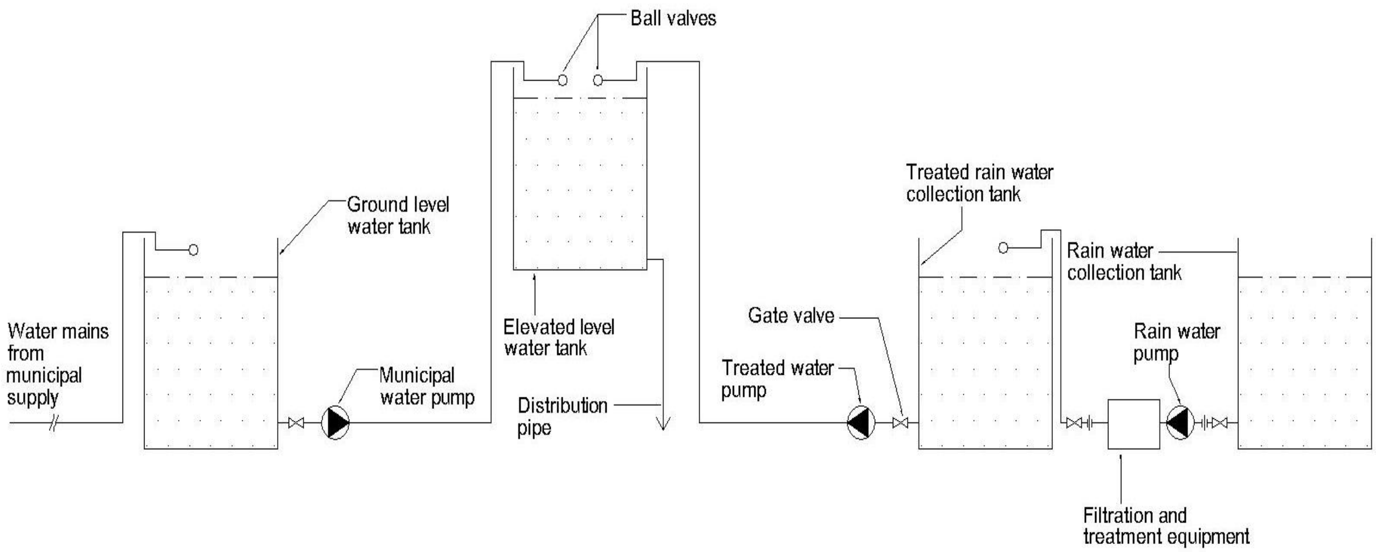

Fig. 3

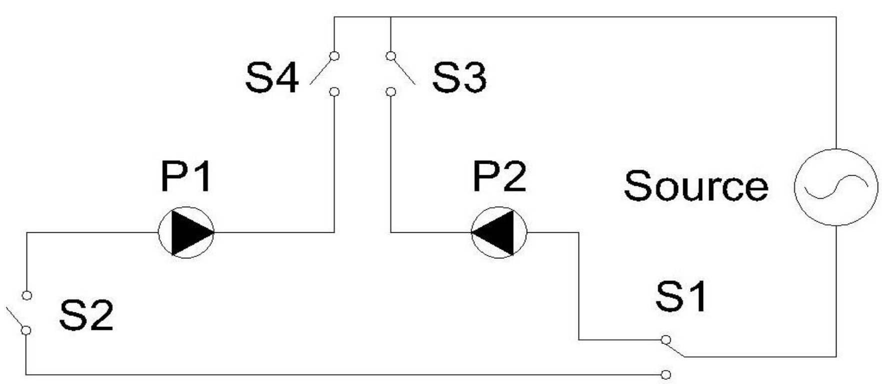

Fig. 4

V. DISCUSSION

Water resources management in buildings can be achieved by leakage prevention, utilizing of low water usage sanitary fittings and appliances, grey water recycling and rain water utilization. Grey water recycling and rain water utilization are faced by the following challenges;

- Automation of the conveying of rain water to utility points in preference to traditional water sources is a big challenge. Two arrangements and their possible solutions have been discussed in this paper. Other challenging arrangements exist, for example when one has municipal water, underground water, private reservoir water and rain water. Logic circuits for the pump and solenoid valves control panel for this arrangement needs to be designed and customized (for this specific arrangement). The designer of the logic circuits needs to bear in mind thermal overload protection, current overload protection, over and under supply voltage protection, phase asymmetry and phase failure protection and run dry protection [7]. Professional design and manufacture of the custom-made control panel makes rain water harvesting and utilization expensive. Programming of programmable logic circuits for the same problem needs a professional.
- Treatment of rain water to make it potable is a big challenge. The capital and running costs of rain water treatment makes it prohibitive to many potential users.
- Pipework segregation; should a user desire to utilize recycled gray water and rain water for such non-drinking uses as toilet and urinal flushing, separate/segregated pipe work should be put in place. Potable water should run in separate pipes from non-potable water to avoid contamination. Alteration of existing pipe work to separate potable from non-potable water could proof tooxx costly for most users.

VI. REFERENCES

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