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Information Sheet

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LOW IMPACT DEVELOPMENT ON INTEGRATED WATER RESOURCES MANAGEMENT

Abstract:

The purpose of this paper is to investigate an appropriate approach in urban development, the control of storm water, treatment and recycle usage. It is undeniable that climate change has become an alarming environmental issue. Urbanization increases with economic wealth of countries and decreases permeable surfaces in cities and city edges. In order to create a sustainable society, it is essential to minimize the increment of impermeable surface and land covered by building and concrete paving that result in "Urban Heat Island Effect". In general, compensation can be achieved by greening, such as "Green Roof, Vertical Greening, Modular Wetland, Floating Wetland or Constructed Wetland". The success of the captioned method will not be possible without an "Integrated Water Resources Management Plan". In recent years, many countries have introduced and implemented various approaches in reducing stormwater runoff impacts and to improve runoff quality. Low impact development has been developed to meet this need. Findings from four cities, namely Singapore, Hong Kong, Seattle and Sydney were analysed. There are various stormwater management technologies, such as physical, chemical and biological processes are suggested to improve the quality of stormwater runoff and integrate water resources management.

Key words: Integrated Water Resources Management Plan, Low Impact Development, Stormwater Management, Sustainable Development

INTRODUCTION

Low Impact Development (LID) is a comprehensive tool that improves environmental performance and controls stormwater impacts, leading to an Integrated Water Resource Management Plan (IWRM). It manages and develops water resources with the three underlying principles, namely social equity, economic efficiency and ecological sustainability as shown in ***Figure 1***. With reference to Global Water Partnership (GWP), IWRM has been defined as "a process that promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" [1].

Figure 1 The Cross-sectoral integration of IWRM [2]

According to the United States Environmental Protection Agency (USEPA), LID is defined as "an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible." [3]. Many countries have been implementing the LID principle in order to maintain a sustainable stormwater practice.

In Hong Kong, stormwater management falls under the responsibility of the Drainage Services Department (DSD), mainly in charge of planning, design and management of sewerage treatment. The first stormwater management strategy "Territorial Land Drainage and Flood Control Strategy Study" Phase I and Phase II were completed in 1990 and 1993 respectively. In the preceding year, Hong Kong has enacted the Land Drainage Ordinance [4], which empowers the Government to carry out maintenance of main natural watercourses. Two years later, the Drainage Services Department carried out Stormwater Drainage Master Plan Studies, to review the conditions and performance of the existing drainage system in Hong Kong. Even though Hong Kong has been working on stormwater management for many years, there is still a lack of co-ordination and integration in stormwater management system.

REGULATIONS & REGULATORY BODIES

UNITED STATES OF AMERICA The Clean Water Act was amended in 1987, which required USEPA to tackle the stormwater management issue. This leads to an additional National Pollution Discharge Elimination Systems (NPDES) permit requirement for the discharge of stormwater. States are required to develop Total Maximum Daily Loads (TMDL), which are the maximum daily pollutant load a water body can receive and still meet the water quality standards, under section 303(d) of the Clean Water Act [5]. Often, stormwater runoff contributes a large fraction, which yet has to be reduced.

AUSTRALIA has developed various programs in managing urban stormwater runoff, including National Water Quality Management Strategy (ARMC-ANZ-ECC 2000), Urban Stormwater Initiative, Clean Seas programs (Commonwealth of Australia 2002), etc. [6]. These programs are highly effective in reducing pollution in urban stormwater runoff and to create an ecological sustainable development. Backed by statistics, 12% of rainfall reaches surface waters as runoff; however it reaches 90% in urban areas. Polluted urban runoff has therefore been recognized as a significant source of water pollution in Australia.

SINGAPORE has implemented the Earth Control Measures (ECM) programme in construction sites since 2006 [7], aiming at preventing silt from polluting the waterways and generating bare surfaces. Therefore, contractors are required to implement an ECM plan with Public Utilities Board (PUB), Singapore's national water agency, designed and endorsed by a Qualified Erosion Control Professional before the commencement of work.

A dam called Marina Barrage, as shown in ***Figure 2***, was built in Singapore to provide water storage, flood control and recreation in 2008. It is the first reservoir located in the heart of the city, out of the fifteen existing reservoirs. This newly developed reservoir increased water catchment from half to two thirds of Singapore's land area in 2011 [8]. It manages to alleviate flooding in low-lying areas; the nine 30-meter-long hydraulically operated steel crest gates will be activated during low tide to release excess stormwater into the sea. Also, the Marina Barrage is always the best location for recreational activities.

Figure 2 Overview of Marina Barrage [9]

STORMWATER TREATMENT PROCESSES

Urban stormwater is the leading cause of water pollution, which causes biological integrity and habitat alteration. Urban stormwater contains a mixture of substances, including nutrients, metals, chloride, oxygen-demanding substances, hydrocarbons, bacteria and viruses. Multiple processes like physical, chemical and biological processes can be used as treatment practices to improve the quality of stormwater runoff, reduces the volume and peak flow of runoff.

Physical Process

Silt trap is designed to prevent waterways suddenly being filled with suspended sediment at any building or construction activities as shown in ***Figure 3*** and ***Figure 4***. Using the law of gravity and physics associated with liquid suspensions, the trap allows the denser, heavier particles of the suspended sediment to drop out of the suspension by creating an artificial break in the current. These particles are easily picked up by water runoff moving with a certain amount of speed, but when the current of water is slowed or completely eliminated by the silt trap, the heavier particles of sediment will naturally drop to the bottom of the trap.

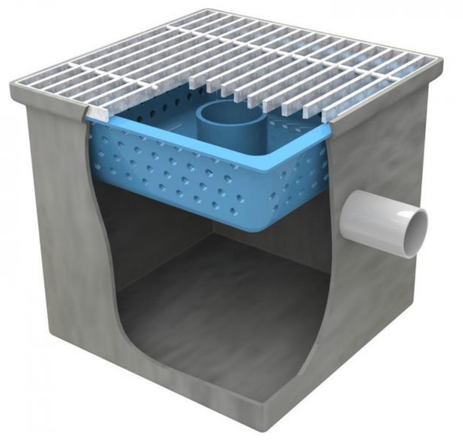

Figure 3 Silt Trap [10]

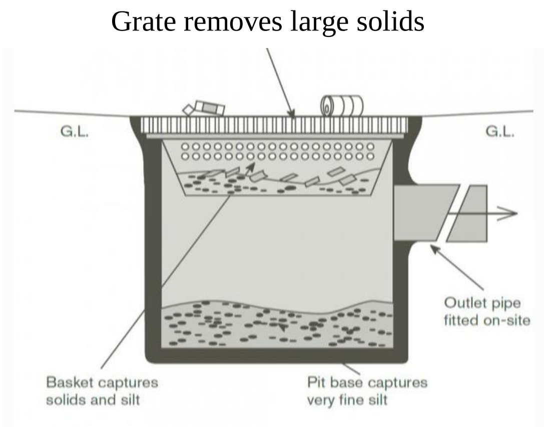

Figure 4 Design of Silt Trap [11]

This device has a low installation cost but high operation cost. The silt trap requires frequent clean-up, which is very labour intensive, and therefore only suitable for very small projects.

Sand and organic filters direct stormwater runoff through a sand bed to remove floatables, particulate metals and pollutants, as shown in ***Figure 5***. Sand and organic filters provide water quality treatment, reducing sediment, biochemical oxygen demand (BOD), and fecal coliform bacteria although dissolved metal and nutrient removal through sand filters is often low. Sand and organic filters are typically used as a component of a treatment train to remove pollution from stormwater before discharge to receive waters, to groundwater, or for collection and reuse. Variations on the traditional surface sand filter (such as the underground sand filter, perimeter sand filter, organic media filter, and multi-chamber treatment train) can be made to fit sand filters into more challenging design sites or to improve pollutant removal.

The Sand and organic filter requires a large area to install and allow machinery access to remove sediments. If runoff contains cements or grouting, the application cannot be applied and most urban project might not be able to accommodate this design.

Figure 5 Sand and Organic Filter

Chemical Process

Construction activities such as site formation and building projects will generate wastewater or runoff, that is high in pH and contain various pollutants like cement, grouting, heavy metals. In order to treat wastewater effectively, Chemical Enhancement Primary Treatment is adopted to this purpose. The quality of the treated water was found meeting the requirement of most regulatory bodies, if appropriate treatment agents were chosen. Furthermore, it also requires a lamella clarifier to settle the floc particles.

The use of clarifier is to separate liquids and solids by settling. The bottom cone design is critical to remove sludge that cannot be free flow or suck out by pumps. ***Figure 6*** shows the configurations of the horizontal parallel plate clarifier. Raw materials enter the influent and pass through the flocculation tank to create larger and heavier particles. Fluid will flow through the plates and effluent will pass through the adjustable weir into collection troughs.

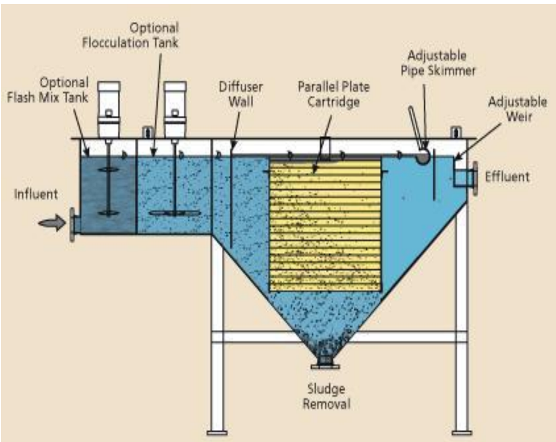

Figure 6 Horizontal Parallel Plate Clarifiers [12]

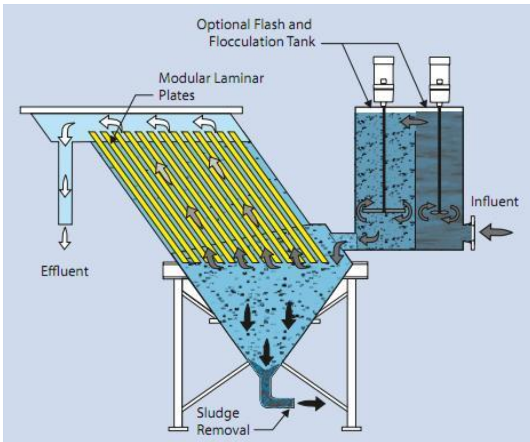

Figure 7 Vertical Parallel Plate Clarifiers [13]

Figure 7 shows the configuration of the vertical parallel plate clarifiers. The difference between horizontal and vertical is that the liquid will flow in different directions, of which liquid flows vertically in vertical parallel plate clarifiers. Raw materials enter in a low area, waste fluid flows upwards to the laminar plates and slide down to the removal area.

The most common treatment agents classified as Coagulants, Flocculants, Absorbent and Oxidants.

Coagulants ~ Polyaluminium Chloride (PAC) has been widely used for neutralizing the charge of the particles that were created during grinding, crushing and drilling process in construction works [14]. The usage of PAC should be monitored as over-dosing may cause contamination to water body and soil.

Flocculants ~ Formed by long-chain organic polymers that are widely used in wastewater treatment. Anionic polyacrylamide is a non-toxic chemical material for controlling soil erosion and sedimentation on construction sites, whereas Cationic polyacrylamide is highly toxic to aquatic life and must never be employed [15].

Oxidants ~ Used in water treatment processes to reduce the pollutant level and remove inorganic substances. Hydrogen peroxide and ozone are the most powerful oxidants. The reaction of the oxidation can be enhanced by Advanced Oxidation Process, with the use of ultraviolet, ferric ion etc. The amount of hydrogen peroxide can be calculated using the hydrogen peroxide calculator [16].

Figure 8 Wetsep in Sydney

Absorbent ~ Activated carbon can be used as territory treatment when Chemical Enhanced Primary Treatment is employed, followed by secondary treatment such as bag or sand filters. In between sand and activated carbon filter, injection of hydrogen peroxide will enhance the process and regen of activated carbon and prevent ozone from escaping to the atmosphere if over-dosing occurred.

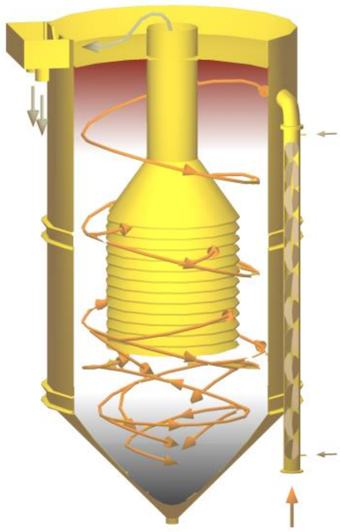

Figure 9 Impinging Stream Reactor in using coagulation and flocculation

pH adjustment ~ Many reagents can be used for neutralizing the pH valve, such as sulphuric acid and it is a controlled chemical in many countries. Handling accident is not a limited case in job site, the application of carbon dioxide is getting popular in many developed countries like Japan, USA and Europe. It was also found to be cost effective; especially when work safety is a major concern.

To increase the pH value by the addition of alkaline for removal of dissolved metals, followed by carbon dioxide can be considered as the most environmental friendly method for contaminated ground water with heavy metals.

Biological Process

Constructed wetland is defined as system designed to maximize the removal of pollutants from stormwater runoff through settling both uptake and filtering by filtration [17]. They are widely used in controlling water runoffs, which acts as a natural filter. Not only can it remove pollutants, it can also provide excellent wildlife habitat.

The Hong Kong Wetland Park is an example of constructed wetland as shown in ***Figure 10***. The Wetland Reserve is especially designed for waterbirds and for tourists to discover the diversified wetland creatures in the Park.

Figure 10 Hong Kong Wetland Park

Another alternative is to build **rain garden**, which is an easy and cost-effective planted depression for improving stormwater management. Particularly in Singapore, since the implementation of the Active, Beautiful and Clean (ABC) Waters Program in 2013 [18], the building authority also recommended rain garden as one of the options to deal with storm water run-off in their Green Mark Guide. Not only can rain garden create an eco-city, but also satisfies the green building requirements.

Rain garden, as shown in ***Figure 11***, can be easily constructed by using various properties of soils, plants and microbes. Pollutants can be removed by four major processes, namely settling, chemical reaction, plant update and biological degradation in root zones [19].

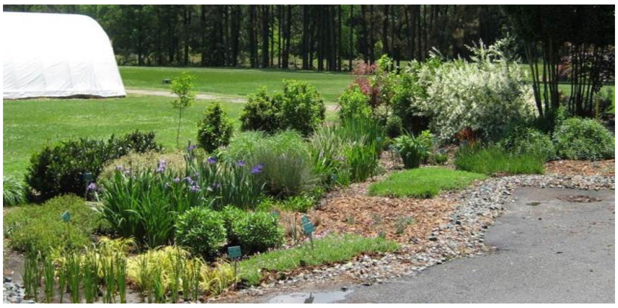

Figure 11 Rain Garden in Singapore

Runoffs first entered the rain garden and gradually slowed down due to physical depression of the garden and its vegetation. Settling occurs when soil and debris are being deposited. Followed by that, the soil and debris interact with pollutants and cause adsorption, upon evaporation, volatilization occurs. The plants absorb nutrients from their roots for growth and other purposes.

Last but not least, the microbes in the soil are broken down into organic and inorganic compounds; thus nitrogen will be removed by nitrification and denitrification.

FINDINGS

Singapore vs Hong Kong

Singapore is a tropical island with flat and low-lying areas along the southern and eastern costal fronts. Its green and clean environment has gradually integrated from Garden City to City in a Garden. Hortpark is a unique gardening hub developed by the National Parks Board [20], as shown in ***Figure 12.*** It is the first park in Asia that brings together gardening-related, recreational, educational, research and retail activities under one roof.

Figure 12 HortPark in Singapore

In Singapore, the Building and Construction Authority (BCA) launched a benchmarking scheme called the Green Mark Scheme in 2005, which aims at promoting environmental awareness in construction and real estate sectors. It has incorporated the best practices in environmental design and the adoption of green building technologies.

Singapore has designed a holistic stormwater drainage system to regulate runoffs and hence improve runoff water quality with the Source-Pathway-Receptor approach. A project was carried out in Punggol called Waterway Ridges [21], which is a 3.98 hectare public housing project. The major purpose of this project is to integrate collection, detention, treatment and conveyance of stormwater runoff with a residential development. Results showed that 70% of the stormwater is conveyed, detained and treated through a series of bio retention basins and vegetated swales before being discharged from the development into the roadside drains, which reduces the velocity and volume of runoff into the drainage system.

Similar to other countries, Singapore encourages rainwater harvesting. Changi Airport consists of a utilization system with rainwater harvesting. Rainfall collected from the runway will be diverted to the two reservoirs; one for collecting runoff for non-potable functions, the other balancing the flow. Rainwater harvesting saves up to a total of S$390,000 per annum.

Hong Kong has a tropical monsoon climate, stormwater problems arose during rainy seasons. Hong Kong has been putting emphasis on solving flooding problem but has not considered integrating the stormwater management system. For instance, urban green technologies and Best Management Practices (BMPs) are still limited in Hong Kong, compared to other countries as there are no specific policies from the Government.

Comparatively, Hong Kong has more parks and country side areas than Singapore. Statistics showed that out of the total 1,108 square kilometres of land, about three-quarters of land is countryside in Hong Kong [22]. However, in Singapore, only 0.5% of the total land area is assigned to agricultural purposes. Therefore, Hong Kong should have more opportunities to enhance its BMP and integrate the stormwater management system.

Seattle vs Sydney

Both Seattle and Sydney are cities that are highly concerned about the environment; they have implemented programs and regulations to enhance wastewater management with the integration of resources. Seattle is a costal seaport city in the United States, generally has a wet and rainy climate. A comprehensive Stormwater Management Program (SWMP) was issued in 2007 that satisfies the requirement of the Clean Water Act. The City Council and Mayor of Seattle successfully managed 700 million gallons of storm water runoff using green infrastructure in 2013 [23]. A permit is required for stormwater discharge under the Federal Clean Water Act in Seattle.

Apart from SWMP, the City of Seattle designed stormwater codes to protect the citizens and the environment [24]. These codes satisfy and comply with the Municipal Stormwater Discharge National Pollutant Discharge Elimination System (NPDES) Permit issued by the Washington State Department of Ecology. The stormwater codes address various issues, for instance the importance of green stormwater infrastructure (GSI), drainage control submittal, etc.

On the other hand, Sydney has temperate climate with warm summer and mild winters, the weather is moderated by proximity to the ocean, thus does not experience extreme differences in seasons. Sydney focuses much on building and sustainability. The Building Sustainability Index (BASIX) is one of the strongest sustainable planning measures in Australia implemented under the Environmental Planning and Assessment Act [25], which aims at delivering equitable, effective water and reducing greenhouse gases.

The Sydney Water has built the Stormwater Quality Improvement Devices (SQIDS) [26] in large stormwater drains to trap litter and improve stormwater quality. Till now, 65 SQUIDS have been installed and managed to stop 2,000 m^3 of litter and 4,000 tonnes of sediment from entering waterways every year.

To secure water supply, sewer mining was introduced in Sydney [27], as shown in ***Figure 13***. It undergoes extraction and upon treatment, wastewater can be recycled and safe to use as water. A typical example with the application of sewer mining is the Sydney Olympic Park; it was the first large scale urban recycling scheme in Australia. Wastewater was recycled through sewer mining and being used for irrigation and residential non-drinking. Not only does sewer mining manage to reduce 50% of demand for drinking water, it also increases green space for irrigation using the recycled water.

Figure 13 Sewer Mining in Sydney

IMPLEMENTATION

The Hong Kong Government should urge on integrating the water resources management technologies. We have experience with the physical, biological and chemical processes mentioned above to treat the runoff and stormwater but limit to integration. We have many urban greenings, it improve aesthetically. But we are using too much water from town mainly for such propose.

Hong Kong may consider implementing Flo-Tank® Modules in parks [28], as shown in ***Figure 14***, a lightweight structural component used for water retention, water detention, water storage and water infiltration for stormwater management. These modules are highly popular in different parts of the world as you can build them in a quicker, safer and cheaper cost when compared with conventional soak wells. They are installed underground to preserve the outlook of the property and reduce excavation and disposal. Not only can they create green reservoirs, they can also control water based on specific requirement as the tanks can be tailored and installed in any configurations. The tanks can capture water from roofs, gardens and driveways, increase the water retention and reduce the need for irrigation.

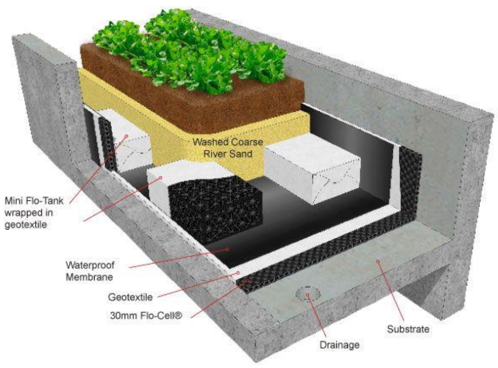

Figure 14 Installation of Flo-Tank® Modules

Among the four cities discussed above, ***Table 1*** shows a comparison of cities on integrated water management resources. Singapore has a holistic approach and performs the best in terms of integration and enforcement. Singapore put the most effort in reuse for water sustainability, the Singapore Water Reclamation Study (NEWater Study) was initiated to treat used water through various treatment processes. Similar to Singapore, Sydney introduced sewer mining to recycle wastewater for irrigation and residential non-drinking. However, Hong Kong is the worst city in integration, enforcement, reuse and resources management but the best in use of seawater.

Table 1 Comparison among cities on integrated water management resources

City	**Hong Kong**	**Sydney**	**Seattle**	**Singapore**
Integration	★★	★★★★	★★★	★★★★★
Enforcement	★★	★★★	★★★★	★★★★★
Reuse	★★	★★★★	★★★	★★★★★
Resources Management	★★	★★★★	★★★★★	★★★
Use of seawater	★★★★★	★	★	★

Note: ★★★★★ Best in integrated water resources management

Hong Kong may consider taking Singapore as a starting reference in integrating water resources management. Singapore started off by implementing a few pilot projects, which demonstrated water resources management is a good practice in their area, and then began doing modifications to improve the functionality and effectiveness before proceeding to the next step. Perhaps Hong Kong may consider taking one district out of eighteen to start off, and gradually expand to other districts once the practice has become mature and widely accepted by the citizens. A linkage in among government departments and town planning should be established.

In addition, Hong Kong should encourage rainwater harvesting like Sydney, to reduce the consumption of fresh water; Singapore has already set a good example in this area. Not only does rainwater harvesting save money but also satisfies the Hong Kong BEAM Plus for New Buildings under Category 5.1 “Water Conservation” – WU 4 (Water Recycling) respectively.

CONCLUSION

Integrated Water Resources Management is vital in all parts of the world as it is an important watershed health strategy. And yet, best management practices (BMPs) help address all the adverse impacts to the environment. In order to maintain a sustainable urban environment in the densely-populated Hong Kong, stormwater management technologies should be integrated. This would enhance public awareness to promote the green movement in Hong Kong and reduce carbon footprint through integrated the water resources management system.

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