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Abstract

The Tanggul River in Surakarta City is a tributary that empties into the Bengawan Solo River. Domestic activities located on river borders can pollute with the waste generation. Therefore, managing waste sources such as storage and collection is crucial in waste management. This study aims to analyze waste management from river debris storage and collection around the study site. The technique used in this research is direct observation of the study area and performing a decision analysis for alternative processing. Decision support system has one model, namely Multi-Criteria Decision Making for environmental development. The activities for collecting and sorting river debris in the Tanggul River are not yet available. The existing river debros collection used a 7 cm diameter net that has been installed at the sluice gate of the Tanggul River. Considering aspects or criteria in implementing accommodation activities needs to be carried out before determining the best alternative. Therefore, several measures need to be considered in determining the container based on SNI 19-2454-2002 concerning Operational Procedures for Urban Waste Management and Minister of Public Works Regulation Number 3 of 2013. The collection activity in alternative 1 uses the Brute Boom system: Heavy Duty Containment Boom equipped with a galvanized weir mesh net attached under the boom. The collection activity in alternative 2 uses a floating cube. The floating cube is a cube-shaped Waste holder that can float in the river to effectively hold waste floating on the surface of the river body. It is imperative to prevent river pollution from activities by providing infrastructure for storing and collecting waste. However, it does not have a more significant impact, such as the Tanggul River to the Bengawan Solo River in Surakarta City.
Keywords: Collection; River Debris; Storage; Surakarta City.

1. Introduction

River debris is defined as any solid material floating on the river and can be classified based on their origin: coastal industries, illegal dumping, and domestic waste (Jang, 2014). Global warming has significantly increased the frequency of weather events and extreme climates have caused river flows to increase and can carry river debris (Zhou et al., 2022). Rainfall is an important factor to bring about debris flow in rivers, and the empirical relationship between the occurrence of debris flow (Zhu et al., 2021). Indonesia has many rivers and only about 2% meet water quality standards.

The construction of housing and settlements to fulfill one of the basic human needs, as well as to improve the quality of the living environment, give direction to regional growth, expand employment opportunities and stimulate economic activity in the context of increasing and equitable distribution of people's welfare. In this regard, efforts to build housing and settlements continue to be improved to provide housing with an increasing number. Many accommodations on the Bengawan Solo River Border are due to the economic squeeze and the lack of land that a rapidly growing population will inhabit. There are many dangers if living on the Bengawan Solo River border, including floods, landslides, river pollution because waste disposal can cause damage to environmental systems (Putra et al., 2021; Suryanto et al., 2021).

The lack of awareness of the people living around the riverbanks about the impact of throwing waste into the river and the lack of waste management at the source level are some of the factors of river pollution caused by household waste (Sari et al., 2021). Operational techniques in waste management consist of activities from storage to final disposal that must be integrated (Maharani et al., 2019; Yong et al., 2019). In principle, there are 2 (two) efforts to tackle pollution, namely non-technically and technically. Garbage disposal activities into rivers are generally carried out by residents who live and/or work on riverbanks. Therefore, the priority to reduce the amount of waste dumped into rivers is more emphasized on people who live and/or work near rivers (Indrawati, 2011).

It is sorting and storing based the type such as landfill, recyclable, compost, or energy (Gopalakrishnan et al., 2021; Suryawan et al., 2022). The waste sorted is organic waste, inorganic waste with economic value, and other inorganic waste. The collection of river debris or debris is slightly different from waste on land and land-based debris entering a river system (Bauer-Civiello et al., 2019). Waste collection can be done by creating a bubble curtain that pushes the plastic to the side of the drain. Some rivers in Bali, including several other rivers in Indonesia, have now installed thrash barriers to collect various kinds of waste (Koski-Karell,

2019). By installing trash barriers and trash nets, we hope to clean up the river flow, which will eventually lead to river debris (Helinski et al., 2021). This study aims to analyze waste management from river debris storage and collection around the study site

2. Methods

The research stages are started from problem identification, literature study, data collection, and data processing which is then analyzed. This research was conducted in the December 2021. First, identify the problem where waste management in Tanggul River. There is no waste management application with the 3R concept, which includes a storage and collection system and the potential for people to throw waste into the river. The research stages used in planning the waste management system at the study site can be seen in Figure 1.

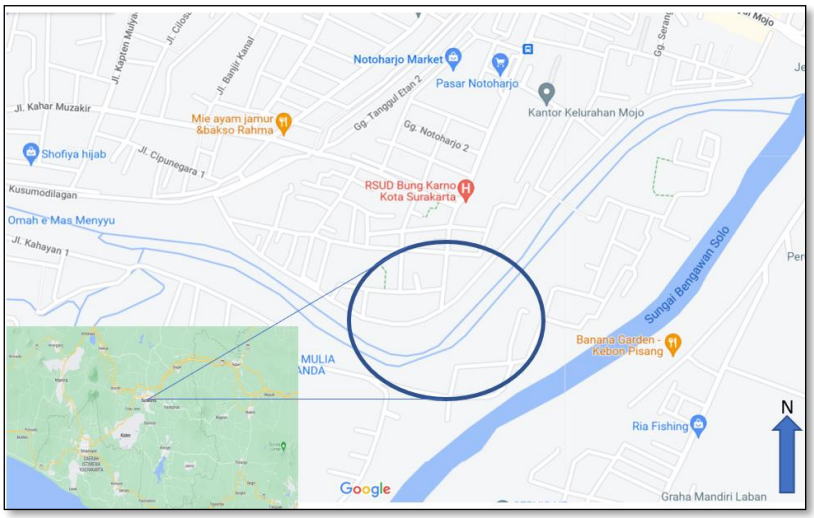

Figure 1. Study Location

Source: Google Map (2021)

This literature study aims to collect and study theories regarding household waste management, especially waste collection and storage, generation, composition, characteristics of waste and community participation. Literature is obtained from books, journals, related standards, and regulations.

Existing observation is observing waste operational activities, namely from waste collection and storage, so that problems in waste management can be identified in living conditions. The method used is the method of observation or direct observation and documentation related to the object of storage and collection of waste in the Tanggul River.

Decision support system has one model, namely Multi-Criteria Decision Making (MCDM) for environmental development (Kumar et al., 2017; Rousta & Araghinejad, 2015). Functions

to assist in decision making with the Multi-Attribute Utility Theory method. There are four decision-making steps in MCDM including: identification of problems, develop preferences, evaluate alternatives, and determine the best alternative. The description is as follows, namely determining the relevant criteria and alternatives; attach a numerical measure of the relative importance of the criteria and the impact on alternatives to those criteria; processes numerical values to rank each alternative.

Having many criteria and various alternatives is a technique in the decision-making process using the Multi-Attribute Utility Theory method. To get the best choice, supplier selection begins with determining the normalization of the matrix. Functions influence the assessment and calculation results of the Multi-Attribute Utility Theory method by multiplying the weight of each predetermined criterion. The purpose of these results is for decision-makers. In the Multi-Attribute, Utility Theory method produces a ranking for the development (Youngblood & Collins, 2003). The assessment of this method uses the scale according to Table 1.

Table 1. Conversion of Verbal Values on 1-3 Scale

Weight	Information
1	Difficult, low, very potential
2	Medium, potential
3	Easy, high, no potential

3. Results and discussions

Handling of river debris in Surakarta City is done manually with the help of supporting tools by the Surakarta City Public Works and Housing Office in the field of water sheed management with working areas in the form of rivers, reservoirs, irrigation canals, and lakes. The handling of river debris from various activities is carried out when there are complaints from the public or waste begins to cover the flow of water so that the handling of river debris is carried out in a different place every day. The river debris management system in the Tanggul River in the existing condition can be seen in Table 2.

Table 2. Existing Conditions of Storage and Sorting and Collection of Waste in the Tanggul River

No	Process	Existing Condition
1	Storage and sorting	Activities for collecting and sorting river debris in the Tanggul River are not yet available
2	Collection	Water waste collection activities in existing conditions are carried out routinely every day but in different places from 08.00 - 14.00 WIB. The collection uses a 7 cm diameter net installed on the Tanggul River floodgate. The collected waste is then taken manually by workers equipped with supporting equipment and equipment in nets, trash baskets, and sacks.

Waste reduction activities include limiting waste generation, recycling waste, and reusing waste, while waste handling activities include sorting, collecting, transporting, processing, and final processing (Demirbas, 2011). According to SNI 19-2454-2002 concerning Procedures for Waste Processing Techniques, waste storage will be carried out at the waste source and is planned to be divided into three types of containers, namely organic and inorganic waste with the color of the container as a differentiator. Green containers for organic waste and yellow containers for inorganic waste (Maharani et al., 2019; Puspitasari et al., 2022). The housing pattern used is communal because the placement location is in an open space and a public place (Surya et al., 2018). The container used for river debris is a level-3 container, a central container that can accommodate large volumes of waste. From the measurements at the study site, the maximum volume of waste achieved at the study site is 5.7 m^3/day. Therefore, the container used must adjust to the waste generation size and the availability in the market. Characteristics of river debris with a high water content of 60% -80% (Jang, 2014) will determine the container material used for river debris.

Considering aspects or criteria in implementing accommodation activities needs to be carried out before determining the best alternative. Therefore, several measures need to be considered in determining the container based on SNI 19-2454-2002 concerning Operational Procedures for Urban Waste Management and Minister of Public Works Regulation Number 3 of 2013 as shown in Table 3.

Table 3. Criteria for Waste Storage

No.	Criteria	Design	Information
1	Not easily weathered and strong	UNP 100 type steel coated with fiberglass	According to SNI 07-0052-2006 regarding Hot Rolled Process U Channel Steel, UNP 100 Steel has a tensile strength of 4385 kgf/cm^2. Furthermore, UNP 100 iron has high flexibility, namely the ability to withstand tensile stress. However, when the UNP 100 iron accepts or withstands a heavy load, the UNP 100 iron is not easy to expand.
2.	Not easy to corrode	UNP 100 type steel coated with fiberglass	It should be noted that the corrosion rate of mild steel and high-strength steel does not change (Ispandriatno, 2016). Therefore, steel requires a composite material as a corrosion-resistant layer. The material used is fiberglass. This fiber has properties as a good insulator conductor, is resistant to corrosion, has better tensile strength than metal, has a lighter weight, and has lower production costs.
3.	Easy to move and empty	Mounting the wheels on the bottom of the container	Waste containers must be easily moved to make it easier for officers to empty or move containers for specific purposes. Therefore, a pair of wheels and supporting legs were added to the bottom of the container for each right and left side so that the trash can could move and stand upright. The container is also equipped with an anchor hook on one side of the container to facilitate moving using transportation.
4.	Aesthetic Elements	container cover	The purpose of the storage is to avoid scattered waste by paying attention to aesthetic aspects (Menteri Pekerjaan Umum Republik Indonesia, 2013). The aesthetics in question are like a container with a cover that does not open directly so waste is not scattered, and no animals enter.
5.	Separate organic and inorganic waste	The barrier between organic and inorganic waste	There are differences in components between organic and inorganic, and the container is given a partition so that the waste does not mix and complicate the following process.

The UNP 100 steel container covered with fiberglass is stronger than the container with cement and brick material. According to SNI 15-2094-2000 regarding solid red brick for masonry walls, red brick has a strength of 150 kgf/cm^2. The choice of the container with UNP 100 steel material has a higher probability of experiencing corrosion, but the presence of a

fiberglass layer slows down the corrosion process. The shape and design of the fiberglass steel container tend to be neater and more ergonomic because it is a manufactured product equipped with a lid and wheels. The container will be placed close to the source of the waste, namely near the waste net on the Tanggul River. The container design can be seen in Figure 2.

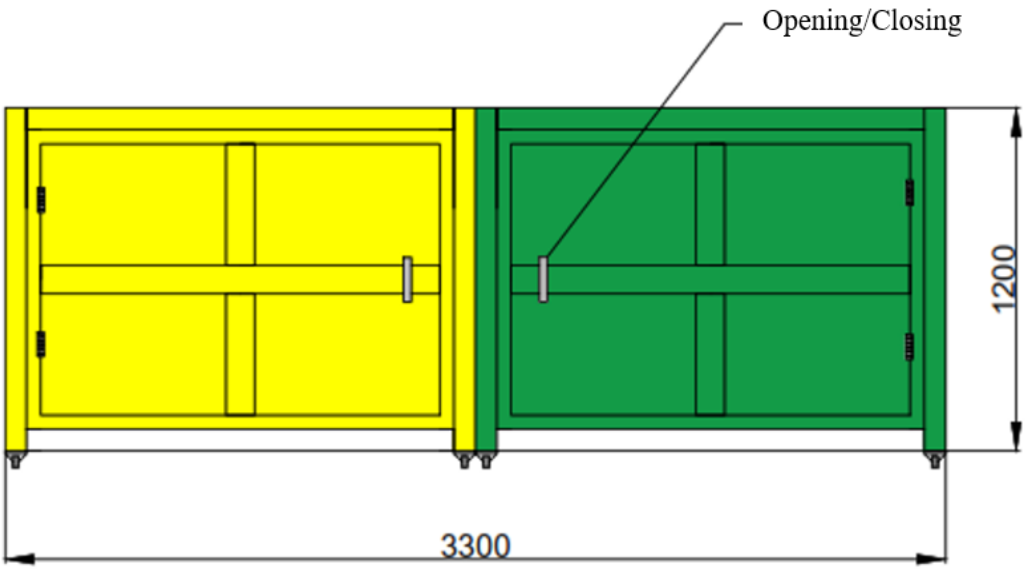

Figure 2. Waste Storage Plan in the Tanggul River

Water waste collection activities in existing conditions are carried out routinely every day but in different places from 08.00 - 14.00 WIB. During the sampling activity, the minor diameter of the waste found was straws with a diameter of 0.5 cm and a length of 15 cm, while the size of the net installed had a diameter of 7 cm x 7 cm. Therefore, waste with a size of less than 7 cm x 7 cm will escape from the net. Consequently, it is necessary to design a waste collection technology on the Tanggul River. The planning of waste collection referring to SNI 192454-2002 is as follows:

1. Rotation 1-4 times/day
2. Periodize once a day, every 2 days, or a maximum of 3 days, depending on the condition of the waste composition, such as: the higher the percentage of organic waste, the periodization is carried out at least once a day. Periodize every three days or more for dry waste. Completion of the applicable provisions for hazardous waste. They have a fixed service area. Implementing officers work regularly and can be moved periodically. Workload evenly and fairly with criteria for waste transported, distance traveled, and regional conditions.

The two alternatives that can be applied in determining the collection of river debris can be seen in Figure 3. First, installing a river debris collection also traps debris in the river to not flow into the sea (Helinski et al., 2021; Manickavasagam et al., 2020; Winterstetter et al., 2021). The trapped debris is then collected and managed by the local waste bank, which can then become additional income for the surrounding community (Sari et al., 2021).

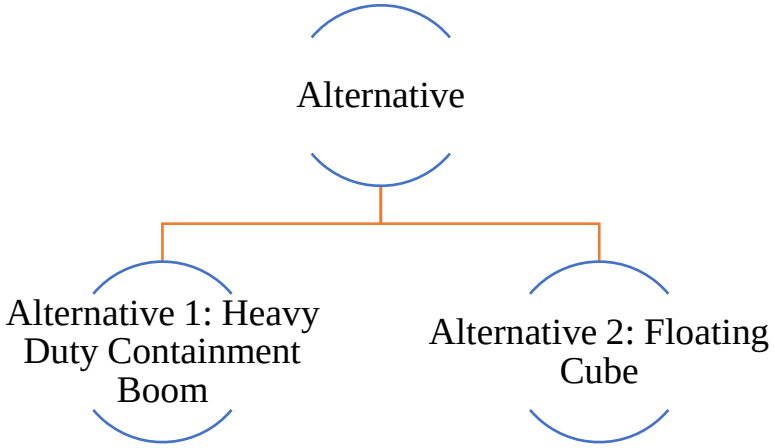

Figure 3. Waste Collection Alternative Design in the Tanggul River

3.1. Alternative 1: Brute Boom: Heavy duty containment boom

The collection activity in alternative 1 uses the Brute Boom system: Heavy Duty Containment Boom equipped with a galvanized weir mesh net installed under the boom. This tool can firmly accommodate tree trunks, debris, wood, leaves, plastic, and other waste. One Brute Boom: Heavy Duty Containment Boom has a length of 3.45 m and a mass of 75 kg without a net, while the weight of a brute boom with a net is 116 kg with a capacity of 409 kg. The Embankment River has a width of 40 m. Brute Boom: Heavy Duty Containment Boom is designed to have an angle of 45º (Amiruddin, 2020) from the river's width so that the Brute Boom is 56.57 m long.

It is made of 0.6 m diameter double-walled corrugated HDPE material filled with closed-cell polystyrene foam. This polystyrene foam serves to maintain buoyancy even if the outer wall of the HDPE is damaged. In addition, the inside of the floating boom is equipped with galvanized steel weights which can increase the horizontal and vertical strength. Made of galvanized steel with a working load of up to 4.75 tons to withstand heavy waste generation loads and continuous flow rates. In addition, the connections between the floating booms make installation and removal easy. It is made of flexible polyester with a UV-resistant coating. It reduces the escape of floating waste generation between the floating boom connections.

Galvanized wire mesh netting is made of low-carbon steel wire, which goes through a welding process so that the outer layer is coated with a galvanized layer. One of the advantages of galvanized wire mesh netting is that it is resistant to weather, acids, and bases and is resistant to corrosion. Brute Boom: Heavy Duty Containment Boom combined with a net can increase the ability to catch waste, but it will be challenging to operate and install the tool.

3.2. Alternative 2: Floating cube

The collection activity in alternative 2 uses a floating cube. The floating cube is a cube-shaped Waste holder that can float in the river to effectively hold waste floating on the surface of the river body, the floating cube can hold up to 360 kg of Waste with HDPE material measuring 0.5 meters x 0.5 meters x 0.4 meters and weighing 8kg/unit. he floating cube is designed to have an angle of 45 (Amiruddin, 2020) from the river's width so that the length of the floating cube is 56.57 m. Therefore, the number of floating cubes required is 102 units for designing the width of the floating cube, which is 1 m with a unit having a width of 0.5 m so that the length of the floating cube is multiplied by 2. The total number of floating cubes used is 204 units.

The floating cube is strong, safe, environmentally friendly, and recycled because it uses HDPE material. Resistant to sunlight and anti-corrosion, which makes the floating cube have a long service life of up to 15 years. The anti-slip top surface design can increase safety and stability when workers pick up the stuck waste. A recapitulation of the comparison of alternative 1 and alternative 2 can be seen in Table 4.

Table 4. Recapitulation and Assessment of Each Alternative

Parameter	Alternative 1	Alternative 2	Weight
Capacity	409 kg	360 kg	3
Price	Rp 11,858,404.00	Rp 183,600,0000.00	3
Ability to catch trash	Tall	Low	3
Operational	Difficult	Easy	2
Ease of Installation	Difficult	Easy	2
Potential for corrosion	Potential	No potential	1

The chosen alternative in the collection is alternative 1 brute boom: a heavy-duty containment boom equipped with a net. In terms of capacity, the brute boom has a larger

capacity than alternative 1. The larger the capacity of the Waste collection tool, the more river debris is retained so that the capacity parameter has an important factor and has a weight 3. In terms of cost, the units in alternative 2 are more, so the price of alternative 2 is higher than alternative 1. The cost parameter will affect the budget plan later so that the weight given is 3. In terms of efficiency in capturing waste, alternative 2 has a higher chance of waste leakage, while alternative 1 is smaller.

In alternative 1, the brute boom is equipped with a flexible and robust inter-floating guard so that floating waste does not pass through the gaps between the booms. In addition, the brute boom is also equipped with a net made of galvanized with a diameter of 4 mm. This is because the diameter of the waste is larger than the diameter of the net so that the waste will not easily pass through the net. The smaller the diameter of the net, the higher the ability to catch river debris (Amiruddin, 2020), so this parameter is given a weight of 3. A complete assessment of the two alternatives can be seen in Table 5.

Table 5. Assessment of Numbers and Determination of Values

Parameter	Alternative 1	Alternative 2	Worst Value	Best Value
Capacity	409	306	306	409
Price	Rp 11,858,404.00	Rp 183,600,000.00	Rp 183,600,000.00	Rp 11,858,404.00
Ability to catch trash	3	1	1	3
Operational	1	3	1	3
Ease of Installation	1	3	1	3
Potential for corrosion	2	3	1	3

The chosen alternative in the collection is alternative 1 brute boom: a heavy-duty containment boom equipped with a net. In terms of capacity, the brute boom has a larger capacity than alternative 1. The larger the capacity of the Waste collection tool, the more river debris is retained so that the capacity parameter has an important factor and has a weight 3. In terms of cost, the units in alternative 2 are more, so the cost of alternative 2 is higher than alternative 1. The cost parameter will affect the budget plan later so that the weight given is 3.

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net so that the waste will not easily pass through the net. The smaller the diameter of the net, the higher the ability to catch river debris (Amiruddin, 2020), so this parameter is given a weight of 3.

Table 6. Alternative Assessment Using Utility Theory

Parameter	Alternative 1	Alternative 2	Weight	Standars Weight
Capacity	1	0	3	0.2143
Price	1	0	3	0.2143
Ability to catch trash	1	0	3	0.2143
Operational	0	1	2	0.1429
Ease of Installation	0	1	2	0.1429
Potential for corrosion	0.5	1	1	0.0714
	Total		14	1.0000
Utility Value	0.679	0.357		
Ranking	1	2		

Seven workers will carry out the collection activities to transport the trapped waste. The collected waste is then taken manually by workers equipped with supporting equipment and equipment in nets, trash baskets, and sacks. The collection design can be seen in Figure 3.

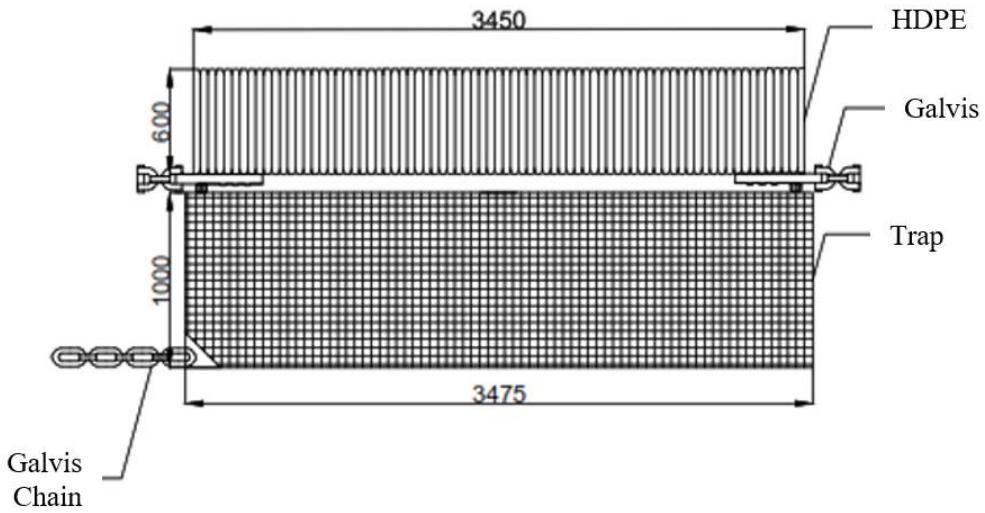

Figure 4. Waste Collection Plan in the Tanggul River

Research related to waste processing using the MCDM method are as follows: the calculation results show that social (0.292) and environmental (0.249) criteria are the main

considerations in choosing alternative organic waste processing. Social sub-criteria, namely public acceptance of technology (S1) is a dependent sub-criterion with the highest dependency. Meanwhile, economically, the maximum direct benefit is a sub-criterion in the linkage cluster with the highest driving power. Synthesis of priority composting scenarios at village-scale sources and landfilling is the preference with the highest weight (0.320).

4. Conclusion

The collection activity in alternative 1 uses the Brute Boom system: Heavy Duty Containment Boom equipped with a galvanized weir mesh net installed under the boom. The collection activity in alternative 2 uses a floating cube. The floating cube is a cube-shaped Waste holder that can float in the river to effectively hold waste floating on the surface of the river body. In terms of the potential for corrosion, alternative 1 has a greater chance of corrosion on components made of galvanized than alternative 2, which is only made of HDPE. It should be noted that all metal-containing materials will corrode due to changes in the surrounding environmental conditions. This needs to be added another alternative in the marine debris transportation scheme.

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Author Contribution

Conceptualization, M.M.S, and T.I.; Methodology, A.P.N.; Validation, X.X., Y.Y., and Z.Z.; Formal Analysis, R.K.H.; Investigation, A.P.N.; Writing – Original Draft Preparation, I.W.K; Writing – Review & Editing, K.Y, S.K; Visualization, S.S. and I.Y.S; and Funding Acquisition, S.N., M.M.S, and T.I.

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