# ENVIRONMENTAL IMPACT OF NAVIGATION IN INLAND WATERWAYS

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## ABSTRACT

The development of inland waterway transport is growing. The Melaka River, located in the historical city of Malacca, Malaysia, was once utterly filthy. However, after upgrading and beautifying the river, it has become attractive. Melaka River Cruise has become one of the tourist attractions in Melaka. Nevertheless, with the rapid increase of boats navigation, environmental sustainability will also decline. Therefore, a study on the pollution resulting from the boat navigation and also the level of pollution caused by boats navigation in the Malacca River is necessary. The data were collected from the enforcement of the Malacca River, Jabatan Pengairan dan Saliran (Drainage and Waterways Department), Melaka and also from the authorities of the Melaka River Cruise River, which is Perbadanan Pembangunan Sungai dan Pantai (River and Beach Development Authority), Melaka. Results from this study will help the authorities to minimize contamination of the Malacca River by from the boat. This study also provides recommendations that can be used in addressing the solution of pollution resulting from the use of boats.

## KEYWORDS

Pollution; IWTS; river waste

## INTRODUCTION

Inland water transport is one of the oldest, economically and environmentally sustainable modes of transportation for passengers. In some areas, the only means of mobility and access to basic services is through barge and cargo. This sector encompasses vessels ranging from simple non-motorized boats to highly automated pushers, operating in waterways ranging from small tributaries to major rivers.

In Malaysia, a specific sub-sector that has received particular attention is the Rural Water Transport (i.e. Inland water transport that is used by lower income citizens) due to its potential to help reduce isolation and thus poverty. Rural Water Transport (RWT) mostly consists of small family owned boats or canoes that operate in river and canal networks. Such boats are used to provide transport services, trading opportunities, employment and food (through fishing and access to markets).

The planning of inland waterway transport is very complex, as it is one of the many aspects of water resources and part of the overall industrial or commercial fabric. Thus, in order to be sustainable, inland waterway transport planning must also be considered as an integral part of water resource planning. Inland waterways are the oldest continental transport system. Navigation through inland waterways has experienced many stages of technological development. Industrialization was the prime mover of modern waterways development in the 18$^{th}$ and 19$^{th}$ centuries, with the formation of network of navigable rivers and canals in England at the forefront of this type of development [1].

Nowadays, many researchers concentrate on the study of transportation system that can reduce the traffic growth, has less negative social impact and is more environmental friendly. Studies in China [2] have shown that before the founding of the People's Republic of China, the facilities of Inland Water Transport (IWT) were very outdated. Only after four decades of effort, IWT has progressed until now. This also helps to sustain the economic growth because IWT offers the possibility of facilitating a significant national commodity movement for barge, bulk and containerised cargo.

Despite the advancement in other modes of transport such as rails, roads, and air transport, IWT is still among the cheapest mode of transport. Even though IWT is not as fast as highway and railway, it continues to compete in transporting bulk products. Thus, inland waterways are extremely important as transportation routes for people and supplies. The order of the ratios between water, railway and road transportation a 1:2:5 for cost, and 2:3:8 for energy consumption, respectively [3].

Inland waterways can be defined in several ways depending on the description point of view. It can be described in general as any natural stream of water that flows in channel with defined bank. Inland waterways is a part of water, such as a river, canal or lake, and it can be navigable if it is deep, wide and slow enough for a vessel to travel. If there are bridges, it must have sufficient clearance for vessels to pass through. However, high water speed, rocks and trees may make a channel unnavigable.

Studies in the US [4] concluded that inland waterways can be defined as a water area that provides means of transportation from one place to another, principally a water area providing a regular route for water traffic such as bay, channel, passage, river or regularly travelled parts of the open ocean. The network of navigable rivers and canals is important, particularly in central and eastern United States. Some of the most important waterways in US are the open navigation in the Middle and Lower Mississippi from St Louis to the Gulf of Mexico, and from the Missouri River from Sioux City in Iowa downstream; major canalized rivers such as the Upper Mississippi, Ohio, Tennessee, Lower Columbia and Arkansas Rivers [1].

Inland waterways and ocean have the most impact on the ecosystem in the world. Energy production, freshwater transfer, agriculture, deforestation, pollution, urbanization, drainage, river regulation, and flood protection schemes can lead to ecological deterioration and loss of important functions. Solid waste is the most severe pollution issue for the Indian Ocean Islands. At least 2.8 million tonnes of solid waste are produced annually in the region, of which only thirty per cent is collected regularly [5]. In addition to impact on coastal and marine ecosystems, solid wastes also disturb local leisure industry, damage fishing nets and risk the safety and livelihood of fishers and recreational boaters. This is because, the ports in the region lack waste collection facilities, while many ships dump their waste in waterways [5].

Solid waste generated by a ship includes glass, paper, cardboard, aluminium, steel cans, and plastics; either non-hazardous or hazardous in nature. Solid waste that enters the ocean or inland waterway may become marine debris, and can pose a threat to marine organisms, humans, coastal communities, and industries that utilize marine waters. Marine mammals, fish, sea turtles, and birds can be injured or killed from entanglement with plastics and other solid wastes that are released or disposed by ships.

Oil tankers, vessel accidents, coastal oil refineries and pipelines are all potential sources of spills which can cause significant, although mostly short-term, impacts on the environment. Closely 5,000 oil spills in the Niger River delta were reported between 1976 to 1996, releasing nearly 375,00 tonnes of oil in total [5].

In 2009, the paper presented at 104$^{th}$ Congress of the German Society for Marine Technology by Dr. Ing. Dietrich Wittekind stated that the number, size and speed of ships increase continuously, which leads to increase in noise levels. In addition, according to measurement in the US by McDonald et al. [6] and Andrew et al. [7], the shipping noise levels have increased by 10dB from the 1960s to 1990s, which shows that there is increment of 3dB per decade in noise levels.

## METHODOLOGY

Methodology is very important to ensure that this research can be complete. Methodology refers to the theoretical analysis of the methods appropriate for the field of study involving three main stages to ensure that the objective can be achieved, which are literature review, data

collecting, and data analysis. Every state will be explained briefly in their respective chapter. The following is the research procedure of environmental impact for navigation in inland waterways. The scope of research covers the area of research in Melaka River, while the investigation for IWTS is narrowed down to the Melaka River Cruise because one of the recreational activities in Melaka River as the tourism attraction.

For this research, the literature review focuses on inland waterways and the environmental impacts due to the navigation activity. Hence, the expected result from literature review will be used as a data reference, which is also sourced from the Melaka River authority. Data collecting method is an important aspect. Inaccurate data collection can affect the result of a study and ultimately lead to invalid results. In this research, the data is collected from Jabatan Pengairan dan Saliran/ Drainage and Waterways Department, Melaka (JPS), Perbadanan Pembangunan Sungai dan Pantai Melaka/ River and Beach Development Authority (PPSPM), and Alam Sekitar Malaysia/ Malaysian Environment (ASMA).

Jabatan Pengairan dan Saliran/ Drainage and Waterways Department Melaka (JPS) has appointed Perbadanan Pembangunan Sungai dan Pantai/ River and Beach Development Authority Melaka (PPSPM) for developing Melaka River as a tourist attraction. Therefore, PPSPM is responsible to control all issues along Melaka River. However, only 4.5 km of Melaka River is under the authority of PPSPM, while the remaining is still under control of JPS. Data collected from PPSPM included the details of boat (Melaka River Cruise) operation, detail of engine used, total number of passenger Melaka River Cruise, and concerns from PPSPM about the environment caused by the boats. Based on the interview session with officer from PPSPM, the organization's function had been explained and some suggestions had been made to ease the process of this research. Other than the data from PPSPM, other data collected from Alam Sekitar Malaysia/ Malaysian Environment (ASMA). ASMA is a systematic and comprehensive monitoring network for air and river water quality in the nation. Therefore, by collecting the data from ASMA, the water quality of Melaka River was obtained. Usually, the water quality test is done twice a year. Hence, from the result of water quality, all particulars in river water shall be found. For this research, the focus is only on the oil and grease reading, considering oil release from boat navigation.

## CASE STUDY

Case study of this research covers all the data collection from three organisations that have been authorised to Melaka River which are Jabatan Pengairan dan Saliran/ Drainage and Waterways Department (JPS), Pembangunan Perbadanan Sungai dan Pantai Melaka/ River and Beach Development Authority (PPSPM) and also Alam Sekitar Malaysia/ Malaysian Environment (ASMA).

### Background of Melaka State and the development of tourist in Melaka

Melaka covers 1,650 square kilometers ($km^2$) and is divided into three districts, namely Melaka Tengah, Alor Gajah and Jasin. Melaka is a state full of heritage and historical value that can be visited. These assets have huge potential toward the development of tourism industry in Melaka. The tourism industry shows a steady increase every year. The number of tourists increases from 1.9 million in the year of 1992 to 12.6 million in the year of 2013 (Utusan, 13 Mei 2014). Hence, realizing the facts that tourism industry is on the rise, in 2007, the organization under the state government, Perbadanan Pembangunan Sungai Dan Pantai/ River and Beach Development Authority, Melaka (PPSPM) planned to beautify and upgrade Melaka River as a centre of water sports, recreational area and tourism attraction, which could generate income for the nation.

The new development also could improve the lives of the residents, develop the city and ensure the environment near the river sustained. Before upgrade, the condition of the Melaka River, in the center of the city, was very bad, but after the upgrade, the river can be used to attract tourists. This idea established in certain Europe Nation such as Italy, France etc. The main purpose of upgrading Melaka River is to establish the area as a tourism center, recreational and modern water transport center. The plan includes the development of the inland waterways for tourism purposes. All the development covers areas along the Melaka River. The project to develop and beautify the Melaka River, from the Hang Jebat bridge to Gadek in Alor Gajah, ranges about 39 kilometers (km), and started in the year 2003 with an allocation of RM285 million (Projek Melaka Maju, 2012). The first phase of the project involves the work of beautifying, deepening the river and building water taxi terminal at Hang Jebat Bridge.

## Tourist of Melaka River Cruise

On 11th November 2005, Perbadanan Pembangunan Sungai dan Pantai Melaka/River and Beach Development Authority (PPSPM) launched the Melaka River Cruise that offers boat (Table 1) rides along Melaka River (9km) which takes approximately forty-five minutes to complete.

Table 1: The List of Melaka River Cruise Boats (Source: PPSPM)

| NO. | NAME | DATE RECEIVED | TYPE OF ENGINE USED | NOTE |
|---|---|---|---|---|
| 1. | Tun Fatimah | 11/11/2005 | HONDA 130HP | |
| 2. | Tun Teja | 11/11/2005 | HONDA 90HP | Docking |
| 3. | Tun Perak | 18/07/2007 | SUZUKI 140HP | Docking |
| 4. | Tun Tuah | 03/09/2007 | SUZUKI 140HP | |
| 5. | Tun Mutahir | 09/10/2007 | HONDA 130HP | |
| 6. | Tun Sri Lanang | 17/11/2007 | SUZUKI 140HP | |
| 7. | Tun Mamat | 17/11/2009 | SUZUKI 140HP | |
| 8. | Tun Ali | 29/12/2007 | SUZUKI 140HP | |
| 9. | Tun Kudu | 29/12/2007 | TORQEEDO (SOLAR) | Docking |
| 10. | Tun Kecil | 02/02/2008 | SUZUKI 140HP | |
| 11. | Tun Perpatih | 02/02/2008 | SUZUKI 140HP | |
| 12. | Tun Perpatih Sedang | 02/02/2008 | SUZUKI 140HP | |
| 13. | Laksamana Cheng Ho | 20/08/2008 | HONDA 130HP | Docking |
| 14. | Puteri Hang Li Po | 27/08/2008 | SUZUKI 140HP | |
| 15. | Hang Lekir | 27/10/2008 | SUZUKI 140HP | |
| 16. | Hang Kasturi | 18/11/2008 | HONDA 130HP | |
| 17. | Hang Lekiu | 28/11/2008 | SUZUKI 140HP | |
| 18. | Hang Jebat | 09/01/2009 | SUZUKI 140HP | |
| 19. | Hang Nadim | 22/01/2009 | HONDA 130HP | Docking |
| 20. | Tun Bijaya | 13/02/2009 | HONDA 130HP | |
| 21. | Tun Hamzah | 13/02/2009 | HONDA 130HP | |
| 22. | Munshi Abdullah | 30/03/2009 | SUZUKI 140HP | |
| 23. | Dato Dol Said | 30/03/2009 | HONDA 130HP | |
| 24. | Tun Tan Siew Sin | 09/05/2009 | HONDA 130HP | |
| 25. | Tun Ghafar Baba | 27/05/2009 | HONDA 130HP | |
| 26. | Adi Putra | 15/07/2009 | HONDA 130HP | |
| 27. | Tun Sambanthan | 15/07/2009 | HONDA 130HP | |
| 28. | Tun Tan Cheng Lock | 14/08/2009 | SUZUKI 140HP | |
| 29. | Dang Anum | 14/08/2009 | HONDA 130HP | Docking |
| 30. | TunSenara | 04/09/2009 | SUZUKI 140HP | |
| 31. | Panglima Awang | 04/09/2009 | HONDA 130HP | |
| 32. | Dato Onn Jaafar | 14/09/2009 | HONDA 130HP | |
| 33. | Dato Shamsudin | 14/09/2009 | HONDA 130HP | Docking |
| 34. | Laksamana Yin Chin | 10/11/2009 | HONDA 130HP | |
| 35. | Tunku Abdul Rahman | 10/11/2009 | SUZUKI 140HP | |
| 36. | Tun Abdul Razak | 10/11/2009 | HONDA 130HP | |
| 37. | Tun Hussien Onn | 07/01/2010 | HONDA 130HP | |
| 38. | Tun Leong Yew Koh | 07/01/2010 | HONDA 130HP | |
| 39. | Tun Haji Malek Yusof | 07/01/2010 | YAMAHA 150HP | |
| 40. | Haji Abdul Aziz | 02/03/2010 | HONDA 130HP | |
| 41. | Rescue 1 | FOC | SUZUKI 60HP | |
| 42. | Rescue 2 | 28/02/2009 | SUZUKI 60HP | |
| 43. | Water Taxi Melaka | 06/10/2009 | HONDA 150HP x 2UNIT | |

Table 2: The Dimension of Melaka River (Source: PPSPM)

| PARTICULAR | VALUE | UNIT |
|---|---|---|
| **Length** | 4500.00 | m |
| **Breadth** | 9.144 | m |
| **Depth** | 3.048 | m |

Table 2 shows the Melaka river characteristics. Based on the data given by Perbadanan Pembangunan Sungai dan Pantai Melaka (PPSPM), the number of Melaka River Cruise passenger shows yearly increment since launching, as tabulated in Table 3. The following Figure 1 shows the projection of Melaka River Cruise passenger.

Table 3: Projection of Melaka River Cruise Passenger (PPSPM, 2014)

| YEAR | NO. OF PASSENGER |
|---|---|
| **2008** | 380,000 |
| **2009** | 605,320 |
| **2010** | 826,765 |
| **2011** | 1,029,510 |
| **2012** | 1,100,485 |
| **2013** | 1,040,507 |
| **2014 (1 Jan – 27 Apr)** | 260,188 |

The level of environmental impact of navigation along Melaka River is linearly proportional to the number of passengers. The lack of environmental action will affect the prospect of increasing number of tourist visit to Melaka.

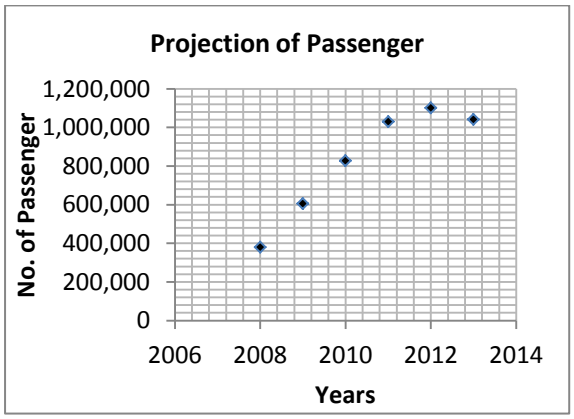


Figure 1: The Projection of Melaka River Cruise Passenger

## Boat navigation

The idea of Melaka River Cruise is inspired from the Venice River in Italy, so the Chief Minister of Melaka State suggested using the Venice River Italy boat design. The design of Melaka River Cruise boat is based on a catamaran hull. It is locally built by the local contractor. There are three different contractors with different boat particular. The following is the boat particular that has been used for Melaka River Cruise. Table 4 shows the particular and dimension constructed by the three different contractors. The most notable used engines for navigation are engines from Honda with 130HP and Suzuki with 140HP. The list of boat is sorted based on the date received from contractor.

Table 4: Melaka River Cruise Boat (PPSPM, 2014)

| CONTRACTOR | PARTICULAR | DIMENSION (m) |
|---|---|---|
| **Contractor 1** | Length | 8.53 |
| | Breadth | 3.04 |
| | Depth | 0.12 |
| | GRT | 7.01 |
| **Contractor 2** | Length | 9.00 |
| | Breadth | 3.13 |
| | Depth | 1.20 |
| | GRT | 0.29 |
| **Contractor 3** | Length | 7.62 |
| | Breadth | 3.04 |
| | Depth | 0.12 |
| | GRT | 6.40 |

The number of boat is proportional to the number of passenger Melaka Cruise (Figure 2). As the number of passenger increases, the demand to provide more boats also increases. In 2005, there were only two boats, and 2014 sees addition to forty boats, including two boats for rescue and one boat for water taxi.

Figure 2: Melaka River Cruise

In the year 2012, PPSPM took up the Chief Minister's challenge towards green technology in Melaka state. Therefore, one boat was installed with Torqeedo solar energy engine from Germany, but only for special events. It was designed with the Tun Kudu hull boat.

## RESULTS AND DISCUSSION

Based on the data collection in previous chapter, the scope had been narrowed down in order to determine the environmental impact of navigation along Melaka River. The environmental impact is categorised into four, which are:

1. Solid waste
2. Oil and Grease (water quality)
3. Emission
4. Erosion and Sedimentation

### Results

#### Solid Waste

Based on the research done in 2010 by Seth Iskandar, the result from questionnaire survey shows that the solid waste from the passenger of Melaka River Cruise is higher than the litter from people walking along the river bank. Therefore, by assuming that one 9km trip of Melaka River Cruise will contribute to 10g of solid waste (Figure 3). Hence, from the total number of passenger in a year, calculation for trips for a year can be calculated.

Figure 3: Solid waste in Melaka River

The trend line of the graph in Figure 4 clearly shows that the solid waste is linearly proportional to the years. As mentioned earlier in previous chapter, the increase of number of passengers will contribute to more solid waste in the river. So, as the authority of Melaka River Cruise, PPSPM must take strict action. In the interview session with PPSPM Officers, Mr. Imran and Mr Said, they stated that PPSPM has hired workers to collect rubbish every day in the evening. However, they do not weigh the rubbish that they collect every day for the purpose to know the level of pollution and research.

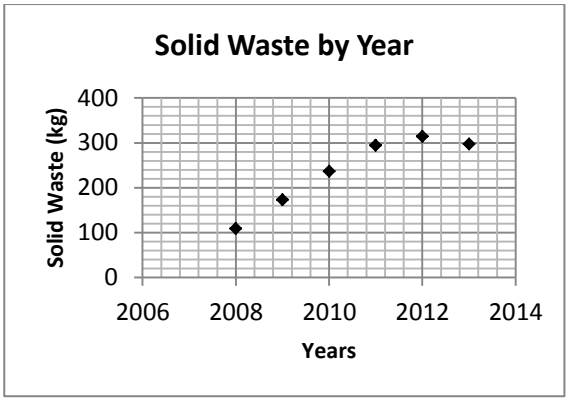


Figure 4: Volume of Solid Waste from 2008 to 2013

#### Oil and grease

Alam Sekitar Malaysia (ASMA) Sdn. Bhd. provided the information on the water quality along Melaka River from year 2008 to 2012. For the case study along Melaka River Cruise route as shown in Figure 5, three points were selected as references to analyse the impact of navigation, at 1M01, 1M02 and 1M12, according to the code given by ASMA. The following Figure 6 shows the oil and grease level in the water in Melaka River from year 2008 to 2012.

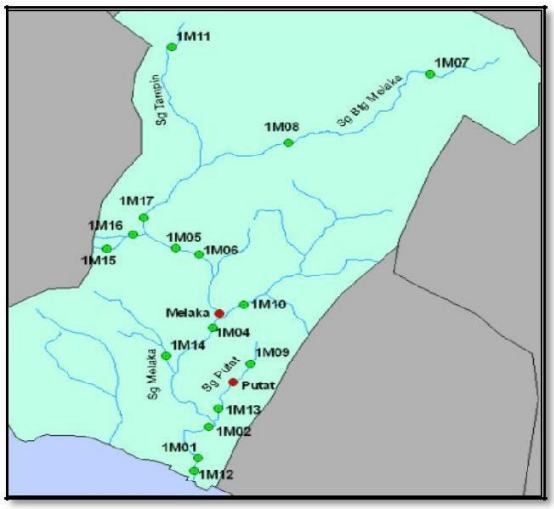


Figure 5: Location of Three Point on Melaka River

As seen in Figure 6, the level of oil and grease reading is not too critical. Based on the table of data for water quality given by ASMA, at every single point, the reading recorded up to 3mg/L. The highest reading of oil and grease in Melaka River is at point 1M01, where the point is within the area of the boat path. In general, the reading of oil and grease shows that the quantity of oil and grease in Melaka River increases from 2008 to 2012. Overall, the oil and grease reading in Melaka River still low compared to the table of water pollution level.

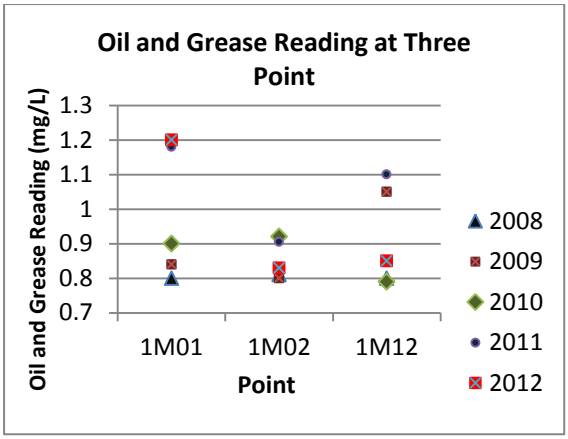


Figure 6: Oil and Grease Reading from route of Melaka River Cruise

### Emission

From the literature review, in average, the emission of $CO_2$ release from 140HP Suzuki engine during navigation is 139g/km (Suzuki Spec., 2007). Therefore, it can be assumed that one 9km trip of Melaka River Cruise will contribute to 139g/km of $CO_2$ in air. This assumption is made minimum because the trip will be more than expected if passengers in a boat are not in maximum arrangement. Hence, from the total number of passengers in a year, a calculation for trips for a year may be calculated.

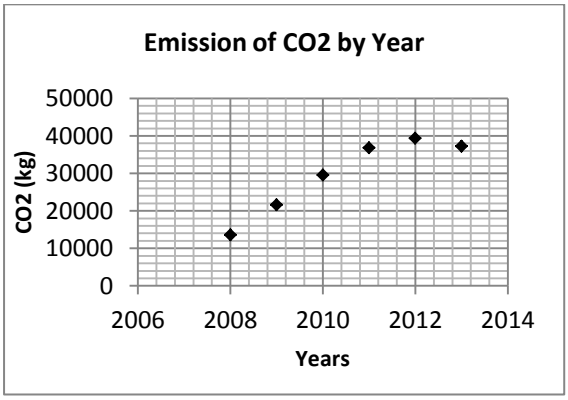


Figure 7: Emission of CO2 Every Year from 2008 to 2013

Based on Figure 7, the trend line of the graph clearly shows that the emission of carbon dioxide, $CO_2$ is linearly proportional to the years. The number of trips every year is increasing, due to the increasing combustion of petrol during navigation.

### Erosion and Sedimentation

The proposal to upgrade Melaka River includes concerns about the issue of erosion and sedimentation, as Melaka River is a tidal river. The barrage gate plays an important role to maintain the water quality of Melaka River because once the river is shallow, the river becomes muddy water. When the river is shallow, the boat will also cease to operate. During the upgrading and beautifying the Melaka River, erosion and sedimentation have been successfully prevented earlier. Dredging process in Melaka River is also in progress in order to maintain the river water quality.

## Discussion

This section discusses the overall case study, covering the environmental impacts from navigation. The parameters of impacts as shown in the results above and will be discussed in more detail. All the results however are limited to the data collection from Perbadanan Pembangunan Sungai dan Pantai/ River and Beach Development Authority Melaka (PPSPM), Alam Sekitar Malaysia/ Malaysian Environment (ASMA), Jabatan Pengairan dan Saliran/ Drainage and Waterways Department (JPS), thus there are some data that cannot be used under their organization policies.

### Solid Waste

Based on the research by Seth Iskandar and also by interviewing workers of Melaka River Cruise, assumption was made that one trip would at least produce 10g of solid waste, since the daily collected rubbish from the river is not weighed. Therefore, in future plans, the rubbish collector must know the weight the rubbish and make it systematic. Therefore, at the end of the year, they would be able to estimate the volume of solid waste in Melaka River, especially along the route of Melaka River Cruise. This data is very important because Melaka River has high reputation as the main tourist attraction.

### Oil and Grease

In the early phase of the research, there was plan to collect data from engine manufacturers about how much oil drips from the engine during navigation in one kilometer (1km). This is because oil may leak from the head gasket. However, there were a lot of constraints such as classes and time. Hence, the graph was plotted using the data collected from ASMA but only from the year 2008 until 2012. The latest data, 2013 could not be obtained from ASMA because of ASMA policies. Estimation was done by projecting the data from the previous year but using this method would not be accurate and exact as there might be many errors. According to the PPSPM Officers, the result

of water quality will not be sent to them and only two organizations can keep the result; which are JPS and ASMA. PPSPM basically plays the role of the end monitor of Melaka River to maintain the water quality.

### Emission

Recreational activity such as Melaka River Cruise is a relaxing activity and to be enjoyed with family members. However, if recreational activity affects the environment negatively, the activity should be discontinued. The environmental impact must be taken into consideration in the long run. PPSPM needs to study the emission release of their engines boat to control the emission since the engine efficiency ages with time.

## CONCLUSION

The overall analysis shows that the level of every environmental impact due to navigation activities along Melaka River has slightly increased, but still under control. Even though the result is not too critical and harmful, in the future, it will bring along negative effects. The reputation of Melaka River as tourism attraction will deteriorate if the surroundings of Melaka River are polluted. Hence, the numbers of tourist to Melaka River Cruise could also drop drastically.

In conclusion, the overall situation is still under control. The plan to make Melaka River more sustainable can be a model for other rivers that have the potential to be a tourism attraction. The water quality of the river is the most important aspect to develop the river for tourism, and there is a need to pay more attention on sustainability.

### Recommendation

Recommendations are useful to suggest ways to minimize the impact of pollution at Melaka River. Some suggestions may not be cost effective and hard to execute, but they could help to overcome the problems.

Firstly, since the size of the river is not large, any issue of oil spill or oil drip is very serious. During maintenance, oil spill or oil drip can be reduced by not conducting the maintenance in the river. Otherwise, the changing of lube oil may be done in the river but the lube oil needs to be pumped and sucked out using a tube and pump. Therefore, the lube oil will not spill into the river.

The next recommendation is to have the filtrations system. All the piping system should have filtration system before releasing wastes into the river. This could reduce the impact of odour of Melaka River as all the sanitary or sewages have been treated. There could be a water treatment plant before the water is released to the river.

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