DESIGN OF IRRIGATION SYSTEMS FOR GARDENS BY ALTERNATING GREYWATER AND WELL WATER

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Abstract: *Water is the basic source of life for plants, animals, and humans. However, the impact of climate change drastically reduces its sources. Rational consumption of clean water leads to the need for finding alternative water sources for irrigation of gardens. As an alternative source, greywater can play an important role. Greywater is waste water from households, which does not contain faecal compounds. The aim of this paper to present design concepts of systems for collecting, purifying and application of greywater and well water for irrigation of gardens. The concept is developed using previous own research results, as well as available literature, on the benefits and risks of using greywater, and the effects of purifying greywater and well water through various treatment systems. The paper presents two systems: (1) a system which allows the storage and irrigation using raw greywater and (2) a system where greywater supply is not continuous. The second system is suitable not only for households but also for other facilities, e.g. touristic, recreational and weekend resorts. This system proposes alternate irrigation with grey and well water for resolving two problems: inappropriate greywater quality and inappropriate water quantity. In general, the system reduces the risk of soil degradation and is water saving by automatically adjusting irrigation with regard to the soil moisture content.*

Keywords: GREYWATER, WELL WATER, IRRIGATION, SYSTEMS, DESIGN CONCEPT

1. Introduction

Water is the basic vital substance necessary for the survival of life on the Earth. However, the increasing impact of climate changes, the increased consumption of clean water and its pollution are causing a drastic decrease of this resource (UN Water, 2017). Regarding to this, it is necessary to find adequate solutions for the conservation of clean water supplies.

One of possible solutions is to find an alternative source for irrigating gardens. One of the potential alternative sources of irrigation water is grey water. Grey water is domestic wastewater originating from dishwasher, sinks, showers, bathtubs and washing machines (EPA, 2018). Grey water could have different characteristics (Dabić et al., 2019). Grey water potentials are its availability in large quantities and its nutrient content (WHO, 2006a; Siggins et al., 2016). Because grey water does not include toilet wastewater, it does not contain elevated levels of pathogens as municipal wastewater (WHO, 2006). Nevertheless, the presence of effluent from a kitchen in grey water can cause an elevated bacterial content (Maimon et al., 2014). Proper management of grey water, including collection, treatment and reuse or disposal, prevents direct contact with grey water and limits transmission, as well as the further spread of pathogens. Purified grey water is used for various purposes around the world, but it's most common application is for irrigation purposes (Imhof B. & Mühlemann J., 2005). In addition to grey water, well water can also be a significant irrigation source for various types of green spaces. The quality of or both, grey water and well water, is of great importance in irrigation. Since grey water consists of effluents from the kitchen, it may contain residues of food that could create the condition for the development of bacteria, and thus the increased biochemical oxygen demand (BOD_5). In addition, unpleasant odors can develop by keeping grey water for a long period (if it is not consumed for a short period of time).

Grey water is most commonly used in arid regions and/or areas affected by insufficient amount of clean water. Back in 2006, there was a trend of increasing use of grey water in the US, where most households used grey water from a washing machine for garden irrigation (Roesner et al., 2006). There are numerous projects in developing countries, as well as derived solutions for the collection, treatment and reuse of grey water for various uses, as well as different degrees of grey water purification (Abdo, 2001; Bark & Drabo, 2001; Dallas et al., 2004; May-Le Ng, 2004; Imhof & Mühlemann , 2005; Al-Hamaiedeh & Bino, 2010; OMICK, 2014).

One of the undesirable substances in well water is iron. Long-term application of well water containing an elevated iron concentration may lead to coloring of the surface treated with this water. Usually these surfaces become copper-orange over time. In addition, elevated iron concentrations adversely affect the quality and service life of the irrigation system. The long-term application of water of such quality leads to the deposition of iron in the pipes of the overfill system, which causes difficult flow of water, blockage of the system, as well as additional maintenance costs. In regard to both mentioned irrigation alternatives, in order not to cause negative effects on the environment and irrigation systems, adequate collection and purification of both grey and well water is necessary.

Although the problematic in not new, authors felt that it should be refreshed and upgraded, since during previous two years of research and investigation of this topic conducted by Dabić and associates (Dabić et al., 2017; Dabić et al., 2018; Dabić et al. 2019), safe application and proper installations are shown to be important aspects concerning grey water utilisation. Therefore, the aim of this paper is to present the design concepts of systems for collecting, purifying and applying grey and well water for irrigating gardens.

2. Method

The concept was developed using previous research findings, as well as the available literature, on the benefits and risks of using grey water, as well as the effects of purifying grey water and well water through different treatment systems. Two systems are presented in the paper: (1) a system that allows storage and irrigation using raw grey water and (2) a combined system in cases where the supply of grey water is not continuous.

Two systems are presented in the paper: (1) a system that allows storage and irrigation using raw grey water and (2) a combined system in cases where the supply of grey water is not continuous. Both systems are designed for private single-family residential buildings and are smaller in size than systems for multi-family residential buildings, tourist complexes, etc. The dimensions of the storage and irrigation system, that is, the reservoir in which the mechanical treatment and storage of raw grey water is carried out are 2 x 1 x 1 m (2 m^3), while the dimensions of the reservoir for the treatment - storage of grey/well water are 1 x 1 x 1.6 m (1.6 m^3). The raw grey water storage and irrigation system is a simple filter, according to the study on grey water purification technology through coarse filtration (Hall et al., 1974), while the combined system is somewhat more complex. This system consists of two tanks for the purification and storage of grey/well water separately. In addition, the purification filter itself is more complex and consists of a combination of many different materials used for these purposes (Zuma et al, 2009; Al-Hamaiedeh & Bino, 2010; Parjane & Sane, 2011). The combination of materials includes: small gravel

(5 cm - 0.05 m^3), large gravel (5 cm - 0.05 m^3), sand (30 cm - 0.3 m^3), geotextile (0.5 cm) and wire construction (3 cm).

3. Results and discussion

Raw grey water storage and irrigation system

The raw grey water storage and irrigation system is a simple system. Household waste water, including waste water from sinks, showers and tubs through the PVC pipes goes to the sewer or grey water collection tank. The direction of wastewater flow is determined by the automatic controller (Figure 1).

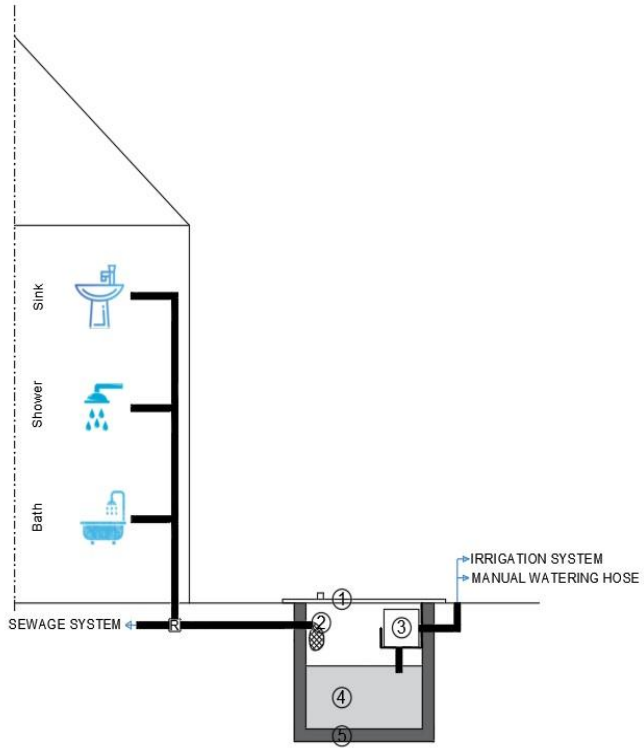

Fig. 1 *Design of raw grey water storage and irrigation systems. 1-cover; 2-sieve; 3-pump; 4-raw greywater; 5-concrete; R-regulator.*

The principle of operation of the regulator is by means of a sensor that allows the flow of wastewater into the tank to a maximum level of collection. When the maximum level of grey water is reached in the reservoir, or during the year when irrigation is not required, the regulator will automatically direct the wastewater towards the sewer. When the PVC pipe enters the tank, the waste water passes through a mechanical filter in the form of a wire sieve to collect the large particles of waste (e.g. food waste). By manually removing the tank cover, it is possible to obtain a mechanical filter, which needs to be cleaned occasionally and returned to its original position. Inside the tank there is a pump that pumps raw grey water in two directions: (1) to an underground irrigation system, in the form of a vessel buried into the soil near the plant root system (see Figure 2), and (2) to a valve for a hose intended for manual irrigation. The pumping of raw grey water from the reservoir takes place in two cases: (1) for system number 1, the sensor at the bottom of the vessel which regulates the water flow depending on the soil moisture (Figure 2), while (2) manually opening the manual irrigation valve where there is an automatic pumping of water from the tank. This system design is suitable for lawn irrigation, as well as for ornamental plants that are not used in as food.

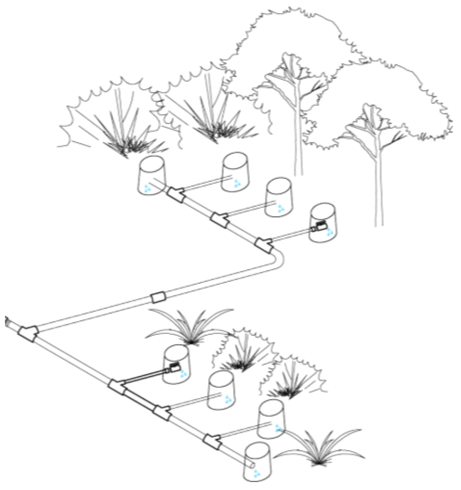

Fig. 2 *Underground irrigation system for grey water application*

Combined system

Combined system is a system for purification, collection and irrigation of grey and well water. Household waste water, including waste water from sinks, showers, bathtubs, sinks, and dishwashers through PVC pipes goes to the sewer, or grey water treatment tank, while the well water reaches the well water treatment tank by pump (Figure 3).

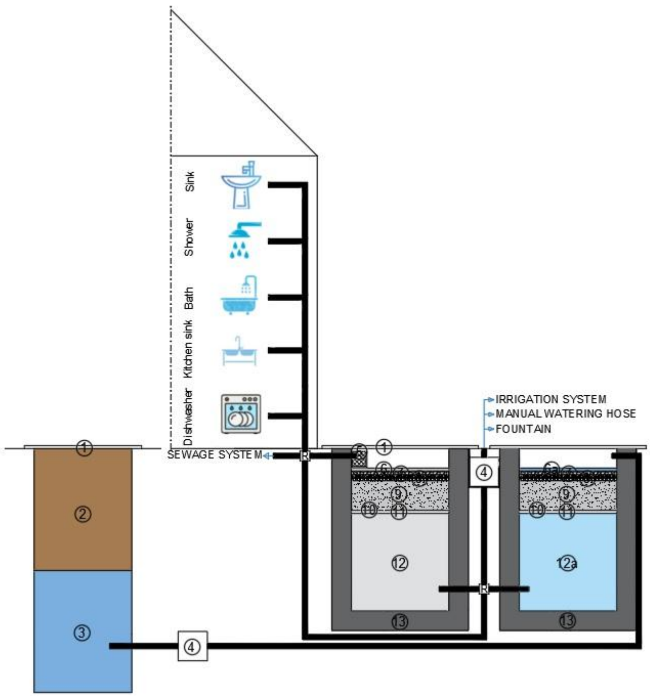

Fig. 3 *Design of the combined system for the treatment, storage and irrigation of grey and well water. 1-Cover; 2-Part of wells without water; 3-Well water; 4-Pump; 5-Sieve; 6-Greywater; 6a-Well water; 7-Large gravel; 8-Small gravel; 9-Sand; 10-Geotextile; 11-Steel construction; 12-Purified greywater; 12a-Purified well water; 13-Concrete; R-Regulator.*

Disinfection with generally applicable disinfectant would avoid biological degradation of grease, small food particles, detergents, etc. Similarly as with the previous system, the automatic controller determines the direction of the waste/well water, depending on the amount of purified grey/well water, or the period of the year. This system consists of two tanks for the purification and collection of grey and well water separately. Both tanks contain the same purification filter, but before the grey water tank, the grey water passes through a mechanical wire filter to collect large waste before filtering. Also, by manually moving the tank lid, it is possible to get a wire filter which needs to be cleaned if necessary. The water purification filter consists of coarse gravel, fine gravel, sand, geotextile, steel structure that carries the aforementioned materials, and parts of a reservoir for storage of purified grey or well water. The purified grey and well water is pumped in three directions with the help of a pump: (1) into the underground irrigation system (as in the previous system), (2) to the manual watering valve and (3) to a fountain, or other type of water element. This design of the system is suitable not only for households but also for other facilities, for example, touristic recreational and weekend resorts where the inflow of grey water is not continuous. This system proposes alternative irrigation with grey and well water to solve two problems: inadequate quality and inadequate supply of grey water. In general, the system reduces the risk of soil degradation by providing good water quality. Additionally, it saves water by automatic irrigation adequate to plants requirements, by determining soil moisture content using sensors.

Common irrigation problems concerning grey water application

When it comes to the design of irrigation systems, it is first necessary to start by collecting and storing grey water. The common opinion of the authors who have elaborated the issues of grey water storage is that it is difficult, and that there is a danger of an increase in the number of pathogens. Another problem is the depletion of oxygen during the degradation process, which leads to sulfide production and unpleased odor of grey water. However, most authors agree that disinfecting grey water can solve these problems. Also, it was observed that the degradation of organic matter occurs already in the first days of storage (the first 7 days), as well as that the ratio of COD:BOD of water decreased, indicating faster biodegradation of waste. In addition, an increase in the concentration of coliforms was observed during the first 5 days, while after 15 days of storage of grey water, the concentration of coliforms decreased. However, although the number of indicator species is increasing, this does not mean an increase in pathogenic microorganisms as well as risk (Imhof B. & Mühlemann J., 2005). Therefore, the period of storage plays an important role in the quality of grey water, i.e. with a prolonged storage period the quality of grey water decreases. Eriksson et al. (2002) confirm this fact. The cited authors found that storing grey water for up to 24 hours improves its quality, while storing it for more than 48 hours can be a serious problem due to the consumption of dissolved oxygen. However, as long as the storage of grey water is included in the irrigation system, it is essential that storage tanks are available for washing/cleaning (Christova Boal et al., 1996).

In addition to storage, its important role in the use of grey water is its purification. There are numerous problems related to the use of untreated grey water. Exposure to microorganisms in water leads to the risk of disease spread. Due to the fact that it is resistant to water purification processes, Legionella poses a special threat because it can spread through aerosols as well as inhale during irrigation or flushing of toilets (Dixon et al., 1999). Surface spraying of untreated grey water is not recommended because it increases the possibility of coming into direct contact with grey water, which can cause disease to humans and animals. For this reason, it is proposed to use protective equipment when coming into direct contact with grey water, as well as to apply an underground irrigation system (Siggins et al., 2016). However, suspended solids can cause clogging of the distribution system, and grey water to be used for irrigation must be of satisfactory physical quality (Eriksson et al., 2002). Depending on the economic aspect and the quality of grey water required, the degree of treatment before use or storage depends on it. Three levels of treatment are usually defined (Morel, 2002): (1) Primary treatment - the first treatment step that is used to remove most floating or precipitating materials. About 30% of BOD_5 can be removed with this treatment; (2) Secondary treatment - at this stage the bacteria consume organic waste and it is possible to remove about 90% of BOD_5 and suspended matter. Disinfection represents the final stage of secondary treatment; and (3) tertiary treatment - represents the last stage in which nutrients such as phosphorus, nitrogen, BOD_5 and suspended matter are removed. The level of treatment depends on what purposes the grey water will be used for. Grey water intended for surface irrigation must be well filtered and disinfected, while grey water intended for underground irrigation will require only coarse filtration as the risk of human contact is reduced (Finch et al., 2003).

4. Conclusion

According to the above examples of systems for purification and use of grey water, the needs for such systems exists, as well as certain advantages of the system for storage and irrigation of raw grey water, as well as the combined system. The main advantage of these systems is that they are underground and that no odors are spread. In addition, these systems occupy a much smaller area, since all the necessary filters are contained in one tank, compared to the above examples of systems consisting of multiple tanks. Another significant improvement of the combined system is the combination of grey and well water. In addition to well water being an additional alternative water source, it can also dilute grey water by improving its quality. Also, these two systems allow for safe irrigation, meaning, directing excess water into the sewage system reduces the risk of soil wetting and degradation.

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6. References

Abdo, K.M. *Water Reuse in Palestine*, Ministry of Agriculture, General Directorate of Soil & Irrigation, Ramallah, Palestine, 2001, 22.

Al-Hamaiedeh H. *Efect of grey water reuse in irrigation on soil and plants* - Desalination, 256 (1), 2010, 115-119, (Al-Hamaiedeh H., and Bino M.).

Bark K. *Amélioration de la gestion communale en matière d'eau et d'assainissement à Koulikoro, Mali*, Rapport de project ecosan Koulikoro – Mali, OtterWasser GmbH / GTZ, 2001, 1-11, (Bark K., and Drabo K.M.).

Christova Boal, D. *An investigation into greywater reuse for urban residential properties* - Desalination, 1996, 391-397 (Christova Boal, D., Eden, R.E., McFarlane, S.).

Dabić B. *Greywater In The Service Of Horticultural Crops.* In: 21st Century Water Management in the Intersection of Sciences, II International Conference on Water Sciences in Szarvas, Szent István University, Hungary, 2019, 258 – 263, (Dabić B., Grabić J., Mladenović E.).

Dabić B. *The Impact of Water Quality on the Physiological and Morphological Parameters of Red Clover (Trifolium pratense L.).* In: XXII International Eco-Conference® 26nd-28th September, Ecological Movement Of Novi Sad, Safe Food, Novi Sad, Serbia, 2018, 90-97, (Dabić B., Dragić V., Grabić J., Gvozdenac S., Vasiljević S., Đurakovac A., Mladenović E).

Dabić B. *Preliminary research on morphological features of plant Berberis thunbergii DC. upon grey water irrigation*. In: ECO-Conference „Environmental protection of urban and suburban settlements“, 27-29 September, Novi Sad, Serbia, Proceedings 2017, 99-106, (Dabić B., Grabić J., Mladenović E., Orlović, S., Benka P., Čukanović J., Pavlović L.).

Dallas S. *Reedbeds for greywater treatment - case study in Santa Elena - Monteverde, Costa Rica, Central America* - Ecological Engineering, 23 (1), 2004, 55-61, (Dallas S., Scheffe B., Ho G.).

Dixon, A. M. *Guidelines for greywater reuse: Health issues* - J. CIWEM, 13, 1999, 322–326, (Dixon, A. M., Butler, D., Fewkes, A.).

EPA. *Greywater (archived)*, The Environment Protection Authority, South Australia, 2018. Available: https://www.epa.sa.gov.au/environmental_info/water_quality/programs/grey_and_black_water_discharge/grey_water

Eriksson, E. *Characteristics of grey wastewater* - Urban Water, 4 (1), 2002, 85-104, (Eriksson, E., Auffarth, K., Henze, M., Ledin, A.).

Finch, C. *Graywater literature research*, San Antonio Water System, Texas Cooperative Extension, The Center for Water Research, UTSA, 2003, (Finch, C., Lillibridge, B., Fry, E., Lesikar, B., Silvy, V., McNally, M., Innis, E., Ovuegbe, E.).

Imhof Barbara. *Greywater treatment on household level in developing countries – a state of the art review*, Swiss Federal Institute of Technology Zurich, 2005, 1-98, (Imhof Barbara, Mühlemann J Oëlle,).

Maimon A. *Parameters affecting greywater quality and its safety for reuse* - Science of the Total Environment, 487, 2014, 20–25, (Maimon A., Friedler E., Gross A.).

May- Le Ng. *Household Greywater Reuse for Garden Irrigation in Perth*, Environmental Engineering Project 640.406, Centre for Water Research, University of Western Australia, 2004, 1-92.

OMICK. *Graywater Systems*, 2014. Available: http://www.omick.net/graywater/graywater.htm

Roesner L. *Long-term Effects of Landscape Irrigation Using Household Graywater: Literature Review and Synthesis*, Water Environment Research Foundation (WERF) and Soap and Detergent Association (SDA), Washington DC, USA, 2006, (Roesner L., Qian Y., Criswell M., Stromberger M., Klein S.).

Siggins A. *Effects of long-term greywater disposal on soil: A case study* - Science of the Total Environment, 557-558, 2016, 627-635, (Siggins A., Burton V., Ross C., Lowe H., Horswell J.).

UN Water. *Water and Climate Change*, United Nations, 2017. Available: http://www.unwater.org/water-facts/climate-change/

WHO. *Overview of Greywater Management Health Considerations*, (Report WHO-EM/CEH/125/E), World Health Organization, Geneva, 2006.

WHO. *WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume IV: Excreta and greywater use in agriculture*, World Health Organization, United Nations Environment Programme, 2006a.