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THE POTENTIAL APPLICATION OF WATER-SENSITIVE DESIGN IN URBAN SLUMS (A CASE STUDY IN MANADO CITY, INDONESIA)

Nico Halomoan[1*], Shella Zahrawani[1], Ahmad Soleh Setiyawan[1], Prayatni Soewondo[1], Prasanti Widyasih Sarli[1], Dion Awfa[2]

[1,]Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia;
[2]Department of Environmental Engineering, Institut Teknologi Sumatera, Indonesia

*Corresponding Author, Received: 15 March 2022, Revised: 09 March 2023, Accepted: 02 April 2023

ABSTRACT: Water-sensitive design (WSD) is created to manage water sensitivity, such as rainwater management and water supply. Manado City is strategically located in North Sulawesi Province, Indonesia, which is growing rapidly but has slum areas and is prone to flooding. Slums do not meet standards, including water management. The application of WSD to residential areas in urban areas affects the utilization of rainwater flows and the availability of alternative water sources. Previous studies did not look at the potential for implementing WSD to increase the settlement quality in slum areas. This study aims to identify the potential for implementing WSD in the urban slum area of Manado city by considering the existing situation and conditions. Furthermore, this study reviews the physical, non-physical, and supporting aspects for the potential implementation. Three locations of Manado city slums were reviewed as case studies. For data collection, this study uses the interview method through structured questionnaires, area observations, and secondary data. The physical aspect reviews the rainwater drainage system fed by greywater and the water supply including groundwater and refilled water. The non-physical aspect reviews incomes, ownership of houses, and limited land. The study results show that the application of WSD is very potential given the location conditions, but some challenges need to be considered according to the characteristics of the location.

Keywords: Water-Sensitive Design, Urban Slums, Manado City, Potential

1. INTRODUCTION

Slum settlements are characterized by high population density in small sizes with inadequate public services, such as water, sanitation, and other environmental facilities [1]. Water and sanitation problems can create other potential wastes in residential areas [2].

Manado is the capital of the province of North Sulawesi, Indonesia. It is located downstream with five major rivers flowing into Manado Bay. Thus, the rivers are vulnerable to flooding, which increases rapidly. Manado City is some bordered by the beach with bumpy and hilly land contours. The city center of Manado is in a relatively flat lowland between the mountains and the sea and suffers from chronic pluvial flooding [3] Manado City has a population density of 2,787.95 people/km^2. In addition, Manado City has 25 slum areas located in 9 districts. Of the population, 76,078 (17.5%) people in Manado are classified as poor.

Water sensitivity is the prevention and control of runoff which is not handled or utilized in water management, including water supply, sanitation, and flood protection, in realizing environmental protection services that guarantee sustainability, continuity, and long-term resilience [4]. The application of water sensitive design make cities support a way of life for all urban communities. One of the WSD applications is rainwater as a source of water in developing appropriate technology and designs. In its application, all aspects of the urban water cycle are considered valuable resources [5].

The principle of the water-sensitive design can increase viability, sustainability, climate change resilience, rapid urbanization, degraded ecosystems, and age infrastructure. The application integrates rainwater treatment by leveraging existing properties to reduce runoff and peak flows and protect water quality [6].

Interventions involving WSDs can be implemented in slums as stand-alone systems or combined with centralized rainwater and wastewater distribution systems, reducing exposure to environmental contamination and resulting in improved health [7]. WSD implementation protects the environment by providing a design suitable for site conditions [8]. This intervention is supported by a community approach to understanding WSD as the key to the transition to sustainable urban water management in slum areas, which applies a complex adaptive systems perspective [9].

The current WSD implementation is limited to urban general residential areas, as in Parma, Italy, and has not been in slum areas even though it can increase city resilience [10]. WSD implementation in slum areas can improve the quality of life, which supports the improvement of water and sanitation quality [11].

Furthermore, WSD implementation by improving the function of infrastructure for the utilization of water supply and rainwater can increase the livability of urban areas. However, it is necessary to identify the strengths and limitations of its implementation [12].

This study examines technical and non-technical conditions of slum settlements using structured interviews. Previous studies examined the behavior and physical aspects of wastewater management to manage sanitation in slum settlements for improvement, one of which was through interviews in Manado City [13]. However, previous studies did not show the necessary conditions. The physical aspects assessed include drainage management conditions, rainwater management, land availability, and rainfall conditions. While the non-physical aspects assessed include land ownership, economic factors, and other social factors. The study results show the structured interviews and documentation can be used to identify the potential for implementing WSD in urban slums in Manado City considering its physical and non-physical aspects.

2. RESEARCH SIGNIFICANCE

This study was conducted to see the potential of WSD implementation in slum settlements in Manado City, Indonesia. The significance of this study is to see the potential of WSD implementation by considering the physical and non-physical aspects based on the settlement characteristics to support WSDs that utilize water and manage rain. It has been widely applied, however this study can be continued by finding the right technology to be applied in study sites.

3. METHODOLOGY

3.1 Characteristics of Study Sites

The slum settlements in Manado City refer to the Manado Mayor Decree No. 163/KEP/LT.02/Bappeda/2015 on the Location of Slum Residential Areas in Manado City. The study sites were verified by visiting the selected area. Data and information were collected through interviews with stakeholders. Three slum settlements were determined with different characteristics of physical location and topology; these locations are Titiwungen Utara Village, Sario District, by the sea; Singkil Satu Village, Singkil District, with hills; and Wawonasa Village, Singkil District, with a riverbank.

3.2 Structured interview

A structured interview was conducted in the study sites to obtain some information. Then, coordination was carried out through meetings with community representatives. This was done because one solution to improving the quality of slum areas must be location-specific [14]. A representative group of respondents was interviewed using open-ended questions to obtain qualitative responses. In addition, it was accompanied with site visits [15]. The questions asked in the interviews are related to the physical and non-physical aspects of the slum areas.

The physical aspects reviewed are related to the physical infrastructure of water supply and rainwater drainage systems. Non-physical aspects reviewed are related the condition of the community's settlements, including the economic data of the population, work, home ownership, and experiences of disasters. The results are displayed in a graph showing the potential for WSD implementation in slum areas. The structured interviews involved 100 households selected using the clustered random sampling method. The sample calculation uses the Yamane formula with a 10% margin of error. Sampling was carried out in November 2021. The supporting aspects are displayed based on the water disasters and rainfall conditions, which support the analysis of the potential for implementing WSD in the slums areas. Finally, the aspects assessed are recapped to see the potential for implementing WSD in the slum areas of Manado City

4. RESULTS AND DISCUSSION

This section discusses the study results of physical aspects, non-physical aspects, and supporting aspects from the secondary data, and discussions related to the analysis of potential applications.

4.1 Physical Aspect

The physical aspects used in this study are related to drainage management and water supply for daily activities. Drainage channels are one of the infrastructures directly related to WSD. Several WSD applications utilize drainage channels with a concept of ecodrainage. The conditions of the study sites show that most of the drainage channels do not function properly, where only rainwater should be channeled through the drainage channels. In fact, the drainage channels are mostly used as greywater channels (Fig. 2).

Another problem is the inadequate width of the drainage channels so during heavy rains, water overflows onto the roads. The habit of the residents throwing garbage in the drainage canals becomes a problem in the drainage canals. Blockage or clogging by garbage, oil and grease from kitchen activities, drainage channels that are higher than the road cause inundation and flooding during the rainy season (Fig. 1). Water supply is a physical aspect to be considered. This is related to WSD, which can help water supply by retaining water and taking advantage of the water cycle.

Fig. 1 Condition of the drainage channels in the study sites

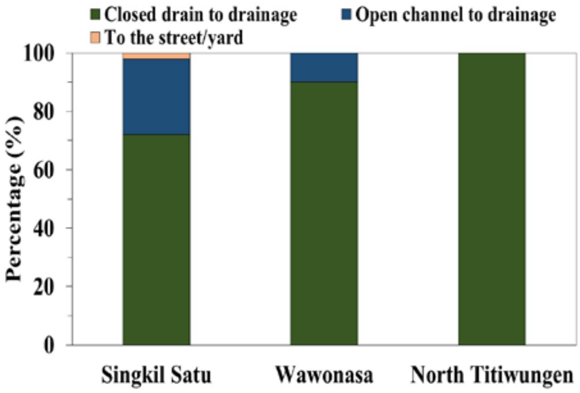


Fig. 2 Types of waste disposed into drainage channel

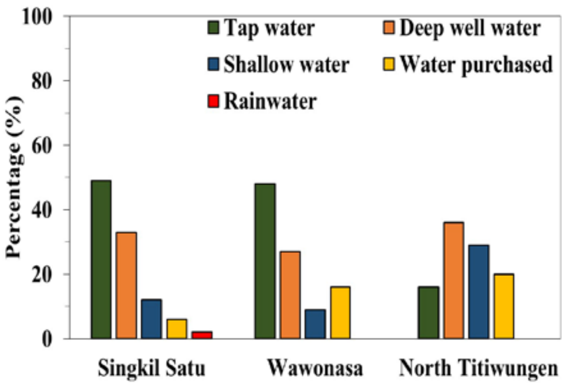


Fig. 3 Percentage of water sources used by residents

Water use was a concern where most of the population in North Titiwungen uses groundwater as a source of clean water. This was also found among the population in Singkil Satu and Wawonasa, and only a few residents use tap water because the water supply company is not optimal in providing water [16] (Fig. 3). Ground water (Fig. 4.) is mostly used for daily needs except for drinking. This was because the piping system served by the water supply company was not optimal.

(a) Deep water pumps

(b) Stored in temporary storage

Fig. 4 Intake of water by households at the study location

For drinking water, the community prefers refilled water to groundwater or tap water because the quality of groundwater is not always good, depending on the season and the characteristics of the existing groundwater (Fig. 5). Therefore, refilled drinking water is a practical and economical choice. Based on these two conditions, there is a need for the continuous availability of water as a source of clean water. With the application of WSD, there is potential for using rainwater as a source of water to support water availability, especially to improve the quality and increase the quantity of groundwater.

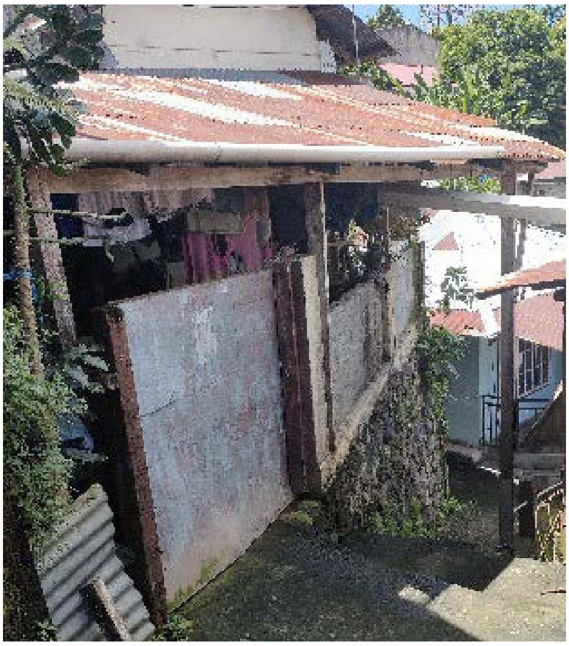
Fig. 5 Well water quality in the study locations

The next physical condition is related to the condition of the houses owned by residents. The house conditions affect the readiness of WSD applications; some applications of WSD change the function of parts of the house, such as changing the function of the roof, yard, or drainage channel. Most houses in the study sites are permanent (Fig. 6), but not all are homeowners. The houses owned by residents in the study area generally use roofs made of iron sheeting and tiles with a slope arranged to drain rainwater that falls on it (Fig. 7). Some use water pipes as gutters and continue the water falling on the roof (Fig.8). This can collect rainwater that falls to be stored for use by residents. Residents in Pontianak City, Indonesia, widely apply this.

4.2 Non-Physical Aspects

The non-physical aspects studied are income, employment, and home ownership. This aspect supports the application of WSD in terms of investment readiness, management, and sustainability. The economic level of households in the study locations is, on average, low; less than 33% of the population has an income of over 3 million rupiahs per month (Fig. 9).

The most active jobs are traders/self-employed in each region. Most Singkil Satu and Wawonasa residents live in their own homes, while in the North Titiwungen area, more people live with their families. With permanent and private home ownership, it is an added value to implement WSD (Fig. 10). This is because having private ownership status can increase risk awareness and greatly influences community decisions to provide appropriate facilities.



(a) semi-permanent

(b) permanent housing

Fig. 6 Examples of housing in the study location

Fig. 7 Examples of types of roofs in settlements

Fig. 8 Examples of the use of pipes to drain rainwater

The non-physical aspects include experience and understanding of disasters caused by water. Wawonasa is very close to the Tondano Watershed, and flooding often occurs during the rainy season. More than half (60%) of the community stated that flooding occurs several times a year (Fig. 11), and can reach the knee height of an adult, making this area prone to flooding. North Titiwungen is very close to the Sulawesi Sea. Most of the floods occur during high tide, or are potentially affected by tidal floods. Most residents stated that the floods are usually as high as an adult's heel.

In contrast, in Singkil Satu, water only flows when it rains, but no flooding occurs due to the contours of the area. The application of WSD can reduce the impact of flooding and inundation so the occurrence of water-related disasters is an opportunity for implementing WSD.

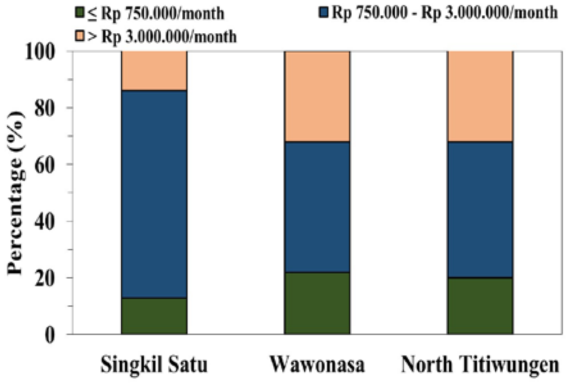


Fig. 9 Percentage of household economic income capacity

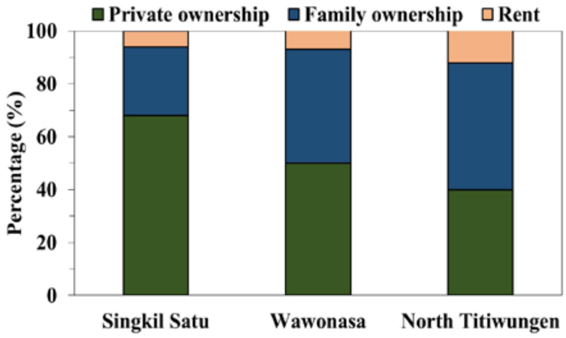


Fig. 10 Percentage of household ownership in the study area

4.3 Supporting Aspect

Supporting aspects in this study are related to the potential and occurrence of disasters due to the potential for water and rainfall. The highest rainfall that occurred in Manado City was recorded in November at 583 mm, and the average throughout the year in 2021 was 348 mm. Rainfall between 300-500 mm, including high rainfall and above 500 mm is very high (Fig. 12). The potential for high average rainfall can support the application of WSD.

Related to the potential for flood disasters that occur in Manado City, deltares research [4] has concluded that major floods caused by inundation from high river water levels have occurred more frequently in the last ten years. The flash floods increased the water levels, affecting a large area along the affected river. Fluvial flooding is becoming a growing problem in Manado. The height of the inundation can reach quite high depths, but the flood area is limited due to the relatively large slope of the terrain and the deep profile of the river. The characteristics of the river and its location in Manado City are prone to flooding.

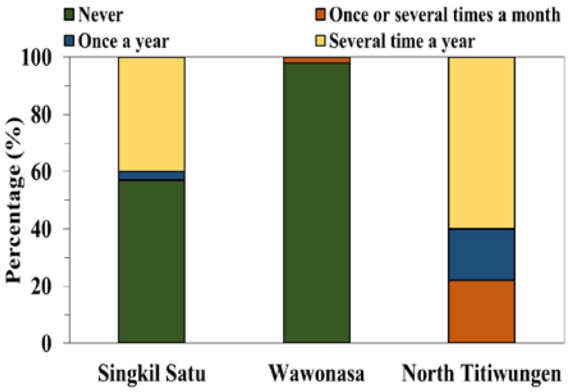


Fig. 11 Percentage of flood events at the study area

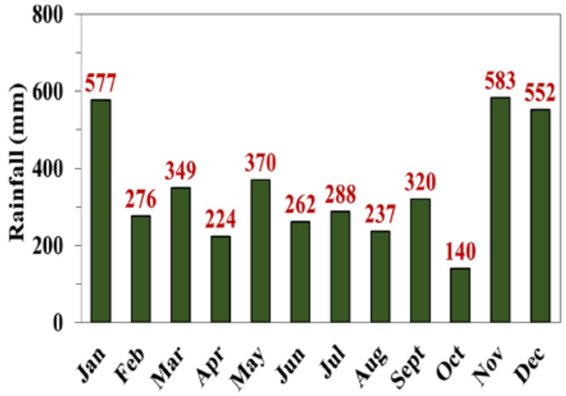


Fig. 12 Monthly rainfall in Manado City in 2021 (source: Central Bureau of Statistics for Manado City)

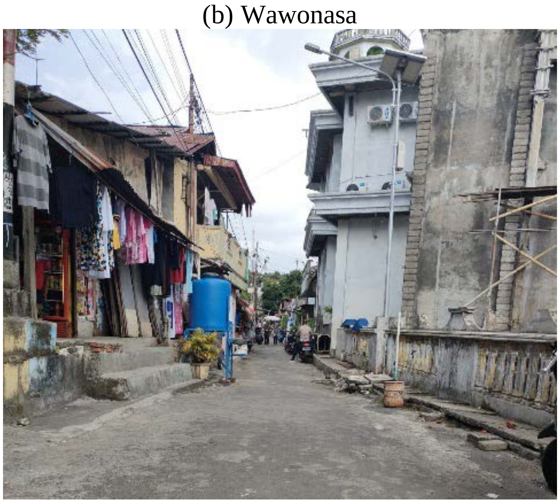
4.4 Challenge to Implementation

One of the main points of the interview was regarding the community's response if it was hit by a flood and the preventive measures that would be carried out. Most people strongly agree if they were given counseling, outreach and understanding regarding the dangers of flooding, water management, and sanitation. This is a positive opportunity where people are willing to learn and understand WSD in socialization and counseling related to flood and water management. Many challenges were found in implementing WSD in slum areas in Manado City from field observations. The first challenge is the high population density with adjacent houses. This makes it difficult to provide land for the implementation of WSD, since it requires land for absorption and growth of vegetation (Fig. 13).

Another WSD application is to infiltrate water and absorb water into the soil. One of the applications is that with limited drainage channels, it can be used as ecodrainage for rainwater infiltration. However, it first needs to prepare management for greywater and sediment barriers [10]. Another challenge is when trying to implement rainwater for daily needs. It is necessary to add supporting units so that the water produced can be directly used as a source of clean water. Another challenge is the characteristics of each regional topology resulting in more specific applications, so further research is needed to find the most suitable WSD to be implemented at each location.

(a) Singkil Satu

(b) Wawonasa



(c) North Titiwungen

Fig. 13 Dense settlement conditions in the study location

5. CONCLUSIONS

The implementation of WSD is potentially applied in three slum areas in Manado City referring to the surveys and interviews related to physical, non-physical, and supporting aspects. Socio-economic conditions are a challenge, with most people have income under 3 million/month. However, private home ownership supports the potential implementation of WSUD technology. Drainage infrastructure conditions need to be improved. This needs to be supported by community understanding and water availability. People still rely on groundwater and do not use rainwater. Drinking water relies on refilled gallons of water. This technical condition is very potential in applying WSUD, especially in increasing water availability for residents. However, there needs to be a study on the potential of rainwater and soil infiltration. Seeing the challenges and opportunities, it is necessary to consider the community to implement WSD. Further research on the most appropriate type of application needs to consider the character of the location. The results of this study can then be followed up with the appropriate selection of technology to be applied in the study sites.

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7. REFERENCES

[1] Hutchings P., Wilcock S., Lynch, K., Bundhoo D., Brewer T., Cooper S., Keech D., Mekala S., Mishra P.P., and Parker A., Understanding Rural–Urban Transitions in The Global South Through Peri-urban Turbulence. Nature Sustainability, Vol. 5, Issue. 11, 2022, pp. 924–930.

[2] Nur A., Soewondo P., Oginawati K., and Setiyawan A.S. Current Overview of Polyethylene Terephthalate as Biofilm Media in Communal Wastewater Treatment Plants in Indonesia. Sanitation Value Chain, Vol. 5, No. 1, 2021, p. 44.

[3] Deltares, Architecture O., Kita K., and Wiratman. Designing Flood Resilient Cities, Integrated Approaches for Sustainable Development Bima, Manado and Pontianak. Indonesia: The World Bank, GFDDR, Bappenas, 2020. pp 1-370.

[4] Wong T.H.F., Rogers B.C., and Brown R.R., "Transforming Cities through Water-Sensitive Principles and Practices," One Earth, Vol. 3, Issue 4, 2020, pp. 436–447.

[5] Wang Y., Van Roon M., and Knight-Lenihan S., Opportunities And Challenges In Water Sensitive Industrial Development: an Auckland Case Study, New Zealand, International Journal of Sustainable Development & World Ecology, Vol. 28, Issue 2, 2021, pp. 143–156.

[6] Rogers B.C., Dunn G., Hammer K., Novalia W., de Haan F.J., Brown L., Brown R.R., Lloyd S., Urich C., Wong T.H.F., and Chesterfield C., Water Sensitive Cities Index: A diagnostic tool to assess water sensitivity and guide management actions, Water Research, Vol. 186, 2020, pp. 1–13,

[7] Leder K., Openshaw J.J., Allotey P. Ansariadi A., Barker S.F., Burge K., Clasen T.F, Chown S.L, and Duffy G.A., Study Design, Rationale and Methods of the Revitalising Informal Settlements and their Environments (RISE) Study: a Cluster Randomised Controlled Trial to Evaluate Environmental and Human Health Impacts of a Water-Sensitive Intervention in Informal Settlements Indonesia and Fiji, BMJ Open, Vol. 11, Issue 1, 2021., pp. 1-14, 2021,

[8] Soedjono E.S., Fitriani F., Rahman R., and Wijaya I.M.W., Achieving Water Sensitive City Concept Through Musrenbang Mechanism in Surabaya City, Indonesia, International Journal of Geomate, Vol. 15, Issue 49, 2018, pp. 92–97.

[9] Chadfield S.J., Wei Y., and Lieske S.N., Water Sensitive Communities: a Systematic Review With a Complex Adaptive Systems Perspective, Journal of Environmental Planning and Management, 2022, pp. 1–27.

[10] Dada A., Urich C., Berteni F., Pezzagno M., Piro P., and Grossi G., Water Sensitive Cities: An Integrated Approach to Enhance Urban Flood Resilience in Parma (Northern Italy)," Climate, Vol. 9, Issue 10, 2021. pp. 152–174.

[11] Defi L. P., Kusumayanti I., Fatimah W.M., Sarli P.W., and Soewondo P., The Rise of Rainbow Village: Optimizing Aesthetical Program Ta Accelerate Sanitation Access, International Journal of Geomate, Vol. 22, Issue 90, 2022, pp. 118–124.

[12] Rashetnia S., Sharma A.K., Ladson A.R., Browne D., and Yaghoubi E., A scoping review on Water Sensitive Urban Design aims and achievements, Urban Water Journal, Vol. 19, Issue 5, 2022. pp. 453–467.

[13] Soewondo P., Sulasiah D., Putra A., Zakiyya N., Sarli P.W., and Handajani M., Visual Improvement of Slum Areas to Accelerate Universal Access to Domestic Wastewater Treatment (Case study of Yogyakarta, Semarang and Manado), in IOP Conference Series: Earth and Environmental Science, Semarang, Indonesia, Vol. 409, Issue 1, 2020, pp. 1–10.

[14] Sutherland C., Raynaert E, Dhlamini S., Magwaza F., Lienert J., Riechmann M.E., Buthelezi S.,

Khumalo D., Morgenroth E., Udert KM., and Sindall R.C, Socio-technical Analysis of a Sanitation Innovation in a Peri-urban Household in Durban, South Africa, Science of The Total Environment, Vol. 755, 2021, pp. 1-12 2021,

[15] Kwiringira J.N., Kabumbuli R., Zakumumpa H., Mugisha J., Akugizibwe M., Ariho P., and Rujumba J., Re-conceptualizing Sustainable Urban Sanitation in Uganda: Why the Roots of 'Slumification' must be Dealt With, BMC Public Health, Vol. 21, Issue 1, 2021., pp. 1-12.

[16] Zahrawani, S., Setiyawan, A.S., Sarli P.W., Soewondo P., and Awfa D., Strategies for Increasing Access to Water and Sanitation in a Water Sensitive Area. 12th International Conference on Geothecnique, Construction Materials and Environment, 2022, pp 474-479.