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Optimization Of Storm Water Harvester

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Abstract:

Amongst many practices in water conservation, harvesting is one of the best practices. It helps to check depleting water table. Whereas rooftop harvesting is a simple task, storm water harvester often faces maintenance issues. Clogging of the storm water harvester is a limitation of these trenches. Clogging time can be enhanced by specially designing these trenches. We can further address the maintenance issue by increasing the plan area of the harvester. It helps in physical treatment of water and reduces the TDS in water. Harvesters with different configurations were tried and optimization was done for filter media and design of the harvester. If two harvesting units are joined at the top, it increases the clogging time exponentially. Further a simple solution of replacing the top 50 cm of sand in the filtration media can make them operational again.

INTRODUCTION

There has been a change in the hydrology of the areas due to rapid urbanization, unplanned growth and shifting of agricultural practices in the past two decades. This has led to the decline of the water table. Whereas the water table was 70-80 feet below ground level two decades back in Punjab , it has gone down to 150to 200 feet & up to 300 feet below ground level insome areas.(Krishan et al, 201) This has resulted in an increased infrastructural requirement for pumping out water from greater depths. Just two decades back, water for drinking could be pumped out with hand pumps and for irrigation with mono block pumps. Now all those methods have been replaced by submersible pumps. This has also resulted in increased demand for electricity to pump out water. This has increased the cost of water for domestic and agricultural needs and made farming a less lucrative venture. Water requirement in cities is 130-150(LCPD) Liters per capita per day. Due to the increase in the population of the cities, the water demand has also increased. This demand is chiefly met by pumping out of the waterfrom aquifers. As a result, there is the rapid and massive withdrawal of water to cater to domestic needs. This problem is further compounded in cities due to the paving of roads & rooftop surfaces where no infiltration takes place. There is a lot of areas which is impermeable where no infiltration takes place. This runoff combined with pumping out of water year after year has severely depleted the water table. The sowing of paddy which is not

the natural crop of this area has made the matter worse. Paddy is a natural crop of coastal areas. Paddy requires 150 cm of water during the sowing season.(Krishan et al, 2015) Another 5 cm is required for taking the seed to the sapling stage. Two third of this requirement is met by pumping out of water. The last two decades saw the water table going down at the rate of .5m to 1m per year. Rainwater harvesting is the panacea for depleting water tables, soil erosion & flooding of streets during storms. Rainwater harvesting is collecting, conveying, purifying, and storing water for use once the monsoon is over. It is one of the best practices in water conservation. It offers a variety of advantages. Though the chief advantage of harvesting is to improve the water table, it also offers a host of other advantages like the prevention of soil erosion and flooding. It is our obligation also to restore hydrology to pre-development levels. Whereas rooftop harvesting is a simpler task, stormwater harvesting is a daunting and challenging task.Stormwater harvester has a limitation in terms of maintenance issues. Stormwater has to be filtered before it is discharged into aquifers. There are two types of storm water harvesting. Structural and nonstructural. Nonstructural measures include ponding whereas structural measures include infiltration trenches. Infiltration trenches are considered as the best management practices in water conservation. They can be designed in many ways. Infiltration trenches have limitations in terms of maintenance issues and clogging. Clogging time can be enhanced by properly designing the trench. Increasing the size of de silt chamber also increases the clogging time. Further replacing the top 50 cm of filter media can make these trenches functional again. Urban storm water management strategies are based on both structural measures (a physical device) and; non-structural measures. Infiltration trenches are the most commonly used systems to tackle the problem of flooding, soil erosion and to recharge aquifers. These systems are cheap to build and amenable to space constraints. They are also mandated by building bylaws. Most of these systems tend to clog within one year of operation. They are rarely monitored after installation.

Chandigarh University has designed a stormwater harvester to overcome these limitations. It is patented with patent number 367360 and application number 202011019224. This accomplishment has been achieved with the combined efforts of the Authors. The university has designed a system where the clogging time for the system has been increased to at least five years. The designed system has very low maintenance. There is a simple solution of replacing the top 50 cm of sand layer after the clogging is reported. Clogging is said to have occurred when the infiltration rate is reduced tofive percent of the infiltration rate at the beginning when the system is installed.

POLLUTANTS IN STORMWATER

Sediments solids: Fine sediments or PM2.5 are the chief pollutants in any stormwater. PM2.5are particles with a size less than 2.5 micrometers in diameter. (Burton and Pitt, 2002). These particles are clay particles and are responsible for the turbidity of water. As high as two-third of nutrients and metals are attached to these clay particles. (Duncan, 1999; Deletic and Orr, 2005). These sediments cause turbidity in water. They also render this water unfit for drinking. Sometimes they can cause pollution in the water which can be detrimental to the survival of certain aquatic species and can eventually disturb any lentic or lotic ecosystem.

Metals: There are various metals like cadmium, chromium, copper, nickel, iron, lead, manganese, sodium and zinc which cause carcinogenic diseases. These metals come out from industries as waste sweeps or they come with effluents. They are attached to fine sediments. Cancer which is the second leading cause of deaths worldwide is caused by consumption of water-containing metals beyond permissible limits, these metals instormwater also adversely impact aquatic life.

Nutrients: Phosphorous and nitrogen are the nutrients that are found on topsoils. They are also present in organic matters found in the soils. They are chiefly responsible for biological clogging and can stimulate the growth of algae and plants which reduces the levels of dissolved oxygen in the water and eventually harm plant and aquatic life. (Makepeace et al., 1995; Mayer et al., 1996).

Oil and surfactants: They are mostly present on road surfaces due to leakages in various mechanical operations like hydraulic systems, braking systems and other fuel conveyance operations. (Makepeace et al., 1995; Brown and Peake, 2006). Their presence in stormwater and water bodies can reduce dissolved oxygen and also cause eutrophication. They are toxic to the survival of fish and can eventually disturb the whole ecosystem. They are toxic for, invertebrates and macrophytes. The presence of fossil fuels related pollutants can hamper photosynthesis and can be detrimental to the growth of algae and other plants.

Various other pollutants in stormwater include organic matter and micro-organisms. Organic matters are those which are decomposed from plant biomass and contain mainly carbon, hydrogen and oxygen. (Francey et al, 2010) They oxidize readily to form simpler end products like nitrates and sulfur. Microorganisms like bacteria's are added to stormwater from bird feces and domestic pets. They are also added to water stagnating as interception losses during rain, leakages, or overflows. (Burton and Pitt, 2002, McCarthy et al., 2009).

Studies have suggested that as most of the pollutants are removed by simple processes of sedimentation and filtration by aggregates. These pollutants are mainly adsorbed on the sediments. It is the Physical clogging that is prevalent and more significant which needs to be addressed. (Sriwardene et al,2008) Therefore, as many pollutants associate with sediment, it has been suggested that the removal of suspended sediments from urban stormwater flows could help improve our downstream water quality. This is particularly the case for nutrients (such as phosphorus) and heavy metals such as zinc, which can cause eutrophication and toxicity to fish, respectively (Burton et al., 2002).

BACKGROUND OF THE INVENTION

Water harvesting is one of the major systems in water conservation which is needed to be promoted and developed for maintaining the sustainability of water on the planet earth. Regular enhancement in the technology of water harvesting practices is need of the hour to cope up with the problem of water scarcity in coming years. The harvested water can be either stored or recharged into the groundwater. Instead of allowing the water to run off, it should be allowed to recharge groundwater.

Traditionally followed water harvesting techniques are surface runoff harvesting, rooftop rainwater harvesting, etc. All the previously used techniques have less clogging time. Clogging means blockage or obstruction in the flow or its movement. During harvesting, the filter drains out the clear water and takes up the impurities such as leaves, pebbles, other particles, etc but after certain use the permeability of the filters reduces and it starts to clog. Hence it is important to increase the time of the clogging and maintain permeability so that system works efficiently.

Clogging needs a remedy to limit the system from turning into a wetland. Clogging limits the lifetime of a system. A greater understanding of clogging is required to improve the efficiency of the system and enhance performance. Till now no such efforts have been made to increase the permeability and clogging time in water harvesting.

WORKING OF A HARVESTER

A de-silt chamber brings the stormwater through concrete channels. It is joined with aharvesting unit with a PVC pipe. The harvesting unit consists of a pit circular in shape and the depth of the pit is up to the first sand bed. This pit is lined with brick masonry on sides whereas the bottom of the pit is left as it is. This pit is filled with filter material of specific sizes and depths. There is a drainage layer at the bottom of these units. The flux from this drainage layer is further taken to the second sand layer with the help of a reverse well point. The reverse well point is a Perforated PVC pipe with geotextile wrapped on it. A bridging network develops behind the PVC screens and very fine particles are trapped immediately as they enter the filter media. Water-free of pollutants is obtained as it is recharged into the aquifers. Stormwater pollutants consist of sediments, metals, oil and surfactants. Most of these pollutants are removed with filtration as these pollutants are associated with sediments present in the stormwater. Further two harvesting units are joined at the top with an inclined PVC pipe which increases the clogging time exponentially.

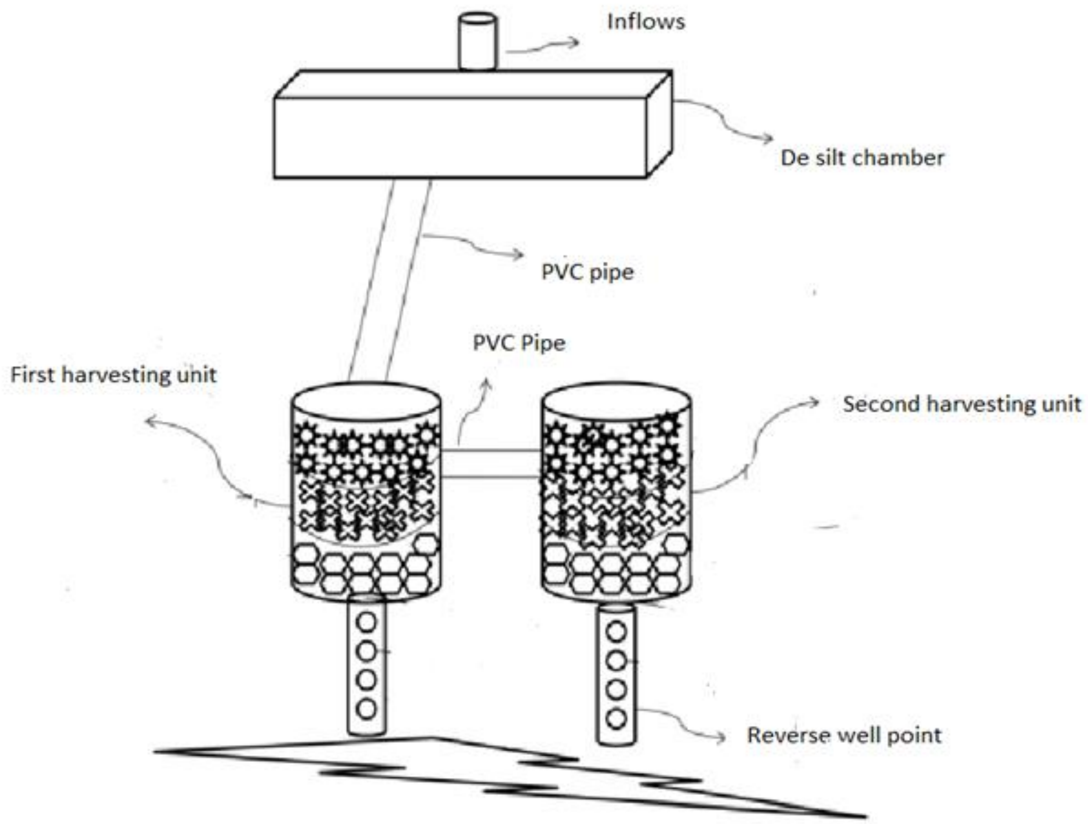

Fig .1 Storm Water Harvester

CONCLUSIONS

Water sensitive urban designs are based on considering storm water as a resource. These designs are based on structural measures and non-structural measures. Non-structural measures include ponding whereas structural measures include infiltration systems. Structural measures are more suitable for places with high density of population and stressed infrastructure. But these systems have limitations in the form of clogging. Various combinations and adjustments are made to make these systems suit the site specific requirements. After trials on various systems an endeavor has been made to develop an economical and efficient system which can address the maintenance issues. The most interesting observation made during the experiment was that whereas a normal infiltration trench requires cleaning at least thrice a year, the one designed above does not clog for at least five years. Another important observation made during the experiment was the importance of the de-silt chamber. A correlation was also observed between clogging time and the size of the de-silt chamber. If the size of the de-silt chamber is increased, it considerably reduces the velocity and sedimentation occurs. The size of the de-silt chamber should be such that the velocity of flow is reduced to less than .1m /sec. When water flows at a velocity less than this, sedimentation starts taking place. The targeted particle size should bemore than PM2.5. PM2.5 size particles are those particles whose size is less than 2.5 microns.This means that we should remove all particles which can be classified as silt particles. Any particle with a size range of 2 microns to 75 microns is classified as silt particles. This also explains why it is called a desilt chamber. Further, it was also observed that the depth of the desilt chamber has a limited role in slowing down of water. It is the area of the desilt chamberthat has a major imperative on the velocity. A graph was plotted between clogging time on

ordinate and the area of the de-silt chamber on the abscissa. With other parameters remaining the same, it was observed that there was a direct correlation between clogging timeand the area of the chamber. It clearly shows that the amount of sedimentation increased in proportion to the reduction in velocity. Further, the reduction in velocity is a factor of the area.

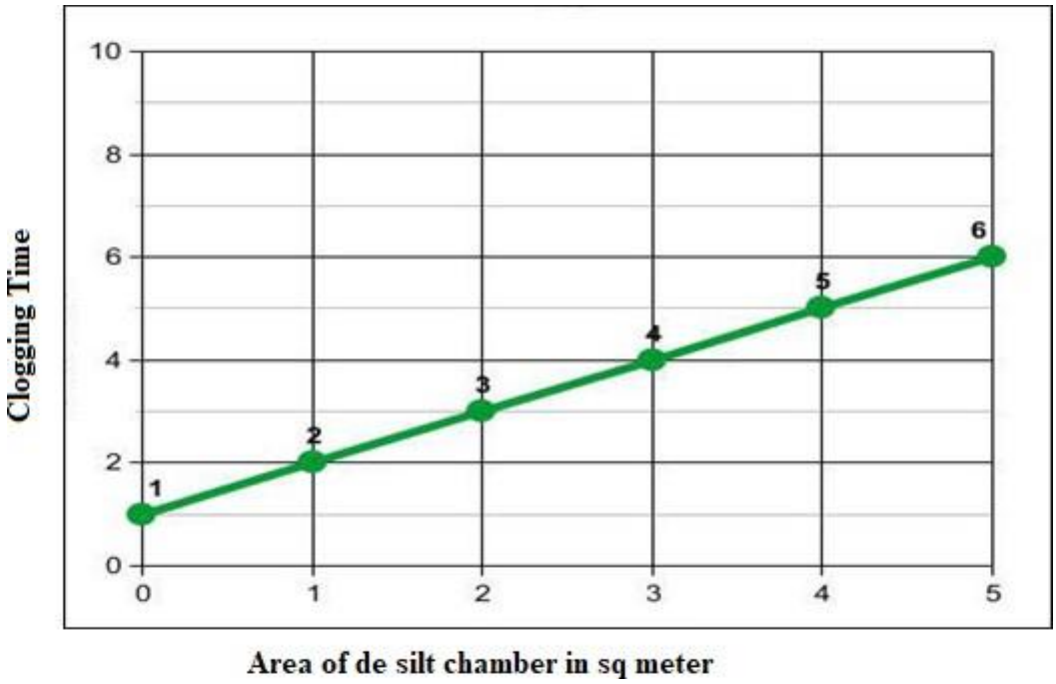

Fig. 2 Graph Showing Variation of Clogging Time with Area of Desilt Chamber

Another important observation was that as we use reverse well points to take the purified water to the second sand layer, there is again an increase in clogging time. This is attributedto the fact that the perforated pipe takes the water from the drainage layer where the water is free of impurities. This water from the drainage layer is without any clay particles. So as the water from the drainage layer finds its way to dried aquifers, vacuum pressure is developed inthe air voids and it causes a suction pressure. This suction pressure increases the permeabilityof the filter layer and has the effect of negating the effect of clogging and hence increases the operation time of the trench. The clogging time increased to 3 times with the same parameterswith the introduction of reverse wellpoint if compared with a simple trench. But the real increase in clogging time was observed when two harvesting units are joined at the top. This increases the clogging time exponentially. The clogging time is increased to a minimum of five years in case there are two harvesting units. Flux to the second unit is taken from the top of the first harvesting unit. This water is further free of impurities due to sedimentation taking place in the water standing in the first harvesting unit. So while the clogging is observed in the first harvesting unit, there is no clogging in the second harvesting unit. Initially, all the water is harvested through the first unit. As some clogging is reported in the first unit, water starts to stand in this unit. Only then the water starts flowing to the second unit. The flux received in the second unit is relatively more clean and pure as compared with the first harvesting unit. This explains why the clogging time increases exponentially as we increase the number of units.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of thispaper.

Acknowledgments

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