AN APPRAISAL OF COST-EFFECTIVE APPROACHES FOR THE PUSU RIVER REHABILITATION

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ABSTRACT

The Pusu River and its tributaries that flow through the International Islamic University Malaysia (IIUM) Gombak campus have been suffering from river pollution for years. Hence, one of the efforts that can be made to address this issue is the rehabilitation of polluted rivers. Since the cost of treating the polluted rivers is high, proper measures to rehabilitate the Pusu River are important. Consequently, a study was conducted to identify and propose suitable approaches to rehabilitate the Pusu River, IIUM Gombak. The present study also focuses on the costs associated with rehabilitation work. The primary data for the study was collected using one round of Delphi questionnaires. The outcome of the Delphi study shows that the major sources of pollution in the Pusu River are sand mining, earthwork, land clearing activities for land development, stormwater runoff, waste dumping, and leakage from the wastewater treatment plant. Furthermore, the top three cost-effective methods to be proposed for the rehabilitation of the Pusu River, IIUM Gombak, have been established. The methods include aquatic plant use, a gentle approach to riverbank protection, and sediment dredging. Overall, the outcome of this study contributes to the development of river management strategies to control the pollution issue in the Pusu River. Academically, this study adds to the current body of knowledge in the context of river management, specifically for the Pusu River, IIUM Gombak.

Keywords: Cost, Pollution, Rehabilitation, River, Delphi Approach

1.0 INTRODUCTION

The river is a source of existence not only for human beings; indeed, other creatures also depend significantly on the river. The river supports habitat, provides transportation, recreation, and sports activities, and supplies water, food, agriculture, and energy (National Geographic Society, 2019; IMPOFF, 2020; Arindom, 2021). In parallel with the urbanisation and industrialisation advancing in Malaysia, the national population and human activities also expanded and grew throughout the years. This rapid development has changed the condition of Malaysia's rivers, especially in areas where progress appears to be rapid. The stormwater from the developing area is washed out along with the harmful contents on the land surfaces, changing the water's quality and resulting in a considerable number of polluted rivers (Singh, et al., 2020). According to Norjima et al. (2019), statistics from around the world indicate that overall river quality is deteriorating. The writers also emphasised that the rivers are vulnerable to stress and difficult to manage. It is because rivers are easily influenced by the complex relationship between land and water (Noorjima et al., 2019).

This study was conducted based on the rivers in the IIUM Gombak campus area because there has been an increasing number of published articles, news, and reports concerning this issue. Besides, it is also believed that these rivers have the potential to be graded up and rehabilitated. Even though the rivers in IIUM are not used for consumption or water-based activities, there is some interrelationship between the university community and the rivers. There are seating areas directing the views to the rivers, crossing bridges that the university community uses daily, and the international status of IIUM. These rivers are part of the downstream and tributaries of the Pusu River, namely, Anak Sungai Pusu and Batang Sungai Pusu (Nuruzzaman et al., 2017a). The total catchment area of the Pusu River that flows in the IIUM Gombak campus is estimated to be about 12km². The rivers are narrow and shallow since they are located downstream of the Pusu River (Al-Mamun et al., 2016). According to Nuruzzaman (2017a), the river has received wastewater mainly from two parties, the people of Kampung Sungai Pusu and the university community located upstream and downstream of the Pusu River. Fig 1 below illustrates the IIUM Gombak area from the plan view.

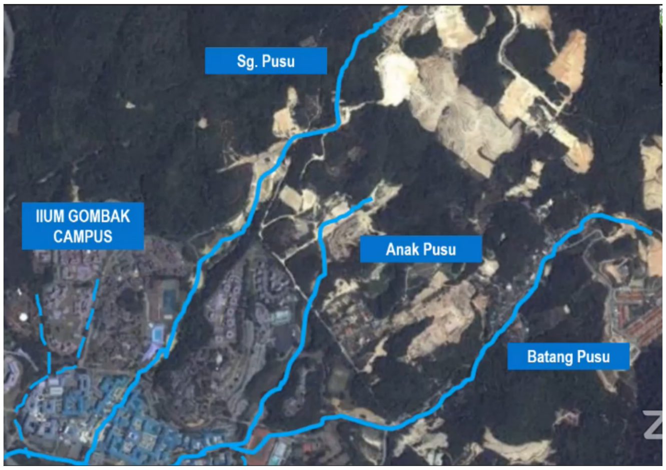

Fig 1:Pusu River and its tributaries that flow through the IIUM campus area
(Source: Ma'an Fahmi, 2020)

It has been observed that the ecosystem has been degraded as a result of this pollution, leading to environmental impacts such as flash floods (Nor Zalina et al., 2017). Moreover, the Pusu River in IIUM is said to be contributing to the Gombak River (Ma'an Fahmi, 2020). The river will then be joined with other rivers to form the main Klang River (Ma'an Fahmi, 2020). Since the Gombak River is one of the rivers monitored by Department of Irrigation and Drainage (DID) for the River of Life Project, thus, the pollution that occurs at the Pusu River will influence the Pollution at Gombak and Klang Rivers. Hence, the Pusu River rehabilitation is considered one of the potential solutions to this problem.

2.0 LITERATURE REVIEW

2.1 River Water Quality Classification

The Malaysian Department of Environment (DOE) is a government agency that monitors the status and quality of rivers in Malaysia yearly (Malaysia Environmental Quality Report 2017 as cited in Global Environment Centre, 2019; Hairun Aishah et. al., 2019). The DOE will collect the water samples from the designated stations to determine the characteristic of the water concerning the physic-chemical and biological characteristics (Lembaga Urus Air Selangor & Jurutera Perunding Zaaba Sdn. Bhd., 2017). This effort is made to identify environmental changes that may harm humans and the environment (Lembaga Urus Air Selangor & Jurutera Perunding Zaaba Sdn. Bhd., 2017).

In general, there are several methods for classifying river water quality; however, the Interim National Water Quality Standard (INWQS) and Water Quality Index (WQI) are the most widely used (Afroz & Mohammed Ataur, 2017). Other authors stated that these two methods could indicate the rivers' health condition (Lembaga Urus Air Selangor and Jurutera Perunding Zaaba Sdn. Bhd., 2017). The INWQS is classified into six water use classes (i.e., I, IIA, IIB, III, IV, and V) with approximately 72 parameters defined by the National Water Quality Standard (NWQS) (Global Environment Centre, 2019; Hairun Aishah et al., 2019). The class is sorted in descending order of water quality, with class I being perceived as the best while class V is the worst (Afroz & Mohammed Ataur, 2017).

On the other hand, the WQI is quantified based on the six parameters, namely, the dissolved oxygen (DO), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), ammoniacal nitrogen, total suspended solids (TSS), and pH (Afroz & Mohammed Ataur, 2017; Global Environment Centre, 2019). Additionally, these parameters are quantified in a number ranging from 0 to 100 to make the categorisation of the river quality level easier to understand (Hairun Aishah et al., 2019). These parameters are then classified into three categories; i) the highest index value (81-100), which represents the best water quality and meets the requirements, ii) the moderate (60-80); and iii) the polluted, which does not meet the requirements (0-59) (Lembaga Urus Air Selangor & Jurutera Perunding Zaaba Sdn. Bhd., 2017; Hairun Aishah et al., 2019). It is also mentioned that the WQI was monitored by the DID (Hairun Aishah et al., 2019). Overall, these two methods are some of the methods to classify river water quality. Thus, determining the river water quality can be the initial step in addressing the issue of river pollution and may be beneficial for river rehabilitation.

2.1 Pusu River Pollution Issues

Various authors have reported the pollution issue in the Pusu River for several years. Zaki et al. (2014) have stated that the Pusu River, which flows through the IIUM campus, is polluted due to increased Suspended Solids levels detected in the river during rainfall. The water has been muddy and murky for years due to high turbidity and sediment content (Zaki et al., 2014; Al-Mamun et al., 2016). A previous study found that the river was significantly polluted with highly organic levels in the mid-section, surrounded by commercial activities such as cafes and restaurants (Zaki et al., 2014). Despite numerous studies to inform the public about the situation and raise awareness about these issues, the Pusu River's condition remained polluted. In 2017, the rivers were reported to be polluted again (Nuruzzaman et al., 2017a). Due to this pollution, the ecosystem has degraded, resulting in environmental consequences such as flash floods (Nor Zalina, Mazlina & Safiah, 2017). Additionally, according to the Environmental Quality Report 2018, the Pusu River obtained an average WQI score of 68. It was classified as a III-class river, which means it is slightly polluted (Department of Environment Malaysia, 2018). More recently, it was reported that the Pusu River in IIUM was polluted when the water became shallow and muddy due to land exploitation near the Pusu River (Norafiza & Asyraf, 2021; Norafiza, 2021). The incident affected not only the university community but also the residents that live nearby the river, as it is stated that the drains become dirty and covered with slime (Norafiza & Asyraf, 2021). Despite complaints made to the authorities, the issues have not been resolved. Thus, the significance of rehabilitating the polluted river has been highlighted, specifically in the IIUM campus, Gombak, Selangor.

2.2 Sources of Pollution at Pusu River, IIUM Gombak

Pollution sources are generally divided into point and non-point sources (Afroz & Mohammed Ataur, 2017; Hossain & Chowdhury, 2020). The direct discharge of a pollutant into a body of water at a location that can be easily identified is defined as a point source of river pollution (Singh et al., 2020). In contrast, the non-point sources are pollutants that come from diffused areas and are difficult to identify (Afroz & Mohammed Ataur, 2017). It is important to determine the source of river pollution because identifying the sources of pollution is one of the most important steps in controlling river pollution. (F. Othman et al., 2014).

According to Nuruzzaman et al. (2017a), sand mining is the primary source of pollution in the IIUM river. Based on reports, even though the sand mining was done with permission and license from the authorities, the site was not properly cleaned (Al-Mamun et al., 2016). Additionally, the silt produced by sand mining has filled the river with a very high concentration of suspended solids, increasing the water's turbidity (Nuruzzaman et al., 2017a). Moreover, the earthwork and land clearing activities may also be one of the sources of pollution of Pusu River IIUM (Zaki et al., 2014; Nuruzzaman et al., 2017a), as a large amount of sediment has been discovered in nearby ponds due to the improper land clearing activities along the main tributaries of the Pusu River (Nuruzzaman et al., 2017a). Similarly, environmental activist Shariffa Sabrina Syed Akil claimed that pollution in the Pusu River is caused by rampant land exploitation and clearing activities (Norafiza, 2021). Another source of pollution is waste dumping because the university is close to a residential area, increasing the possibility of being exposed to daily pollution (Noor Faizul Hadry et al., 2018).

These findings suggest that the source of pollution in the IIUM river could be both point and non-point. Mining operations and residential waste are considered the source of pollution (Nuruzzaman et al., 2017a; Afroz & Mohammed Ataur, 2017). However, if the mining sites are abandoned, the pollution is considered a non-point source (Singh et al., 2020). Furthermore, land clearing can be classified as non-point source pollution because it is initiated by an earthwork and land clearing activities, and the surface deposition can be washed away as runoff into rivers during rainfall, resulting in river pollution (Afroz & Mohammed Ataur, 2017; Hossain & Chowdhury, 2020).

2.3 Impact of River pollution on Pusu River, IIUM

The pollution in the IIUM's river may have harmed the environment and disrupted biodiversity (Norafiza, 2021). The Pusu River modification and exploitation activities resulted in sedimentation, which changed the physical character of the river, such as channel width and depth reduction, as well as increased the slope, which may increase the erosion rate (Nor Zalina et al., 2017). The water was of poor quality and contained a large amount of sediment (Al-Mamun et al., 2016). The rivers in IIUM became murkier and more polluted as the polluted Pusu River and Batang Pusu River flowed into the campus area with sediments and pollutants (Norafiza, 2021). Aside from that, the river appears incapable of supporting healthy aquatic life due to pollution (Nuruzzaman et al., 2017a). Furthermore, the impact of river pollution can also be visibly critical during the rainfall event as it became one of the causes of flash floods in the IIUM Gombak campus area (Norafiza & Asyraf, 2021; Nor Zalina et al., 2017). The two most notable flash flood cases reported were in 2017 and 2014, which caused property damage (Ma'an Fahmi, 2020). In addition, even though the Pusu River in IIUM is not intended for human consumption, the river must be preserved because it is the university's responsibility to provide a comfortable, clean, safe, and healthy campus environment for the students and university community (Nor Zalina et al., 2017). If the campus fails to provide a healthy environment for the student, achieving the students' well-being will be challenging. Overall, this demonstrates the significance of river sustainability. When rivers become polluted, it will not only harm the environment but may also impact human health, although they were not intended for consumption.

2.4 River Rehabilitation

For many years, the terms rehabilitation and restoration were frequently used interchangeably. According to Simsek (2012), rehabilitation and restoration are the most commonly used concepts in literature to improve the treatment of running waters. To comprehend the concept of rehabilitation, the concept of restoration must first be defined. According to the literature, some authors define restoration as restoring an ecosystem to its pre-disturbed natural condition (Roni et al., 2005, as cited in Ayres et al., 2014; Nuruzzaman et al., 2017b;). Similarly, restoration entails restoring a deteriorated river to its original state (Minakshi & Goswami, 2014). It also can be defined as actions taken to the rivers and their basins that have experienced critical pollution damage to their natural habitats to return the rivers to their original states before the damage (Saad et al., 2019). However, some researchers have asserted that river restoration may be impossible to achieve; thus, the work to treat the condition is commonly referred to as rehabilitation (Rutherfurd et al., 2000). Park and Lee (2019) also agreed with the previous authors that it is essential to realise that river restoration is hardly possible to be established.

Still, rehabilitation can improve the river environment and mimic the original ecosystem condition. According to Nuruzzaman et al. (2017b), rehabilitation connotes the same course as the restoration but does not perform as a whole. Because the ecosystem cannot be restored, these actions are more accurately conveyed as rehabilitation. Furthermore, if the damage to the river is irreversible, river rehabilitation is no longer a viable option (Park & Lee, 2019). In such cases, it is suggested that the appropriate treatment chosen is remediation, as the original state is no longer the relevant goal for the river (Park & Lee, 2019). The remediation aims to improve the ecological condition of the river, but the result does not have to be identical to the river's original state (Rutherfurd et al., 2000; Park & Lee, 2019). Concerning the present study, it is believed that the most suitable term to be implied is rehabilitation. It was based on the findings from the previous research that referred to the efforts to tackle the issue of river pollution in the Pusu River as river rehabilitation (Al-Mamun et al., 2016; Nuruzzaman et al., 2017a; Nuruzzaman et al., 2017b; Ma'an Fahmi, 2020). Fig 2 illustrates the differences between the terms restoration, rehabilitation and remediation.

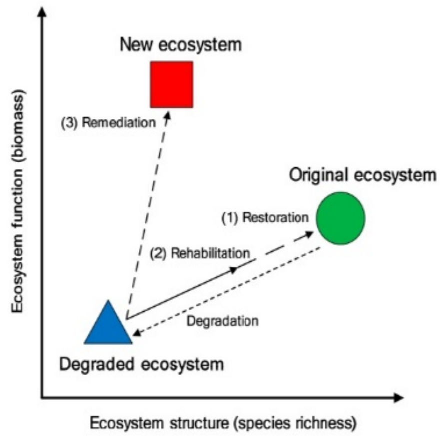

Fig 2: Difference between restoration, rehabilitation and remediation
(Rutherford et. al, 2000 as cited by Park & Lee, 2019)

2.5 River Rehabilitation Methods

Saad et al. (2019) suggested that two approaches are primarily used to treat the river. The first approach is self-purification, in which the rivers will purify themselves through actions like flowing, dilution, deposition and absorption and recreating their natural course and flooding scheme (Saad et al., 2019). However, despite the river's ability to purify itself, it has a limit. Some rivers can be damaged to the point where the water quality degrades and the time required to self-heal is longer than usual, and as a result, the second approach, known as an active treatment, is used to treat polluted rivers (Saad et al., 2019).

When rivers become polluted, it may take several years or longer to recover, depending on the extent of the damage (Saad et al., 2019); thus, selecting appropriate river water treatment methods is critical for river ecosystem rehabilitation (Hossain & Chowdhury, 2020). According to Kalithasan (2021), each river has unique characteristics and features; thus, different rivers may require different approaches, and work must be done in collaborative efforts with the natural environment. Various methods are being selected to rehabilitate the river, as reviewed by previous studies (Saad et al., 2019; Hossain & Chowdhury, 2020). The methods can be combined in two or more to ensure efficient treatment because a single method may not be effective in treating a heavily polluted river (Hossain & Chowdhury, 2020). Some of the river rehabilitation methods are explained as follows;

2.5.1 Sediments Dredging

Sediment dredging is a method to remove the sediments and debris from rivers, lakes and other water bodies to reduce internal nutrient loading (Lyu et al., 2020). It is claimed that this method can potentially improve the river's capacity to carry water downstream since the fundamental aim of dredging is to remove silt that consists of clay, fine sand and small particle of rock (BBC [British Broadcasting Corporation], 2021). Besides, sediment dredging can also reestablish the width and depth of the channel, thus helping to prevent flooding. Nevertheless, frequent maintenance of dredging is required to maintain a proper channel depth because the river channel will eventually receive sediments, causing the river's depth to decrease (River dredging & maintenance, n.d.). Over time, the river's depth will be shallowed and increase the chance of flooding. Thus, river dredging can only reduce the risk of flooding and does not prevent it from occurring (River dredging & maintenance, n.d.). However, if dredging is performed improperly, it can result in additional pollution (Bai et al., 2020; Hossain & Chowdhury, 2020) because the pollutant can deviate to other locations, which can harm the environment and health (Fauziah et al., 2019). Besides, dredging is also associated with relatively high operating costs (Lyu et al., 2020; Hossain & Chowdhury, 2020), due to the use of dredging machines like excavators, vacuum pumps, hydraulic backhoes, draglines and suction dredgers, and the cost will vary depending on which machine is used to remove the sediments (Hossain & Chowdhury, 2020; BBC, 2021).

2.5.2 Aquatic Plants/ phytoremediation

Previous studies have identified that using aquatic plants to remove pollutants from rivers is known as phytoremediation treatment (Haris, 2018; Hossain & Chowdhury, 2020). According to Hossain and Chowdhury (2020), aquatic plants can purify river water through pollutant absorption, adsorption, accumulation and breakdown. According to the researcher, phytoremediation is an environmentally friendly method of cleaning pollutant elements (Haris, 2018). It can create a visually appealing environment, does not require post-filtration, and can treat a large volume of polluted water (Ali et al., 2020). Furthermore, numerous studies have found this technique to be a low-cost method compared to other available methods (Hossain & Chowdhury, 2020). Despite its benefits, Haris (2018) commented that the results of the phytoremediation process will not be immediately visible because the plants will take a long time to trap the pollutants, and the works must be carefully managed so that the plants will not block the waterways completely. Among the aquatic plants that have been used for this treatment are water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), pondweed (*Potamogeton spp.)* and duckweed (*Lemnagibba*) (Haris, 2018; Hossain & Chowdhury, 2020).

2.5.3 River Slope Stabilisation

River slope stabilisation is a method of reducing or stopping the erosion of bank material into the river channel (UNESCO, 2016). The riverbank protection aims to address the bank erosion problem while reducing the sediment load entering the river channel (UNESCO, 2016). There are generally two approaches to riverbank protection: hard bank revetment and planting vegetation (TrapBag, 2020).

2.5.4 Hard Bank Revetment

Hard bank revetments are ideal methods for protecting the edges and beds of rivers from erosion (Aird, 2017). Typically, it entailed layering rocks alongside the river slope (TrapBag, 2020). This method is suggested to be constructed as gabions (box, mattress, rock rolls), rock (riprap, block stones, hand pitched stone, grouted stone) and also block (loose/interlocking and linked) (Environment Agency, 2015). Depending on the scale and nature of the work, this method can be used by hand or by equipment like a tracked-mounted backhoe or a power crane (Aird, 2017). Because riprap and gabion are permeable, they allow water to flow freely and prevent the buildup of hydrostatic forces behind the composition (Aird, 2017). However, a broader perspective has shown that riprap can reduce the friction point, increasing current speed, and diverting water to hit other unprotected areas of the riverbanks, thereby worsening the erosion (TrapBag, 2020).

2.5.5 Vegetation/ Bioengineering

Saad et al. (2019) highlighted that this technique is mostly used for the rehabilitation and restoration of rivers, and the measure of using vegetation as riverbank protection is recognised as bioengineering (Saad et al., 2019). This method is a more cost-effective and sustainable alternative to hard engineering approaches (The Environment Agency, 2015). It has been observed that it can improve the appearance of the riverbank, enhance the ecosystem and wildlife, and prevent soil mass movement, which is common during the rainy season (TrapBag, 2020). The plant's deep root structure helps to strengthen the soil and thus provides stability to the slope area (Saad et al., 2019). Furthermore, another author mentioned that plants depend on weather conditions and local wildlife. Hence, the author suggested that suitable plants native to the area be chosen (TrapBag, 2020). In contrast, despite the advantages mentioned, Saad et al. (2019) have commented that excessive plantation can reduce the channel's capacity, potentially leading to flooding.

2.5.6 Effective Microorganism (EM) Mudball

Another method that can be used to treat polluted rivers is by using effective microorganisms (EM) (Ahmad Firdaus & Shamila, 2018). EM is one of the biological treatment techniques used in the river rehabilitation process that Teruo Higa developed, a Japanese horticulturist from the University of Ryukyus, Okinawa, Japan (Ahmad Firdaus & Shamila, 2018). EM is available in solid and liquid forms and can suppress algae growth, decay sludge, destroy pathogens, and reduce odours in rivers (Ahmad Firdaus & Shamila, 2018). Besides, EM is also able to reduce the concentration of total suspended solids (TSS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD) and pH (Wahidah, 2016, as cited in Ahmad Firdaus & Shamila, 2018). The EM mudballs, a solid form of EM, were biologically produced using soil, rice paddy, brown sugar and active microbes (Ahmad Firdaus & Shamila, 2018). In addition, according to Ahmad Firdaus and Shamila (2018), using microorganisms to improve the quality of polluted water is effective and extensive because it is practical and less expensive than other chemical treatments. Nowadays, the usage of EM technology, particularly the EM mud ball for river rehabilitation, is increasing. The Sebulung River, for example, is stated to be treated using EM (Ahmad Firdaus & Shamila, 2018).

2.6 Significance Of River Rehabilitation

According to UNESCO (2016), the main reason for river rehabilitation is the pressure for more and better freshwater ecosystems. Previous research has explained the importance of river rehabilitation. Firstly, river rehabilitation can improve the water quality by recreating the floodplain and detaining the pollutant (Saad et al., 2019). When the river's condition improves, it will help preserve and conserve nature. River rehabilitation is important for preserving and improving the river's function (Shafaghat et al., 2019). It can help conserve nature by protecting the plants and animals that live near rivers (Saad et al., 2019). In addition, river rehabilitation is also important for flood protection. Saad et al. (2019) examined that river rehabilitation can provide an additional flood storage area. For example, river sediment dredging can help remove polluted sediment while maintaining the necessary cross-section of the river channel (Hossain & Chowdhury, 2020). Hence, the river's width and depth can be improved, increasing the river's capacity, particularly during heavy rains. Regarding the present study, river rehabilitation is significant as part of the efforts to combat the river pollution issue in the Pusu River. In a study by Al-Mamun et al. (2016), the authors reported that the rivers' inability to transport the high flow and debris blockage are among the causes of the flood on the IIUM campus. Besides, due to the sedimentation issue in the Pusu River, IIUM Gombak, caused by point pollution, the width and depth of the rivers were reduced, resulting in the river's limited capacity to support greater flow during rainfall events (Nor Zalina et al., 2017). Thus, it is suggested that Pusu River rehabilitation at IIUM has a high potential to protect the campus from flooding (Al-Mamun et al., 2016). Furthermore, the river has generally been identified as a valuable natural heritage that needs to be preserved (Zin et al., 2017). In some places, the local community perceived the rivers as representing the history of their whereabouts (de Bell, Graham & White, 2020). For the case of the present study, since IIUM has an international reputation that must be maintained, thus, when the rivers on the campus are polluted, it will leave an unpleasant impression on the entire university community, including local and international visitors (Al-Mamun et al., 2016; Nuruzzaman et al., 2017a).

Furthermore, river landscapes can also be improved through river rehabilitation (Saad et al., 2019). An improved river landscape can produce a healthy environment that benefits the surrounding community's well-being (Nor Zalina et al., 2017). Based on previous research, the authors discovered that the river, in essence, helps in relaxation, reduces stress and ear soothing (de Bell et al., 2020). Therefore, river rehabilitation is significant to be performed and managed.

3.0 METHODOLOGY

This study aims to identify and propose suitable approaches to rehabilitate the Pusu River, IIUM Gombak, that is considered cost-effective. The study employed a Delphi method to collect the primary data. The Delphi approach gathers the experts' opinions to reach a group consensus (Dufresne, 2017). It is also said to be a practical research methodology when no true or knowable answer exists, for instance, in decision-making, policy or long-range forecasting (Dufresne, 2017). The Delphi approach has four characteristics: anonymity, iteration with controlled feedback, statistical group response, and expert resources (Dufresne, 2017; Vishwanath & Begum, 2019). The current study, however, did not fulfil the second criterion, the iteration of controlled feedback, because the Delphi questionnaire was only administered once. It is stated that the number of rounds in the Delphi approach can be determined by considering factors such as the amount of available time (Hasson et al., 2000, as cited in Nor Khalisah, 2018). The number of rounds of iterations performed was stated to be dependent on when the panellists reached a consensus or if the researcher was satisfied with the results (Fink-Hafner et al., 2019). Due to time constraints, this study conducted one round of questionnaires. Since there is a lack of current and reliable data, as well as insufficient theory in the works of river rehabilitation of Pusu River, IIUM Gombak, thus, this method also helps in obtaining the opinion from the experts to propose the most cost-effective river rehabilitation methods for the rehabilitation of Pusu River, IIUM Gombak.

In terms of the panellist, no exact numbers of panellists need to be achieved to carry out the Delphi technique (Avella, 2016). It could consist of as few as four panellists or as many as 100 or more (Skulmoski & Hartman, 2007, as cited in Nur Syaimasyaza, 2017). Concerning the current study, the number of panellists chosen was four. The panellist group was kept small because there was not enough time to find a larger number of panellists who were available to participate in the study. Moreover, the number of experts involved in river management who are familiar with the Pusu river is limited. Besides, the smaller size of the panellist group can aid in providing quality and valuable responses from the panellists (Mohd Fairullazi, 2014, as cited in Nur Syaimasyaza, 2017).

Furthermore, a meeting session was conducted with all the panellists for data collection; this session was known as Delphi communication (Fink-Hafner et al., 2019). This meeting allows the researcher to provide clear information and explanation about the questionnaire to the panellists and increase the rate of response from the panellists. The meeting session was conducted on Friday, July 30, 2021, at 9.30 am through Zoom's online platform. Upon the questionnaire submission, a code name was assigned to each panellist as part of the effort to respect the confidentiality of the panellists. The panellists were named after the alphabet letter based on the submission order (i.e., from panellist A to panellist D).

For the data analysis, the study employed the descriptive group statistical analysis technique because the data presented were the collective response and consensus of expert opinion in the Delphi study. The previous scholars suggested this method as a suitable method to evaluate and validate the level of consensus of expert opinion. (Mohd. Fairullazi, 2014; Nur Syaimasyaza, 2017; Nor Khalisah, 2018). This study used the mode score to determine the most frequent score assessed by the panellists, while the Relative Importance Index (RII) ranked the item responses. This technique was used to analyse the question that required the panellists to indicate their level of agreement on the sources of pollution in the Pusu River and the rehabilitation approaches for the Pusu river. A higher score of RII indicates a higher ranking, which conveys the importance of items to be included in the answer set (Mohd. Fairullazi, as cited in Nur Syaimasyaza, 2017). Moreover, the 'very significant' items have an RII score of 0.80 or higher (Hamimah & Morledge, 2003, as cited in Mohd Fairullazi, 2014), whereas the 'significant' items have a score between 0.79 and 0.60 (Nur Syaimasyaza, 2017). Items with a score of less than 0.60 are deemed insignificant and will be excluded from the answer set. In addition, the RII is also used to determine the rank of the river rehabilitation method from the most cost-effective approaches to the least approaches to be proposed for the Pusu River rehabilitation. The answer set will include all item responses, which will be rearranged and ranked in a preference hierarchy. It will help the author to assess the important responses and determine which items can be regarded as the best and most cost-effective approach to be proposed for the rehabilitation of the Pusu River.

The findings from the Delphi questionnaire were reviewed with the literature review to look for any corresponding elements or arguments from both data sources regarding the current study. Overall, the methodology for this study is believed to be sufficient to achieve the objectives of the study, which are; i) to review the current problems of the Pusu River, IIUM Gombak, ii) to study the river rehabilitation methods and (iii) to propose cost-effective river rehabilitation approaches for Pusu River, IIUM Gombak.

4.0 RESULTS AND DISCUSSION

4.1 Panellists' Background

Based on the results of the panellists' background information, all have higher educational qualifications (i.e. Master's degree and Doctoral degree), and they are all academicians. Besides, the panellists disclosed that they have prior experience with river management or any river-related project. Two panellists (Panellists A and B) have 5 to 10 years of experience in river management or any river-related projects. In contrast, the other two panellists (Panellist C and Panellist D) have been involved in the required area for 11 to 15 years and more than 20 years. Furthermore, in terms of the involvement of the panellists in the consultancy projects, Panellist B had one year of experience in the field of water management. In contrast, Panellist D had worked as a consultant for more than 20 years. Overall, all of the panellists met the criteria or qualifications specified in the Delphi study; thus, it is believed that the panellists' opinions and views are adequate for the current study.

4.2 The Findings on the Present Issues Of Pusu River, IIUM Gombak, Selangor

The finding from the Delphi study noted that all of the panellists agreed that the Pusu River is currently in poor condition, with 75% and 25% perceiving the river as polluted and severely polluted. It can be said that the results from the Delphi questionnaire are consistent with the literature, as several authors have reported the Pusu River pollution issue (Zaki et al., 2014; Al-Mamun et al., 2016; Nor Zalina et al., 2017; Md Nuruzzaman et al., 2017; Noor Faizul Hadry et al., 2018). In terms of the sources of pollution, the literature has identified the sources of pollution associated with the Pusu River: sand mining, earthwork and land clearing activities, stormwater runoff and waste dumping. The results from the Delphi study have deduced that all panellists have agreed that the listed sources as the Pusu River's pollution sources. Table 1 below shows the Delphi study's summarised result based on the RII score calculation.

Table 1 Summarised responses of sources of Pollution in Pusu River, IIUM Gombak

River Rehabilitation Methods	RII scores	Rank	Significant
Sand mining	1.00	1	Very significant
Earthwork and land-clearing activities	1.00	1	Very significant
Stormwater runoff	0.9	2	Very significant
Waste dumping	0.8	3	Very significant

Besides, according to the response (Panellist C), leakage from the wastewater treatment plant could be an additional finding to the study, as it has not yet been mentioned in the literature as one of the sources of pollution at Pusu River. Furthermore, depending on the situation and condition of the sources, the pollution sources found in the Pusu River can be both from point sources and non-point sources. In this case, sand mining, earthwork and clearing activities for development, and waste dumping can be classified as point sources of pollution if the point of pollution release is identifiable. The leakage from the wastewater treatment plant is also thought to be a point source of pollution because the discharged point has been identified. Stormwater runoff, on the other hand, is a non-point source of pollution.

i. The Findings on the Available River Rehabilitation Approaches Currently Being Practiced in Malaysia and Other Countries.

According to the Delphi study, all the listed river rehabilitation approaches were appropriate to be chosen and proposed for the rehabilitation of the Pusu River. Based on the RII score, sediment dredging, a softer approach to riverbank protection, and the use of aquatic plants are the top three approaches with the highest RII scores. In addition, some of the advantages and disadvantages parallel the findings in the literature, while some are contradicted. For example, there are similarities between the advantages and disadvantages of the sediment dredging approach as expressed by the panellists as those described in the literature (Fauziah et al., 2019; River dredging & maintenance, n.d.); Hossain & Chowdhury, 2020; Bai et al., 2020; Lyu et al., 2020; BBC News, 2021;). Also, no finding from previous literature has indicated the need for frequent maintenance of the EM mud ball approach. However, most panellists agreed that this approach necessitates frequent maintenance. The results of the panellists' opinions on the advantages and disadvantages of each of the river rehabilitation methods are illustrated in Table 2 below.

Table 2 The summary of the advantages and disadvantages of each river rehabilitation method from the panellists' views.

River Rehabilitation Methods	Advantages	Disadvantages
Sediment Dredging	• Remove pollutants • Improve the quality of water	• Need frequent maintenance • Create additional pollution • High cost of operation • Can cause erosion on the unprotected area of the riverbanks
Riverbank protection (softer approaches: bioengineering and vegetation)	• Remove pollutants • Improve the quality of water • Improve the appearance of the riverbank • Protect and improve the stability of the slope area • Eco-friendly • Low-cost	• Need frequent maintenance • High cost of operation • The result cannot be seen instantly
Using aquatic plants	• Improve the quality of water • Improve the appearance of the riverbank • Eco-friendly • Low-cost	• The result cannot be seen instantly • Blocking the waterway • Reduce the capacity of the channel • Flood
Effective microorganism (EM) mudball	• Remove pollutants • Improve the quality of water • Eco-friendly	• Need frequent maintenance
Riverbank protection (hard approaches: riprap, gabion, retaining wall)	• Protect and improve the stability of the slope area • Prevent flood	• Need frequent maintenance • High cost of operation • Can cause erosion on the unprotected area of the riverbanks • Reduce the capacity of the channel

Furthermore, Panellist D has made an interesting point about stopping the source of pollution upstream that contribute to the pollution since the methods proposed will be ineffective if the river is still conveying the massive sediment from upstream. Moreover, other panellists (Panellist C) suggested a different approach that needs to be well enforced: the erosion and sediment control plan (ESCP). However, the panellists also stated that this approach necessitates government involvement, which can sometimes be difficult due to land privatisation. In brief, it can be stated that these findings are important to determine whether the methods discovered through the literature were suitable for the rehabilitation of the Pusu River, IIUM. The advantages and disadvantages found were also significant because they will serve as the foundation for selecting the most appropriate methods to rehabilitate the Pusu River, IIUM.

ii. The Findings on River Rehabilitation Approaches That Are Cost Effective and Suitable to Be Proposed for The Rehabilitation of Pusu River, IIUM Gombak, Selangor

There has been very limited previous literature that reports and discusses the associated costs for these approaches. The findings revealed that all approaches were associated with a maintenance cost (Table 3). Besides, it is notable that most approaches were associated with material cost, except for the sediment dredging approach, which is associated with operation and maintenance costs. On the other hand, it is important to bear in mind that the list of costs may not accurately represent the cost-effectiveness of the approaches. The least associated costs of an approach do not necessarily imply that it is the most cost-effective. It is because other aspects must also be considered to make it more comprehensive. According to the panellists' assessment, there are only two costs associated with the sediment dredging method. Nonetheless, the need for frequent maintenance, also the high operation cost must be considered before choosing this approach. Thus, while these findings may aid in understanding the costs associated with the river rehabilitation work, they do not indicate the cost-effectiveness of the approaches.

Table 3 Costs that can be associated with each of the river rehabilitation approaches from the opinion of the panellists

River Rehabilitation Approaches	The cost that can be associated with the approaches
Sediment dredging	Operation cost
	Maintenance cost
Using aquatic plants	Material cost
	Maintenance cost
Riverbank protection (hard approaches: riprap, gabion, retaining wall)	Construction cost
	Material cost
	Maintenance cost
Riverbank protection (softer approaches: bioengineering and vegetation)	Construction cost
	Material cost
	Maintenance cost
Effective microorganism (EM) mudball	Material cost
	Operation cost
	Maintenance cost

The results of the cost-effective methods are illustrated in Table 4. According to the RII scores, using aquatic plants is the most cost-effective approach, while the hard approach of riverbank protection is the least cost-effective. The advantages and disadvantages of these approaches may influence their ranking. It can be seen that approaches that involve landscaping and soft engineering elements were voted to be the most cost-effective as they are inexpensive, environmentally friendly, effective at removing and reducing pollution and aesthetically pleasing. From the result, it can be highlighted that the top three cost-effective approaches are aquatic plants, the soft approach of riverbank protection, and sediment dredging. As a result, these three approaches would be regarded as top-priority approaches suitable to be proposed for the rehabilitation of the Pusu River, IIUM Gombak, Selangor.

Table 4 Rank the river rehabilitation approaches in order of cost-effectiveness, from most cost-effective to least cost-effective, according to the panellists.

River Rehabilitation Methods	**Rank**
Using aquatic plants	1
Riverbank protection (softer approaches: bioengineering and vegetation)	2
Sediment Dredging	3
Effective microorganism (EM) mudball	4
Riverbank protection (hard approaches: riprap, gabion, retaining wall)	5

Not to mention, the panellists added some points and suggestions to the findings to ensure that river rehabilitation can be cost-effective. The panellist (Panellist C) stated that the chosen material can significantly impact the cost, and using the most sustainable materials will help reduce costs. Another noteworthy comment made by panellist C is that the approaches should be integrated because one approach will not completely solve the problem. This view is similar to the literature as it has been stated that the rehabilitation approach can be combined into two or more approaches to ensure the efficiency of the treatment and achieve cost-effective because a single method may not be practical to treat a heavily polluted river (Hossain & Chowdhury, 2020). Based on the findings of both data, it can be concluded that relying solely on one method to rehabilitate the river is insufficient and ineffective in terms of cost and execution of the entire work. It is mostly because each method has its advantages and disadvantages. For example, sediment dredging is said can create additional pollution, while using aquatic plants may cause blockage to the channel of the rivers. Also, the result cannot be seen instantly. Besides, the operation cost of sediment dredging is noted to be high, whereas the aquatic plant approach is a low-cost method. Thus, combining these approaches will help complement one another and produce better results. In essence, it is believed that it is important to identify the appropriate approach for each of the Pusu River's tributaries that flows in the IIUM Gombak campus and integrate the implementation of the approaches as suggested by the findings to ensure that the Pusu River rehabilitation works are achievable.

5.0 CONCLUSION

In conclusion, this paper has presented the study's outcomes on the cost-effective approaches to rehabilitating the Pusu River, IIUM Gombak. Consequently, the study results have met the study's aim and objectives. This study's first and second objectives are achieved through literature review and Delphi approaches. Whereas the third objective is achieved through the Delphi approach. The study has established that the Pusu River is currently polluted; thus, river rehabilitation is deemed to be one of the primary efforts to address this issue. The researcher has encountered several limitations throughout this study, including the availability of the panellists to participate in the study and the time constraint. Therefore, it is suggested that a similar study be conducted in the second phase of the study to develop, evaluate and validate a more comprehensive framework of river rehabilitation approaches with a group of experts in river rehabilitation.

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