4. Environment

Environmental quality is considered to be a public good. It affects the public and the community in terms of economic, social welfare, and quality of life. Ecological sustainability is a key factor for sustainable economic and social development. The most pressing environmental issues in Penang are air and water pollution, flash floods, waste management, and landslides. Short-term action is needed while maintaining a long-term perspective.

4.1 Pollution

Different types of environmental pollution have been reported in Penang, the major ones being open burning, air pollution, and water pollution. These pose serious risks to the environment, public health, and even the economy.

4.1.1 Air pollution

Malaysia uses the Air Pollution Index (API) to describe the ambient air quality based on the health risks of air pollution. The API reflects the air's effect on human health, ranging from good to hazardous. API levels of up to 50 are considered good, between 51 and 100 moderate, 101 and 200 unhealthy, 201 and 300 very unhealthy, and 300 and above hazardous. An API system includes the major air pollutants which may cause potential harm to human health if they reach unsafe levels. The air pollutants included in Malaysia's API are ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), suspended particulate matter of less than 10 microns in size (PM_{10}) and suspended particulate matter of less than 2.5 microns in size ($PM_{2.5}$) (Department of Environment Malaysia, 2018).

The air quality of Penang is monitored at four stations, Seberang Jaya, Seberang Perai, Balik Pulau, and Minden. In 2019, the overall air quality in Penang worsened as the number of days with good API levels decreased and the number of unhealthy days increased compared with 2018 (Table 4.1). On average, the air quality was good 12.4% of the time, moderate 85.6%, unhealthy 1.7%, and very unhealthy 0.5% of the time. Over the years, the air quality has worsened mainly because of industrialisation, the rising number of motor vehicles, and the seasonal haze in the country.

Table 4.1 Air quality status in Penang, 2018–19

		Balik Pulau	Minden*	Seberang Jaya	Seberang Perai
2018	Good	122	50	11	39
	Moderate	241	285	352	322
	Unhealthy	2	2	2	2
	Very unhealthy	0	0	0	0
2019	Good	57	50	30	44
	Moderate	298	305	330	317
	Unhealthy	8	8	5	4
	Very unhealthy	2	2	0	0

** Minden has 28 days missing values in 2018.*
Source: Department of Environment, Malaysia.

4.1.2 Water Pollution

Rapid population growth and urbanisation have led to both increasing demand for water consumption and greater levels of water pollution in the country. Rapid development has produced significant amounts of wastes, including domestic, industrial, and commercial, which mostly end up in bodies of water. Therefore, access to a clean and safe water supply has become an important challenge for the government to overcome.

The Water Quality Index (WQI) is the most effective method of measuring water quality and level of pollution. According to the Department of Environment, WQI is computed based on six main parameters: biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen (AN), acidic and alkaline (pH), dissolved oxygen (DO), and total suspended solids (TSS). WQI levels of between 81 and 100 are considered good/clean, 60 and 80 moderate/slightly polluted, and 0 and 59 unhealthy/polluted.

The overall river basin water quality in Penang is moderately polluted. In 2018, within Penang's river basins, 8 (20.5%) were found to be clean, 21 (53.8%) slightly polluted, and 10 (25.6%) polluted. The overall WQI increased by about 5.4% in 2018 compared with 2017 (Table 4.2).

Marine environment is also exposed to pollution. The pollution can be from point or non-point sources. Point sources of pollution include sewage/municipal wastewater and industrial wastewaters. Non-point sources are runoffs from urban, agriculture, land clearing, construction activities, and deposition from atmospheric sources. In addition, the marine water is also exposed to threats from shipping activities, offshore oil and gas exploration, and exploitation activities. The Marine Water Quality Index (MWQI) is used to determine the marine water quality status and has seven main parameters: DO, nitrate (NO_3), phosphate (PO_4), unionised ammonia (NH_3), faecal coliform, oil and grease (O&G), and total suspended solid (TSS). These pollutants would pose threats to marine resources and endanger the stability and diversity of the marine ecosystem and wildlife, as well as affect the livelihood of coastal communities. The MWQI, with a scale between 0 and 100, defines the category of the marine water quality, ranging from "Poor" to "Excellent".

In 2018, the overall marine water quality in Penang with respect to coastal areas improved compared to the previous year. Five stations (29%) recorded as Excellent, two stations (12%) as Good, 10 stations (59%) as Moderate, and no stations were categorised as Poor (Table 4.3). The number of stations recording Excellent and Good increased from three stations in 2017 to seven in 2018. Areas such as Pantai Sungai Batu Ferringhi and Pantai Miami saw significant improvements in MWQI in 2018 when compared with 2017.

The overall marine water quality for estuaries in Penang improved slightly in 2018 compared with 2017. As presented in Table 4.4, the MWQI monitoring results for estuarine areas classified five stations as moderate and two stations as Poor in 2018. The most polluted estuaries were Kuala Sungai Tengah and Kuala Sungai Juru.

Table 4.2 River water quality status, Penang, 2017–18

	River basin	River	Number of stations	WQI	
				2017	2018
Clean	Pinang	Air Terjun	1	92	93
		Batu Feringghi*	2	-	84
	Kluang	Ara	2	80	82
	Perai	Kulim	4	79	85
	Kerian	Kechil	1	84	82
		Selama	2	76	86
		Kerian	4	81	82
		Terusan Bagan Serai*	1	-	91
Slightly polluted	Bayan Lepas	Tiram	2	69	74
		Bayan Lepas	1	65	70
	Jawi	Machang Bubok	1	71	72
		Junjong	1	70	67
	Juru	Ara*	1	-	70
		Permatang Rawa*	1	-	74
		Kilang Ubi	4	63	68
	Kluang	Relau	1	69	79
		Dua Besar*	1	-	65
		Kluang*	1	-	70
	Pinang	Dondang	1	69	71
		Pinang	2	57	70
		Jelutong	1	49	67
		Titi Kerawang*	1	-	65
		Air Itam	5	67	76
	Perai	Jarak	3	68	70
		Kubang Semang*	1	-	61
		Seluang*	1	-	62
		Keladi	1	70	76
	Kerian	Semang*	1	-	80
		Serdang*	1	-	75
Polluted	Jawi	Jawi	1	44	47
		Tengah*	1	-	49
		Chempedak*	1	-	39
	Juru	Juru	2	53	58
		Pasir	1	62	59
		Rambai	1	49	54
	Perai	Perai	2	57	59
		Seluang Bawah*	2	-	59
		Kereh	1	50	56
		Pertama	1	49	54

** New category.*
Source: Department of Environment, Malaysia.

Table 4.3 Marine water quality status for coastal areas in Penang, 2017–18

Area	MWQI value		Category (2018)
	2017	2018	
Gertak Sanggul	71	81	Good
Kawasan Perindustrian Bayan Lepas 1	67	59	Moderate
Pantai Bersih	50	66	Moderate
Pantai Miami	68	93	Excellent
Pantai Pasir Panjang	86	93	Excellent
Batu Feringgi (Casuarina)	67	67	Moderate
Luar Pantai Teluk Bahang	85	93	Excellent
Persiaran Gurney	63	66	Moderate
Rumah Pam Baru Perai	59	64	Moderate
Rumah Pam Lama Perai	64	65	Moderate
Selat PP Selatan (Jelutong)	49	59	Moderate
Tanjung Bungah	84	67	Moderate
Teluk Tempoyak	61	75	Moderate
Batu Maung	59	62	Moderate
Pantai Sungai Batu Ferringhi 1*	51	85	Good
Pantai Sungai Batu Ferringhi 2*	61	93	Excellent
Pantai Sungai Batu Ferringhi 3*	62	93	Excellent

Note: The MWQI is classified into four categories, namely Excellent: 90–100, Good: 80–<90, Moderate: 50–<80, and Poor: 0–<50.
** New station.*
Source: Department of Environment, Malaysia.

Table 4.4 Marine water quality status for estuaries in Penang, 2017–18

Estuary	MWQI		Category (2018)
	2017	2018	
Kuala Sungai Jawi	49	54	Moderate
Kuala Sungai Juru	49	47	Poor
Kuala Sungai Kerian	56	60	Moderate
Kuala Sungai Pinang	52	61	Moderate
Kuala Sungai Perai	52	59	Moderate
Kuala Sungai Tengah	58	37	Poor
Kuala Sungai Pinang (Balik Pulau)	55	64	Moderate

Note: The MWQI is classified into four categories, namely Excellent: 90–100, Good: 80–<90, Moderate: 50–<80, and Poor: 0–<50.
Source: Department of Environment, Malaysia.

4.2 Waste management

Rapid population growth and economic development, insufficient infrastructure and expertise, and land scarcity have turned solid waste management into one of Penang's most critical environmental issues. Poor waste management will result in land and air pollution, health issues for the communities, and bottlenecks to economic growth. To overcome this issue, a sustainable waste management and the increased use of technology are needed.

Municipal solid waste (MSW) includes all types of solid waste generated by households, industries, and commercial establishments. Landfilling is the only method of MSW disposal available in the state. However, this method is not sustainable and brings a host of issues if not managed. The generated landfill leachate should be appropriately treated before being discharged into the environment. Currently, aeration and recirculation systems are being applied to the landfill to flow the leachate out. A leachate collection pond has also been built.

4.2.1 Solid waste disposal and recycling

Over the past decade, the generation, recycling, and disposal of MSW in Penang has changed substantially. Generation of waste increased from 0.8 million metric tons in 2009 to 1.5 million metric tons in 2019—an average increase of 6.3% (Table 4.5). In 2019, the total waste disposed at landfills in Penang was about 2,220 metric tons per day (705 metric tons per day on Penang Island and 1,516 metric tons per day in Seberang Perai), an increase of nearly 13% over 2018 (Figure 4.1). In 2019, the per capita waste generation rate was about 2.4 kilograms per person per day[57], of which domestic waste was the primary source. Rising living standards and changes in household consumption patterns have greatly accelerated the rate and amount of domestic waste generation.

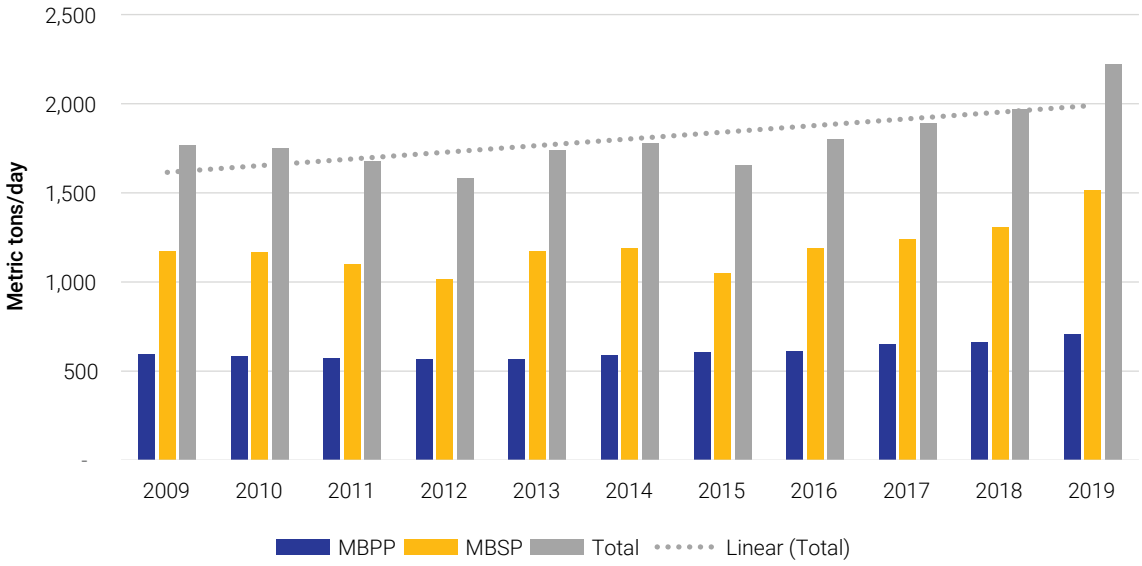
Table 4.5 Total waste generation in Penang, 2009–19

	Waste disposed at landfill (metric tons)			Recycling (metric tons)			Total waste generation (metric tons)	Recycling rates (%)
	MBPP	MPSP	Total	MBPP	MPSP	Total		
2009	216,456	428,563	645,019	61,307	132,039	193,346	838,365	23
2010	213,591	426,152	639,743	63,756	129,804	193,560	833,303	23
2011	209,701	401,663	611,364	72,314	144,682	216,996	828,360	26
2012	205,972	370,989	576,961	82,405	157,286	239,691	816,652	29
2013	207,968	427,706	635,674	80,050	207,849	287,899	923,573	31
2014	214,609	434,164	648,773	80,233	233,791	314,024	962,797	33
2015	221,576	383,528	605,104	84,100	282,932	367,032	972,136	38
2016	222,386	434,009	656,395	86,465	322,189	408,654	1,065,049	38
2017	237,236	453,035	690,271	100,123	345,329	445,452	1,135,723	39
2018	241,078	476,991	718,069	109,349	425,640	534,989	1,253,058	43
2019	257,237	553,223	810,460	116,777	590,773	707,550	1,518,010	47

Source: Penang Island City Council (MBPP) and Seberang Perai City Council (MBSP).

[57] Includes domestic and industrial waste disposed at landfills and recycling items.

Figure 4.1 Waste disposed at landfill per day in Penang, 2009–19



Source: Penang Island City Council (MBPP) and Seberang Perai City Council (MBSP).

The sorting and segregating of MSW at the source is one of the most important and traditional methods in solid waste management. Over time, recycling rates have increased from 23% of solid waste generated in 2009 to nearly 47% in 2019. In 2019, the total solid waste recycled in Penang was about 707,550 metric tons (116,777 metric tons on Penang Island and 590,773 metric tons in Seberang Perai)—an increase of about 32.3% compared with 2018.

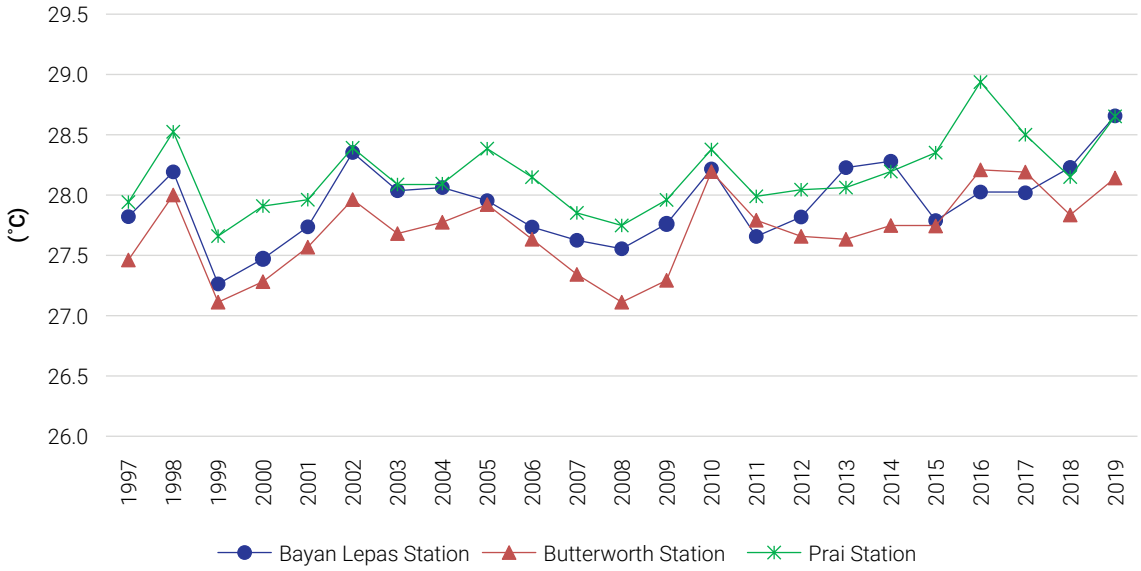
The quantity and composition of MSW are important to determine the proper handling and management of these wastes. MSW generally comprises food waste, plastics, glass, paper, metal, landscape waste, and others. Food waste accounts for the largest share of MSW in Penang (Universiti Sains Malaysia, 2014). Significant amounts of food waste end up in the landfill which leads to many environmental issues such as methane emission, leachate, groundwater contamination, and the potential release of toxic gases and odors. A more sustainable and integrative food waste handling system is needed. In addition, changes have to be made at every stage, from farmers and food processors to supermarkets and consumers. Recycling food waste into new products such as fertilizer and biogas in a responsible manner will also help reduce food waste sent to the landfill. The state has introduced various programmes and initiatives to minimise the amount of food waste entering the landfill. For instance, the state has launched a food waste-to-energy biogas project at the Batu Maung solid waste transfer station in June 2019. Under this project, all biogas created would be used to fuel a gas-powered generator to generate electricity that will be fed into the power grid (Sekaran, 2019). The state had installed bio-regen food waste machines in several locations to convert such waste into bio-liquid soil enhancers since 2011.

4.3 Climate change

The regional climatic trends in Malaysia are in line with the increases in average surface temperature as well as large variations in rainfall trends. Penang has experienced temperature and rainfall variations, especially in the last two decades (Figure 4.2 and Figure 4.3). Over the past two decades, the average temperature in Penang has increased by 0.13˚C per year, with the mainland experiencing slightly higher

average temperatures than the island. The historical temperature data in Penang indicates that 2019 was the warmest year since 1997. This is in line with global mean temperature changes, as 2019 was the second-hottest year since 1880 (NOAA, 2020). In 2019, the average temperature in Penang increased to 28.5˚C from 28.1˚C in 2018, an increase of 0.4˚C. The year 2019 began with a weak El Niño event and ended with neutral conditions. Internal weather variability, such as El Niño and La Niña, creates year-to-year temperature changes which occur alongside the long-term warming trends (Berkeley Earth, 2020). The temperature increase brings significant consequences such as endangering flora, fauna, and human beings; rising sea levels; floods and droughts; threatening coastal environments; and the destruction of the food chain and economic resources.

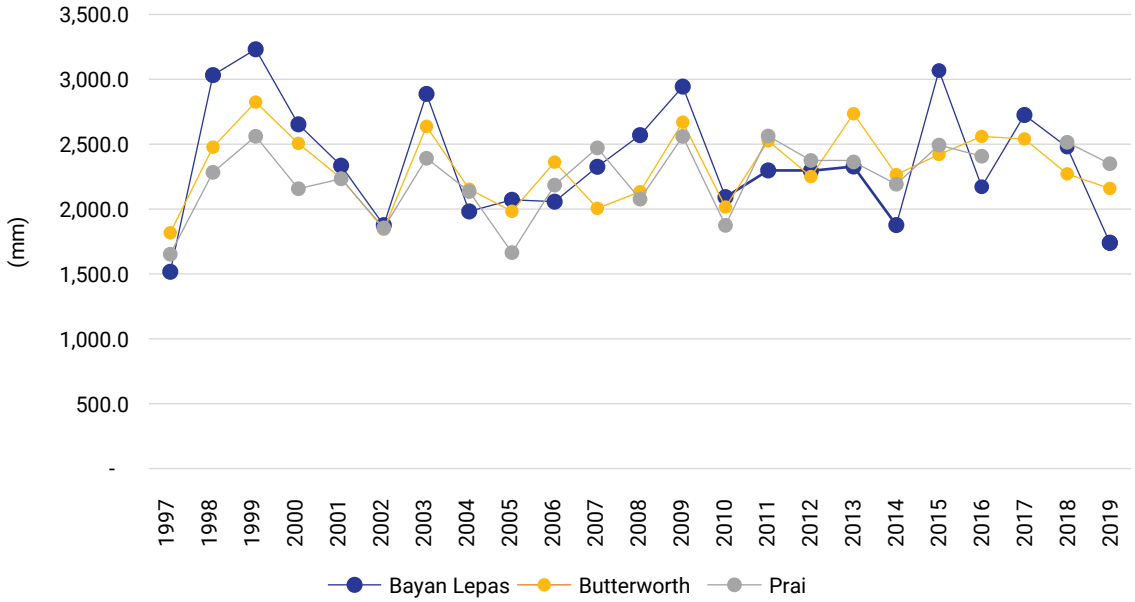
Figure 4.2 The average annual temperature in Penang, 1997–2019



Source: Malaysian Meteorological Department.

As temperatures rise, more moisture evaporates from land and water into the atmosphere, affecting overall rainfall patterns. Historical rainfall data shows an increase in the variability of rainfall during the past 20 years. Over the last decade, the number and size of extreme wet and dry spells in different parts of Penang have significantly changed. In 2019, the average rainfall and the number of rainy days in Penang decreased by about 14% and 17.8%, respectively, compared with 2018.

Figure 4.3 The average annual rainfall in Penang, 1997–2019



Note: Data for 2017 is not available for Prai station.
Source: Malaysian Meteorological Department.

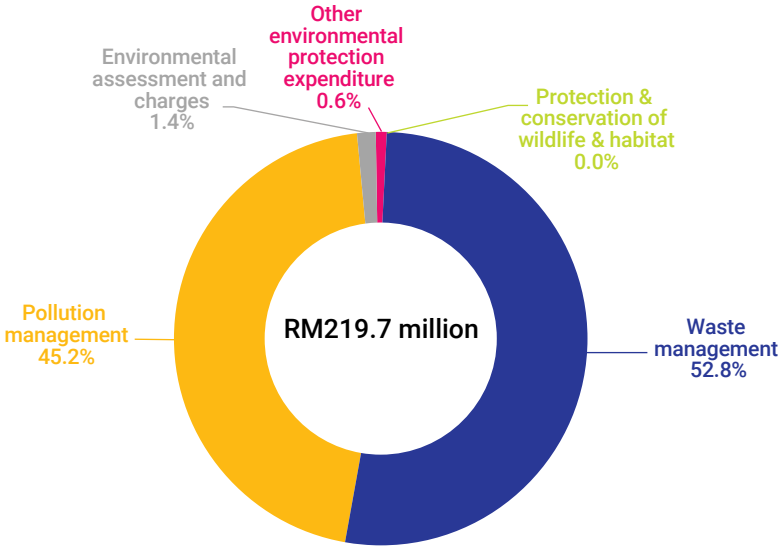
Future projections show a continuous increase in temperature, highly variable rainfall, and increased frequency of extreme weather events until the end of the 21st century (Tang, 2019). Climate change is a global challenge with no borders. Mitigating and adapting to this phenomenon would be highly dependent on policy, enforcement of laws, formulation and implementation of plans, and global and regional collaborations.

4.4 Environmental protection expenditure

In 2018, Penang spent about RM219.7 million on environmental protection, a decrease of 22.2% over 2017. The state contributed about 8.2% of the country's total environmental protection expenditure in 2018. As presented in Figure 4.4, waste management expenditure was the largest contributor at RM116 million (52.8%), followed by pollution management at RM99.3 million (45.2%). Overall, operating expenditure[58] was the largest contributor at 83.7%, while 16.3% was spent on capital expenditure[59]. Pollution management was the highest capital expenditure at 98.6%, while for operating expenditure, waste management recorded the highest share at 62.9%, followed by pollution management at 34.8%. Penang recorded the sixth-highest environmental protection expenditure in the country after Selangor, Johor, Kuala Lumpur, Negeri Sembilan, and Terengganu (Figure 4.5).

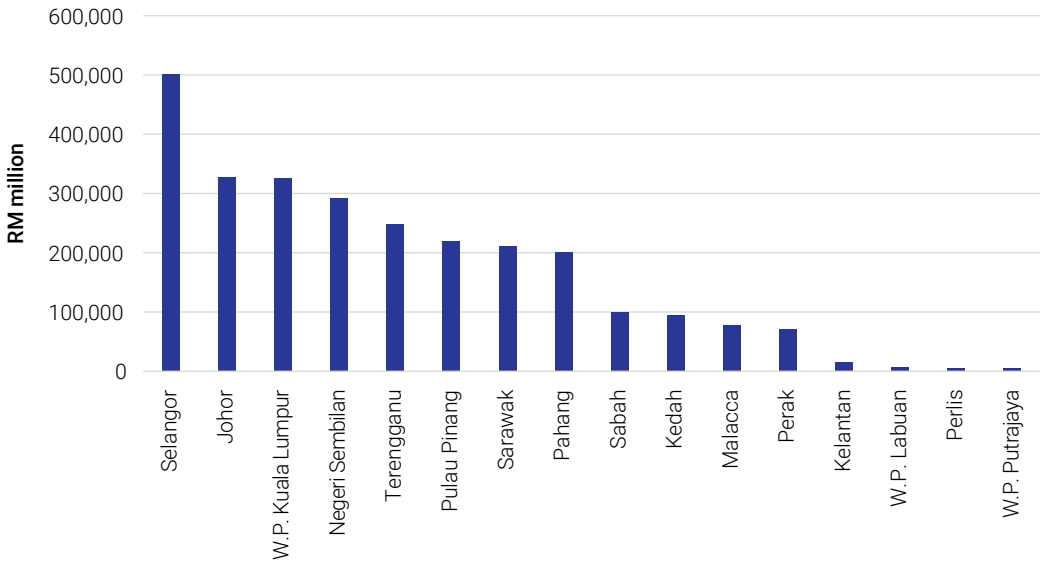
[58] Operating expenditure includes all expenses related to environmental protection incurred for labour, materials and supplies, maintenance and repair, and purchased services (include fuel and electricity expenses for machinery and equipment with the sole purpose of protecting the environment).
[59] Capital expenditure includes all relevant outlays for machinery and equipment and their installation and repair that have been capitalised, as well as for the construction of non-residential facilities (contractors or own employees).

Figure 4.4 Environmental protection expenditure by type of expenditure, Penang, 2018



Source: Department of Statistics, Malaysia.

Figure 4.5 Environmental protection expenditure by state, 2018



Source: Department of Statistics, Malaysia.