Urban Water Recycling: Rainwater, Greywater, and Blackwater Systems

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INTRODUCTION

Urbanization is happening on a rapid scale across the globe. Because of this, our natural resources are at risk of becoming scarce and must be conserved (Furumai, 2008). If we want to continue to increase the size of urban systems, sustainability must be a priority in retrofittings and future constructions. One way to do this is to employ urban water recycling systems in cities worldwide. Urban water recycling systems are put in place in order to improve water utilization, efficiency, and to reduce waste (Tao, 2020). These systems involve capturing previously-used water or rainwater and redistributing it across a city or an individual building, most often for non-potable uses. They are of utmost importance in drought-prone areas, as they can help optimize water use in order to conserve as much as possible.

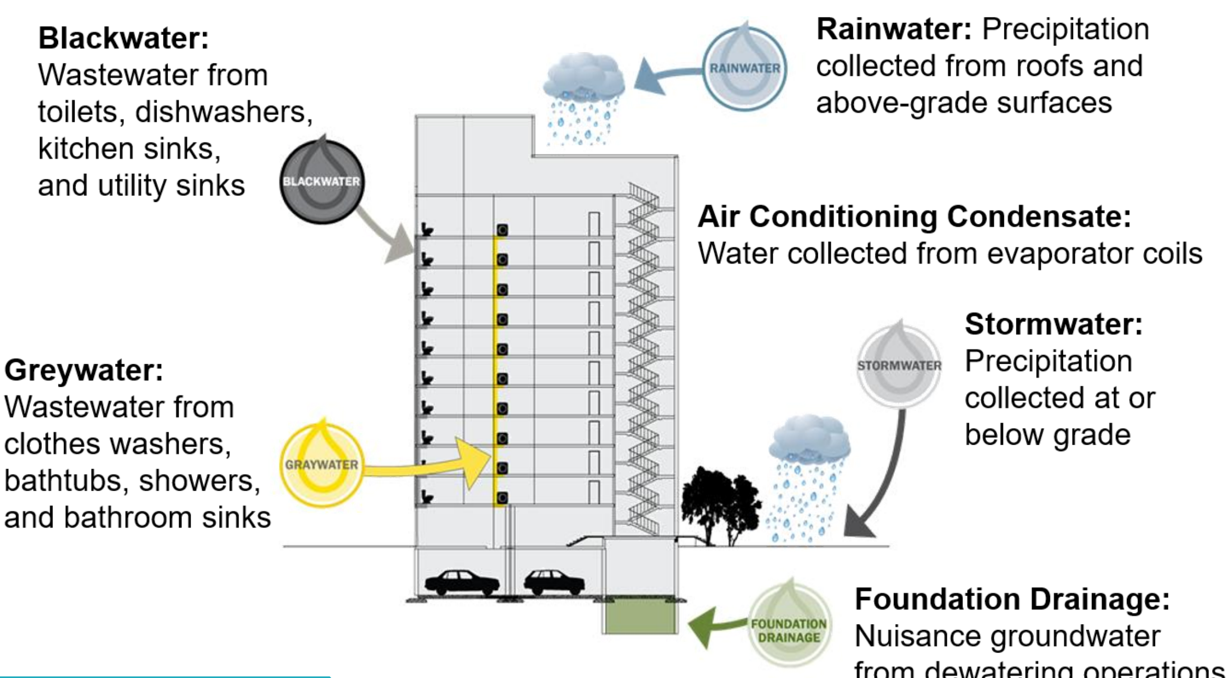
DISINFECTION TECHNOLOGIES

The two primary technologies used for the disinfection of water include physical and chemical technologies. Physical technology includes, most commonly, ultraviolet (UV) radiation. UV rays are incredibly harmful to living beings, and can therefore kill potentially harmful bacteria and pathogens that are present in contaminated water. The most prominent chemical technology is chlorination. Chlorine is added to water in order to kill off bacteria and disease. UV rays and chlorination can be used together in order to provide extra decontamination for infected water (Salgot & Folch, 2018).

TECHNICAL DETAILS

Decontamination systems can be centralized or decentralized, or a mix of both. Decentralized systems include water being captured and disinfected at different sites, then distributed across multiple residential or commercial areas. These are more common among city-wide water recycling systems. There are also centralized, non-potable water reuse systems. These systems include water being sourced at one particular site, it being filtered, treated, or disinfected there, and then redistributed across the same site (Arden et al., 2020). This paper will explore the three primary types of water recycling systems: blackwater, greywater, and rainwater recycling systems.

- *Blackwater recycling* includes capturing blackwater from sources such as toilets and dishwashers and heavily chlorinating it in order to make it reusable ("Blackwater recycling systems", n.d.).
- *Greywater*, on the other hand, does not necessarily contain potentially dangerous bacteria. Its sources could be, instead, showers, sinks, and washing machines ("Blackwater recycling systems", n.d.).
- *Rainwater* systems include collecting runoff from rainfall, filtering, and redistributing it across a system (Renewable Energy Hub, 2018).



Source: SF Public Utilities Commission

APPLICATIONS

There are many application categories of municipal wastewater reuse. However, we are going to be focusing on the non-potable urban uses. Typical non-potable urban applications can be broken down into four categories: landscape irrigation, non-irrigation urban uses, in-building recycling, and environmental enhancement and recreational uses.

Source: Inhabitat

Source: Mongabay India

LANDSCAPE IRRIGATION

Landscape irrigation is the primary application of urban water reuse and consists of the irrigation of public parks, sports fields, green belts, (the natural or undeveloped land surrounding urban areas), as well as private, commercial, and residential areas and gardens. Depending on the lanscape of irrigation, there are different levels of restriction necessary. Irrigation of certain plants, especially for ornamental purposes, needs more careful analysis of water quality, while other irrigation needs, such as common grasses, are more tolerant of less filtered water containing more salinity. The techniques of distribution, such as sprinklers and drip irrigation, may also increase the requirements for filtration depending on storage, pressure, and water control (Lazarova & Asano, 2013).

NON-IRRIGATION URBAN AND IN-BUILDING USES

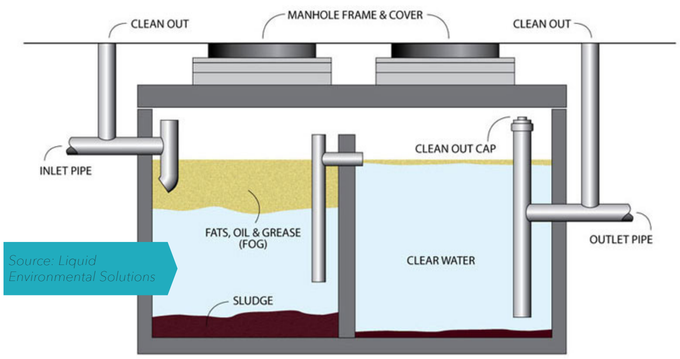
Non-irrigation water reuses found within urban areas consist of street cleaning, fire protection, air conditioning, and toilet flushing. These uses can be supplied by urban water recycling systems outside of the building or area, or through in-building recycling, the system often collecting and reusing water within high-rise buildings and large commercial facilities. Urban in-building use is often limited to these high-density sites due to the financial cost of installing a dual distribution system, a system of potable and reclaimed recycled water (Lazarova & Asano, 2013).

ENVIRONMENTAL ENHANCEMENT AND RECREATIONAL USES

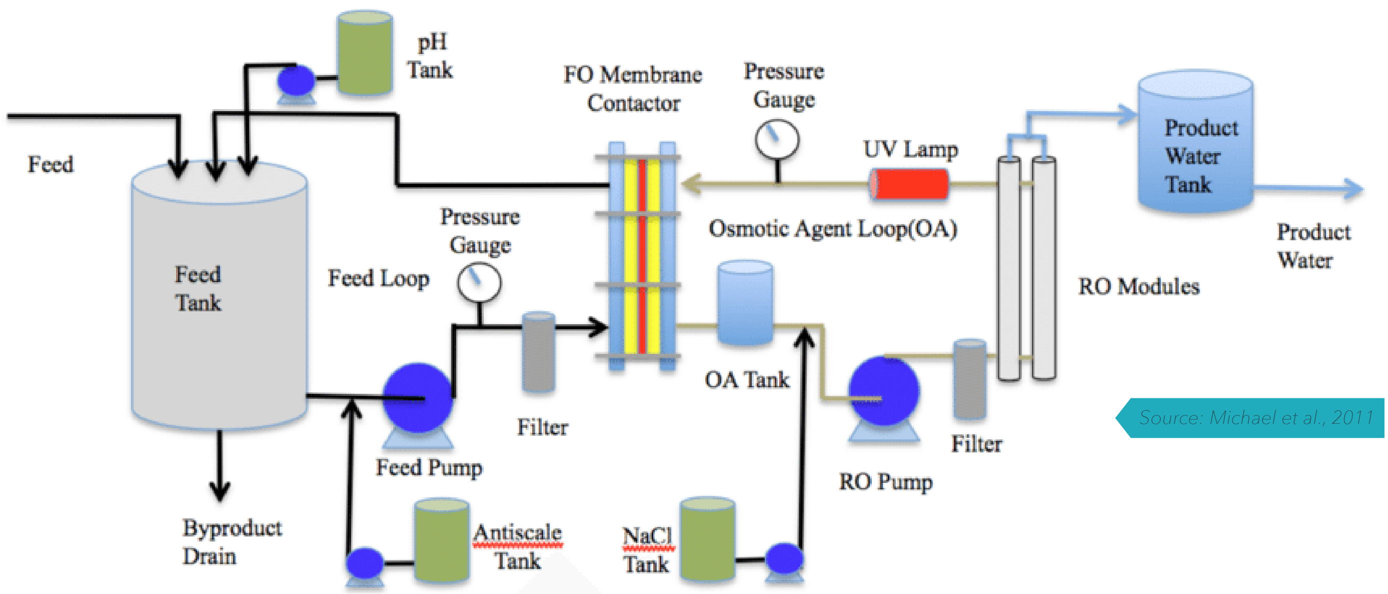
Water reuse can also fill and restore river flow or wetlands, create artificial lakes, and make artificial snow. Additionally, it can be used to fill bodies of water for swimming or fishing purposes. Similar to landscape irrigation, the quality of water is dependent on the application. Recreational uses involving human contact or environmental uses that could impact the ecosystem and its health depend on having access to non-hazardous water. Therefore, regulatory standards are most important for these applications.

TYPICAL DETAILS

Water recycling systems typically follow a generalized process of being captured, cleaned, and then reused. This process follows five steps to effectively and safely recycle the water. Starting with the capturing of water: the system will collect water from various sources, depending on the type of system being implemented, and store it in a tank. After the water is collected and stored, it can enter the rest of the cleaning process. First, large particles are removed. This is primarily done with a device known as a triple interceptor (left). A triple interceptor is composed of 3 tanks of varying levels of size and depth. Each tank removes smaller and finer particles as the water cascades between them. After this broad filtration, oils must be removed. Oils are often dangerous or hazardous and must be removed from the water before



Source: Liquid Environmental Solutions



Source: Michael et al., 2011

it can be reused. Separating oils from water generally happens in two ways: gravity or membrane filtration. Due to water having a higher density than oil, allowing a mixture of oil and water to sit will cause the oil to rise above the water and be easily skimmed from the surface. The other method involves using a specialized membrane that will cause oil to coalesce upon it and be removed from the water tank. Step three is the filtration of smaller particles. These particles are significantly smaller than those removed in the triple interceptor. They can be filtered out, however, by flowing the wastewater through very narrow sieves that will only allow for water molecules to pass through. The next step is typically the removal of detergents and soaps. Detergents and soaps work by mixing with the oil and soils they are to remove and creating a residue that can be easily rinsed away by water. This residue contains detergent chemicals, oils, and any other wastes that were removed. Detergents are usually removed from wastewater through the use of specific chemicals which allow harmful molecules to coagulate into larger particles that can be removed. Finally, the water is sterilized of any organic particles that could still remain, such as organic materials, pathogens, viruses, and any other microbiological contaminants. This is done through either a chemical process, using chlorine, or a physical process, using UV radiation. After being cleaned, water is now ready to be used for various purposes, ranging from potable uses to non-potable uses, such as irrigation.

CASE STUDY #1

Greywater and Groundwater Recycling System: Millennium Dome, London

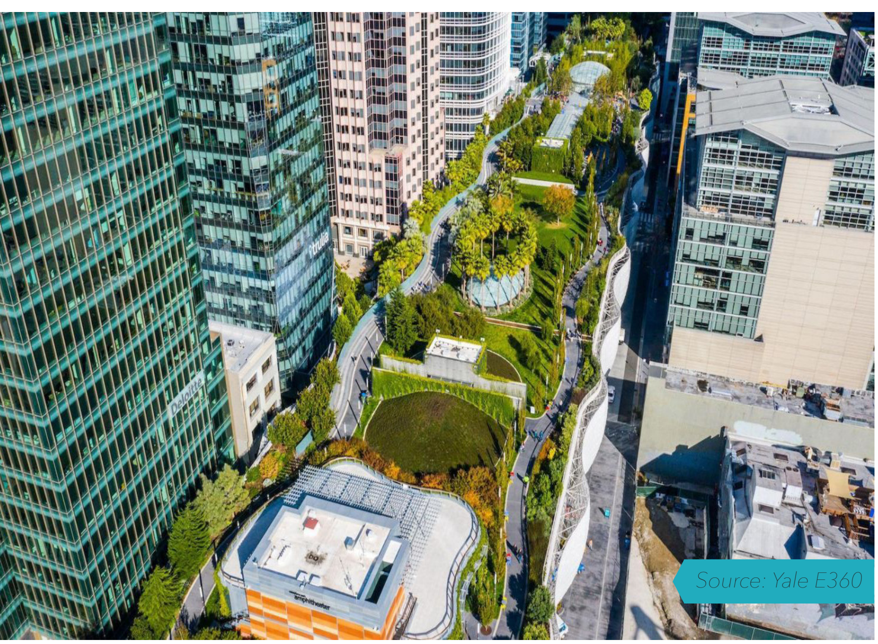
The Millenium Dome in London represents a particularly useful and interesting case study into the treatment and recycling of groundwater and greywater. First, the designers determined that the usage of biological aerated filters and a variety of membranes that focused on the utilization of biochemical oxygen demand would be the best method for treating sink and shower greywater. This uses typical setups similar to the one explained previously, relying on reedbeds as natural filters. The greywater is passed through these membranes and filters before being returned to the building for use. The groundwater was tested and revealed to have issues involving hydrogen sulfide gas and higher-than-expected salt and iron content. These two factors must be treated before the water can be used again. The solution for this was a system created to clean the water. First, the groundwater was exposed to hydrogen peroxide to oxidize metal contaminants. Next, membrane filtration removed any remaining organic materials, and a reverse osmosis filtering membrane desalinated the groundwater. This filtration system was mixed with treated greywater that passed through reedbeds. Finally, the water was re-hardened, meaning that beneficial minerals were added back to it, disinfected, and returned to the Dome as treated water that could be used for any non-potable uses.

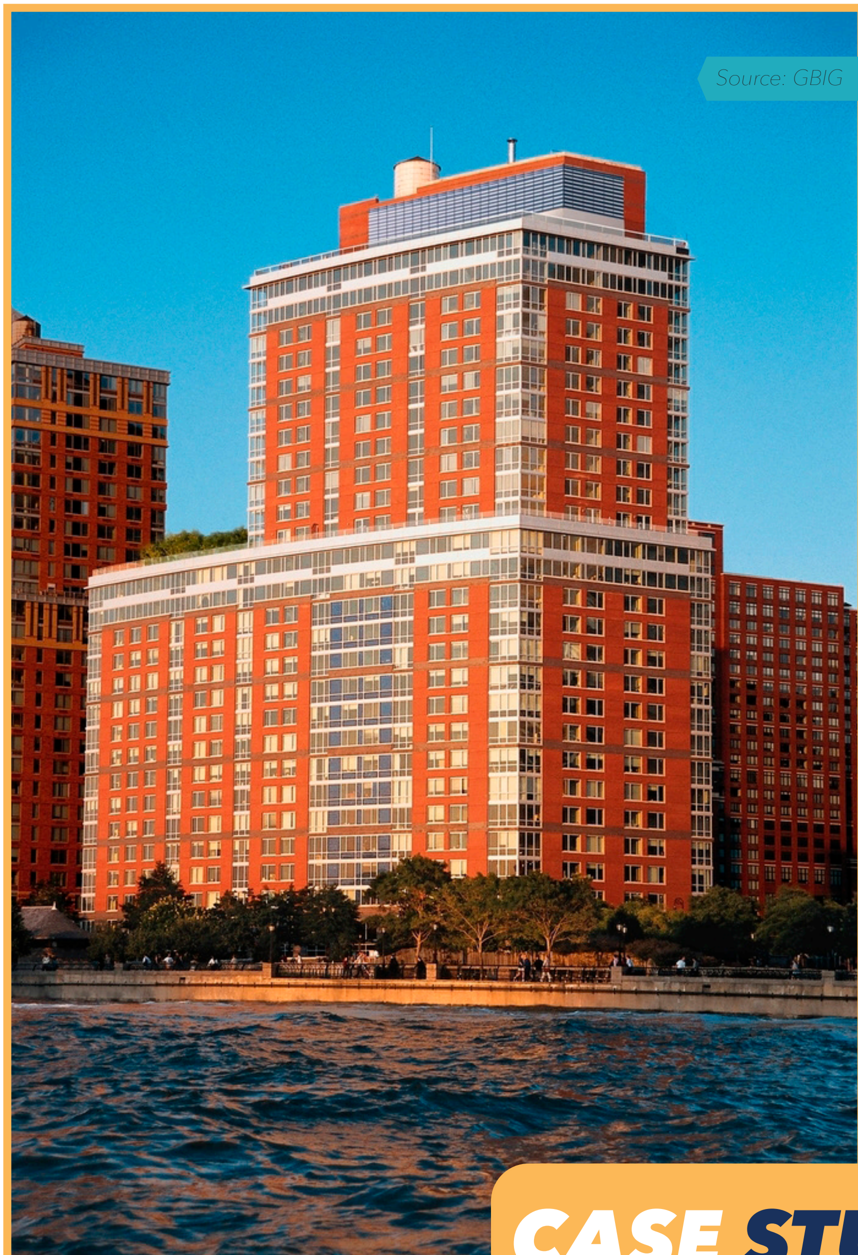
Blackwater Recycling System: Salesforce Tower, San Francisco

The Salesforce Tower uses the Aquacell S series, on-site blackwater filtration system. Located in the basement, this system collects sewage, or "black", water from the building, then is pumped with bacteria to break down the waste. The water is then aerated, settled, and irrigated and chlorinated. Finally, it is transported back for use in non-potable settings, such as drip irrigation and toilets ("Blackwater recycling systems", n.d.). This commercial, centralized system is the largest of its kind in the United States. This filtration is key in reducing the tower's water use, a critical adaptation to drought-ridden California. San Francisco is at level 3 severity of a 5-level drought scale, as defined by the United States Drought Monitor (National Integrated Drought Information System, 2022). This system treats approximately 150,000 liters of water per day, and saves Salesforce Tower up to 7.8 million gallons of water per year (Sisson, 2021).


Source: Wikipedia

CASE STUDY #2


Source: Yale E360



CASE STUDY #3

Rainwater Recycling System: The Solaire, New York City

The Solaire Apartment building in lower Manhattan, New York City incorporates advanced technology to reuse wastewater and collected rainwater. Focusing on the rainwater recycling system, Solaire's vegetated rooftop utilizes a stormwater retention system designed using a mat below the soil surface. The excess water that is not absorbed and utilized by the plants and vegetation on the roof is then collected in a 10,000-gallon tank in the basement of the high-rise to be used for the landscape irrigation purposes of the facility. This rainwater system irrigates 930 square meters of rooftop gardens and allows for a reduction of stormwater to the city's combined sewer system. Along with the recycling and reuse of gray and black water waste, this in-building water recycling system reduces their use of the city's public water supply by 50% and allows for 35% less energy consumption (Lazarova & Asano, 2013).