

BENEFITS OF RAINWATER HARVESTING IN URBAN INDUSTRIAL AREAS

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Abstract

The aim of this paper is to introduce the benefits of rainwater harvesting in general, considering growing water demands and to emphasize these benefits focusing on industrial areas in developed urban regions. We carry the study out by virtue of several operating projects worldwide that reuse rainwater in different activities. The actuality of this study is verified by the fact that although consumption of fresh water and economy is growing, the practice of rainwater reuse along with its benefits is still unexploited. As far as industry is concerned, rainwater may be reused directly either as process water or social water usages. Process water usually needs the softening of the community tap water even though rainwater harvesting could bring productive use of soft rain. Utilization of rainwater as an alternative water resource improve water efficiency by indirectly managing water demand through reducing dependency on treated tap water produced from traditional water resources along with enhancing the closure of the water cycle through aquifer recharge measures.

Keywords: *aquifer recharge, benefits of rainwater harvesting, indirect reuse, direct reuse, green infrastructure, industrial water management*

1. INTRODUCTION

Climate change, land use, economic activities such as energy production, industry, agriculture and tourism, urban development and demographic change causes interlinked negative impacts on water status. Pressure from these causes among others pollutant emissions and water over-use (Figure 1.) therefore action must be taken to preserve our resource base for life, nature and the economy and protect human health.

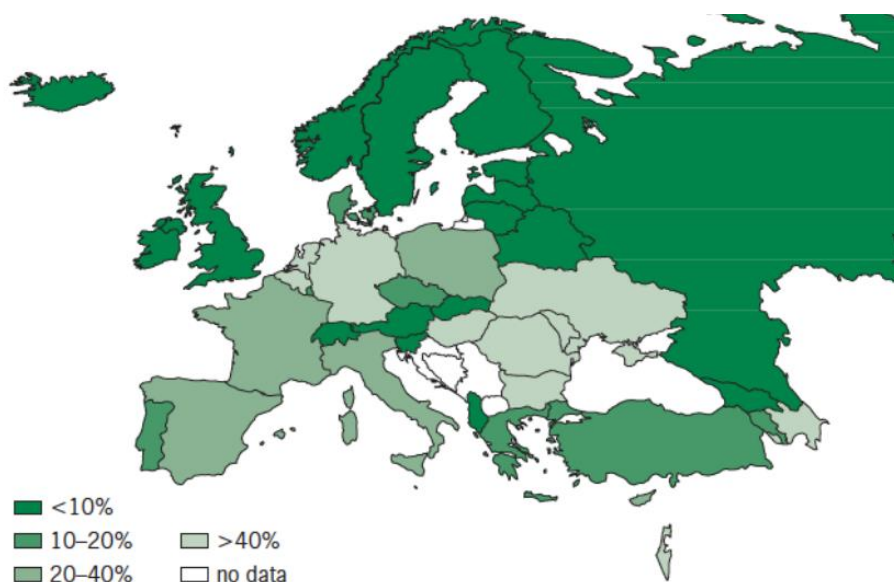


Fig. 1. Water withdrawals as percentages of renewable resources in Europe

Source: Compiled from The United Nations System-wide Earthwatch

The EU needs to focus on green growth and become more water efficient to achieve a sustainable recovery from the current economic and environmental crisis, adapt to climate change and build resilience to disasters [1]. Water efficiency measures should be taken to save water and, in many cases, to save energy too. As evidenced by the Commission's Review of the Policy on Water Scarcity and Droughts there is a high untapped potential for water efficiency measures in all the main water-using sectors including agriculture, industry, distribution networks, buildings and energy production (Figure 2.). The dominance of industrial water use in Europe is represented in Figure 3.

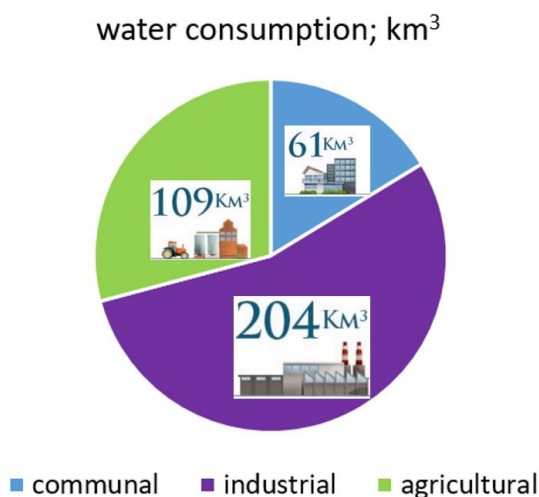


Fig. 2. In Europe 61km³ water is used for communal purposes - homes, offices, etc.-, 204 km³ in industry and 109 km³ in agriculture; compiled from

Source: Fabio Kaczala, PhD Linnaeus University Faculty of Health and Life Sciences
http://www.tvrl.lth.se/fileadmin/tvrl/files/Landfill/Integrated_Water_Management_in_Industries-_Fabio.pdf

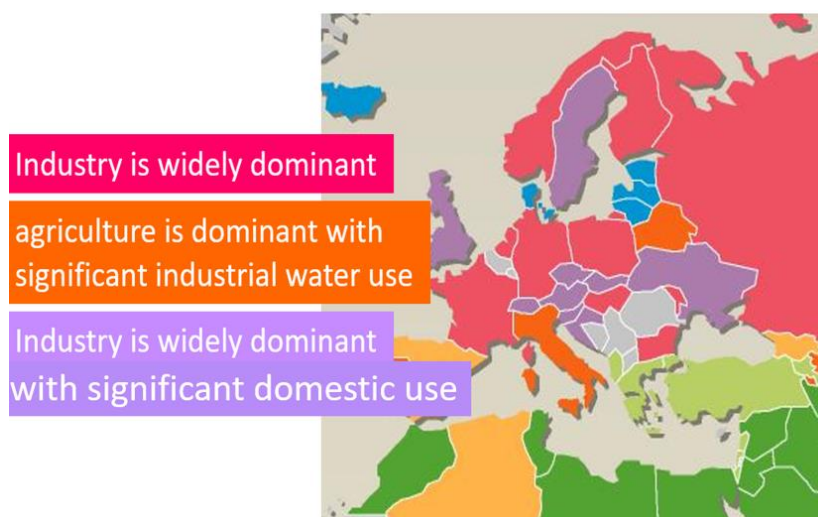


Fig. 3. The dominance of industrial water use in Europe

Compiled from: World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life, World Resources Institute (WRI), Washington DC, 2000.)

Countries which has high risks of water shortage due mainly to the growth of the urban population and the development of different economic activities, such as industry in regions with major hydrological

constraints and under the effect of global climate change the need to develop alternative water supplies to respond to the growing demand of water in is stressed. Rainwater constitutes an alternative water supply for uses that require lower quality than that provided by tap water.

2. MATERIALS AND METHODS

2.1. Elements of an integrated industrial water management

Effluent Zero Release Concept is a direction, the supreme possible result of an implemented Integrated Industrial Water Management Plan. It is a direction in which we need to implement changes. However, it must be sustainable - reasonable and economical - at the same time. A set of procedures and considerations are applied in order to cause no damage to and to improve the receiving water body in quantity and quality. Site specific facts and characteristics influence which measures can be applied sustainably therefore we list them without ranking:

- Evaluation of the available water resources with the purpose of using the least vulnerable one. In this aspect rainwater harvesting is a relatively new alternative to be considered. Rather than treating wastewater for reuse purposes Rainwater harvesting and storm water recovery can achieve similar effects of freshwater savings - Urban design systems which incorporate rainwater harvesting and reduce runoff are known as Water Sensitive Urban Design (WSUD) in Australia, Low Impact Development (LID) in the United States and Sustainable urban drainage systems (SUDS) in the United Kingdom. This is an aspect also to be considered thoroughly in case of industrial parks where several different industries and other activities characterized with different water demand may operate.
- Evaluation of the available water resources regarding technical issues of water production of the required quantity and quality for industrial uses;
- Evaluation of manufacturing steps which use and produce large volumes of water and wastewater respectively with the purpose of their optimization.
- Evaluation of manufacturing steps with the purpose of identifying possibilities of water cascade uses without previous treatment;
- Evaluation of remained effluents with the purpose of concerning possibilities of recycling or reclamation for use in another manufacturing process and of selecting adequate treatment technologies;
- Evaluation of existing similarities among the different effluents with the purpose of finding opportunities of collecting and treating them together; this is an aspect to be considered thoroughly in case of industrial parks where several different industries and other activities characterized with different effluents and water demand may operate. There may be much more possibilities here since the user may be different from the producer.
- Evaluation of wastewater reuse possibilities within the industrial area; This is an aspect to be considered thoroughly in case of industrial parks where several different industries and other activities characterized with different effluents and water demand may operate.

2.2. Anticipated outcomes of integrated industrial water management

Site specific facts and characteristics influence the chosen measures we apply sustainably therefore we list the anticipated outcomes - both the absolute as well as those compared to the conventional water management - of the integrated industrial water management without ranking (Figure 4.).

- minimization or at least rationalization of industrial water use
- improvement and modification of manufacturing processes where appropriate
- minimization of effluent along with quality improvements



Fig. 4. The main process of Integrated Industrial Water Management

2.3. Rainwater harvesting in the industry

The aim of rainwater harvesting is to reuse rainwater instead of other water sources thus enhancing water conservation goals. Reuse of rainwater may include either irrigation of landscape and other direct reuse for processes after the needed treatment or indirect reuse for replenishing groundwater, the latter also called managed aquifer recharge. Harvested storm water is now being considered as an alternative water source in several cities because of concerns over water scarcity and population growth [7.]. It is important to note that we can reuse water not only directly but indirectly [5.]. Rainwater reuse, as an alternative water source reduce the ecological footprint can provide significant economic, social and environmental benefits, which are key motivators for implementing such reuse programs [5.,20.]. Reuse of rainwater increases water availability through tap water substitution. It reduces the over-abstraction of surface and groundwater. In favorable endowments it reduces energy consumption associated with production, treatment, and distribution of water compared to using deep groundwater resources, water importation or desalination, thus reducing manufacturing costs.

2.4. Applications of rainwater harvesting in the industry

There are many applications in which harvested rainwater can be used and these are available in the form of many products [13.]. For example, WC and urinal flushing, irrigation and landscape watering, vehicle washing, laundry, cooling or with fire sprinkler systems. Rainwater harvesting systems in a diverse range of buildings, from offices, shops, museums and visitor centers through to universities, schools and colleges, industrial facilities, like warehouses and factories, hospitals, care homes, prisons and apartment blocks can benefit from having a rainwater harvesting system installed.

2.5. Rainwater harvesting as a part of the urban green infrastructure

Reuse of rainwater may include either direct reuse or indirect reuse for replenishing groundwater resources. In this case it is essential to harmonize the design with the urban green infrastructure in order to become a biologically active element of it. Vegetation and water covered urban areas can be developed into a system called green infrastructure which provide several ecosystem services to help tackle current urban challenges, such as preventing a loss of biodiversity, adapting to climate change, microclimatic regulation services and fostering recreational and healthy urban environments. ecosystem services can be best exploited in case of proper design of green infrastructure meeting several requirements.

2.6. Site specific aspects to be concerned

There are site specific aspects, decision variables, constraints or favorable endowments that influence the combination of measures we apply. Here we introduce some of the less obvious ones:

2.6.1. Design aspects

It is beyond the scope of the paper to deal with designing a rainwater harvesting system. It takes into account an array of aspects - flow rates, peak demand periods, yield and demand, and suitable filtration levels to maintain a clean and clear rainwater supply, the amount and intensity of rainfall, the size and

type of roof or collection surface, and the number and type of intended applications - in order to comply when designing the most efficient units of the systems. Units suitable for this purpose are well introduced in available guides and manuals for example in the Ciria Suds Manual [2.].

2.6.2. Industrial parks

Industrial parks or zones are located - according to modern urban land use management – on the edge of the urbanized areas of towns. This provides for favorable infrastructural endowments, more efficient and easier- to- control environmental management including monitoring in the first place. Regarding our aspect of rainwater harvesting it is easier to carry it out here since there is a great surface appropriate for rainwater collection and it is easier to find a company that is ready to use it directly for some process. Otherwise it is also easier to make a design for infiltration trenches in industrial zone since the permitted built-in area - amount of lot coverage - is determined for the whole area and the remnant serves for infrastructure and green spaces which is also given as a minimum percentage. For example, in Debrecen, Hungary an industrial estate can be built within 40% and the green spaces covered with vegetation must be at least 30%. Green spaces are appropriate for replacing rainwater infiltration units. Furthermore, it will become part of the urban green infrastructure. Additionally, set-back requirements are higher for industrial zoned properties. Setbacks are used to assure space between buildings and from roads for a many of purposes including drainage and utilities.

2.6.3. Brown fields

There are big potentials in Vegetation-covered urban brownfields therefore they should also be – after proper assessment of contaminated soils - accepted as vital elements of the urban green infrastructure [4].

2.6.4. Material of the roof

A water quality analysis of rainwater collected from different roof catchments in rural, urban and industrial areas was conducted to determine its suitability for reuse. The different roof types had an influence on the rainwater quality with zinc concentrations higher in galvanized iron roof catchments, while pH, conductivity and turbidity levels were higher in concrete tile roof catchments. The pollution of rainwater collected from roof catchments was mainly due to the diffused pollution from atmospheric deposition, and the number of dry days preceding a rainfall event affected the collected rainwater quality [11.].

2.6.5. Firefighting

There may be a need to provide water for firefighting if the site is located outside the urbanized area provided with tap water mains. In this case rainwater may be collected for this purpose in a pond basin. This practice also reduces the need for freshwater thus conserving freshwater resources.

2.6.6. Regulatory and institutional barriers

Full-scale implementation and operation of water reuse schemes still face regulatory and institutional barriers which may vary by country and is not the subject of the paper [16]. Harmonizing with standards for new buildings and zone requirements is needed and is under way in many countries.

2.6.7. Economic viability

Economic viability of water reuse schemes may be a barrier to implementation [16.]

2.6.8. Costs of water quality monitoring

Costs of water quality monitoring and identification of contaminants may be a barrier to implementation [9.]

2.6.9. Full cost recovery

Full cost recovery from water reuse schemes can be calculated only in case of subsidies [7.]

2.6.10. Pollution control

Pollution control is a great issue and plenty of guides and manuals provide up to date information and offer proper measures to be used [10.]:

- source control measures: operational best management practices and structural source controls
- structural measures of storm water management
- runoff control to minimize the quantity of storm water that contacts potential pollutants. For example, keep the area of industrial activities as small as possible; separate the area from parking lots, to prevent run-on; and roof or enclose the area if possible. Design your storm water conveyance system to isolate the areas where storm water contacts potential pollutants and convey water from those areas separately from water that runs off "clean" and nonindustrial parts of the site.

3. RESULTS

Results of the following eight papers studying the impacts and viability of rainwater harvesting are introduced here to highlight the state of the art. These articles were not studied thoroughly, just the aims and the summarized results are abstracted briefly. No paper was found focusing on integrated water management in the industry in Europe.

1. Effectiveness of rainwater harvesting in runoff volume reduction in a planned industrial park, China Xingqi Zhang, Maochuan Hu
2. Rainwater harvesting to control storm water runoff in suburban areas. An experimental case-study, Guido Petrucci, José-Frédéric Deroubaix, Bernard de Gouvello, Jean-Claude Deutsch, Philippe Bompard & Bruno Tassin
3. Evaluation of rainwater harvesting methods and structures using analytical hierarchy process for a large-scale industrial area, V. Jothiprakash¹, Mandar V. Sathe², ¹ Dept of Civil Engineering, Indian Institute of Technology Bombay, Mumbai, India, ² Centre for Technology Alternatives for Rural Areas, Indian Institute of Technology Bombay, Mumbai, India E-mail: vprakash@iitb.ac.in, mandarsathe@gmail.com Received September 3, 2009; revised September 21, 2009; accepted October 30, 2009
4. Rainwater quality from different roof catchments, P. R. Thomas; G. R. Greene Water Sci Technol (1993) 28 (3-5): 291-299.
5. Rainwater harvesting in petrol stations in Brasília: potential for potable water savings and investment feasibility analysis, Enedir Ghisi Davi da Fonseca Tavares Vinicius Luis Rocha
6. The downstream externalities of harvesting rainwater in semi-arid watersheds: an Indian case study, Jetske A. Bouma Trent W. Biggs Laurens M. Bouwer
7. Water quality of rooftop rainwater harvesting systems: a review, V. Meera; M. Mansoor Ahammed
8. Financial feasibility and environmental analysis of potential rainwater harvesting systems: a case study in Spain, Tito Morales-Pinzón Rodrigo Lurueña Joan Rieradevall Carles M. Gasol Xavier Gabarrell

Rainwater harvesting practices are traditionally widespread in the first place in countries with great stress on water resources, but industry is not in the focus area. Viability of RWH systems vary regionally. Industrial water management practices include mainly wastewater treatment and recycling in order to improve water efficiency and effluent quality but RWH is not in the focus. Chinese studies on rainwater harvesting does not prove financial savings (1.) but prove that runoff volumes causing flood risk can be efficiently reduced (1). An experimental case-study of rainwater harvesting to control storm water runoff in suburban areas of Paris rainwater tanks have been installed on 1/3 of the private parcels. The main findings are that although they affect the catchment hydrology for usual rain events, are too small and too few to prevent sewer overflows in the case of heavy rain events (2.). An Indian study is aimed at

providing best techno-economic rainwater harvesting structure so as to minimize or eliminate the dependency of the industry on purchased water. It found that the first step is to find the volume of water need to be stored.

Then the systematic methodology of analytical hierarchy process was applied to identify most appropriate RWH structure to store the required quantity of water with given conditions. AHP is applied last time to identify the right combination of tank size and number of tanks (3). A study proved that the pollution of rainwater collected from roof catchments was mainly due to the diffused pollution from atmospheric deposition, and the number of dry days preceding a rainfall event affected the collected rainwater quality (4.). The objective of a Brazilian article was to evaluate the potential for potable water savings by using rainwater for washing vehicles in petrol stations located in Brasília, Brazil. An investment feasibility analysis was also performed (5). According to the findings the average potential for potable water savings by using rainwater is between 9.2% and 57.2%. The main conclusion regarding feasibility obtained from this work is that using rainwater for washing vehicles in petrol stations in Brasília is a feasible investment for most cases.

The results of an Indian study indicate that benefits of an upstream rainwater harvesting system in a semi-arid basin in Southern India are insufficient to compensate downstream losses (6). There has been a growing interest, especially in developing countries, in rooftop rainwater harvesting as an alternative source of drinking water. A paper reviews the available information on the water quality of rooftop rainwater harvesting systems and concludes that appropriate treatment of collected rainwater would be necessary to make the harvested rainwater fit for drinking (7). A Spanish study finds that rainwater harvesting (RWH) is a good option in Spain but the financial feasibility does not necessarily indicate the environmental viability. RWH systems with higher energy consumption show better performance. The determining factor in the design of RWH systems is the scale of the system, where the neighborhood scale is the best alternative (8). Solutions for Practice E4Water Final Conference was held in 2016 in Brussels on Integrated Industrial Water Management. Rainwater harvesting was not among the topics (<http://www.e4water.eu/>).

4. DISCUSSION AND CONCLUSIONS

Papers focusing on integrated water management in the industry in Europe are not yet published. Although the need for the optimized application of water recycling and the usage of alternative water resources is evident, there is still no guide or exchange of knowledge based on experience or comprehensive studies in this field. Pilot studies are needed to investigate the viability of all the available best practices applied in different sectors of the industry under certain conditions like industrial parks or zones which may allow for applying more of these practices in a feasible way.

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