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Green Infrastructure Intervention To Improve Waste And Water System In Urban Areas

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GREEN INFRASTRUCTURE INTERVENTION TO IMPROVE WASTE AND WATER SYSTEM IN URBAN AREAS

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ABSTRACT

The increase in waste generation and water use in urban areas may lead to local flooding that is dangerous for health if it is not appropriately managed by waste and water systems in urban infrastructure. The Sponge City is a concept that utilizes Green Infrastructures (GIs) to manage waste and water systems while still maintaining open and public spaces functions. This study review the waste and water infrastructure systems in Depok, Indonesia which are compared with Gainesville in the United States, and Cardiff, United Kingdom, to give recommendations for preventing flooding in urban areas. Analysis is by comparison of data based on factors that affect GI implementation, such as (1) management system, (2) policy context, and (3) key organizations or stakeholders. Data was collected using web scraping of the latest news and information to provide digital statistics of the current flooding disasters, water management systems, and waste management systems. This study identified three possible GI implementations that can be arranged in a hierarchy. The GI implementation in Depok focuses on the making of programs and management systems which involve citizen participation that prioritize the development of biopores at the household level. Gainesville focuses on Gainesville Department of Public Works which controls both waste and water management, namely through the prioritization of single-use plastic bans throughout Gainesville. In Cardiff, GI focuses on the attempt of the Wales Government and Cardiff Council to make an integrated development strategy that prioritizes holistic surface water management combined with a waste disposal system. This study open possibilities of GI implementations that reflect the urban areas characteristic in preventing local flooding by managing waste and water systems.

Keywords*: Local flooding; Green infrastructure; Management system; Urban area; Waste and water system.*

INTRODUCTION

Cities growth creates changes and impacts on the current ecosystem, increasing the chances of natural hazards such as flooding (Müller, 2013). Overpopulation and urbanization pose a significant risk of flooding due to inappropriate land use and drainage systems that cannot cope with extreme weathers (Hapsari & Zenurianto, 2016). Meanwhile, adequate and equitable sanitation and hygiene are necessary to improve water quality and reduce pollution in line with the 2030 United Nations (UN) Agenda for Sustainable Development Goal 6 (UN, 2015). According to Zevenberge et al. (2018), the lack of adaptation to the increasing water-related risks in cities is caused by the expansion of urban development to floodplains and lowlands, densification of the remaining open green and blue spaces, and minimum maintenance of current infrastructures. Flooding happens when soil is saturated and the ground cannot collect the rainwater. This can also be caused by insufficient channel capacity or the habit of people throwing solid waste into water drainage that blocks water flow (Hapsari & Zenurianto, 2016).

According to Koop and Van Leeuwen (2017), resource-efficient and adaptive cities use strategies such as solid waste recycling, energy recovery, water efficient techniques, as well as water consumption reduction, and also incorporate climate adaptation into their planning. Green Infrastructure (GI) is a human-made infrastructure to ease environmental pressure such as flood risk and water quality that can be realized through the utilization of public open spaces, urban tree canopies, wet land, and biofiltration (Parker & Zingoni de Baro, 2019). Additionally, Sponge City is a novel concept; it describes a city that can adapt to changes in the water environment like a sponge: absorbing excess water and releasing water when needed. A Sponge City needs a well-developed rainwater system (Guan et al, 2020).

Integrated waste and water management in urban areas is needed to ensure the effective use of limited natural resources. An integrated approach involves bringing together relevant policies regarding water and waste management systems as well as a sustainable approach to future uncertainties such as climate change (Ikhlayel & Nguyen, 2017). A sustainable urban water system must be managed as a system to ensure efficient use (Zafirakou, 2017). Cities also generate a massive amount of solid waste that can lead to ineffective disposal systems and pose a risk to air, water, and soil contamination (Koop & Van Leeuwen, 2017). Systematic thinking such as by incorporating waste prevention, minimization, separation, collection, transportation, and treatment is needed to realize an effective waste management system (Ikhlayel & Nguyen, 2017). In addition, stakeholders (such as institutions, communities, and governments) are important actors that save lives and mitigate damage during floods–meaning, it is important to raise awareness of their role (Terpstra & Gutteling, 2008). Integration between disaster management and community planning is arguably useful to encourage local decision-making processes (Pearce, 2003).

GI such as natural vegetative systems and green technologies collectively provide society with a multitude of environmental, social, and economic benefits which can have both primary and secondary functions (Green Infrastructure Ontario Coalition, 2017). An example of integrated green infrastructure is a Sponge City that absorbs, infiltrates, retains, and purifies water in the event of external precipitation, and releases water when it is dry outside to enhance infiltration, evapotranspiration, and stormwater capture and reuse in the urban environment (Zevenbergen et al., 2018; Liang et al., 2020 in Guan et al, 2020).

Sponge City has four main principles: urban water resourcing, ecological water management, green infrastructures, and urban permeable pavement (Nguyen et al, 2019). Urban water related problems have raised concerns worldwide among the scientific community (Marlow et al., 2013). Some prevalent technologies applied in Sponge City construction are green roofs, green spaces, artificial rainwater wetlands, infiltration ponds and biological retention facilities and water-permeable paving. Successful implementation of a catchment-scale Sponge City can be achieved by maximizing GI-related practices. (Nguyen et al, 2019).

There are three causes of urban flooding: climate change, urbanization, and poor urban planning. In order to ensure a Sponge City successfully uses rainwater as a resource, it is necessary to understand an area's hydrological characteristics, including water surface runoff, flow time, discharge, speed, size and peak time to better connect natural water networks and urban drainage systems to control urban flooding. A permeable pavement is a technology whose goal is to improve rainwater infiltration, and purification of groundwater for urban supply, reduction of water runoff, cooling, humidification, noise reduction, and environmental and ecological soil restoration. In a similar way to GI, this can also be the solution to protect the environment and make urban environments more sustainable (Nguyen, 2019).

Another aspect of urban flooding mitigation is society's behavior towards disaster. Integration between disaster management and community planning is useful to encourage local decision-making processes (Pearce, 2003). Godschalk et al. (1998 cited in Pearce, 2003), explained four community planning options for sustainable hazard mitigation. Their four options concern: (1) stakeholder participation, (2) planning components, (3) plan types and (4) mitigation strategy.

The risk of flooding for any city is closely related to urban waste and water management, thus Green Infrastructure (GI) recommendations can be used to improve a city's underdeveloped existing infrastructure. This study reviews the waste and water infrastructure systems in Depok, Indonesia which are compared with Gainesville in the United States, and Cardiff, United Kingdom, to give recommendations for preventing flooding in urban areas. Due to their different geographical locations, and characteristics, by comparing the three cities' waste and water management systems, integration of waste and water management systems, and community or institution participation to identify the similarities and differences between the three cities and determine the best GI implementations in each city.

METHODS

The studies involved Depok and two other cities, Gainesville, and Cardiff, with different characteristics, to find alternatives uses of GI in waste and water systems to mitigate urban flooding (figure 1). Depok city’s geographical condition is fed by major rivers, namely the Ciliwung and Cisadane rivers and 13 sub-units of watersheds that cause local floods during heavy rain. Gainesville has a risk of flooding from increased rainfall, and water from tropical storms or hurricanes. Cardiff has a risk of flooding from the sea, in addition to the Taff and the Ely rivers that may cause flooding in many built-up areas around the city and have both overflowed during recent storms.

This study used qualitative methods by involving students from Universitas Indonesia, University of Florida, and Cardiff University in the form of an online Focus Group Discussion (FGD) to provide data from each city and country which is conducted on March – April 2022. Each university representative provided data on waste and water management systems, integration of waste and water management systems, and community or institution participation to identify the similarities and differences to provide possible GI recommendations. The study began with the recapitulation of each city’s characteristics, including geographical conditions, flooding areas, and waste and water management issues to analyze the flooding risk and current infrastructure application. Considering the management issues of water and waste in each city, it is necessary to develop a management system that can lead to policy context in each city which involves key organizations and/or communities.

Based on the literature study of sustainable waste and water management by using Green Infrastructure in Urban Area, it can be concluded that the important indicators in making a comparison between cities include, (1) density/population, (2) water management system, (3) waste management system, (4) integration of waste and water management system, (5) community/institution participation, (6) hierarchy of possible GI. The data obtained will have an output in the form of a comparison table of indicators in each city. This comparison is compared based on common challenges in applying GI in response to waste and water management. It also helps to better understand the GI application that are sensitive to geography and societal system.

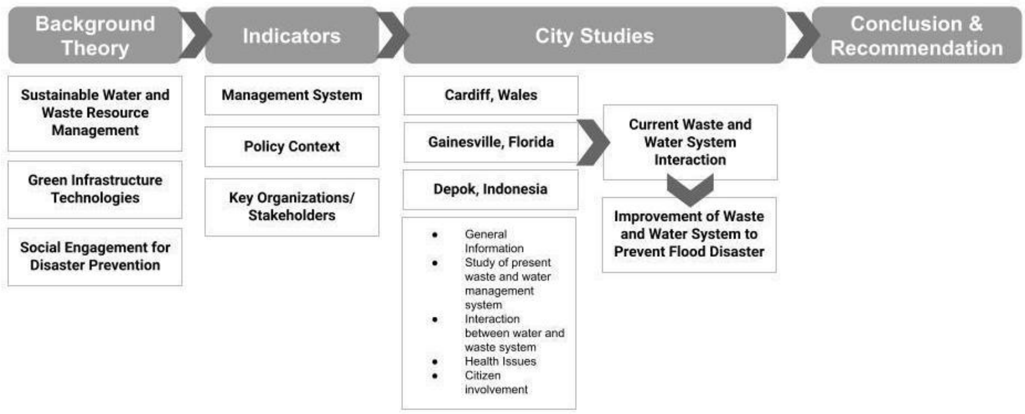

Figure 1. Research Framework

Secondary data is collected through government statistics of current flooding disasters, water management systems, and waste management systems. The data from each city was sourced from appropriate government agencies; for instance, Administrasi Kota Depok provided the data for Depok City, ArcGIS for the Flood Mapping in Gainesville, and Cardiff Council for Flood Map for planning. Apify app was used for web scraping, entering specific terms or keywords to be extracted from various websites to this app. This study used Apify to collect the latest news regarding the research topic keywords, such as flooding disaster, waste and water management, and government programs. Further analysis was conducted by combining information from previous research studies that has observed the city's waste and water management, such as Ristianingrum (2019) mapping of Depok City water absorption area.

The data collected about the existing waste and water management systems in each city was analyzed to produce possible technology applications. Data was then categorized based on the waste and water management systems, integration of waste and water management systems, and community or institution participation. In light of that, this study proposes recommendations to improve the current waste and water system using the comparative lesson learned from each other (Depok, Gainesville, and Cardiff).

RESULT

Depok City

Geographically, Depok is directly adjacent to Jakarta City and is located within the Jakarta Metropolitan Area (Jakarta-Bogor-Tangerang-Bekasi-Puncak-Cianjur/Ja-bo-de-ta-bek-Pun-Jur) in Indonesia. Its geographical condition is fed by major rivers, namely the Ciliwung and Cisadane rivers and 13 sub-units of watersheds. Mostly, Depok's land is used for residential and commercial purposes, with green spaces only present at the perimeter. The domination of the coverage area by settlements in Depok, means that local floods often occur during heavy rain, such as in Sawangan Neighborhood, Cipayung Neighborhood, and Beji Neighborhood (Fig. 2). (Depok's City Communication and Information Office, 2020).

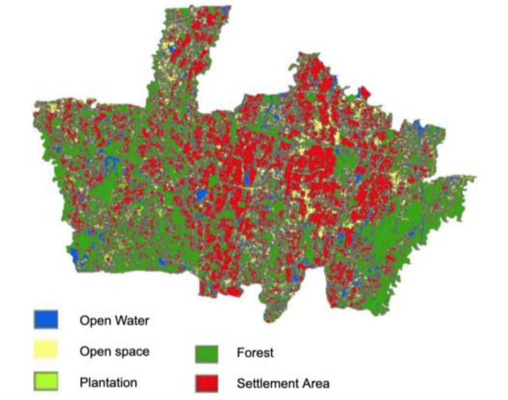

Figure 2. Land Use of Depok City & Flood in Pasir Putih, Sawangan Neighborhood (7/11/2021)

(Source: Ristianingrum, 2019)

Depok has the highest density and population in comparison to Gainesville and Cardiff. This city consists of 2,056,335 people in 2020 (Badan Pusat Statistik, n.d) that covers a total area of 200.29 square kilometer. This fact leads to results in the need for government programs that focus on management systems that involve community participation. Cardiff and Gainesville's water and waste management focuses on government services that interact directly with citizens. The three cities have policies that consider waste separation and water management; however the application of the guideline depends on community or institution participation and involvement.

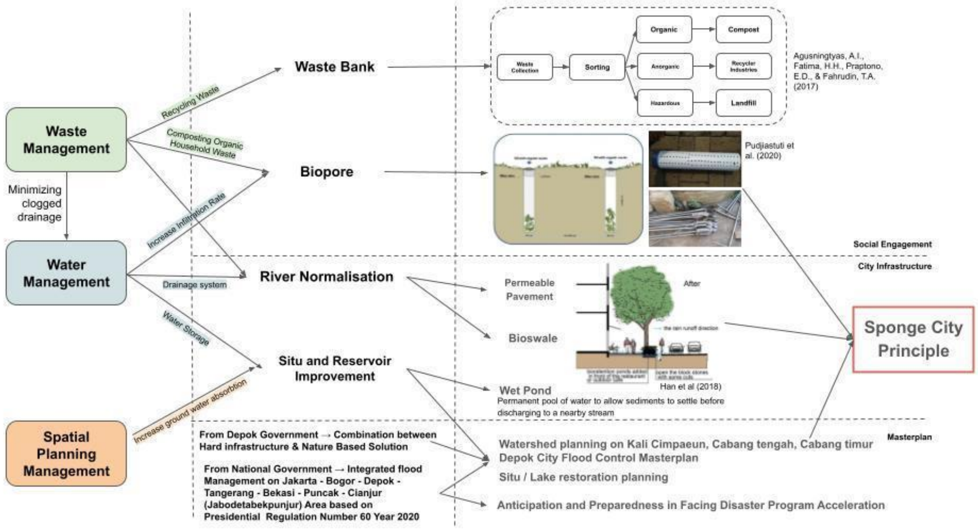

Figure 3. Correlation between Waste Management, Water Management, Spatial Planning Management and Sponge City Principles for Flood Prevention in Depok City

Settlement (housing) makes up the dominant portion of Depok's land use, which is 12.416,5 Ha (61,52%). Such a settlement comprises high, medium, and low-density settlements. Other land uses include for forest, green open space, and plantation (Ristianingrum, 2019). A contributing factor to the flooding problem in Depok is the lack of greenspace and forests. Thus, there are three aspects to manage in order to prevent flooding in Depok: waste management, water management, and spatial planning management (Fig. 3). Further, there are two approaches that can be taken, namely establishing waste banks in the local neighborhoods for waste recycling and establishing biopores for organic household waste composting and water management.

Those two approaches require active community participation at the neighborhood level. As for water management, there are three approaches that can be taken: development of drainage systems, river normalization by widening the river body and water storage through lake and reservoir improvement. Lastly, for spatial planning management, Depok's local government needs to provide a policy to increase ground water absorption through a combination between hard infrastructure and nature-based solution, and the national government needs to realize an integrated flood management policy for Jakarta Metropolitan Area. All these are related to the Sponge City principles.

Gainesville City

Gainesville has a population of 134,993 as of the 2020 census. It is located in the North-Central region of Florida in the United States, which positions the city in-between the Gulf of Mexico and the Atlantic Ocean. Gainesville's weather conditions are long hot summers and short cool winters. The temperature varies year-round ranging from 44°F-90°F (WeatherSpark, n.d). The hot season begins in May and declines in September, with the cooler season lasting from December-March. There is increased humidity in Gainesville, with muggier periods lasting from May-October. Rainfall occurs throughout the year in Gainesville, with July experiencing the most rain with average rainfall of 6 inches. Furthermore, the state of Florida is relatively flat and near sea-level, which puts the city at risk of flooding from increased rainfall, and water from tropical storms or hurricanes. Other risks include heat-related health risks and increased mosquito quantity due to the presence of bodies of water and humidity.

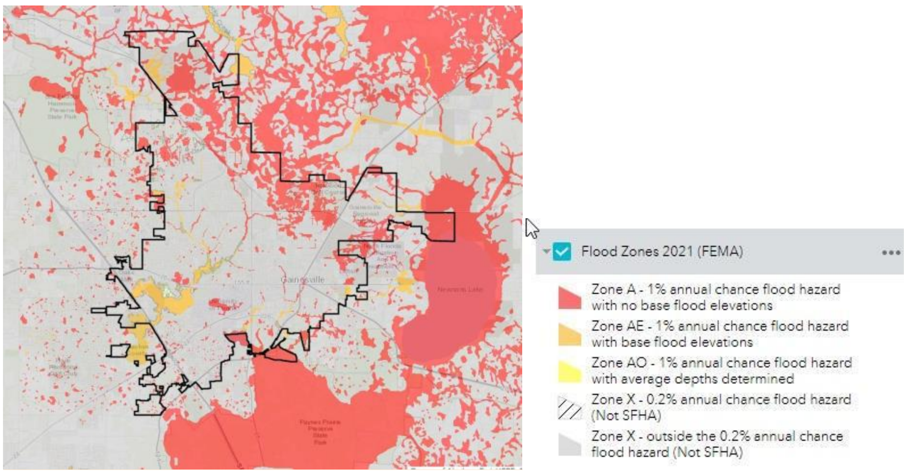

Figure 4. Gainesville Flood Zones 2021
(Source: ArcGIS Flood Zone, n.d.)

Cardiff City

Cardiff is located in the south-east of Wales, on the coast of Wales, and fed by Taff and Ely rivers in the United Kingdom. It is the largest city in Wales with population of 362,400 people in 2021 (Roskams, 2022) and belongs to the Euro cities network. Its weather is warm in summer and partly cloudy and cold, wet, windy, and mostly cloudy in winter. Over the course of the year, the temperature typically varies from 3°C to 21°C and is rarely below -2°C or above 25°C (WeatherSpark, n.d). Cardiff is at risk of flooding from rivers and the sea, reservoirs and surface water with 11.3% area is at risk of flooding from the sea (Hayward, 2021). As Fig. 7 shows, Cardiff is the 6th most at risk city from global warming (ranked out of the 85 cities studied by Nestpick-funded research) due to rising sea levels and has a high chance of being under water if climate change continues at its current rate (Hayward, 2020).

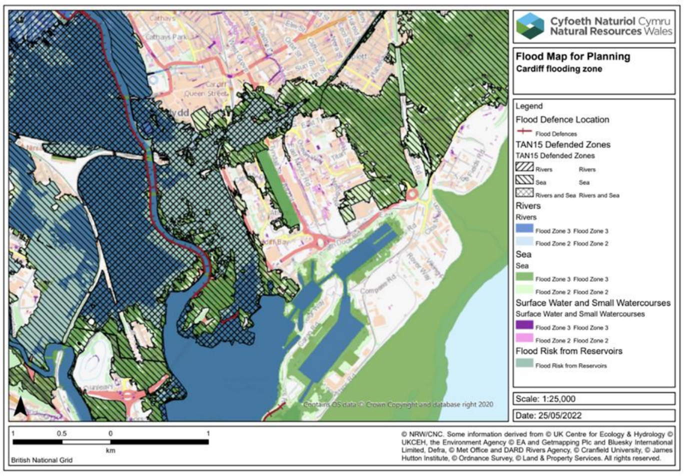

Figure 5. Cardiff water management map
(Source: Welsh Government, 2020)

In terms of the water system, Sustainable Drainage (SuDS) is used in all new development of Cardiff where communities and householders are well engaged in water planning (Welsh Government, 2019). Not only does the Local Planning Authority give guidelines to the construction, but also provides more opportunities for designers, property developers, and other interested parties by allowing more contribution to decision making on water management and land use property. The statutory SuDs provide standards, approval, and adoption policy for the city's water management including runoff destination, hydraulic control, water quality, amenity, biodiversity, and construction-operation-maintenance. The participation of local communities in land use decisions offers the potential to enhance the environment's resilience and develop holistic integrated surface water management systems to prevent some zones from flooding. Moreover, multifunctional GI that integrates the water system and city land use planning system has been promoted (Cardiff Council, 2017).

Waste management is given a high priority and is organised around a hierarchy that gives priority to prevention, followed by reuse, recycling, other recovery, and disposal (Welsh Government, 2012). The guidance is implemented in the development of infrastructure (e.g., with bins that classify different types of materials). Cardiff citizens are expected to separate all recyclable waste items and food from the non-recyclable waste so it can be collected separately (Cardiff Trade Waste, 2021). From this study, the effort in Cardiff focuses on the provision of integrated guidelines and service by the national and city governments to be adhered to by the infrastructure designers and citizens.

DISCUSSION

Based on the result of the study of each city, there are several indicators found, namely density or population, water and waste management system, integration of waste and water management system, community or institution participation, that will help to shape the hierarchy of possible GI investments. Each city recommended a sustainable drainage system and stormwater management for the water management system. Several parties that may be involved in doing this include the government, designers, property developers, and local authorities. Each city also has a different hierarchy for possible GIs based on the issues faced (Table 1).

Table 1. Comparison of Possible Green Infrastructure for Each Cities

Indicators	Depok	Gainesville	Cardiff
Density/Population	**Density:** 10,266 per square kilometer that covers a total area of 200.29 square kilometer **Population:** 2,056,335 people	**Density:** 826 people/square kilometer that covers 163.37 square kilometer **Population:** 134,993 people	**Density**: 2,583 people per square kilometer and covers a total area of 140.3 square kilometers **Population:** 362,400 people
Water Management System	Conventional drainage system, which delivers surface water runoff as soon as possible to the drainage channel.	Stormwater Management Utility	Sustainable Drainage (SuDS) as guideline
Waste Management System	Door-to-door solid waste collection system from households to Cipayung-Landfill-Waste Bank	Solid Waste Division	"Waste Hierarchy": Devoted to preventing waste in the first place. Focus on re-use, then recycling.
Integration of Waste and Water Management System	Inappropriate waste management can cause drainage clogging resulting in flooding.	Gainesville Department of Public Works (controls both waste and water management)	Depends on Wales government and Cardiff Council to make a development and strategy in common
Community/ Institution Participation	Government focuses on making programs and management systems that involve citizen participation.	City commission signs ordinances pertaining to both into law. There are partnerships with other city/county/federal entities	Designers, property developers, local authorities, and other interested parties
Hierarchy of Possible Green Infrastructure	1. Establish bio pore in households (social engagement) 2. Increase waste bank numbers and function in the citizen	1. Ban single-use plastics throughout Gainesville 2. Promote more conservation of land through central part of Gainesville (SF housing)	1. Develop holistic integrated surface water management systems 2. Combine GI with waste disposal (composting

	3. Integrate Sponge City (additional bioswale, permeable pavement as city Green Infrastructure)	3. Sponge City/Green Infrastructure integration around perimeter of city (flood zones)	facilities） 3. Build multi-functional GI infrastructure (water pumps, stormwater infrastructure)

Source: Authors, 2022

The three cities cover an area of 140-200 square kilometers; however it is shown that the population varies greatly which affects their management system. Depok has the highest density and population in comparison to Gainesville and Cardiff. Depok's condition forces the need for government programs that focus on management systems that involve community participation to be involved in decision making and land use functions in promoting better waste and water management. Cardiff and Gainesville's water and waste management focuses on government services that interact directly with citizens. The three cities have policies that consider waste separation and water management; however, the application of the guideline depends on the community or institution participation and involvement.

From Depok City, the management system for water and waste takes the form of a conventional drainage system that can deliver surface water runoff as soon as possible to the drainage channel, and door to door solid waste collection system from households to Cipayung Landfill that can also be managed by waste banks. Depok local government focuses on the making of programs and management systems that involve citizen participation. The possible GIs that can be applied include the development of biopores at the household level, establishment of additional waste banks, and Sponge City integration with additional bioswale, and permeable pavement. Nevertheless, Depok has focuses on simple and small-scale GI application because it requires socialization to a large number of people considering the large area and high density of Depok City.

As mentioned in the table above, Gainesville's water management system includes a Stormwater Management Utility and its waste system a Solid Waste Division, that is part of Gainesville Department of Public Works. This enables the city to control both waste and water management. The possible GI for Gainesville covers single-use plastics ban throughout the city, better conservation of land promotion through the central part of Gainesville, and Sponge City/GI integration around the perimeter of the city or flood zones.

In Cardiff, the water and waste management is conducted through Sustainable Drainage or SuDS and the application of the Waste Hierarchy. A key objective is to prevent waste in the first place. The focus is on re-use, and then recycling. The participation of designers, property developers, local authorities and other interested parties in planning development constitutes an important aspect. The possible GIs for Cardiff cover: holistic integrated surface water management systems, combination of GI with waste disposal or composting facilities, and establishment of multifunctional GI.

From this comparison, it can be seen that the three cities are facing a common problem of flood risk. However, each city has a big difference in its population density. This factor affects the different priorities and approach in scale to water and waste management systems. For instance, Depok with the highest density should prioritize community participation due to the dominant settlements which affect community-based decision making and settlement land use utilization to maximize of the water and waste management system. While Gainesville and Cardiff focus on large scale government programs because it has relatively smaller populations that gives the government more control over land use and GI intervention. GI implementation needs to consider each city's characteristics, such as population, geography, existing urban management system, and stakeholders to improve their waste and water management.

CONCLUSION

Inappropriate waste and water management systems in urban infrastructure may lead to flooding. This study aims to review the waste and water infrastructure systems in Depok, Indonesia which are compared with Gainesville in the United States, and Cardiff, United Kingdom to better understand how they deal with flood risk. The potential for improvement to waste and water management systems is also examined. The comparison showed that the three cities face flooding issues but do so with different characteristics., Possible GI recommendations, therefore, need to be sensitive the context of each city to improve the urban infrastructure.

This study compares each city and each recommends a hierarchy of three possible GI investments in each city. This study recommends that for each city there should be an identification of a city's characteristic based on (1) management system, (2) policy context, (3) key organization or stakeholders that can affect implementation of GI to optimize urban flooding mitigation. In Depok, a city with the highest population density, the GI focuses on the programs which involve citizen's participation such as establishment of bio pores at the household level and establishment of additional waste banks. In Gainesville, a city with the lowest population density, the GI for waste and water management system is implemented by Gainesville Department of Public Works. Gainesville's GI can be improved through a single-use plastic ban and better conservation of land promotion. In Cardiff, GI is focused on the Wales Government's integrated development which prioritizes holistic surface water management and a combination with waste disposal systems. The most advantageous benefit of GI is its multifunctional and integrated systems in urban areas, such as the idea of a Sponge City, that can generate bigger impact.

A hierarchy of possible GI choices can be provided that goes between small-to-large-scale planning, that involves stakeholders, and that falls under the leadership of the local government and its guidance and policies. The study concludes that the procurement of GI is highly dependent on the existing social conditions and density of a city. Further, GI development does not necessarily have to be large-scale and wide-ranging, but rather it must be adapted to a city's characteristics. For instance, water management interventions on dense urban land can take the form of several water infiltration points (ie. bio pore/infiltration ponds). The same applies to waste management intervention, which can start from community programs or government services. However, further study regarding effectiveness of existing GI services in relation to integrated management system, policy, and stakeholders in an urban area needs to be conducted to provide detailed evaluation and identify priorities for improvements that each city will be required to make in the future.

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