Adaptation to water resource scarcity and quality changes

Demonstration of conceptual scheme for rainwater harvesting and grey water management in Istanbul

Demonstration Report

SEVENTH FRAMEWORK
PROGRAMME

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COLOPHON

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Demonstration of conceptual scheme for rainwater harvesting and grey water management in Istanbul

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Contents

1 INTRODUCTION

Growing population and rapid industrial developments in combination with predictable climate change influences on water sources for Mediterranean basin lead putting into practice improved adopted strategies for Istanbul. The city relays on basically surface water resources which also thought to increase the impacts or risks of climate change. The anticipated impacts are regional momentary drought periods, extreme events of rainfall causing floods becoming more noticeable.

Referring to perception of need for innovative water resources along with pollution control and mitigation of climate change impact issues rainwater harvesting (RWH) and grey water (GW) reuse concepts are experimentally assessed. RWH may be considered as a reliable, ecological and economic option of water supply for non-potable water consumption. Moreover, the concept presents advantages for surface water run- off management and accordingly mitigation of flood risks (CIRIA, 2007; Campisano et al., 2013; BS8515, 2009).

Domestic wastewater segregation into components and treatment and reuse separately is appraised as an innovative approach to achieve resource management. In this manner , GW is presumed as more simple to be treated and more safe for recycling of non-potable purposes such as irrigation, flushing toilets and cleaning (Otterpol at al., 1997; Hocaoglu et al., 2013). A number of GW treatment and reuse technical options including use of rotating biological contactors (RBC) have been tested (Hocaoglu et al. 2010; Baban et al., 2010).

However, there is still need for the assessment for practical implementation for a holistic integrated approach for RWH and GW reuse such as characterization from various sources for relevant parameters associated with climate change, collection, treatment, storage and reuse options. Hence, as an integrated approach at local conditions and considering climate change impacts and relevant challenges for mitigation for GW and RW systems are tested at the pilot implementation site for Istanbul.

Hence, by the appropriate design, implementation and monitoring activities, the achievements are;

- Valuation of the methods highlighting on the conditions/limitations for Istanbul and also applicable to other comparable urban areas,
- Determination of reliability of the tested systems,
- Recommendations for potential solutions for treatment / reuse/recycle track,
- Improvements in innovative water resources concepts which in turn leading to greening cities or sustainable zero waste building concept,
- Contribution to the public recognition for climate change – water related issues and impacts,
- Contribution to carbon foot print analysis and evaluation, economic feasibility of the systems by providing long term operational data,
- Facilitation of up-scaling the obtained pilot scale results for much larger settlement areas in Istanbul.

2 FINDINGS

2.1 Grey Water Treatment and Reuse Pilot Experiments

GW consists of discharges from showers, washing basins, washing machines and kitchen of two lodging buildings located in TUBITAK MRC premises. The GW system components included segregation, screening with coarse (6mm) and 3mm pore size mash screens, biological treatment by RBC, two- layer- filtration (anthracite-sand) and disinfection by UV and chlorination. GW is transported to the pilot site separately. The schematic illustration of the GW system is given in Figure 1. The RBC system was operated for about 1,5 years and pollutant parameters relevant to reuse rules and regulations have been monitored at weekly/monthly intervals. COD loading rate for the RBC was in the range of 8-10 g/m^2-d throughout the operation period.

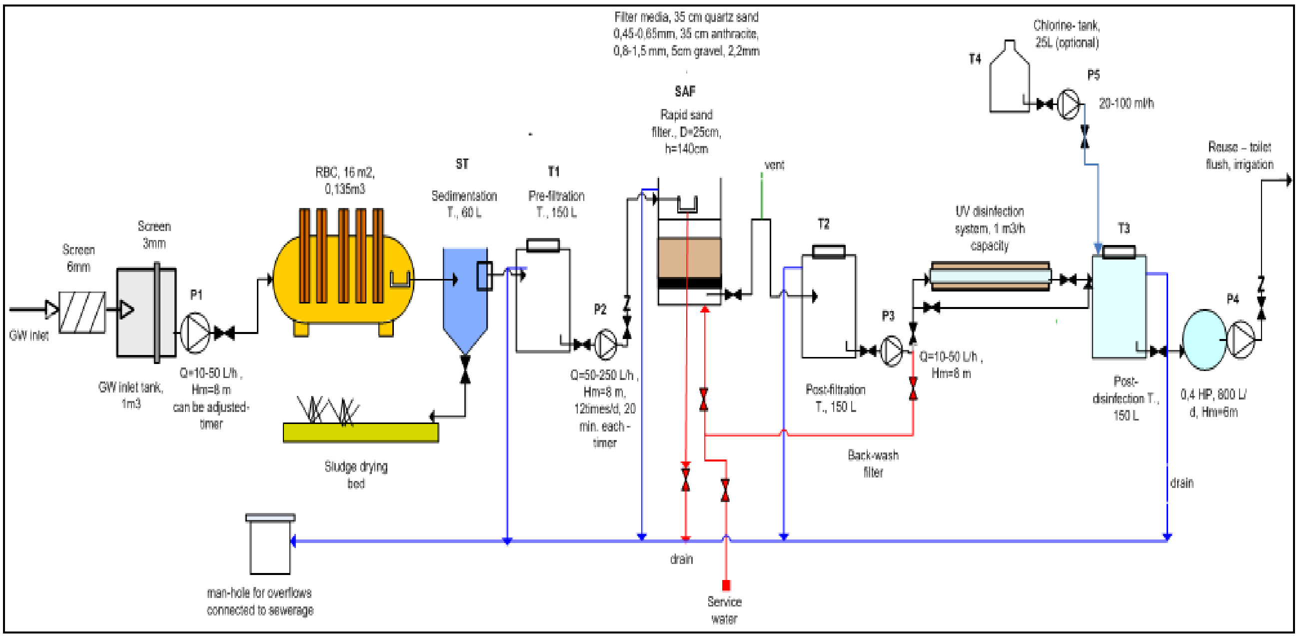


Figure 1. Process flow sheet for GW treatment – reuse pilot experiments

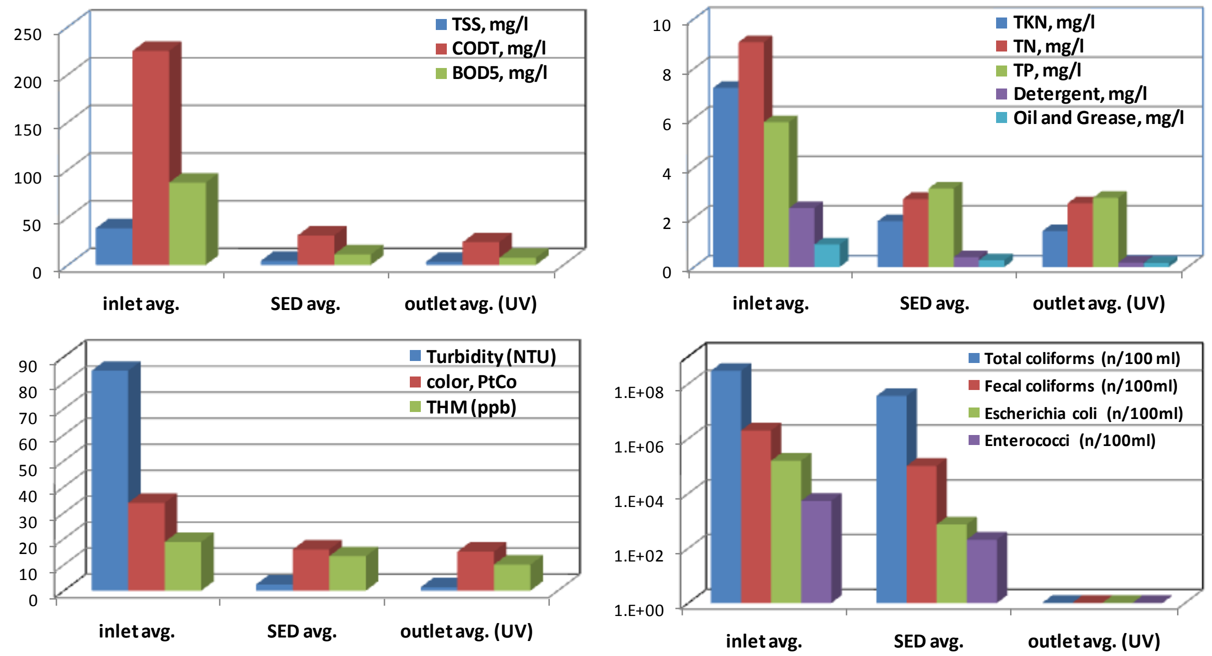
The characteristics of influent GW and the treated GW effluent samples, taken from inlet raw GW, after sedimentation and disinfection processes, obtained throughout the experimental study for some key parameters monitored are illustrated in Figure 2. It is noted that EPA (2004) suggested reuse guidelines states, BOD_5 concentration should not exceed 10 mg L^{-1}, TSS 5 mg L^{-1}, fecal coliforms should not be detected in 100 mL sample and pH should be in the range of 6–9 for toilet flushing and all kinds of irrigation applications.

The average effluent BOD_5 concentration was determined to be 8 mg L^{-1}, which indicates the BOD_5 removal efficiency of about 91%. Whereas, 92% TSS, 98% turbidity and 80% TKN removal efficiencies were attained. In this sense, it was proved that the treated GW effluent satisfied the criteria for non-restricted reuse by all means continuously. THM concentration for the inlet and outlet of the RBC system was also monitored.

The results were also compared with the Membrane Bioreactor (MBR) treatment alternative for GW. The GW treatability study by using MBR was also conducted at TUBITAK MRC within the activities of the Zer0-m project (Regelsberger et al., 2007; Atasoy et al., 2007).

The removal efficiencies attained by the MBR was higher than RBC system used in this presented study in terms of COD and BOD_5 concentrations. Whereas, for the TSS effluent concentration almost comparable results were obtained. Hence, the RBC system, used in this study, may present a reliable method for GW treatment for implementation of reuse for especially residential urban areas, taking into account that it may be installed in basements of the buildings, operational easiness, low cost of operation and maintenance, less technical personnel requirements as well as provision of satisfactory water quality for reuse uninterruptedly. In addition to that the system may be manufactured by using local materials and equipment.

On the other hand, the time period needed for biofilm growth during acclimatization period, continuous electricity supply and back-wash requirements for the filtration process at weekly or 2-3 day intervals have been experienced as prominent drawbacks of the RBC system operation.



BOD: Biochemical oxygen demand, COD: Chemical oxygen demand, TSS: Total suspended solids, TKN: Total Kjeldahl Nitrogen
**THM: Total of chloroform, bromodichloromethane, dibromochlromethane and bromoform concentrations*

Figure 2. The performance of RBC system operation for GW treatment and reuse

2.2 Rain Water Harvesting Experiments

The RWH pilot system, used in the assessment study, is designed to accomplish use of harvested RW for irrigation, various sorts of cleaning and toilet flushing purposes. The pilot system includes collection of RW from the roof of a building in TUBITAK-MRC, first flush filtration-diversion unit with a vortex-fine filter, sand-anthracite filtration layers, storage tank, cartridge type filters and UV disinfection. The RWH system, schematic flow diagram, including the relevant system components are illustrated in Figure 3. A comprehensive characterization and monitoring program was carried out. The samples representing the RW characteristics from roofs are collected from the roof of the lodging building in TUBITAK-MRC. Characterization study for storm water from roads and paved areas has been also accomplished in a residential area in Istanbul (Kurbagalidere).

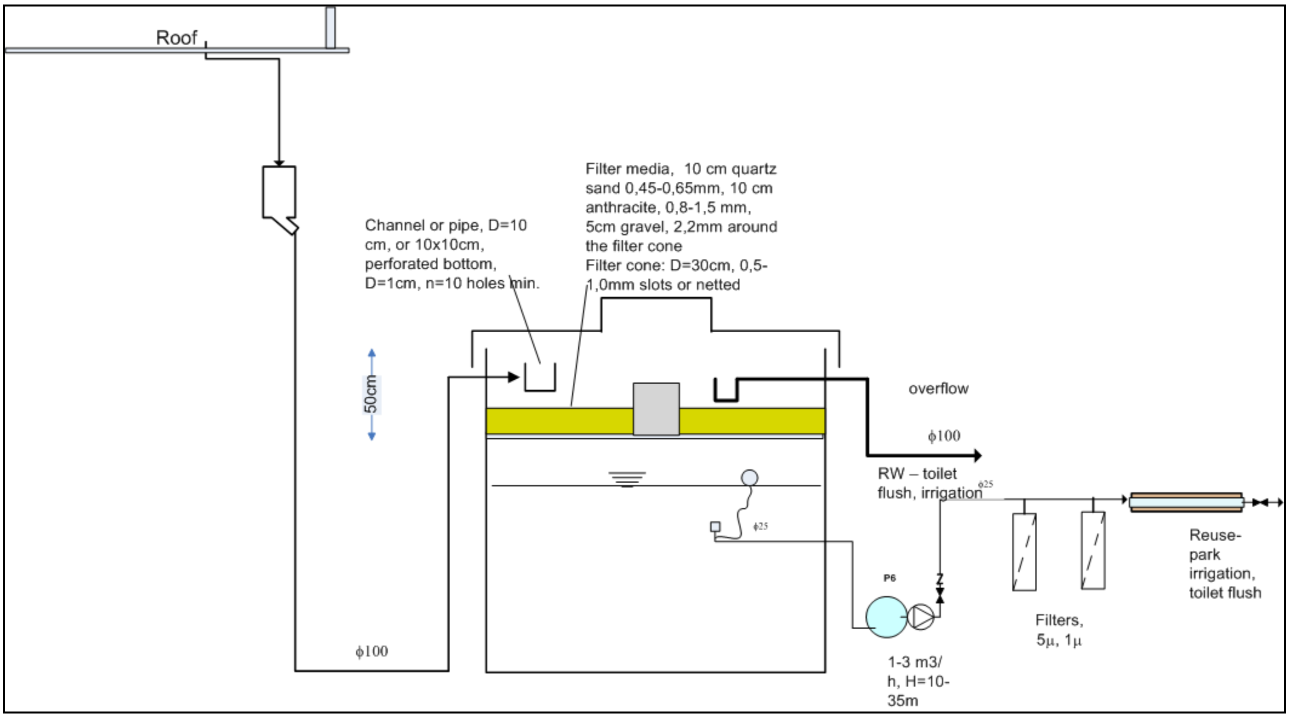


Figure 3. RWH pilot system operated in TUBITAK MRC - sampling points for monitoring (1: RW before filter, 2: collection tank, 3: treated RW following to UV disinfection)

The sampling points were; inlet port (before vortex-fine filter), storage tank content and storage tank outlet. The inlet samples are collected during the rain events. The storage tank content and outlet samples are taken monthly. Some parameters (turbidity, COD and total coliform) have been monitored at weekly intervals.

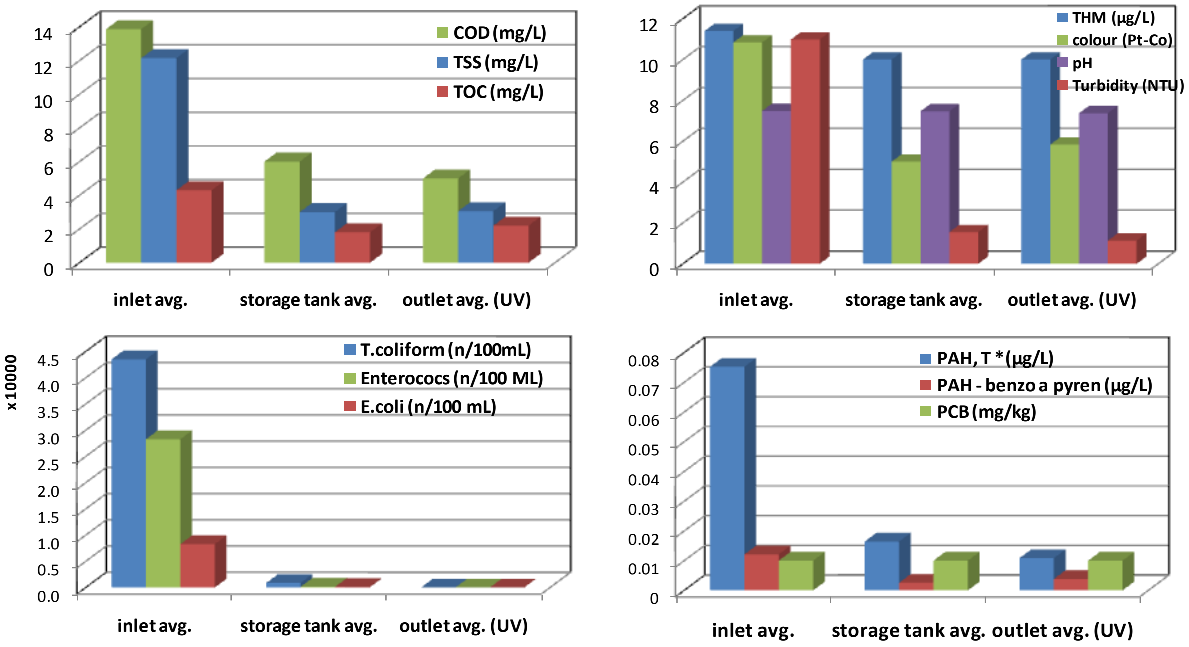
Furthermore, a sampling system was utilized to characterize the discrepancies for first flush. The system included 5L, 10L, 20L, and 50L tanks placed in series and connected to the main roof outlet pipe.

The results of characterization and monitoring study are shown in Figure 4 for some relevant parameters.

The results indicated that the treatment efficiency attained by the multilayer sand and anthracite filtration is satisfactory for non-potable indoor (toilet flushing, cleaning) and outdoor uses (garden, car washing, irrigation).

The criteria for PAH- total is set as 0.1 μg/L whereas, for PAH – benzo-a- pyren compound 0.01 μg/L in drinking water regulations (EC Council Directive, 1998). The inlet PAH concentration results indicated that untreated RW possibly exceeded the criteria set for the drinking water standards. This condition was also encountered for the assessment study of first flush characterization determination at various first flush volumes especially after long dry weather periods. Moreover, it is also considered that there may be a risk of malfunctioning of the treatment system. Breakthrough conditions may occur for the anthracite filtration layer or the flow rate would be so high and the filtration rate criteria set by the design is likely violated. The

UV disinfection unit may not be efficient due to the high inlet RW turbidity if the filtration units are not functioning properly. So, considering the presented RWH system, use of treated RW for drinking is not advised.



**PAH,T: Total of Benzo(b)fluoranthene, Benzo(k) fluoranthene, Benzo(g,h,i) perylene, Indeno(1,2,3-c,d) pyrene*
*** PCB results are less than the detection limit*

Figure 4. The performance of RWH system operation

The first flush assessment experiments yielded that the pollutant concentrations decreased with the increasing time span where the samples were collected for most of the parameters. The pollutant concentrations diverged significantly in accordance with the wet and dry periods where the sampling was accomplished. Hence, the assessment was made individually for wet and dry period samples analysis results. The results suggested that first flush volume of 0,2-0,5 L/m^2 – roof area could be considered for separation.

In general, it should be noted and the study is also proved that the RWH system is simple to install, has operational ease and also advantageous for the points of construction technology and material availability.

2.3 Energy Requirements and Cost Assesment for GW reuse and RWH

The energy requirement of the operated RBC system for the GW treatment was calculated as 1,9 kWh/m^3 GW treated. This value is close to energy requirement for GW treatment by using MBR. The operation and maintenance cost for GW treatment system was assessed as about 1,1 €/m^3 under local circumstances. Whereas, the corresponding energy requirement for RWH system was 0,7 kWh/m^3 RW treated. And, the operation and maintenance cost was estimated to be about 0,7 €/m^3 for RWH.

3 CONCLUSIONS AND RECOMMENDATIONS

RWH and GW reuse pilot systems have been set up, operated and assessed as alternative water resources for Istanbul to achieve sustainable water management, conservation of resources and to cope with impacts due to climate change. The GW treatment system presented robust and operationally simple features, in the meanwhile, provision of re-useable water which continuously satisfies non-potable reuse criteria. In addition to that, RWH pilot study essentially contributed to the appraisal of RWH concept by accomplishing characterization from various sources, focusing conventional physical, chemical, biological parameters and relevant micro-pollutants and testing implementation technologies under Mediterranean conditions for urban areas. The results obtained can be up-scaled for further assessment studies in large residential or catchment areas for the implementation of the concept. It should be pointed out that if suitably designed and operated in integrated manner RWH systems and GW reuse strategies may significantly contribute to the reduction of potable water consumption and also run-off control.

The concept may be considered as a partial adaptation strategy for climate change impacts.

As RWH and GW reuse would cause the occurrence of significant changes in the existing water treatment, distribution, wastewater collection and treatment systems care should be taken in advance.

The holistic assessment of the system is also compulsory as compared to conventional approach for controlled emission of greenhouse gasses. Moreover, considering that depending on the distance between the source and the treatment system and the location GW may have higher temperature than the main water supply, heat recovery from GW may also be considered within the concept, which also constitutes an advantage for sustainability and mitigation of carbon foot print.

Istanbul Water and Sewerage Administration (ISKI) has a strategy plan for 2011-2015 (ISKI, 2010). In this plan, ISKI aims to separate storm and sewerage net works in order to protect the sewerage system, prevent floods and use RW as an alternative water resource. Also, ISKI has targets related to grey and black water reuse and RWH in new buildings and aims to complete a feasibility and three case studies for wastewater reuse and five case studies for RWH by 2015. The demonstration example conducted in PREPARED is in line with the strategy plan. ISKI (2013) indicated that ISKI applied the demonstration study as its strategic target of "Development of alternative water resources - Conduct Feasibility Studies for the Assessment of Rainwater Use".

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