ANALYSIS & DEVELOPMENT OF EFFICIENT WASTE WATER MANAGEMENT SYSTEMS FOR URBAN CITIES OF INDIA.

Sub theme: Goal 6 - Clean Water and Sanitation

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Abstract

Water is essential to human life and activity. Population growth, urbanization, and increased demand have made water management an important area of study. Water is necessary for existence on Earth. A sustainable city must attain efficiency in water supply and waste water treatment as part of the planning for blue infrastructure. Infrastructure development, ecological restoration, and human health are key design considerations. However, there are numerous types, sources, and forms of waste water, which includes grey and black water, industrial waste water, and storm water. Current methods of waste water discharge in Indian cities have caused numerous problems, which involves contamination of source water, insufficient waste treatment facilities, monsoon flooding, drainage system malfunction, destruction of the water ecosystem and aquatic life, and health hazards. A suitable waste management system is required for the efficient treatment of wastewater. When a system is efficient, it accomplishes a task with minimal effort, expense, waste, time, and provides maximum output. The sustainable development goals 2030 focus on enhanced water supply, treatment and aquatic life. Thus, the objective of this study is to analyses and devise an effective waste water management system for urban development. This study's methodology includes a literature review of scholarly articles, a case study of extant efficient waste water management systems, an analysis of the current Indian situation, and the best proposal to be implemented in Indian cities in order to assist policymakers in making the right decisions. The paper concludes with a valuable action plan to address the current shortcomings in waste water management.

Keywords

City; efficient; management; sustainable development; waste water;

1. Introduction

Waste Water management is the most essential city Infrastructure to promote sustainable development of the city. It is associated with the sanitation, quality of water resources, flooding, water scarcity and many common urban issues. India is a developing country with the world's largest population and many number of urban cities. Due to increase in urbanization, the load on water treatment plant increases causing incapability to treat all the waste water. This leads to direct discharge of waste water into rivers, seas and canals destroying the water ecosystem. But the point is not only about environment, ground water recharge, water supply, local sanitation, irrigation and many other activities are dependent on water sources. During times of water scarcity, the polluted rivers are of no use. Filtering and treatment of polluted water is expensive. Huge amount of spending is done on water collection, treatment and we discharge the same water to treat it again. Efficiency is achieved when input is equal to output. The need of figuring out how to meet our water requirements while also effectively managing our water resources is growing to the point where it is absolutely essential. It is crucial to our efforts to ensure a sustainable future that we reuse and recycle the water that we collect.

The current capacity of waste water treatment in India is just 27.3%, according to the estimate that was done in 2021 by the Central Pollution Control Board. Incapability can also be caused by other issues, such as lack of maintenance and repairs, as well as the mixing of storm water and domestic waste water. Before just expanding the number of sewage treatment plants (STPs), India has to first develop a comprehensive action plan and proposal for the waste water network. In the present moment, increasing the total number of STPs is not the sole answer. It is very necessary to have a functional network for the separation of industrial water, waste water, and stormwater. This research evaluates the success of waste water management systems in an array of cities across the world in order to determine what the best course of action may be for Indian cities.

When raw effluent is dumped into a body of water, it will normally go through the natural processes of stream cleansing and self-purification in order to become clean again. On the other hand, as a result of rising populations and widespread urbanization, the rate of effluent discharge has grown at a pace that is substantially higher than the rate at which natural purification occurs. The production of an excessive amount of nutrients has led to the eutrophication of the body of water as well as a gradual deterioration in the water's overall quality.

The results of a study that was conducted in 2017 and used sophisticated modelling techniques in order to investigate the effects of water and agricultural irrigation with untreated compounds revealed alarming conclusions. (A L Thebo *et al*, 2017) According to the report, untreated wastewater has an effect on 65 percent of all irrigated regions that are within 40 km downstream of metropolitan centers, which amounts to 35.9 million hectares. This presents a substantial risk to the health of 885 million people throughout the world, including consumers, food merchants, and producers. Iran, China, India, and Pakistan, together with Mexico, were home to a combined total of 86% of the world's irrigated croplands.

2. Efficient Waste Water Management System

Waste water contains chemicals, impurities, solid particles, soil, sewage and most of organic waste particles. Waste water treatment includes removal of these residue and impurities by extensive treatment process before discharge. Waste Water comprise of major categories: Rainwater/stormwater, domestic waste water (grey water and black water) and Industrial waste water. Storm water is when rainfall occurs and water flows on the hard surface of the city and consists of soil, silt, dry leaves and other garbage fallen on ground. Soil erosion happens due to stormwater and stormwater gets mixed with domestic sewers which is a major problem. Domestic waste water comprises of two types; greywater and black water. Grey water is the waste water containing small particles of impurities and chemicals generally obtained from kitchen sink, bathroom and washbasin. Black water contains solid particles obtained from the WC and toilets. These both waste waters are different and require different treatment processes. Black water cannot travel long distances through pipeline network thus require neighborhood level STPs. To travel long distances, blackwater may need additional water to create flow, which again increases the water volume and decreases the treatment capacity. Grey water can be recycled and reused for outdoor washing, flushing, irrigation, construction activities and landscaping. Industrial waste water contains hazardous impurities and requires separate treatment process, highly leakproof and 100% treatment before discharge.

Categorization of waste water is not only for statements but is useful for segregation of treatment processes. This reduces the load on one Sewage Treatment Plant and efficiency can be achieved. An efficient waste water management system should have Maximum waste water treatment, segregation of waste water types and its plants, minimal energy use, minimal leakage and maintenance and maximum output with cost effectiveness. To achieve all these goals, research and planning is required to formulate an action plan at city level.

Green building rating systems offer guidelines for waste water treatment in the context of large-scale constructions. However, it is imperative that these rules extend beyond the scope of green buildings, as the current number of green buildings remains significantly lower in comparison to conventional structures. Therefore, a comprehensive city-level guideline is necessary to ensure the widespread implementation of these policies. The government currently allocates a significant amount of its revenue towards the management of waste within the city. By incorporating effective planning and addressing current challenges, one might employ a similar level of effort. The present allocation of funds does not provide favorable outcomes for the environment or the city, and this situation is expected to deteriorate with the progression of urbanization. Wastewater can be considered a valuable resource due to its potential to contribute to water resources utilized for water supply purposes.

3. Methodology

The research technique employed in this study is founded upon a comprehensive evaluation of academic literature and the utilization of secondary data sources. The literature review focuses on the need of research and planning for waste water management in India by scholarly authors and also highlight the gaps identified by authors regarding the topic of discussion. The literature review will be a valuable contribution to approach the findings and formulate action plan for Indian scenario. For the acquisition of necessary data, indexed publications, scholarly articles, news items, government reports, and reputable websites affiliated with government entities and organizations are studied. This study aims to examine and evaluate the effectiveness and overall functionality of waste water management systems in various cities via the selection and analysis of relevant case studies. A comparative analysis of the case studies is conducted in order to enhance comprehension of the difficulties and possibilities at hand. The portion of the research paper focuses on the Indian waste water management system, providing an in-depth analysis and outlining the necessary criteria for the implementation of an action plan. Case studies serve as a valuable resource for the purpose of devising effective strategies for wastewater management in India.

4. Literature Review

According to some Literature, Waste water is a critical issue emerging in India. An author states that out of the total sewage generated per day, only 30.72 % sewage can be treated, only the large-scale industries treat waste water which accounts for 60% out of the total industrial waste water. (R Kaur, et.al, 2012) By analyzing the statistics of water availability and use, there is an urgent requirement for efficient waste water management. Irrigation activities consume the highest amount of water according to the reports of water demand CWC 2010. The author stated the cost of treatment plants for various types of filtration systems along with its operation, maintenance, depreciation and all cost factors. This was based on the year 2012 and now the numbers vary too much. However, installation of treatment plants is surely going to cost a lot in the city infrastructure. Thus, efficiency is required for good returns of the investment. Wastewater use is being done by peri urban irrigation in some areas, it is economical and beneficial for employment. The crops cultivated by wastewater are cereals at Hyderabad, vegetables at New Delhi, flowers at Kanpur, Avenue trees and parks at Kolkata, Agroforestry at Karnataka and many more. Waste water treatment systems such as bio refineries remove 90 % of Chemical Oxygen Demand from waste water by the process of anaerobic digestion. Bod removal also takes place and it can be recovered as biogas. Further aerobic treatment reduces the BOD content from waste water. Algae increases the dissolved oxygen and absorbs Carbon dioxide. The generated biomass can be used as organic fertilizers. Manmade wetlands constructed within the city have natural process of water filtration. Other process such as filtration and reverse osmosis hep in recycling the water for reuse.

The India Infrastructure Report 2011 by the Oxford University press shows water resources, its management, challenges, urban and rural scenario, policies, infrastructure, major rivers of India, water rights and water laws of India are discussed. (Kamyotra, J. S., et.al, 2011). Water laws are critical for ensuring equitable access to water, safeguarding water resources, and averting their exploitation. Rural regions continue to be plagued by scarcity and substandard quantities of potable water. For the provision of potable water, groundwater is utilized, despite its elevated sodium content and subsequent impact on the water table. In certain regions, urban areas experience an excessive water supply, while in others, water scarcity is a problem. The absence of balance between them is evident. Storm water has a significant impact on urban areas as a result of increased urbanization. Reuse and recycling of wastewater can fulfil the need for non-potable water inputs. Concerningly, potable water is presently supplied and utilized in large quantities for non-potable purposes as well. The cost and effort required to purify and transport water are extremely high. Recycled water reduces capital expenditures significantly and increases efficiency. Additionally, recycled water can be utilized in the energy sector, agriculture, industries, and groundwater recharge. "Water pollution in India," a paper by M.N. Murty, describes the escalation of pollutants in India's main rivers. Class 1 communities, which comprise the metropolitan regions of India, treat a mere 32% of the generated effluent water. But even in tiny towns, only 8% of the overall effluent water is treated. Extremely detrimental to human health is water pollution. River purification incurs greater costs in comparison to wastewater treatment. The efficacy of river cleansing may be short-lived due to the continuous mixing of sewage with water from river outlets, whereas an investment in water purification infrastructure will undoubtedly yield long-term benefits.

A range of methods can be employed in Wastewater Treatment Plants (Kamyotra, J. S., et.al, 2011). Specifically, the conventional process encompasses chemical, biological, and physical operations aimed at eliminating contaminants. The initial stage of treatment involves the removal of both organic and inorganic particles of significant size. The secondary treatment process involves the use of aerobic digestion to effectively eliminate residue and suspended particles. The activated sludge technique is generally employed to decrease the levels of Biological Oxygen Demand (BOD) in wastewater. Trickling filters are comprised of biofilms that consist of a mixture of stones or other materials. The biofilm functions by filtering trash particles and introducing oxygen into the water. Rotating Biological Contractors (RBCs) consist of stationary films augmented with mobile supplementary material. This procedure effectively eliminates 85% of the biochemical oxygen demand (BOD) and suspended particles from wastewater, while simultaneously introducing oxygen into the system. The upward movement or flow of a substance or The Anaerobic Sludge Blanket (ASB) is a wastewater treatment technique that operates under anaerobic conditions. During this process, the wastewater is directed to flow in an upward direction over a layer of granular sludge. The stages encompassed under this process consist of hydrolysis or solubilization, acidogenesis, and methanogenesis.

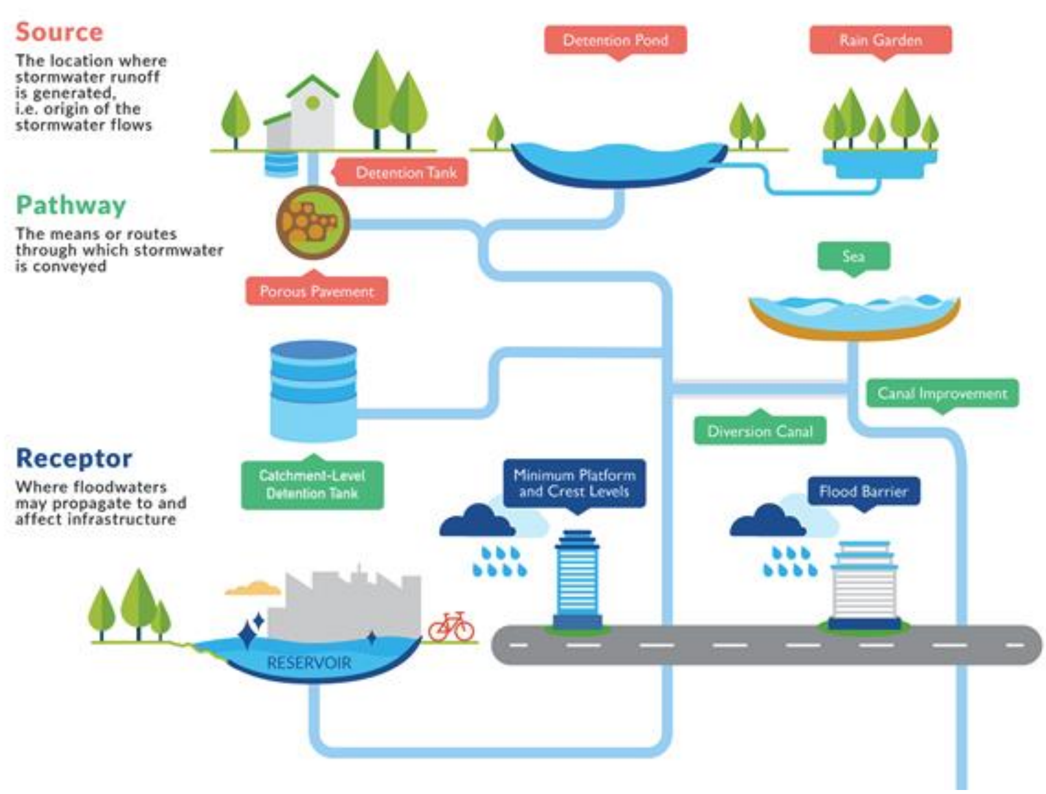
5. Case studies

5.1. Singapore

Singapore is a country located in Southeast Asia which is an island surrounded by many small islands. The population of Singapore is around 60 million and the area of land is 719 sq.km. It has 6 major rivers serving as water resources. The country is well developed with adequate infrastructure and skyscrapers with a strong economy. Major occupation of the country is banking, manufacturing, Information technology, automobiles, telecommunication, real estate and international trade. The country's population, area, natural resources and occupation play a major role in analyzing the water availability, demand and management. Singapore gets its water from four sources: local catchment water, imported water, NEWater, and desalinated water. This diversified water supply plan, known as the Four National Taps, guarantees Singaporeans have a reliable supply of water for future generations.

Rainwater and waste water are collected in Singapore by two distinct methods, respectively. A comprehensive system of drains, canals, rivers, stormwater collecting ponds, and reservoirs is for rainwater collection. This collected rainwater is subsequently treated for the purpose of serving as a drinking water supply in Singapore, where approximately two-thirds of the country's landmass is designated as a water catchment area. Consequently, Singapore stands out among the global community as one of the limited number of nations that actively engages in the collection of urban stormwaters on a substantial level, with the primary objective of meeting its domestic water requirements.

Figure1: Source, Pathway and receptor strategy in Singapore waste water management



Reference: Public Utility Board, Singapore

The Public Utility Board of Singapore is responsible for water management and it uses a 'Source-Pathway-Receptor' method, which takes into account catchment-wide solutions, to improve flood protection by reducing stormwater. At the source level which means at building site level, rainwater is collected by rainwater harvesting, detention ponds or raingardens. The source is where rainwater starts to flow. The pathway is the network of pipeline to carry the rainwater from the roads and sites. Pervious pathways are used to collect water and divert it into stormwater pipes. The receptors are large scale stormwater provisions to cater high flooding. Diversion canals, artificial reservoirs and detention tanks are used to collect storm water and they are connected to the sea further.

The Deep Tunnel Sewerage System (DTSS) is a project conducted by the PUB, Singapore for waste water treatment. In order to address the enduring water requirements of the island nation, it is imperative to establish a comprehensive system for the collection, treatment, reclamation, and disposal of wastewater originating from various sources such as industry, residential areas, and commercial establishments. In this system, two large tunnels, with a combined length of 80 kilometers and a diameter of 6.5 meters, will be dug approximately 50 meters below the surface to transport effluent to three centralized water reclamation (WRP) facilities. The WRPs will clean and treat the effluent in order to produce NEWater, a brand-name reclaimed water of superior quality. The purified effluent will be discharged into the Straits of Singapore via deep sea outfall pipelines. The DTSS project involving the collection and purification of utilized water is anticipated to have a design life of 100 years without requiring any maintenance. The main benefit of this project is that it reduces use of land for water treatment infrastructure by around 50% as the system is underground.

Singapore adopts Efficiency measure in waste water management by the following initiatives:

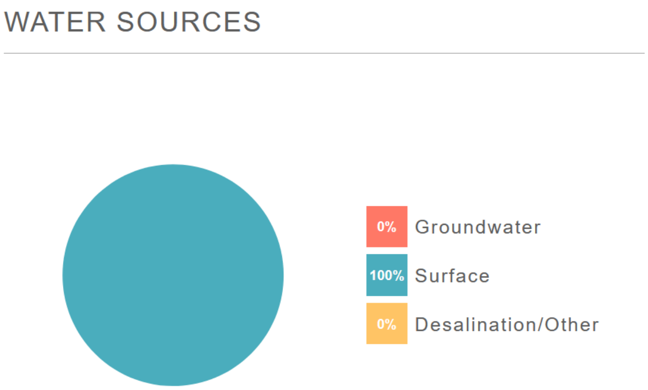
- Large water consumers with net water consumption of atleast 60,000-meter square must install water meters, adopt water efficiency management plan within the building by appointing a manager and executing work.
- Specified consumers must develop a water balance chart, identify potentials of reduction in water use and establish an action plan for water savings. (A water balance chart shows total water input = total water output i.e., supply and use)
- The PUB, Singapore also provides funding to assist implementation of water efficiency projects.

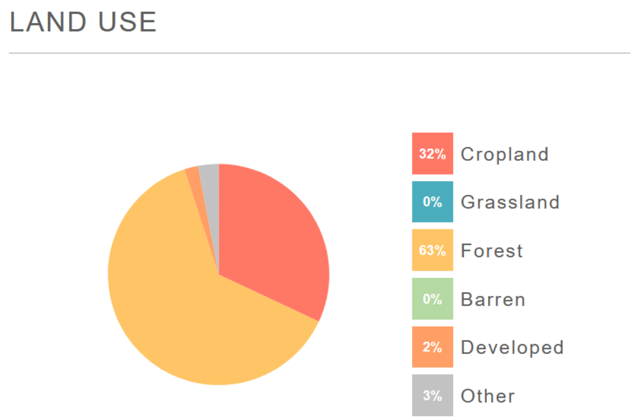
The NEWater initiative which recycles used water and makes it useful for industrial, commercial, energy and other purposes is a success. By the water test reports, it has been claimed to be ultra clean, high grade and fit for consumption. Currently five number of such plants are installed in the country. NEWater had undergone multiple tests and has proven safe and sustainable water resource which fulfils the requirement of drinking water standards. The NEWater is recommended for indirect potable use and mixing with raw water reservoirs to create drinking water.

5.2. Tokyo, Japan

Tokyo serves as the capital city of Japan, functioning as both the political and economic hub of the nation. Additionally, it should be noted that Tokyo holds the distinction of being the most populous city in Japan, and indeed, the most populous city globally. Tokyo city has a population of 14 million with an area of 2,194 km^2. Tokyo is home to a total of 107 rivers, collectively spanning a distance of 857 km. The Tokyo Metropolitan Government is responsible for the management of 710 kilometers of 105 rivers in terms of their length. Conversely, the Ministry of Land, Infrastructure, Transport and Tourism oversees the remaining sections, which include the Arakawa and Edogawa rivers. The principal water source for the Tokyo Metropolitan Area is Sumida River water. Prior to 1955, the Tama River system served as the primary source of water. However, due to population growth and increased exploitation of the Tone River system, the Tone River system and Arakawa River system now provide approximately 80% of the current supply.

Figure2: Water Sources and Landuse of Tokyo, Japan



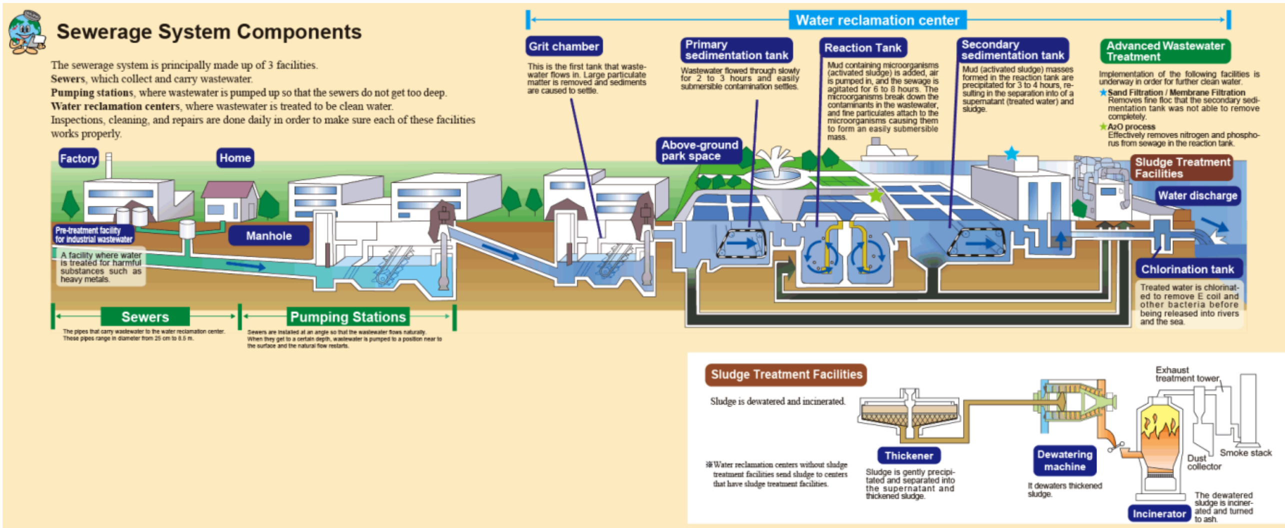


Reference: https://water.nature.org/waterblueprint/city/tokyo/#/c=8:36.69926:139.44672

Tokyo has a notable concentration of industrial facilities, particularly in the vicinity of the Tokyo Bay area. Therefore, the effective management of water and wastewater systems in urban areas plays a vital role in maintaining water quality. Tokyo is subject to several environmental dangers, including floods and storms. Consequently, the municipal administration has implemented strategies to mitigate stormwater runoff, including the allocation of resources towards subterranean infrastructure for efficient water conveyance outside city limits, as well as promoting the use of groundwater infiltration systems. In recent years, the municipality has witnessed a notable surge in the use of recovered water for various reasons. The beginning of water reuse practices in Japan can be traced back to the 1980s, when the nation was facing a critical water shortage situation owing to a combination of circumstances including a prolonged drought and the increasing water requirements that resulted from fast urbanization and economic growth. In the 1980s, Japan faced a dire water scarcity situation due to a combination of causes including the water requirements that resulted from rapid urbanization and economic expansion. The procedure of reusing water may be broken down into three different stages, as seen above. The first step was the installation of water reuse systems in toilet flushing within urban areas. Subsequently, the installation of stream flow augmentation began during the latter half of the 1980s as part of the project's second phase. This phase was known as "stream flow augmentation." During the third phase, multifunctional applications that serve several purposes, such as heat transfer and emergency applications, have been developed. These applications have been a focus of development. (Haruka Takeuchi, et.al., 2020)

Tokyo has adopted various advanced technologies in waste water treatment and efficiency which involves utilizing treated water in flushing and toilets, cleaning urban streams for improving local amenities, disposal of sludge in incineration process, reuse of sludge in construction materials, utilizing wastewater as a heat recovery system(wastewater has characteristics to get warm in winters and be cool in the summers) similar to a passive design strategy, a sewerage mapping and information system tracks the sewers and offers more computerized data and analysis to perform quickly. The computerized system also records rainfall for working of the pump operation and collecting information from the plants by the help of radar. An optical fiber network has been implemented for the purpose of remotely monitoring and controlling pumping stations. Reduction of leakage losses by installing steel pipelines and efficient plumbing system. Reclamation Plants of Tokyo is the Ariake Water Reclamation Center is a large sewage treatment plant which adopts A_2O method (anaerobic-anoxic-oxic process) and biological filtration process. The treated water is discharged at the Tokyo Bay and the sludge generated is sent by pressure pipelines to the Tobu sludge plant for treatment and incineration. A total of 13 wastewater treatment plants are present in Tokyo. (Seisaku Endo and Shuki Koga, 2021)

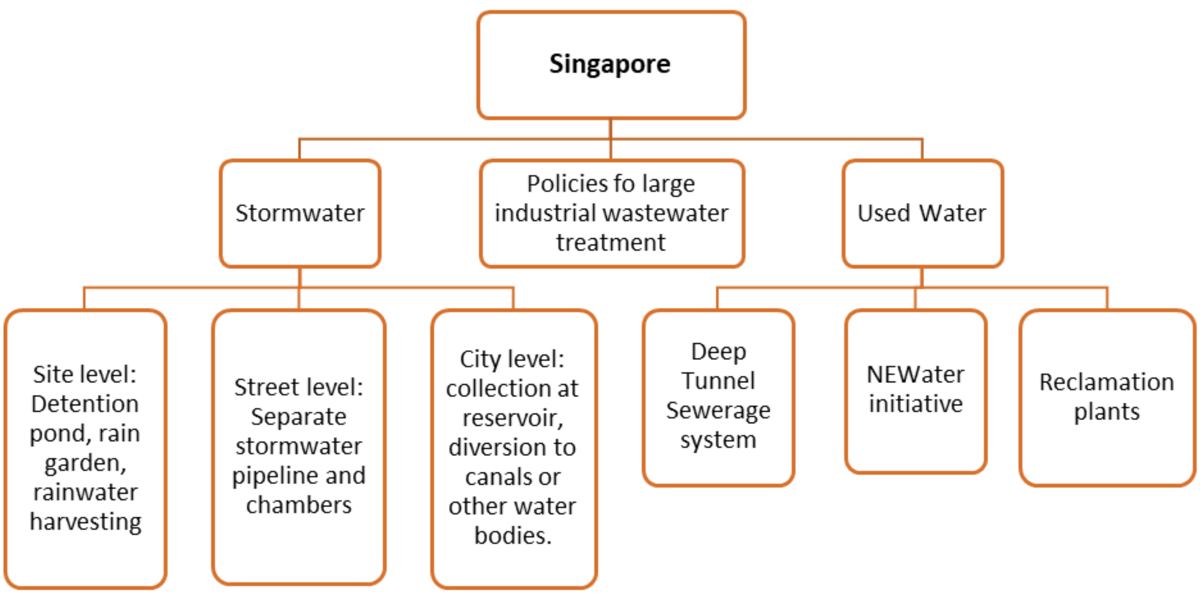
Figure3: Reclamation Center sewerage system and its components located in Tokyo



Reference: https://www.gesui.metro.tokyo.lg.jp/english/aboutus/center06/

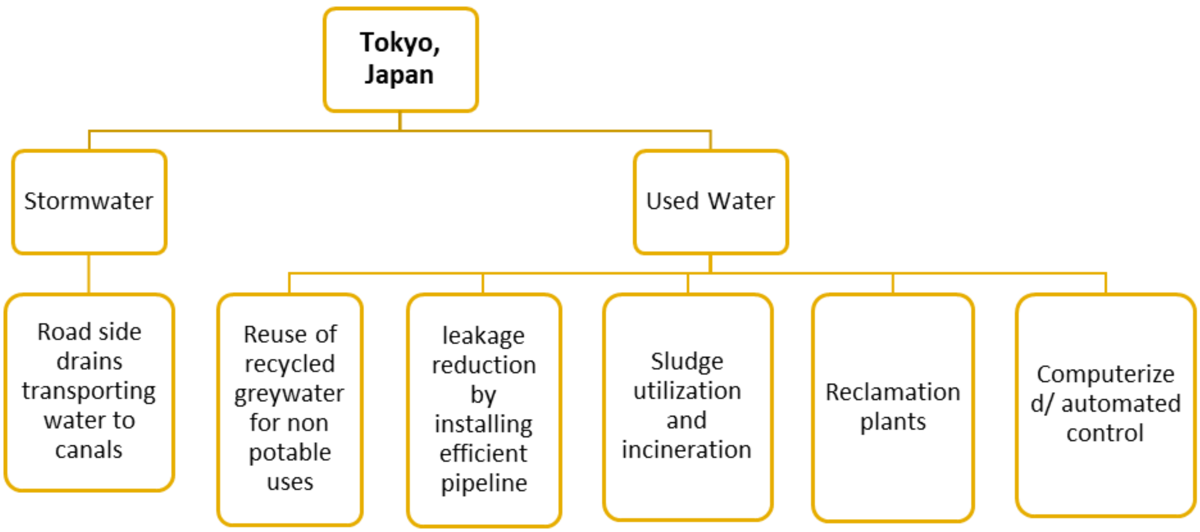
6. Analysis & Discussion

Figure4:Summary of Singapore Waste Water Management:



Reference: Author

Figure5:Summary of Tokyo Waste Water Management:



Reference: Author

By studying the two case studies; Singapore and Tokyo we can understand that water availability, consumer demands and technological advancements are the main factors of waste water management. Both of the cases use different methods of water treatment and reuse. Singapore has very less irrigation occupation while Tokyo has more percentage of irrigation. Singapore has used site level, street level and city level strategies to reduce stormwater and recycle waste water. While Tokyo has advanced reclamation plants, sewerage pipeline system and computerized control of pumping stations and treatment plants. Both the case studies have achieved efficiency in Waste water management systems.

7. Indian Scenario

Indian sewerage works on the water carriage system which was introduced by the British era before independence. The abundance of water made them make such decisions and since then the same system is being followed. Storm water, used water and industrial water are mixed in one combined sewer which often causes clogging, overflow and incapability to withstand huge volume. For proper working of the sewers, additional water is required to maintain the flow. (Mihir Shah, 2014) While the number of Sewage treatment plants are less, thus pipelines travel at far distance and require more amount of water to flow from source point to treatment plant. As a result, many discharge outlets are directly opened towards the river, lake or sea nearby which contaminates the water. (MoHUA, 2019)

The large-scale housing projects in India are implementing site level STP to treat greywater and reuse it for non-potable uses. The green building rating systems such as GRIHA, IGBC and LEED are emerging and being adopted in Indian cities. These rating systems promote stormwater and wastewater management by rainwater harvesting, sustainable site planning, sewage treatment and reuse. Although large projects and green buildings have implemented design solutions for waste water management, the number of such projects are comparatively less than other smaller buildings. The dense urbanization and increasing population lead to problems in the sewerage system.

8. Action plan for Waste Water Management in India

After studying the case studies, need of efficient waste water management plan and analyzing the current scenario of Indian cities, some suggestions are given below. Considering the huge population, less are available, water availability and large agricultural occupation, India has good potential of utilizing waste water and promoting sustainable development.

- Separation of Stormwater, Grey water, Black water and Industrial waste water should be implemented
- The government has control over street level and city level planning; thus, stormwater should be directed to nearby reservoirs, natural or manmade water bodies through streams and canals (this can be done with the help of pumping stations which work efficiently during monsoon), greywater should be treated and neighborhood level and reused, blackwater treatment should be provided at regular intervals and closer than greywater treatment plants.
- Constructed wetlands for stormwater filtration (NITI Aayog, 2022)
- Separate recycled water storage and supply can be implemented for ease of use.
- Large scale industries must mandatorily use recycled water and waste water produced from industrial use should be treated before disposal
- Industrial areas should have separate treatment plants
- Large scale Faming and agriculture must mandatorily use recycled water (Kumar SG, Joseph N, 2012)
- Groundwater recharge should be done by installing dedicated seepage pits near roads or dividers which are in control of the local authorities.
- Treating greywater and blackwater separately will reduce costs and also enable good quality recycled water as black water will not be recycled but grey water will be recycled and used. Sludge separation and use of biogas is possible.
- The road design can be efficient for stormwater and waste water collection.
- Efficiency can be achieved by installing leak proof and durable pipelines.
- Pumping stations are required rather than relying on gravity flow. This reduces the need of extra water supply to just enable the flow of waste water.

9. Conclusions

This research study is important for promoting clean water and sanitation goal of the United Nations Sustainable development goal. A well-developed plan for a city provides enough water supply with good quality and sanitation. We spend a lot of money of making the water safe to drink and use, but we ignore that how much contamination we are adding to the freshwater sources. Contamination of marine water also effects the health of coastal living people and marine ecosystem. Developing countries with high population such as India need to urgently adopt sustainable and efficient strategies to manage waste water generated. (NITI Aayog, 2022) Day by day Indian citizens face scarcity of water and at the same time also facing high flooding. This paper will benefit policy makers to take right decisions and develop a waste water management plan for every Indian City.

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