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Community perceptions on the adoption of stormwater management practices in Kota Kinabalu, Sabah: A pilot study

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ABSTRACT The current practices have included the BMPs to improve urban stormwater quality while reducing critical flood events and stream erosion. However, uncontrolled development in Kota Kinabalu, Sabah, compromises the way water flows. Albeit with MSMA, the community perspectives are also important and should be studied. This work determines the community's perception of the stormwater management practice through a survey. Data collected from 56 respondents (with a varied range of working experiences in the private sector (64%) and government sector (36%)) were descriptively analyzed. With a mean of 2.39, most respondents have knowledge and understanding of stormwater management, despite various working experiences. The findings show that respondents agree that infrastructure developments (<90%) are vital when dealing with stormwater and that proper waste management (79%) should also be emphasized. Then the funding (27%) and enforcement (24%) were highlighted as the main barriers to proper stormwater management implementation. Lastly, with a mean of 3.3, most respondents agreed (39%) and strongly agreed (46%) that there is a need to improve the existing stormwater management practices. Considering stormwater as a valuable green alternate resource, we suggest a sustainable approach to monitoring stormwater quality and flooding events, such as green filtration and IoT integration.

KEYWORDS: Manual Saliran Mesra Alam (MSMA); perceptions; questionnaires; stormwater management; urbanization
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Original Article

INTRODUCTION

Sabah has among the most naturally diverse tropical conditions in Malaysia. However, rapid development in the capital city, Kota Kinabalu (KK), shows some degree of impact on the landscape, with migration from rural areas that trigger developments, causing more changes from pervious into impervious land surface covers (Takaijudin *et al*., 2010). Thus, urbanization remains a massive threat in preserving nature, whereas the most debilitating natural phenomenon that could occur includes the recent flash flood and stormwater pollution.

Stormwater pollution occurs when surface runoff accumulates suspended matter consisting of sediments, nutrients, and metals, as they convey into the drainage. Then it causes silts and physical clogs while deteriorating the water body or river. The nonpoint source pollution complicates this stormwater management (Hwang *et al*., 2019). The impact also worsens during heavy rainfall, leading to a rise in suspended solids. High solids in suspension would increase the temperature while reducing the oxygen concentration in water, endangering aquatic species and the ecosystem (Susilowati *et al*., 2018).

Flood problems are occasionally reported in KK and are associated with intense, prolonged rainfall and inadequate functionality of drainage systems (Hermawan *et al*., 2018). It directly impacted communities and the environment. The immediate effects include property damage, landslides, crop destruction, livestock loss, lifestyle degradation, and decreasing water quality and coastal production.

Designing holistic mitigating systems is challenging (Zakaria *et al*., 2004) to fulfil the diversified demand for water resources due to landuse development. In Malaysia, the Department of Irrigation and Drainage (DID) addresses issues related to water and river through Best Management Practices (BMPs) based on the Manual Saliran Mesra Alam (MSMA) guideline. Nonetheless, as part of the stakeholders, the community perspectives on stormwater management should be reflected as they engage directly with the program's effectiveness, and their perceptions may complement the MSMA guideline. Hence, this pilot study investigates the community's perception of stormwater management practice in Kota Kinabalu, Sabah. The survey was distributed to professionals working in the government and private sector within the district. These findings would help the authorities and relevant agencies develop effective strategies to improve local stormwater management implementation.

STORMWATER MANAGEMENT

Stormwater refers to the rainwater that flows on the ground as runoff that washes over a developed area, including rooftops, roads, and parking lots, usually infiltrates into the soil and is filtered, replenishing aquifers. This stormwater collects various pollutants along its pathway, transporting nutrients, oil and grease (O&G) from the commercial sector, litter, silt, chemical pollutants, bacteria from pet waste or animal dropping, failing septic systems, and sediments from construction activities to the rivers. Thus, reduced vegetation, paved surfaces, and disrupted drainage connectivity (Zakaria *et al*., 2004) further degrades environmental surroundings (Qiao *et al*., 2019).

For urbanized areas, green infrastructure design for stormwater is essential. The MSMA guideline is used to manage local stormwater (DID, 2012) through BMPs, which include structural measures, vegetative techniques, or managerial practices for preventing, reducing, or treating pollution in the river basin and sustainable drainage systems (SuDS). These practices in mitigating stormwater issues are also known as low-impact development (LID), where it involves the interconnection of multiple stormwater management practices (SMPs) that distribute and retain the stormwater flow on-site, compared to traditional conveyance-oriented practices (Funai & Kupec, 2019).

Stormwater management is also vital to reduce risks to the public and preserve environmental quality, including precious water resources. Nonetheless, any potential approaches when dealing with stormwater should be strategized to achieve sustainability. This includes getting the community perspectives as part of the stakeholders. The government would have a significant role in engaging with the communities and industrial players, mainly to improve stormwater management practices. It is worth noting that stormwater would be a valuable asset as an alternative resource for non-potable usage when appropriately managed and treated with the right set of schemes (Ali & Bolong, 2021). Table 1 shows the previous study related to MSMA that used a survey methodology. This paper is expected to contribute to obtaining and engaging with the community perspectives and highlights how essential it is for all sectors to improve the current practices in stormwater management.

Table 1. The previous study (survey) on MSMA.

Author	Year	Findings
(Amirah *et al.*, 2021)	2021	Assessed the public opinion and acceptance of MSMA. The 200 respondents were from government agencies, private sectors, lecturers, students, and others. The results show that almost 70% of respondents were aware of MSMA's existence. Then 93% of respondents strongly agreed to its concept. Lastly, most respondents agreed that the manual could still be improved.
(Al-Hadu *et al.*, 2011)	2011	Developed the main features of an expert system prototype (ESCES) that minimizes erosion and sedimentation due to stormwater from construction activities. Questionnaire distributed to relevant experts. Results show the BMPs recommended accordingly to the site characteristics, as ranked by the relevant experts.
(Mohd Sidek *et al.*, 2004)	2004	Studied the local stormwater management practices. The 60 respondents were developers/contractors, consultants, and local authorities. Identified the barriers to MSMA implementation, including lack of design guidance, experience, modelling tools, costs, operation and management, and issues on adoption and ownership.

METHODOLOGY

A survey consisting of four main sections was adapted from (Mohd Sidek *et al.*, 2004). Section A collects the respondents' background, including their qualification, profession, years of experience, and working sector. Then, Section B identifies the respondents' understanding of stormwater management regarding the functions and objectives. Next is Section C, which determines the factors that cause flooding with closed and open-ended feedback. Lastly, Section D evaluates the functionality and effectiveness of existing stormwater management practices. This section also identifies the barriers to implementing stormwater management. With the Movement Control Order (MCO) due to Covid-19, face-to-face sessions have been replaced with online surveys using Google form and distributed through link-sharing via e-mail platform. From the target respondents (non-random sampling), a total of 56 feedbacks were obtained. The data were administered, processed, and analyzed using Microsoft Excel and IBM SPSS Statistics (refer Figure 1 for clarity).

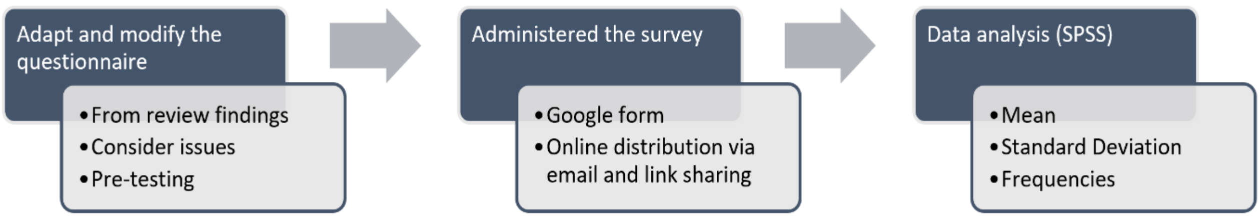

Figure 1. The research flowchart.

RESULTS AND DISCUSSION

For Section A, the respondents' professional background is shown in Figure 2, in which the majority are civil engineers (62%), who are more likely exposed to infrastructure work related to stormwater management. This is followed by consultants (9%), mechanical engineers (7%), environmental engineers (4%), and others (18%). The high numbers of engineers reflect the highest academic qualification of the first degree (78%), which is followed by the master level (16%), diploma certificate (4%), and doctorate (2%). Then, most of the respondents are from the private sector (64%), whereas the remaining (36%) are from the government sector. Additionally, the majority of the respondents have less than five years of experience (30%). This is followed by the respondents with experience between 5 to 10 years (25%) and 18% each for 10 to 15 years and more than 20 years. Those with years of experience between 15 to 20 years were the least (9%). Overall, almost a similar percentage range group of respondents of varied experiences were gathered to contribute to the survey.

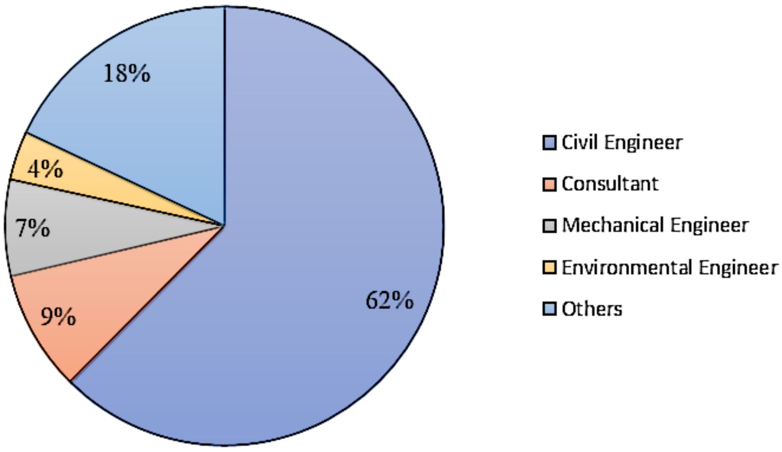

Figure 2. The profession of respondents.

The respondents' general knowledge concerning stormwater management was obtained in Section B, as shown in Figure 3. On the subject discussed, the agreement level on the x-axis begins from 0 (less knowledge) to a rating of 4 (highest understanding). The slightly left-skewed distribution in the histogram indicates that specific frequency values are below mode (2), of a total of 13%. With a mean of 2.39, the majority of respondents have knowledge and understanding of stormwater management at average (44%), followed by higher (30%) and highest (13%), despite various working experiences. Also, more than half of the respondents' feedback highlighted their exposure to stormwater management from experience in their work nature, which dealt with the Department of Irrigation and Drainage, Malaysia.

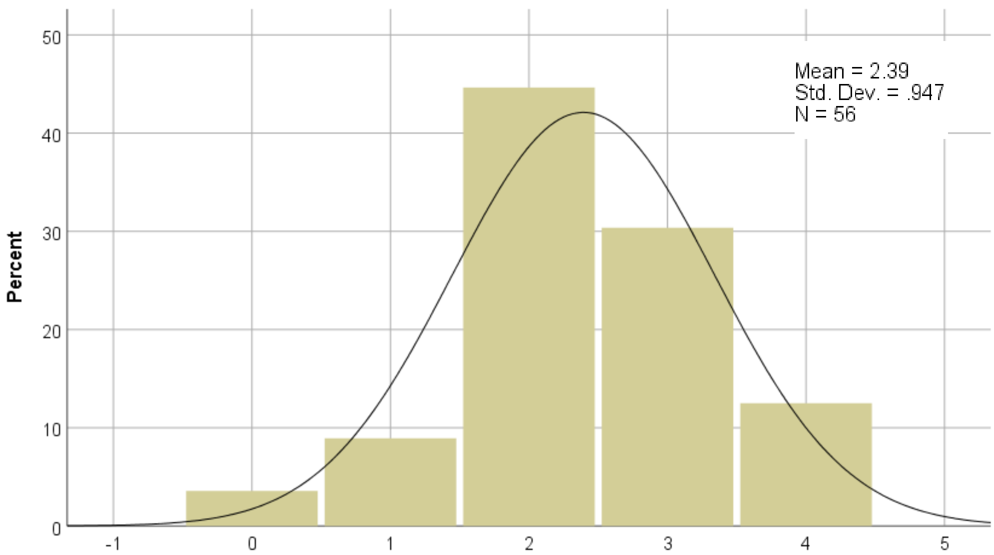

Figure 3. The distribution of respondents' understanding of stormwater management.

For Section C, the urban flooding causes were identified, with respondents referring to the infrastructure, including planning, construction, and maintenance work, primarily related to it. Figure 4 shows that 95% of the respondents agree that the existing drainage systems have deprived performance and a poorly planned waterway design. This highlighted issues, including blockages in drainage systems and their inability to handle the high water capacity (Al-Ghadi *et al.*, 2020). Next is the new development projects (93%). Typically, land development would increase surface imperviousness and reduce infiltration capability (Todeschini, 2016). Then, the topography of the area (91%), in which the landscapes with a geological shape such as "terrain bowl" and the low-lying area (Ali & Ariffin, 2011), may lead to stormwater accumulation and can be prone to flooding. Lastly, improper waste management (79%) leads to pollution and blockages (Ejaz *et al*., 2010), thus reducing the efficiency of the drainages. In addition, based on the open-ended feedback, some responded that the construction of infrastructures lacks in design, monitoring, and maintenance work, hence creating doubts whether the guidelines were not adhered to or just because of the workmanship quality. Some also highlighted the recent flash flooding events in different areas in the city, reflecting the existing stormwater systems' inefficiency.

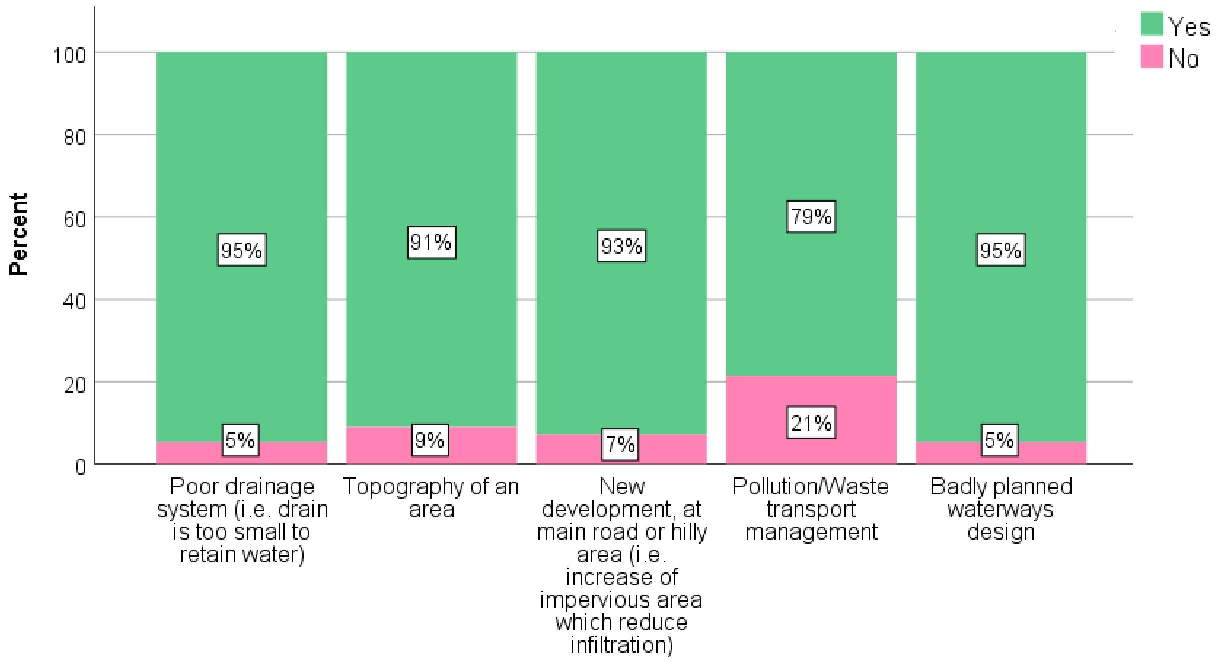

Figure 4. The responses on the causes of urban flooding.

Section D determines the barriers to implementing stormwater management and the level of agreement to improve the existing practices based on their functionality and effectiveness. From Figure 5, most respondents have selected those issues on funding (27%) and enforcement (24%) are the main barriers to implementing proper stormwater management. Funding is considered crucial in any operations since stormwater management systems' initial and maintenance costs can be burdensome. Without sufficient funding resources, the local authorities and industrial players would have constraints to carry out any work related to stormwater management, such as enforcement and maintenance (Zhao *et al.*, 2019). Engaging with the communities (18%) is also lacking in increasing awareness of stormwater management. It is essential as all parties' support is required to improve the existing stormwater management (USEPA, 2016). The lack of expertise/staff (16%) also highlighted the improvements required to reduce operation and maintenance costs in the long term for managing stormwater. As for the others, some have emphasized the limited database on relevant local stormwater information (12%) and late action being taken for mitigation related to stormwater management issues. Hence, the lack of readily accessible information added to the complicated stormwater management may disengage local stakeholders from the main environmental issues (Giacalone *et al.*, 2010).

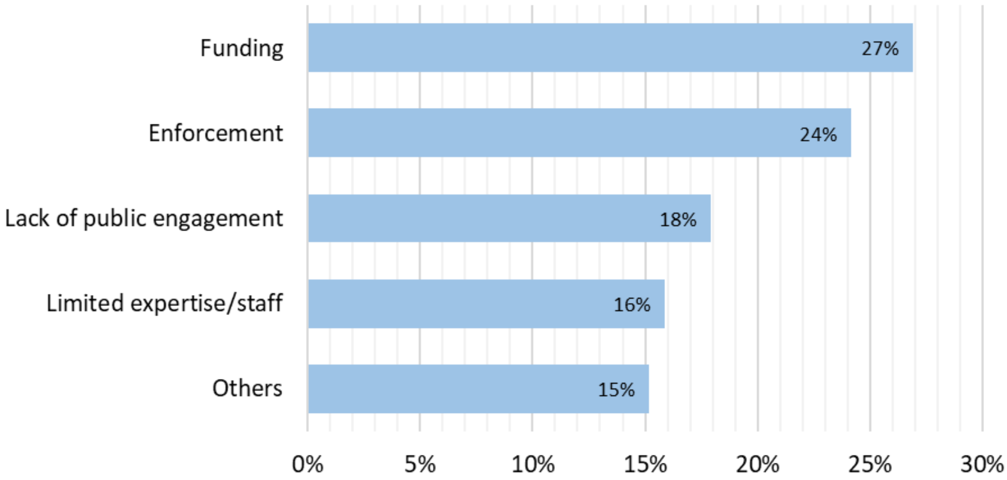

Figure 5. Barriers to implementing proper stormwater management.

Figure 6 shows the respondents' level of agreement on improving stormwater management practices. The agreement level is on the x-axis from level 1 (least agreed) to level 4 (strongly agreed). The left-skewed distribution on the histogram indicates that a few frequency values are less than the mode (4). Hence, with a mean of 3.3, mostly agreed (39%) and strongly agreed (46%) that there is a need for stormwater management practices improvement, particularly when the city is rapidly developing and attracts both investors and tourists (Bassi *et al.*, 2017). This is considerably important to sustain local economic growth and should not be overlooked.

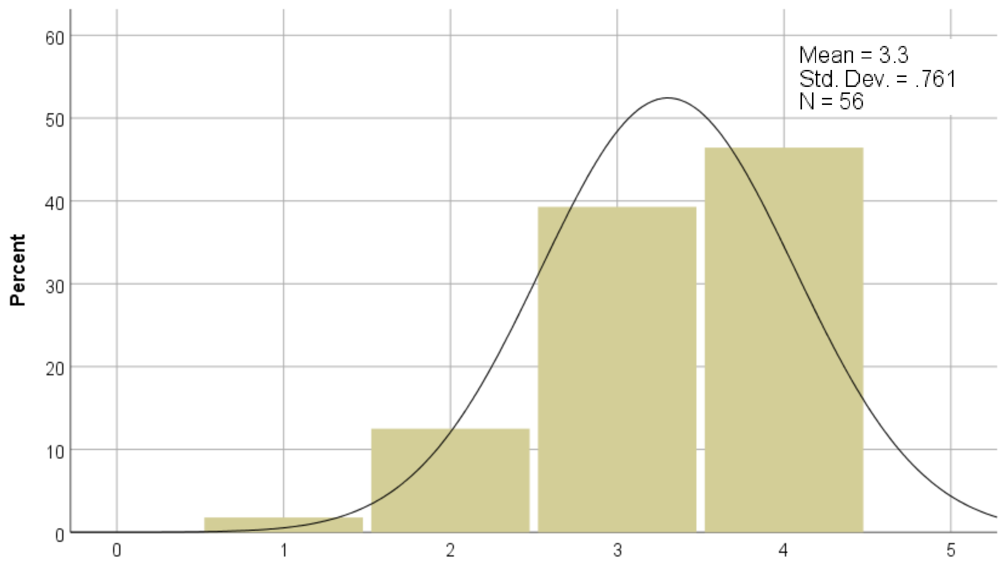

Figure 6. The level of agreement for improving stormwater management practices in KK.

RECOMMENDATIONS

The lacks of funding, enforcement, public engagement, and expertise/staff are persistent factors for any related matter in town development, particularly stormwater management. Since stormwater is a potentially sustainable resource, advancements in research and design should be explored to create more opportunities and alternatives for long-term mitigation. For instance, the stormwater quality can be improved through a filtration approach using green materials such as wastes from construction (Rahman *et al.*, 2015) and the agricultural sector (Yahya *et al.*, 2018; Ali *et al.*, 2021). This would reduce the costs since local materials and labour can be fully utilized.

Previously, most designs for stormwater utilized knowledge and experience acquired from other water treatment systems (Kandra *et al.*, 2014). However, the characteristics of stormwater and its system operations are different from that of water and wastewater treatment aims. Hence, future studies should analyze the stormwater filter design and their maintenance requirement to match the regional characteristics (Kandra *et al.*, 2014; Erickson *et al*., 2018; Hwang *et al*., 2019) to achieve optimized performance with cost-effectiveness as the priority. These studies prove beneficial, such as the LID practices shown in Korea (Maniquiz-Redillas & Kim, 2016) and SuDS in the UK (Allen *et al*., 2019).

Additionally, technology, such as the Internet of Things (IoT), can help manage stormwater. The stormwater quality can be easily monitored in real-time (Manoharan *et al.*, 2019) using sensors and computational programs. For instance, water level, turbidity, or desired parameters can be observed and assessed directly on smartphones and computers. This reduces human resources' needs, increasing the reliability and cost-efficiency of stormwater management. It would aid the process to distribute any necessary information to the public and is time-saving too. Nonetheless, more research is required and engaging the government, private sector, and communities is instrumental in ensuring sustainable stormwater management.

CONCLUSION

The survey data collected from 56 respondents (private sector=64%; government sector=36%) with varied working experiences have been analyzed successfully. Many of the respondents have average knowledge and understanding of stormwater management (mean=2.39). These study findings highlighted that infrastructure development (<90%), including the existing drainage systems and their design, are vital when dealing with stormwater and that proper waste management (79%) should also be emphasized. The main barriers to implementing proper stormwater management were identified as funding (27%), enforcement (24%), public engagement (18%), expertise (16%), and others (15%). Finally, most of the respondents (mean=3.3) agreed (39%) and strongly agreed (46%) that the existing stormwater management practices need improvements. It is suggested that the authorities and relevant agencies explore a more sustainable approach for application in stormwater management, such as using green filtration and the integration of IoT to monitor stormwater quality and flooding events.

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