

Research Article

A Preliminary Observational Study on Coastal Outfalls from Selected Coastal Water of Port Dickson

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Abstract

Research background: The coast of Port Dickson (PD), a popular tourist destination, is known for its recreational purposes. However, even some of the tourist beaches have coastal outfalls. These outfalls, known to discharge both treated and untreated water due to their cost-effectiveness as a sewage disposal method, could potentially disrupt the delicate balance of the marine ecosystem, making this research all the more crucial.

Purpose: The objective of this study was to observe and discuss outfalls as potential pollution sources for the coastal environment and ecosystem in four different coastal areas at Pantai Cermin, Tanjung Biru, Teluk Kemang, and Pantai Purnama, in PD.

Methodology: All photos were taken on November 5th, 2023, using a smartphone (Huawei Mate 20 Pro) in four different coastal areas of PD. The smartphone was lowered into the opening of the outfall, and photos were taken from different angles.

Findings: In total, 14 outfalls were recorded in the four selected coasts. None of the outfalls emitted strong odours except for the outfall near a mangrove area in Pantai Tanjung Biru. Another outfall at the same site was releasing black water directly into the beach. Drainage in Pantai Cermin leading to an outfall was filled with a dark green liquid, which could signify eutrophication. Most of the outfalls were found to have plastic debris within or nearby. Fouling organisms were found attached within and on the structure's exterior part. They could benefit from the outfall as it provides motion of water, acts as a substrate or habitat, and nutrients are discharged from it. However, the weekly number of visitors to the beach remains unaffected.

Significance: Even though this is a preliminary observational study, the present findings provided a significant gap in knowledge towards what was observed and its potential negative impacts on the environment at the coastal waters of PD. In the future, water, sediment, and biological samples should be collected near the selected outfalls to immediately assess pollutants such as plastic, metals, and pathogens. Fouling organisms could be used to assess the same pollutants to determine the potential effect of outfall on the coastal areas of PD. Continuous monitoring should be done to understand the impact of the coastal outfall on the environment.

INTRODUCTION

The Straits of Malacca, located between the Malay Peninsula and the Indonesian island of Sumatra, hold immense strategic importance in global trade and security. As one of the busiest shipping lanes in the world, the Straits of Malacca serve as a crucial maritime route for trade between Europe, the Middle East, and the Asia-Pacific region [1-3]. The Straits of Malacca was also the next to the Indian Ocean and the Pacific Ocean, making

it a vital passage for global maritime transportation. Its location also makes it a strategic chokepoint, prone to potential security threats such as piracy and terrorism [4] and coastal development [5].

Port Dickson (PD), located on the western coast of Peninsular Malaysia in the Straits of Malacca, holds significant importance in various aspects. From a tourism perspective, PD is a popular beach and resort destination, attracting local and international

tourists. Additionally, PD plays a vital role in the region's economic development, particularly through its thriving oil and gas industry. PD's oil and gas industry contributes to the country's energy needs and provides employment opportunities for local communities. The strategic location of PD, with its access to deep waters and proximity to major shipping routes, also positions it as an important port for trade and maritime activities. Moreover, PD serves as a crucial hub for importing and exporting goods, supporting domestic and international trade [2]. Furthermore, PD's well-developed industrial parks, highways, and rail infrastructure provide opportunities for effective operations of the seaports [6]. Overall, the importance of PD lies in its contributions to tourism, economic development, trade, and maritime activities. Hence, PD is a vital hub for tourism, economic development, trade, and maritime activities. However, many studies reported the anthropogenic activities on the coastal waters of PD [7-13].

The population increase and the town's rapid development have increased the district's pollution and wastewater production [14,15]. Outfalls are created to manage the increasing waste. Outfalls are pipes or tunnels that discharge treated or untreated wastewater into natural water bodies. They are the preferred method of sewage disposal because of their low costs compared to land-based treatment plans [16,17]. Besides their cost, outfalls are known to reduce the bacterial contamination of sewage released by 26 to 99% naturally after 32 months [18]. The outfalls rely on the natural disinfection of organic matter, bacteria, and other pollutants with the help of sunlight, predatory microorganisms, and salinity [19]. The sewage is expected to be diluted naturally by the dispersion of ocean currents. They rely on the natural assimilation potential of the coastal water environment. Hence, it is less energy-demanding and uses less land space [20].

Outfall discharges can be treated or untreated [21,22]. The discharge can be domestic wastewater, thermal effluents, or industrial wastewater. According to the Department of Environment [23], major sources of coastal water pollution were land-based pollution activities such as agricultural run-offs, industrial discharges, and sewage. The coastal settlements and industrial activities are also known to increase the concentration of suspended solids [24]. Pollution from the land enters the drainage pipes into coastal outfall through rainfall or storm water runoff [25,26]. Since the pollution source can be affected by rainfall, it is known to be a nonpoint source (NPS) pollution [27].

The major water contaminants of marine water were suspended solids, *Escherichia coli*, and oil and grease. These contaminants can be found in sewage and have been known to degrade the water quality of the coasts by causing eutrophication, releasing excessive amounts of nutrients and bacteria, and reducing dissolved oxygen in the water [28-30]. Tourism can contribute to littering, which can also potentially cause environmental degradation [26]. A study in Thailand found that tourist beaches and hotels during tourist seasons

increased nutrient levels and chlorophyll concentration, and sewage outfalls increased sediments and nutrients [25]. The reef and water quality improved as the distance from sewage discharge increased. The negative effects of wastewater were not concentrated near the outfall but transported by currents and aggravated during the wet seasons [25].

Furthermore, Alkhalidi et al. [14], stated that domestic sewage, industrial effluents, and agricultural runoff were not properly mixed and distributed to deeper water due to the slow tidal currents. So, the non-biodegradable organic matter and pollutants will accumulate and remain immobile in the basin during low tides. Coastal outfalls were also found to be releasing hospital wastes and being used to discharge prohibited wastes [26]. The water temperatures were high near outfalls in shallow bays. The high temperature reduced dissolved oxygen levels, an indicator of marine water health. The changes in physiochemical parameters caused by the outfall have resulted in the death of fish in the area [26].

Aside from sewage discharge, Weng [31], found that thermal effluents from Tuanku Ja'afar Power Station (TJPS), located near the coastal town of PD, were discharged directly into the sea. The abundance and diversity of marine diatoms and bacteria decreased in areas less than 200 m away from the outfall by 56% and 96%, respectively, while areas further out were not affected by the thermal effluent discharge from the outfall.

The objective of this study was to observe and discuss outfalls as potential pollution sources for the coastal environment and ecosystem in four different coastal areas of PD (Pantai Cermin, Tanjung Biru, Teluk Kemang, and Pantai Purnama).

METHODOLOGY

All photos were taken on the date 5th of November, 2023, using a smartphone (Huawei Mate 20 Pro). The smartphone was lowered into the opening of the outfall, and photos were shown from different angles. They were taken in four sites: Pantai Cermin, Pantai Tanjung Biru, Pantai Teluk Kemang, and Pantai Purnama (Figure 1 and Table 1). Pantai Teluk Kemang, Pantai Cermin, Pantai Tanjung Biru, and Pantai Purnama are all well-known tourist beach with resorts and residential built nearby. They were also part of the studies done by [11,28].

The fouling organisms were identified by comparing their morphological features to photographs from the iNaturalist website [32]. Tourists and locals were found at the beach near some of the outfalls. In this study, a total of 14 outfalls were found.

RESULTS AND DISCUSSION

Outfall as potential source of eutrophication

Photos in Figure 2 were taken from Pantai Cermin. Figure 2 shows the open sewer of nearby residents was dark green in colour, with algae and dead insects floating. Figure 2 also shows solid debris of bread and plastic take-out containers. This drainage pipe directly connects to an outfall that discharges its content to the coastal water.

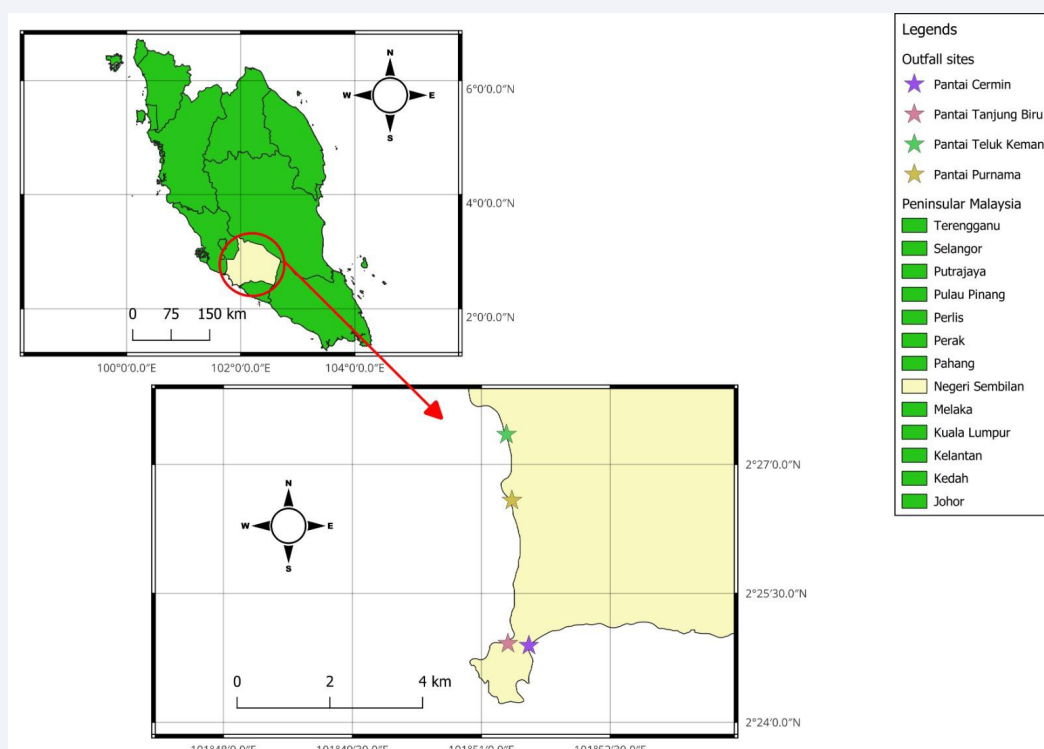


Figure 1 Sampling sites (QGIS, 2023)



Figure 2 Cloudy green water from drainage to outfall at the Port Dickson beaches.

Table 1. Sampling sites and their coordinates.

Sites	Longitude	Latitude
1. Pantai Cermin, Batu 10, Jalan Pantai, 71050 Port Dickson, Negeri Sembilan	02°41'46" N	101°85'87" E
2. Pantai Tanjung Biru, Jalan Pantai, 71050 Port Dickson, Melaka	02°41'55" N	101°85'60" E
3. Pantai Teluk Kemang, 23, Jalan 3/10, Taman Intan Perdana, 71050 Port Dickson, Negeri Sembilan	2°45'46" N	101°85'51" E
4. Pantai Purnama, Jalan Kemang 12, Tanjung Tanah Merah, 71050 Port Dickson, Negeri Sembilan	2°44'44" N	101°85'59" E

The open sewer seen in Figure 2 is possibly showing a phenomenon of eutrophication, where there is a burst of algae growth. The immense growth of the algae population in the drainage is likely the cause of the dark green colouration in the outfall and drainage pipe. Eutrophication often occurs due to excessive amounts of nutrients in water bodies, such as phosphorus and nitrogen. The usual sources of phosphorus and nitrogen are agricultural wastewater, urban wastewater, stormwater runoff and septic tanks [33-35]. No agricultural field was nearby, so the eutrophication could come from urban wastewater, stormwater runoff and septic tanks. Septic tanks are underground chambers used for basic sewage treatment. The increase in housing development near the coast of Pantai Cermin could have also increased the number of septic tanks. According to the United States Environmental Protection Agency [34], the presence of multiple septic tanks in a small can cause nitrogen contamination into groundwater and cause eutrophication. Also, there could have been recent heavy rain, which flushed the fertilizer content into the open sewer.

Outfall as a potential source of plastic pollution

Photos in Figure 3 show an outfall seemingly releasing black water into the coast. According to Tervahauta et al. [36], the black water is likely a mixture of sewage and toilet water. The toilet water consists of urine and faeces. Tervahauta et al. [36], stated that faeces and urine from toilet water could have heavy metals because humans can accumulate heavy metals from ingesting contaminated food and water. Faeces are known to be the main source of heavy metal loading, but they only contribute to 10% of the sewage. Therefore, reducing livestock manure and using artificial fertilizers reduce heavy metal content and faecal release [36]. Aside from the black water, many plastic bags and bottles flow out of the outfall. This can be a source of plastic pollution and faecal microorganisms such as faecal coliform released into the coastal water.

In Figure 3, plastic bags and a broken piece of glass can be seen coming out of a small outfall. The water of this outfall is clear, but there is still littering of plastic and glass. Narayanan's study [37], found that PD's beaches are filled with solid waste such as plastic. His studies found that 41% of the debris collected was hard & film plastic, 27% was fabric & fibre, 21 % was foamed plastic, 4% of polymer and wood, and 1% of glass and ceramics, metals, and wood. Surface water and drainage of PD are still suffering from a plastic littering problem, which can lead to microplastic pollution in coastal areas [38].

Biofouling organisms

The photos were taken in Figure 4 by lowering the smartphone camera into the opening of the outfall. The photograph was taken from the top of the outfall, so obtaining clear photos from different angles is difficult. Figure 4 shows two different outfalls at Teluk Kemang. They are both green in colour but not murky at all. Therefore, this shows the presence of algae. In contrast, Figure 4 from Pantai Cermin has a faint colour of yellow in its water, most likely caused by suspended sediments. In the photos in Figure 4, there is evidence of fouling organisms. Figure 4 also shows a fouling of green algae on the top and side of the outfall. There is also an unidentifiable crab with purple claws and red algae seen at the side of the inner outfall. Many unidentifiable barnacles were found attached at the side of the outfall. Figure 4 also shows an outfall from Pantai Cermin with a few remains of juvenile oysters (family Ostreidae) and an abundance of *Cthamalus sinensis*.

Figure 5 shows an outfall completely covered by biofouling organisms such as oysters and barnacles. Judging from their appearance, the oysters are likely *Saccostrea* sp.

Outfall as potential ecological trap

In Figure 6, two small school of fish were found at the entrance of the outfall found in Teluk Kemang. Figure 5 also shows rocks near the outfall at Pantai Cermin covered in *Saccostrea* sp. shells. All photos in Figure 6 were taken from Pantai Tanjung Biru near a massive outfall. This specific outfall was next to mangrove trees. There is a pungent foul smell near this outfall, and many mollusks were seen. Figure 6 shows shells of *Saccostrea* sp. can be seen all over the rocks near the outfall and even on the nets holding the rocks together. Figure 6 also shows the point of discharge of this outfall. Figure 20 shows cluster of *Prinella* sp. crawling around. The aggregation of this species could be due to presence of resources such as food in the area.

It has been observed that fishes and shellfish were more abundant near the coastal outfalls. This could be due to the outfall acting as an ecological trap [39]. Bivalve, and barnacles were found to be abundant at power plant discharge pipe [25]. Outfall structure both inside and outside are used as a habitat for fouling organisms as seen in Figure 5. This phenomena was observed in a report by Stark et al. [40], where various marine organisms used pipeline structures as their substrate or habitat. Despite effluents from outfall is a major contributor to environmental degradation, highest fish abundance was found in the site nearest to the outfalls [39]. The wastewater will cause endocrine disruption, and reduced fertilization success rate in aquatic organisms. It was found that fish abundance, richness and diversity increased near the outfall only during winter for its warm effluent [37].

In the desalination outfall, it was found that barnacles proliferated and dominated the community while polychaetes, bryozoans and sponges reduced in population. It was concluded that the increased flow of water created by the outfall discharge favor the growth of barnacles [38]. Another study by Kohan stated



Figure 3 Outfalls effluent with plastic debris released directly into Port Dickson's beaches.



Figure 4 The inside of various outfall.



Figure 5 The inside view of various outfalls at Port Dickson's beaches.

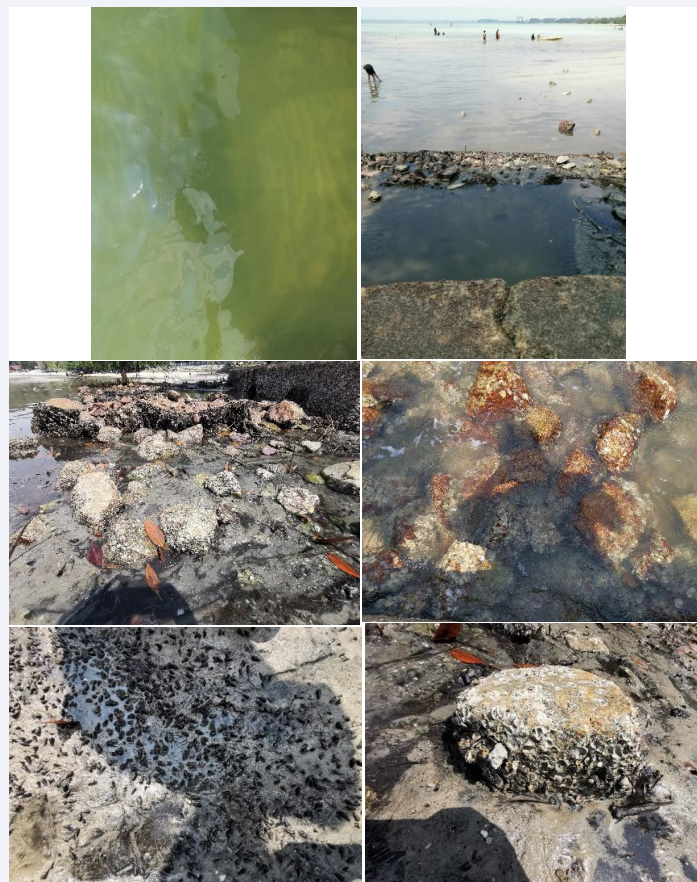


Figure 6 Organisms found near outfall at Port Dickson beaches.

that two fouling species *Amphibalanus amphirite* (a barnacle) and *Saccostrea cucullata* (an oyster) were capable of reducing nitrogen, phosphorus and phytoplankton from aquaculture effluents that was causing eutrophication. They were found to be improving water quality individually but not when used together. Wastewater and nutrients found in the outfalls are potentially being consumed by the two species for their growth, which is why there is an aggregation of fouling organisms on outfall in PD's beaches.

GENERAL DISCUSSION

Solid waste pollution has been reported in the PD beaches [41], in addition PAH pollution [42], fecal coliform bacteria [21,20], nutrient pollution [43], organic or sewage pollution [44,45], and plastic debris [46,47].

PD beaches have been recorded to have 82 wastewater pipelines that discharge sewage from hotels and houses into the sea directly [28]. Hashin [28], reported that that number of *Escherichia coli* (*E. coli*), and fecal streptococci at Public Teluk Kemang beach (Pantai Teluk Kemang) and Blue Lagoon beaches (Pantai Tanjung Biru), were higher than the suggested limit of 100 MPN (most probable number) 100 mL⁻¹ limit for *E. coli*, and 35 CFU (Colony forming unit) 100mL⁻¹ for fecal streptococci, in marine water that is used for recreational activities [28].

A water quality study done by Kamarudin et al. [24], on coastal water of PD 2021 stated that the concentration of ammonia, faecal coliform, oil, and grease decreased by 82.4%, 90.26%, and 99.9%, respectively. However, the total suspended solids increased compared to data from 2020. This was speculated to be due to the COVID-19 pandemic and the enforcement of movement control orders.

Sewage discharge has health risks to beachgoers. A study by Praveena et al. [11], investigated the total coliform concentration and *E. coli* in the beach water of Teluk Kemang. The microbiological water quality in Teluk Kemang Beach is generally safe, except for the sampling location near the outfall. Another study by Praveena et al. [11], assessed the contamination of *Escherichia coli* in tropical beach sands of PD Coastline (Malaysia). The concentration of *E. coli* was found to be high near former sewage outlets in nearby hotels. The most common health symptoms found in beachgoers were skin symptoms, and the exposure duration was significantly correlated to the health symptoms. Similar results were obtained by Hashin [28], where Pantai Cermin and Pantai Tanjung Biru (Blue Lagoon) were found to have more than 100 CFU of *E. coli* colonies per 100 g of sand, and skin symptoms were commonly reported.

CONCLUSIONS

This study only provides preliminary information based on observation. The water coming out of the outfall varied; some were green, and others were black. Green colouration is most likely caused by algae, while black water is most likely caused by toilet water. There was no pungent smell near each outfall, and

tourists did not avoid staying near the outfall. Fouling and other marine organisms were found within the outfall structure and on its exterior. Coastal outfall could be an ecological trap or act as a beneficial substrate for bivalves and barnacles. More knowledge is needed regarding what was observed and its impact on the environment. However, outfalls are a potential nonpoint source of pollution in PD. Most literature studied microbiological colonies near outfalls, but perhaps other pollutants, such as microplastics and heavy metals, could also be assessed. In the future, water, sediment, and biological samples should be collected near the selected outfalls to immediately assess pollutants such as plastic, metals, and pathogens. Fouling organisms could be used to assess the same pollutants to determine the potential effect of outfall on the coastal areas of PD. Continuous monitoring should be done to understand the impact of the coastal outfall on the environment.

REFERENCES

- Long TH, Hiep TX, Binh NT. Maritime Security in the Indo-Pacific Region: A View from the Geostrategic Position of the Malacca Strait. AUSTRAL: Brazil J Strategy Int Rel. 2022; 11.
- Nur M. Indonesia-Malaysia relations from the perspective of maritime history of the straits of malacca. JATI- J Southwest Asian Stud. 2018; 23: 64-74.
- Roosa J. The Straits of Malacca: Gateway or Gauntlet? 2004.
- Permal S. Trafficking in the Strait of Malacca. Taylor & Francis. 2007; 6-13.
- Balqis ARS, Yusoff FM, Hilaluddin F, Karim M. Variations of environmental parameters and zooplankton abundance in Port Dickson coastal waters over a decade of development. In AIP Conference Proceedings. 2023; 2683.
- Jeevan J, Othman MR, Hasan ZRA, Pham TQM, Park GK. Exploring the development of Malaysian seaports as a hub for tourism activities. Emerald Publishing Limited. 2019; 4: 310-327.
- Praveena SM, Aris AZ. A baseline study of tropical coastal water quality in Port Dickson, Strait of Malacca, Malaysia. Mar pollut Bull. 2013; 67: 196-199.
- Praveena SM, Siraj SS, Suleiman AK, Aris AZ. A brush up on water quality studies of Port Dickson, Malaysia. Res J Environ Sci. 2011; 5: 841-849.
- Praveena SM, Chen KS, Ismail SNS. Indicators of microbial beach water quality: Preliminary findings from Teluk Kemang beach, Port Dickson (Malaysia). Mar Pollut Bull. 2013; 76: 417-419.
- Praveena SM, Siraj SS, Aris AZ, Al-Bakri NM, Suleiman AK, Zainal AA. Assessment of tidal and anthropogenic impacts on coastal waters by exploratory data analysis: an example from port Dickson, strait of Malacca, Malaysia. Environ Foren. 2013; 14: 146-154.
- Praveena SM, Shamira SS, Ismail SNS, Aris AZ. Fecal indicator bacteria in tropical beach sand: Baseline findings from Port Dickson coastline, Strait of Malacca (Malaysia). Mar Pollut Bull. 2016; 110: 609-612.
- Praveena SM, Shamira SS, Aris AZ. Beach sand quality and its associated health effects of Port Dickson beaches (Malaysia): an analysis of beach management framework. Beach management tools-concepts, methodologies and case studies. 2018; 821-829.
- Praveena SM, Lin CLS. Assessment of heavy metal in self-caught saltwater fish from Port Dickson coastal water, Malaysia. Sains Malaysiana. 2015; 44: 91-99.

14. Alkhalidi MA, Hasan SM, Almarshed FB. Assessing coastal outfall impact on shallow enclosed bays water quality: Field and statistical analysis. *J Engineer Res*. 2023.
15. Reopanichkul P, Carter RW, Worachananant S, Crossland CJ. Wastewater discharge degrades coastal waters and reef communities in southern Thailand. *Mar Environ Res*. 2010; 69: 287-296.
16. Eeden FV, Retief M, Ballegooyen R, Jacobs G. A Marine Outfall as an Alternative Sewerage Disposal Scheme for St. Helena Island. *Int Sympos Outfall Sys*. 2016.
17. Law AWK, Tang C. Industrial water treatment and industrial marine outfalls: Achieving the right balance. *Front Chem Sci Engineer*. 2016; 10: 472-479.
18. Manning SS, Dixon JP, Birch GF, Besley CH. Deepwater ocean outfalls: A sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): Influences on beach water quality. *Mar Pollut Bull*. 2019; 145: 691-706.
19. Yang L, Chang WS, Huang MNL. Natural disinfection of wastewater in marine outfall fields. *Water Res*. 2000; 34: 743-750.
20. Hamzah A, Kipli SH, Ismail SR, Una R, Sarmani S. Microbiological study in coastal water of Port Dickson, Malaysia. *Sains Malaysiana*. 2011; 40: 93-99.
21. Law AT, Othman A. Fecal coliform bacteria distribution in the coastal waters of Port Dickson. *Pertanika*. 1985; 8: 131-134.
22. McCallum ES, Nikel KE, Mehdi H, Du SNN, Bowman JE, Midwood JD, et al. Municipal wastewater effluent affects fish communities: A multi-year study involving two wastewater treatment plants. *Environ Pollut*. 2019; 252: 1730-1741.
23. Department of Environment. Laws to Protect River and Sea Pollution. 2006.
24. Kamarudin NA, Yusuff FM, Zulkifli SZ, Zainuddin AH, Ali MY, Ekhsan NFM, et al. Port Dickson Surface Water Quality Status: A Year with COVID-19 Pandemic. *IOP Conference Series: Earth and Environ Sci*. 2021.
25. Sasikumar N, Azariah J, Nair KVK. Changes in the composition of a tropical marine fouling community at a power plant discharge. *Biofouling*. 1993; 6.
26. Buzzi NS, Menéndez MC, Truchet DM, Delgado AL, Severini MDF. An overview on metal pollution on tourist sandy beaches: Is the COVID-19 pandemic an opportunity to improve coastal management?. *Mar Pollut Bull*. 2022; 174: 113275.
27. United States Environmental Protection Agency. Basic Information about Nonpoint Source (NPS) Pollution. 2023.
28. Hashin SSS. Fecal Contamination in Beach Sands and Perceived Health Symptoms among Beachgoers in Port Dickson, Malaysia. 2016.
29. Praveena SM, Chen KS, Ismail SNS. Indicators of microbial beach water quality: preliminary findings from Teluk Kemang beach, Port Dickson (Malaysia). *Mar Pollut Bull*. 2013; 76: 417-419.
30. Yang L. Review of marine outfall systems in Taiwan. *Water Sci Technol*. 1995 32: 257-264.
31. Weng LC. The Effects of Thermal Effluent on Marine Diatoms and Bacteria. *Malaysian J Sci*. 2003; 22: 23-27.
32. iNaturalist. iNaturalist. 2024
33. Preisner M, Neverova-Dziopak E, Kowalewski Z. Mitigation of eutrophication caused by wastewater discharge: A simulation-based approach. *Ambio*. 2021; 50: 413-424.
34. United States Environmental Protection Agency. Septic Systems and Surface Water. 2023.
35. Yang YY, Toor GS. Stormwater runoff driven phosphorus transport in an urban residential catchment: Implications for protecting water quality in urban watersheds. *Sci Rep*. 2018; 8: 11681.
36. Tervahauta T, Rani S, Leal LH, Buisman CJN, Zeeman G. Black water sludge reuse in agriculture: Are heavy metals a problem?. *J Hazard Mater*. 2014; 274: 229-236.
37. Narayanan K. Port Dickson's Marine Debris Case Studies. *Sea-circular*. 2019.
38. Clark GF, Knott NA, Miller BM, Kelaher BP, Coleman MA, Ushiyama S, et al. First large-scale ecological impact study of desalination outfall reveals trade-offs in effects of hypersalinity and hydrodynamics. *Water Res*. 2018; 145: 757-768.
39. Mehdi H, Lau SC, Synyshyn C, Salena MG, McCallum ES, Muzzatti MN, et al. Municipal wastewater as an ecological trap: Effects on fish communities across seasons. *Sci Total Environ*. 2021; 759.
40. Stark K, Eash-Loucks W, Jeffery A, Lundt PE. Biological Colonization on High Density Polyethylene Marine Outfall Material in Puget Sound: Year 2 Results. 2017.
41. Yi CJ, Kannan N. Solid Waste Transportation through Ocean Currents: Marine Debris Sightings and their Waste Quantification at Port Dickson Beaches, Peninsular Malaysia. *Environ Asia*. 2016; 9.
42. Keshavarzifard M, Zakaria MP. Polycyclic aromatic hydrocarbon (PAH) contamination of surface sediments from Port Dickson, Malaysia: distribution, sources and ecological risk assessment. *Environ Foren*. 2015; 16: 322-332.
43. Chen M, Chia HK, Martin P, Lee JN, Bettens RP, Tanzil JT. A half-century record of coral skeletal P/Ca reveals late 20th century nutrient pollution in Port Dickson, Malaysia. *Mar Pollut Bull*. 2022; 181: 113875.
44. Alkhadher SAA, Suratman S, Zakaria MP. Occurrence and assessment of organic pollutants residues in the aquatic environment of the coastal sediments. *Sustainability*. 2023; 15: 8365.
45. Alkhadher SAA, Pauzi Zakaria M, Suratman S, Alanazi TY, Al-Bagawi AH, Magam SM, et al. Assessment of sewage molecular markers in Port Dickson Coast and Kim Kim River with sediment linear Alkylbenzenes. *Polycyclic Aromatic Compounds*. 2023; 43: 343-355.
46. Khairunnisa AK, Fauziah SH, Agamuthu P. Marine debris composition and abundance: A case study of selected beaches in Port Dickson, Malaysia. *Aqu Ecosys Health Management*. 2012; 15: 279-286.
47. Hamid FS, Nurul AAI. Plastic Debris Pollution on Recreational Beaches: A Malaysian case study. *Applied Mechanics and Materials*. 2015; 768, 804-809.