Mohd Armi Abu Samah
Mohd Khairul Amri Kamarudin *Editors*

# Environmental Management and Sustainable Development

## Case Studies and Solutions from Malaysia

Springer

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# Preface

*Alhamdulillah*! All praises to Allah and Prophet Muhammad (peace be upon him). We are very thankful to Allah, who has granted us the courage and patience for compiling the articles that form this book, *Environmental Management and Sustainable Development: Malaysian Case Studies*. It is with great humility that we present this book on such a vast and comprehensive topic as environmental management and sustainable development in Malaysia in nine chapters.

The first chapter is about environmental awareness studies in environmental management in Terengganu, Malaysia. Chapter 2 assesses the risk posed to human health by exposure to heavy metals due to ingestion of select freshwater fishes from Sungai Kuantan, Malaysia. The third chapter investigates the quantity of nickel and cadmium in freshwater fishes in Kuantan River and Riau River. Chapter 4, titled "Tourism Sustainability: Perspectives on Past Works, Issues and Future Research Opportunities," looks at tourism from the lens of sustainability. An overview on particulate matter emissions at construction sites in Malaysia, effectiveness of the "polluter pays principle" (PPP) on reduction of environmental pollution, and health risk from municipal solid waste (MSW) is presented in Chaps. 5 and 6. Chapter 7 presents a general overview on the properties, extraction, and application of cellulose and cellulose nanocrystals for successful environmental management and sustainable development in Malaysia. Chapters 8 and 9 discuss the laws regarding wildlife in the field of environmental management.

We would like to thank all the authors for dedicating their time and effort to write the chapters based on their ideas and experiences in environmental management and sustainable development. We have gained much foresight and information from them, which has enriched this book. Finally, we wish to thank those who have made the publication of this book possible.

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# Chapter 1
# Environmental Awareness Studies in Environmental Management at Terengganu, Malaysia

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**Abstract** Environment deterioration issues are increasing day by day related to water quality deterioration, sedimentation, flooding, and uncontrollable domestic sewage that affect communities. Awareness of environmental changes is one of the necessary concerns to control the occurrence of damage caused by human needs. The aim of this study is to compare the environmental awareness level among communities and identify the relationship between environmental awareness level and communities' behaviour. This study was conducted to spread the spatial model of environmental awareness among urban and rural communities using GIS. Four hundred and two respondents were selected randomly. The sample size determination was based on the sample size of Krejcie and Morgan. Discriminant Analysis (DA), descriptive analysis, and two-sample t-test were used to analyze the primary data. The result showed that there are five questions which showed significant p-value < 0.05 (SA1 p-value = 0.0297, SA6 p-value = 0.0028, SB4 p-value = 0.0095, SC9 p-value = 0.0229, and SC10 p-value = 0.0023). It proved that the communities'

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knowledge on environmental issues are significant (p-value = 0.0331 < 0.05). There are significant differences between urban and rural communities. From what GIS analysis showed, majority of the people in urban areas in Terengganu are more aware that environmental care is necessary to ensure the well-being of the environment compared rural areas. The government, consumers, business organizations, consumer associations, and other non-governmental organizations have a shared responsibility for the preservation of the environment.

**Keywords** Rural · Urban · Spatial model · Environmental · Geographic Information Systems (GIS) · Terengganu

## 1 Introduction

Environmental problems are common and are now creating anxiety around the world. Organizations are being affected by fundamental environmental problems as globalization continues. Environmental and widespread problems affect humans and all living species. The decline in drinking water quality and the extinction of living things like flora and fauna has unsustainably affected the quality and well-being of human life. These problems are contributed to tolerant attitudes. According to Knapp (1999) and Callicott (2000), one of the environmental rehabilitations is through the direct involvement of the responsible individuals by subtly changing the communities' moral attitudes and successful practices from mutual self-interest (anthropocentric) to environmental-oriented (ecocentric). Environmental awareness typically plays an important role in naturally influencing and improving human behaviour towards social environments. Responsible individuals who provide good environmental awareness will properly apply their social attitudes in daily life. This accurate statement is mutually supported by Klockner (2013) who correctly argues that environmental care starts from own individuals. This is precisely because the environmental behaviour is in properly handling environmental disasters. Majority of people in every country are of the view that environmental care needs to be done to ensure the well-being of the environment is unaffected and they are willing to pay high taxes if additional income is spent on environmental programs. According to Laroche et al. (2001), environmental awareness and behaviour are influenced by values, attitudes, and knowledge in routine life.

Environmental concerns require us to be aware of our ways of life that will sustain a negative impact on the environment and try to develop attitudes to current attitudes that seek to maintain and promote the quality of the environment. The involvement of individuals and communities in environmental conservation remains the necessary step in environmental conservation efforts. The knowledge about environmental care depends on the individual's attitude and commitment to environmental behaviour (Jusoh et al. 2018; Sungip et al. 2018). According to Abdul Samad (1990), the 1970s and 1980s started the environmental degradation cases but lack of environmental awareness was one of the factors that contribute towards the environmental problems. Most communities in Malaysia obtain knowledge about environmental issues and management but they were lacking the awareness to be involved in overcoming the problems.

Various issues and causes of environmental degradation have been discussed. Among them is the problem of population density that migrated to the city due to employment opportunities with lucrative income compared to rural areas. This resulted in the city being forced to receive an urgent population increase. Hence, community awareness of environmental care is vital in ensuring sustainable nature. Educational and technological awareness in reducing environmental problems from constantly undermining nature's pollution leads to a negative impact on human beings. According to Ahmad et al. (2011), the best way to emphasize environmental awareness is through education to provide knowledge on the value and role of the environment. Encourage the generation to be sensitive and aware of environmental care by applying values, knowledge, and efforts in preventing environmental damage. Hence, the purpose of this study is to determine the comparison of environmental awareness between urban and rural residents along Terengganu, a River Basin including Kuala Terengganu and Hulu Terengganu's regions. Table 1.1 shows the total population in a few districts in Terengganu. This study selected Kuala Terengganu as the urban region and Hulu Terengganu as the rural areas because these regions are located along Terengganu River from Jenagor until Kuala Terengganu's city.

Figure 1.1 shows the models of pro-environmental behaviour which are based on the linear progression of environmental knowledge leading to environmental awareness and concern (environmental attitudes). Pro-environmental behaviours (PEB) are actions that people do in daily life that are comparatively better for the environment in their life. The public outreach and friendly communications efforts from society will fuel behavioural changes among communities, but not adequately in addressing large-scale environmental issues. This manner will be encouraging PEB in daily life which positively influences society and economy in sustainable community development. Besides that, Fig. 1.2 shows the models of predictors of

**Table 1.1** The population intensity in District in Terengganu State

| Regions | District | Total population (%) |
|---|---|---|
| Urban | Kuala Terengganu | 186,100 (16.14%) |
| | Dungun | 173,200 (15%) |
| | Kuala Nerus | 175,200 (15.19%) |
| | Kemaman | 175,200 (15.9%) |
| | Marang | 103,300 (8.96%) |
| Rural | Besut | 162,400 (14%) |
| | Setiu | 63,000 (5.46%) |
| | Hulu Terengganu | 82,100 (7.12%) |

Source: Unit Perancang Ekonomi Negeri Terengganu (2017)


**Fig. 1.1** The models of pro-environmental behaviour

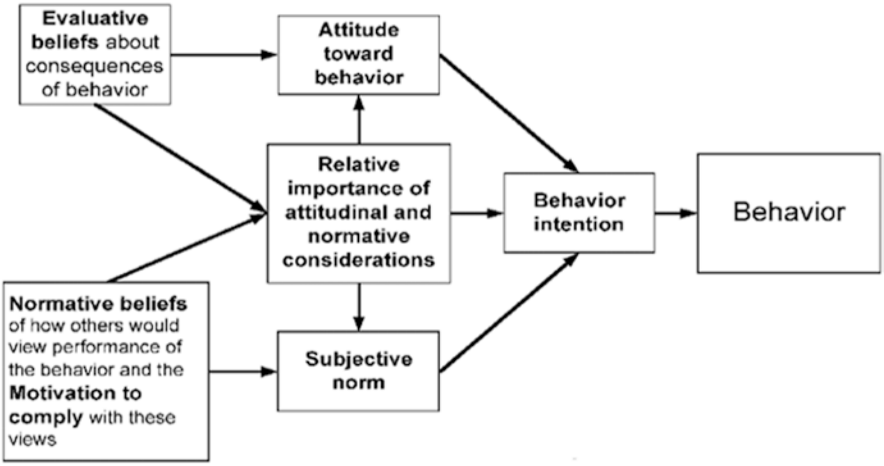



**Fig. 1.2** Models of predictors of environmental behaviour. (Source: Kollmuss and Agyeman 2002)

environmental behaviour, which prove that there is high correlation between attitude and behaviour. The increase in knowledge and awareness among communities lead to increase in their PEB. So, the most important, which are the knowledge and awareness of environmental issues, will trigger the communities to preserve and conserve the environment. Now, there are a lot of environmental non-governmental organisations (NGOs) and government agencies struggling for their communication campaigns and strategies on the simplistic assumption that more knowledge will lead to more enlightened communities' behaviour (Kollmuss and Agyeman 2002).

In Malaysia, there are 45 environmental legislations, but they are not very effective in maintaining the quality of the environment as largely shaped sectorals. Awareness of environmental issues begins with individual attitudes. Environmental attitudes are essential in influencing and promoting human behaviour towards the environment. However, the community's attitudes and responsibilities towards environmental issues need to be nurtured through the efforts of responsible parties to encourage communities to engage in environmental comparable activities. The information obtained by the researcher found that the responsible party rarely conducted the review (Memon 2000; Buniamin 2010).

The campaign has less environmental-related activity. Many villagers are proposing organizing environmental activities like cleanest village competitions, campaign recycling programs, and environmental talks at least once every 2 months.

The government is constantly updating environmental protection and enforcing existing environmental laws, actively promoting environmental awareness campaigns, planning balanced development, providing more efficient public facilities, and so on. The government also needs to ensure that each party engages in environmental protection and environmental education. The use of mass media as a medium of information about the environment is important. According to Jahi (2001), media is used in addressing environmental issues through campaigns and seminars in highlighting environmental issues throughout the country. The role of media in environmental literacy through television and documentary campaigns is important.

# 2 Study Area and Research Methodology

## *2.1 Study Area: Kuala Terengganu and Hulu Terengganu*

The sampling areas along Terengganu River Basin are selected as research locations. Terengganu River Basin is located in the central portion of the State of Terengganu. The catchment area is approximately 4650 $km^2$ and spans across three districts in Terengganu, which are Kuala Terengganu, Hulu Terengganu, and Setiu. Terengganu River is the main stem that begins from Kenyir Lake and flows eastwards, draining into South China Sea. The entire main stem is approximately 64.4 km long. There are 72 villages along Terengganu River Basin which are from Jenagor until Kuala Terengganu. This study selected randomly 72 villages to distribute the questionnaires. Figure 1.3 shows the map of sampling station including Kuala Terengganu and Hulu Terengganu along Terengganu River Basin, Malaysia.

## *2.2 Research Methodology*

The main study, which was a quantitative survey, was conducted among urban and rural residents along Terengganu River Basin through a self-administered questionnaire. This research instrument was developed using well-established measurement scales identified from previous studies. Based on Krejcie and Morgan (1970), sample size determination is to be necessarily conducted prior to administering the self-completed questionnaire in the field survey. The survey period endures 2 weeks, and the total number of respondents were 402. The selected numbers of respondents based on the estimated populations defended two districts, Hulu Terengganu representing the rural areas and Kuala Terengganu representing the urban areas, where the population exceeds 75,000. The questionnaires consist of four particular sections: respondents' demographics, communities' practices on environmental issues, communities' attitudes towards the environment, and communities' knowledge about environmental awareness in Malaysia. There are two statistical analysis

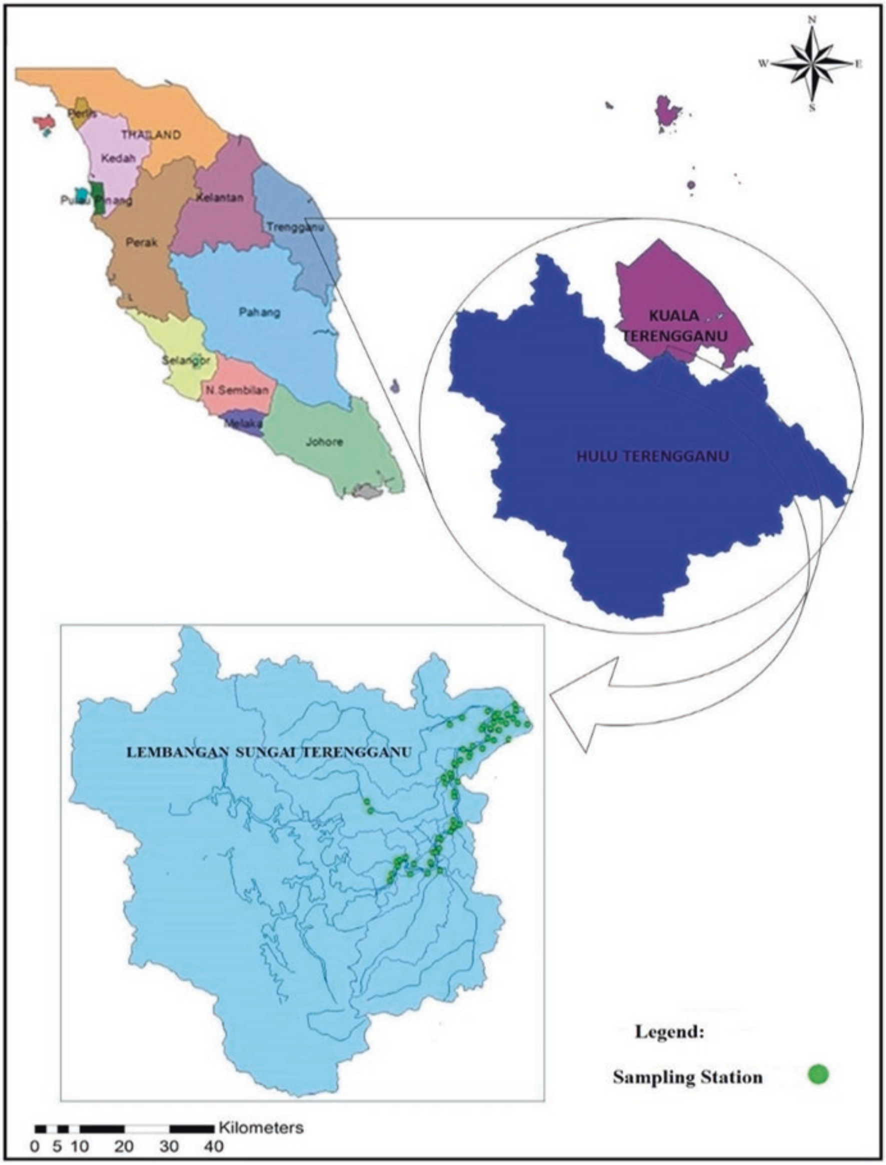



**Fig. 1.3** Map of sampling station, Kuala Terengganu, and Hulu Terengganu along Terengganu River Basin, Malaysia

methods applied in this study like hypothesis testing (two-sample t-test) and Discriminant Analysis (DA) (Fig. 1.4).

This analysis was applied to determine the relationship between two or more natural parameters regrading the level of environmental awareness in aspect

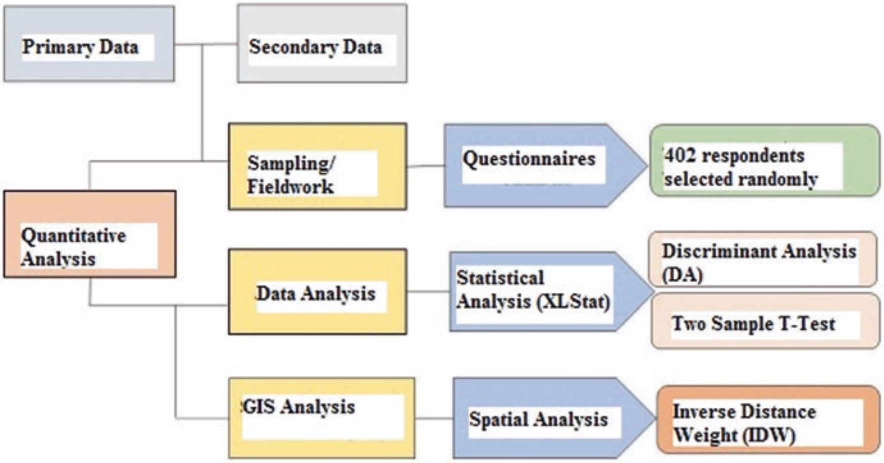
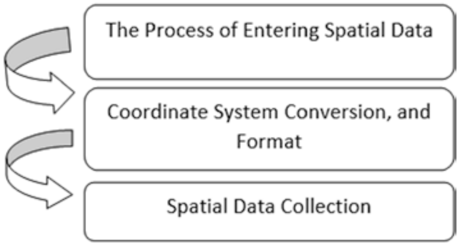



**Fig. 1.4** The framework used in the study of rural urban differences in environmental awareness in Terengganu, Malaysia

**Fig. 1.5** The spatial data mapping process




knowledge and practice among urban and rural residents in Malaysia. It equally describes the whole data set by excluding the less significant parameters with a minimum loss of initial information (Juahir et al. 2018). Figure 1.5 shows the spatial data mapping process, in this study, the components contained in the application of Geographic Information System (GIS) applications. Important components are hardware, software, procedures, data, and people. Spatial data are available in digital form or a paper map, with the help of a scanner to convert it to digital. In addition, components in GIS have a variety of data analyses and rendering functions that have different formats. There are two types of GIS: spatial data and attribute data. Spatial data are of two types: raster data and vector data. Spatial data is information related to the real coordinate point above the ground (Gidado et al. 2018; Kamarudin et al. 2019).

# 3 Result and Discussion

## *3.1 Demographic Profile of Respondents*

To further understand the respondents' background, this study examined four elements of the respondents' profile, namely gender, age, education and employment. Table 1.2 presents the frequency and percentage of respondents' demographic profile in this study. Out of the 402 respondents participated in the study, 230 (57%) were male and 172 (43%) were females. Categories of respondent age are 18–25 and above: 28 (7%) are aged 18–20 years old, 23 (6%) aged 21–22 years old, 36 (9%) aged 23–24 years old, and 315 (78%) are aged 25 and above.

According to the education level, 57 (14%) respondents have a PMR certificate, 156 (39%) have SPM certificate, 39 (10%) have STPM/STAM certificate, and 150 (37%) have some level of education in others. Based on the employment sector, 61 (16%) respondents are employed in the government sector, 32 (8%) in the private sector, 189 (46%) self-employed, and 120 (30%) employed in others.

**Table 1.2** Information on the background of 402 respondents in Terengganu, Malaysia

| Demographics | Frequency | Percent |
|---|---|---|
| Gender | | |
| Male | 230 | 57% |
| Female | 172 | 43% |
| Age | | |
| 18–20 | 28 | 7% |
| 21–22 | 23 | 6% |
| 23–24 | 36 | 9% |
| 25 above | 315 | 78% |
| Education | | |
| PMR | 57 | 14% |
| SPM | 156 | 39% |
| STPM/STAM | 39 | 10% |
| Others | 150 | 37% |
| Employment | | |
| Government | 61 | 16% |
| Private | 32 | 8% |
| Self-employed | 189 | 46% |
| Others | 120 | 30% |

## 3.2 Statistical Analysis

### 3.2.1 Discriminant Analysis (DA)

Based on Table 1.3, for Question 1 Section A (Applying recycling), p-value is 0.0297. For Question 6 Section A (Cycling or walking reduces motor vehicles), p-value is 0.0028. For Question 4 Section B (Pay more for eco-friendly products) p-value 0.0095. For Question 9 Section B (Knowledge of the benefits of natural resources), p-value is 0.0229, and for Question 10 Section C (Knowledge of environmental care), p-value of 0.0023. All the questions having p-value <0.05 showed that there are significant differences between urban and rural areas.

### 3.2.2 Hypothesis Testing

Table 1.4 and Fig. 1.6 showed descriptive analysis of urban and rural respondents in Terengganu River Basin, the selected questions of urban and rural respondents such as SA1: Practices recycle activities, SA6: Proper waste disposal, SB4: Willing to pay more for buying friendly products environment, SC9: The benefits of natural resources, SC10: The benefit of preserving the environment. Based on SA1, the mean of urban areas is 2.2174 and rural areas is 2.0415. The minimum number of urban and rural areas is 1, while the maximum number of urban and rural areas is 4. This shows that majority of communities agree about SA1 but are still in a simple stage. Based on information obtained, most communities hold mineral bottles and old newspapers for resale. The study conducted by Cheku et al. (2014) found that most respondents in Terengganu implemented recycling practices at a moderate level. According to Minton and Rose (1997), environmentally conscious individuals will buy or save, looking for eco-friendly product information, and recycle. Based on SA6, mean of urban areas is 2.5590 and of rural areas is 2.3071. The minimum number of urban and rural areas is 1, while the maximum number of urban areas is 4 and rural is 9. This shows that majory of communities agree about SA6 but still in a simple stage. As a result of observations, researchers found that most people use motorcycles, instead of cycling and walking, to nearby places. The social and individual benefits of bicycling and walking are myriad, ranging from thrift and individual health to community building. Cycling and walking instead of using

**Table 1.3** Significant questions about environmental awareness

| No. | Variable | Lambda | F | DF1 | DF2 | P-value |
|---|---|---|---|---|---|---|
| 1. | SA1 | 0.9882 | 4.7595 | 1 | 400 | 0.0297 |
| 2. | SA6 | 0.9779 | 9.0447 | 1 | 400 | 0.0028 |
| 3 | SB4 | 0.9833 | 6.7929 | 1 | 400 | 0.0095 |
| 4. | SC9 | 0.9871 | 5.2138 | 1 | 400 | 0.0229 |
| 5. | SC10 | 0.9770 | 9.4328 | 1 | 400 | 0.0023 |

**Table 1.4** Descriptive analysis of urban and rural respondents in Terengganu River Basin, Terengganu

| | Urban | | | | |
|---|---|---|---|---|---|
| Statistic | SA1 | SA6 | SB4 | SC9 | SC10 |
| No. of observations | 161 | 161 | 161 | 161 | 161 |
| Minimum | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Maximum | 4.0000 | 4.0000 | 4.0000 | 4.0000 | 3.0000 |
| 1st Quartile | 2.0000 | 2.0000 | 2.0000 | 1.0000 | 1.0000 |
| Median | 2.0000 | 3.0000 | 2.0000 | 2.0000 | 1.0000 |
| 3rd Quartile | 3.0000 | 3.0000 | 3.0000 | 2.0000 | 2.0000 |
| Mean | 2.2174 | 2.5590 | 2.4783 | 1.6087 | 1.4969 |
| Variance (n−1) | 0.7462 | 0.5231 | 0.4886 | 0.5022 | 0.3641 |
| Standard deviation (n1) | 0.8638 | 0.7232 | 0.6990 | 0.7086 | 0.6034 |
| | Rural | | | | |
| No. of observations | 241 | 241 | 241 | 241 | 241 |
| Minimum | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Maximum | 4.0000 | 9.0000 | 4.0000 | 4.0000 | 4.0000 |
| 1st Quartile | 2.0000 | 2.0000 | 2.0000 | 1.0000 | 1.0000 |
| Median | 2.0000 | 2.0000 | 2.0000 | 2.0000 | 2.0000 |
| 3rd Quartile | 2.0000 | 3.0000 | 3.0000 | 2.0000 | 2.0000 |
| Mean | 2.0415 | 2.3071 | 2.2863 | 1.7552 | 1.6846 |
| Variance (n−1) | 0.5483 | 0.7803 | 0.5469 | 0.3273 | 0.3585 |
| Standard deviation (n−1) | 0.7405 | 0.8834 | 0.7395 | 0.5721 | 0.5987 |

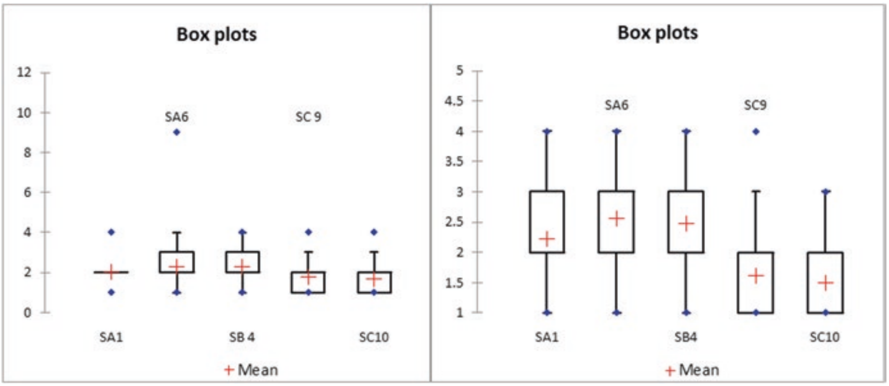



**Fig. 1.6** Urban and rural box plots

motorcycles allows the community to reduce fossil fuels and pollution associated with other environmental damage (Komanoff et al. 1993).

Based on SB4, mean of urban areas is 2.4783 and mean of rural areas is 2.2863. The minimum number of urban and rural areas is 1, while the maximum number of urban and rural areas is 4. This shows that majory of communities agree about SA6 but still in a simple stage. According to Mamun et al. (2018), in their study, there are findings that exhibit that the level of perceived behavioural control among the respondents has a significantly positive effect on their payment behaviour for environmentally friendly products. Based on SC9, mean of urban areas is 1.6087, while the rural areas is 1.7552. The minimum number of urban and rural areas is 1, while the maximum number of urban and rural areas is 4. Most urban and rural communities agree on this question. The mean value among urban and rural areas' respondents of SC10 is 1.4969 and 1.6846 respectively. Based on Table 1.4 recorded the minimum number (Likert scales' answer) among urban and rural respondents is 1 and the maximum number among urban and rural areas' respondents are 3 and 4 respectively. These data indicate the mean values proved the both of urban and rural areas' respondents agree with the SC10 (the benefit of preserving the environment). The minimum number of urban and rural areas is 1, and the maximum number of urban areas is 3, while rural is 4. This indicates that most residents agree with SC10 questions.

### 3.2.3 Hypothesis Testing (Two-Sample t-Test)

Hypothesis Testing (two-sample t-test) was conducted to see the comparison between urban and rural areas related to practices, attitudes, and knowledge on environmental issues. Based on Table 1.5, p-value of community practice on environmental issues is 0.0826, which showed that there are no significant differences with urban and rural communities' practices on environmental issues (p-values > 0.05). It indicates that urban and rural communities have a balanced practice in maintaining the environment. Most respondents practices to preserve the environment are applying to recycle. They keep and sell recyclable materials such as old newspapers, bottles, and glass. This statement which is proved from the mean values of urban and rural areas' respondents as 2.2174 and 2.0415 respectively that the majority of respondents agreed to practice the recycling process.

The section about community attitudes towards environmental issues found that p-value is 0.0826. It indicates that there are no significant differences between urban and rural areas (p-value > 0.05). The attitudes of communities towards environmental issues with urban and rural are balanced. Environmental attitudes, such as contributing a small portion of the income to the environment, do not waste evenly, do not open burning, and so on. Parallel to the Center for Science and Research

**Table 1.5** Hypothesis testing (two-sample t-test) related to communities' practices, attitudes, and knowledge

| No. | Details | p-value |
|---|---|---|
| 1. | Community practice on environmental issues | 0.0826 |
| 2. | Community attitudes towards environmental issues | 0.5058 |
| 3. | Community knowledge of environmental issues | 0.0331 |

Information Technology (MASTIC) from 1998 to 2004 which states that environmental awareness in society is increasing (MASTIC, 1998). The result of community knowledge on environmental issues found that p-value is 0.0331 and shows that there are significant differences between urban and rural areas on their knowledge of environmental issues (p-value $< 0.05$).

The attributed mean of urban is 17.3975 and rural 18.4440, which shows that rural communities have more knowledgeable environmental issues compared to urban communities. The information obtained finds the respondent able to access information through mass media, such as Facebook, Instagram, Twitter, and WhatsApp. Community knowledge of environmental issues is important. This is discussed by Kollmuss and Agyeman (2002) in the preliminary model of PEB around knowledge of the environment and its conservation, which plays an important role in determining behavioural patterns of attitudes toward the environment.

### 3.2.4 Geographic Information System (GIS) Analysis

The researcher applied the Geographic Information System (GIS) technique to develop an environmental awareness model among urban and rural areas' respondents in Terengganu based on the knowledge, attitude and practice about the environment.

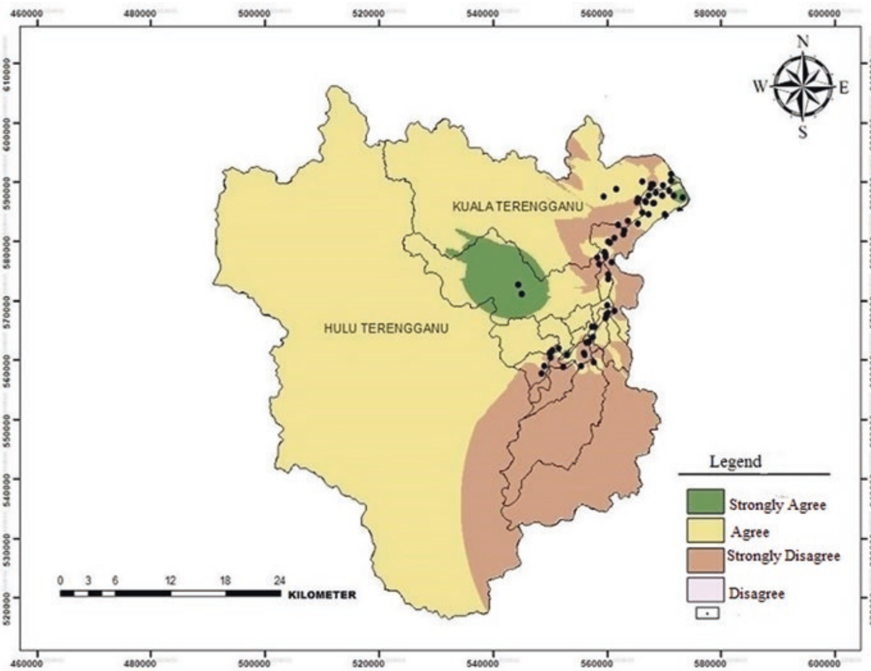



**Fig. 1.7a** Distribution of rural–urban differences in environmental awareness about practicing recycling process

(i) Practice recycling process

Figure 1.7a proves that most of the villages along the urban areas, such as Kampung Bukit Tunggal, Kampung Buluh Gading, Kampung Bukit Kandis, Kampung Pulau Kambing, Kampung Bukit Kecil, and Batu Buruk, much agree to practice recycling process. While the spatial distribution showed mostly the respondents in Hulu Terengganu's district such as Kampung Chapu dan Kampung Tok Lawit disagree to practice recycling process in their life. Overall, it can be recorded mostly in urban areas where most of the respondents agree to practice recycling compared to the communities in rural areas.

(ii) Willing to pay more for environmentally friendly products

Based on Fig. 1.7b, majority of the communities in urban areas strongly agree to willing to pay more for environmentally friendly products, such as Kampung Teluk Belara, Kampung Buluh Gading, and Kampung Gelogor. But there are a few areas that disagree to pay more for environmentally friendly products, such as Kampung Pulau Kudat, Kampung Telaga, and Kampung Butut, which are situated in the district of Hulu Terengganu. According to Chan and Lau (2000), the communities who have higher environmental awareness and attitudes will affect their behaviour. Attitudes and knowledge will trigger the consumers willing to pay more for environmentally friendly products which do not affect the environment and reduce the environmental deterioration level (Fazli and Teoh 2006).

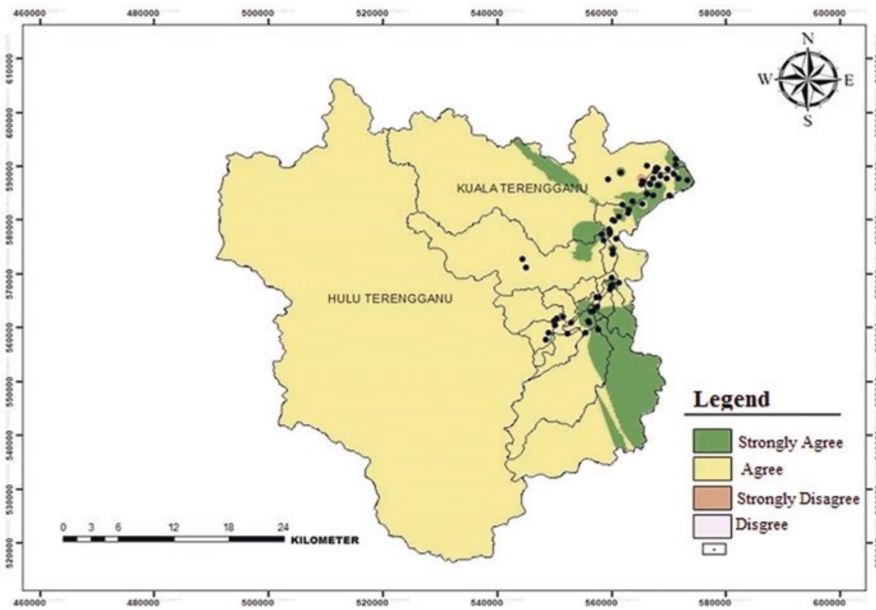



**Fig. 1.7b** Distribution of rural–urban differences in environmental awareness about the willingness to pay more for environmentally friendly products

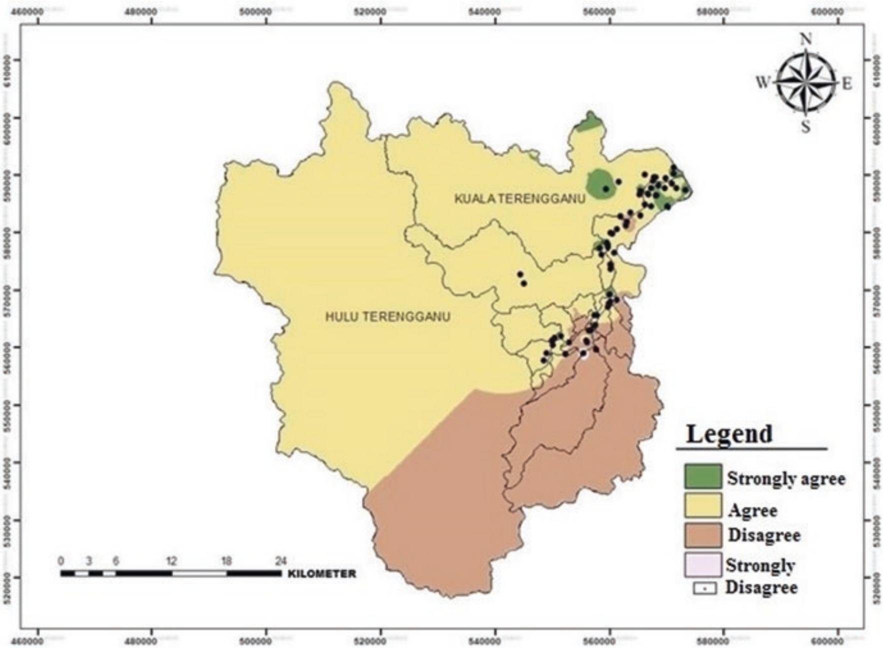



**Fig. 1.7c** Distribution of rural–urban differences in environmental awareness about the knowledge of the existence of recycling centres

(iii) Knowledge of the existence of recycling centers

Figure 1.7c shows that the communities around Kampung Teluk Belara, Kampung Gelugor, Kampung Seberang Takir, and Batu Buruk (Kuala Terengganu's District) have the knowledge of the existence of recycling centers. In the southern part of Terengganu, the communities in Kampung Chapu, Kampung Lawak, Kampung Dura, and Kampung Jenagor have knowledge about that but most of them disagree with recycling centers' activities. Overall, the urban communities are aware and have knowlegde about recycling center in their areas compared to rural communities.

(iv) Knowledge of waste disposal properly and benefits of natural resources

Figure 1.7d recordeds, 99% of communities in Kampung Belara, Kampung Gelugor, Kampung Kuala Bekah, Kampung Pulau Kambing, and Batu Buruk, represented as urban areas, have knowledge of waste disposal properly. Besides that, there are disagreements on the question (knowledge of waste disposal properly) among the communities around Kampung Pulau Nering and Kampung Por (Hulu Terengganu).

It can be concluded that the urban communities were more sensitive and knowledgeable about environmental protection than the rural communities. Knowledge of proper waste disposal is important to maintain the well-being of the environment and to avoid evironmental deterioration.

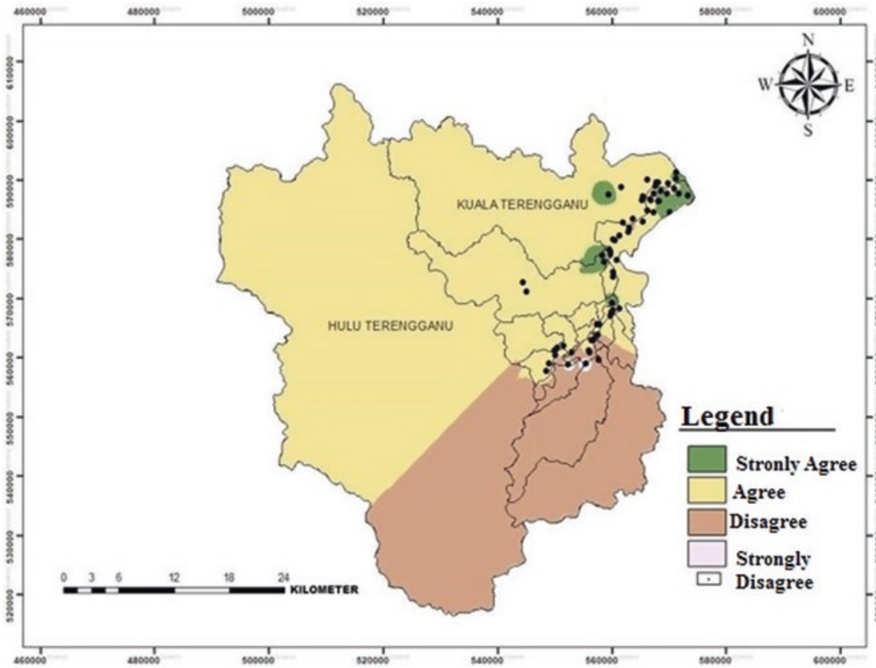



**Fig. 1.7d** Distribution of rural-urban differences in environmental awareness on the knowledge of waste disposal

Figure 1.7e showed, the communities in Kampung Teluk Belara, Kampung Seberang Takir, Pasar Payang, Batu Buruk, Kampung Banggol Paradong, Kampung Buluh Gading, Kampung Banggol, Kampung Pulau Rusa, and Kampung Ladang strongly agree and have knowledge on the benefits of natural resources. In the south of Terengganu, such as Kampung Butut and Kampung Buluh, there is diagreement and lack of knowledge on the benefits of natural resources in their life.

Overall, majority of rural communities disagree on the knowledge of waste disposal properly and benefits of natural resources compared to urban communities. The rural communities did not pay attention to environmental awareness and did not really apply their environmental knowledge in their life.

## 4 Conclusion

The practice, attitude, and knowledge of environmental issues are essential to enhance the community ability to care for the environment, in order to achieve environmental consciousness and ethics, values and attitudes, and skills and behaviours in Malaysia. The effectiveness of education and the development of the environment must be from the early age, especially from the parents. In addition, all parties,

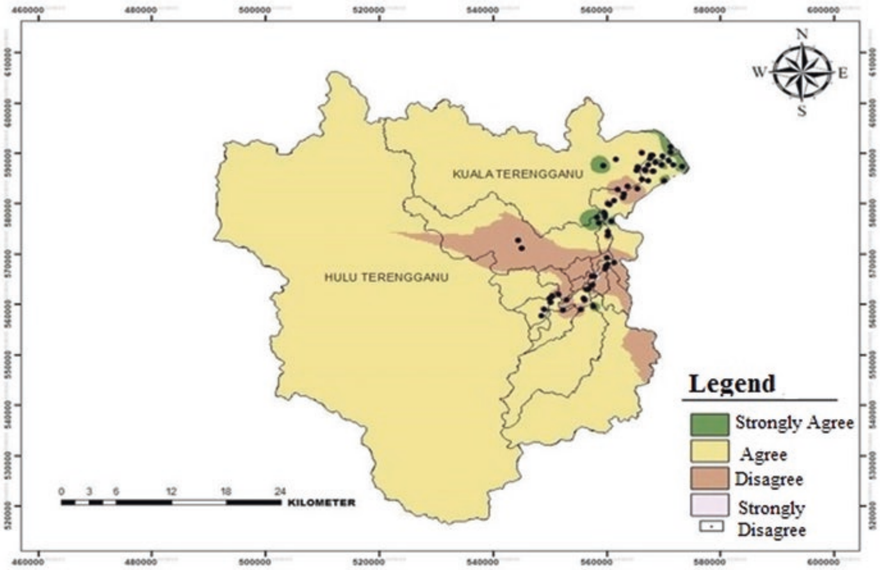



**Fig. 1.7e** Distribution of rural–urban differences in environmental awareness on the knowledge of the benefits of natural resources

especially the government, the private sector, and all levels of society, should work together and move on to solve the problem of environmental issues. Besides that, appropriate actions and programs need to be done to improve existing activities to ensure the level of commitment, attitudes, and behaviours to care and environmental importance. Various parties should be involved in planning various activities that can impact the local community.

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# Chapter 2
# Human Health Risk Assessment of Heavy Metals Exposure Due to Selected Freshwater Fishes Ingestion from Sungai Kuantan, Malaysia

**Nadzifah Yaakub and Wan Marlin Rohalin**

**Abstract** Concerns over human health safety from consumption of fishes originating from Kuantan river remain urgent due to recent rapid anthropogenic activities surrounding Kuantan river including bauxite mining. Health risk assessment is an important tool to evaluate the consequences of human activities and weighs the adverse effects to public health against the contributions to economic development. This study is aimed to estimate the target hazard quotient (THQ) and Target Hazard Index (THI) of heavy metals from commercially important and highly consumed fish species among Kuantan communities. Samples of Sebarau (*Hampala macrolepidota*), Lampam sungai (*Barbonymus schwanenfeldii),* and Lampam jawa (*Barbonymus gonionotus*) were caught by using fishnet gills along Kuantan river between June 2019 and December 2019. The fish were then digested and analyzed using Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). The results revealed that the levels of eight metals (mg/kg) in all fish samples were ranked accordingly to their concentration in descending order of Al > Fe > Zn > Cu > Ni > As > Pb > Cd, suggesting that all the freshwater fishes in Kuantan river were contained with heavy metals. The average concentrations of Al, Fe, Zn, and Cd were the highest in *H.macroleidota* which were (50.0 ± 8.33, 35.25 ± 1.80, 4.58 ± 3.80, and 0.057 ± 0.018) mg/kg. Moreover, the average concentrations of Cu and Pb were the highest in *B.gonionotus* which were 4.23 ± 0.23 and 0.63 ± 0.10 and Ni concentrations were found the highest in *B.shwanenfeldii* (0.34 ± 0.35 mg/kg), respectively. However, metals concentration in all fishes were below the permissible limit stipulated by the World Health Organizations (WHO) (1985), the Food and Agriculture Organization FAO (2003), and the Malaysian Food Act 1983. It was also noticed that consumption of all fishes may bring about health risks from different metals as

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indicated by varied THI values. Consumption of the three species was noticed to promote high health risk from As intoxication as the HQ for As was >1.00. Hence, health risk assessment is required in order to determine the probability of human health risk due to heavy metals following the consumption of fish originating from a collection site. A lot of studies on heavy metal pollution by bauxite mining have been done by many researchers, but few studies have been published related to health risk assessment on heavy metal pollution based on fish consumption.

**Keywords** Kuantan river · Freshwater fishes · Heavy metals · Health risk assessment

## 1 Introduction

Due to its destructible features and the toxicity effects it has on living beings when it exceeds allowable levels, heavy metal contamination is one of the major concerns in the natural environment (Mmolawa et al. 2010). Pollution by heavy metals in rivers affects public water. According to Terra et al. (2008), heavy metal contamination in rivers represents a threat to public water supplies and to consumers of fishery sources. Heavy metals are also well-known to pose adverse health risks when the dosage of human exposure reaches acceptable levels of consumption (Djedjibegovic et al. 2012; Ahmed et al. 2016; Bosch et al. 2016; Saha et al. 2016).

Fish consumption is recommended because fish has an excellent nutritional source as they contain high protein and vitamins. Given the benefits, fish consumption may also pose health risks to people, mainly due to potential detrimental effects of contamination of heavy metals. The water source for freshwater fish may also be heavily polluted by mining, forestry, urban, and industrial contaminants. Mansour and Sidky (2002) mentioned that fish are the most endangered species among the aquatic species as they cannot be protected from the threat of these pollutants. Attributable to large amounts of heavy metals in water, this results in the accumulation of heavy metals in their organs.

People are known to be exposed to toxic chemicals that accumulate through long-term ingestion of fish taken from polluted waters (Han et al. 1994; Svensson et al. 1995). The ability to identify the sources of heavy metal pollutants is useless without measuring its effects on human health. Hence, health risk assessment is required in order to assess the total exposure of heavy metals among the population in a particular place. It helps to formulate preventive measures in order to take care of public health (Sharif et al. 2016; Jamil et al. 2014; Yuswir et al. 2015). Thus, this study is aimed to determine the levels of heavy metals and their possible health risks from consumption of selected freshwater fishes from Sungai Kuantan.

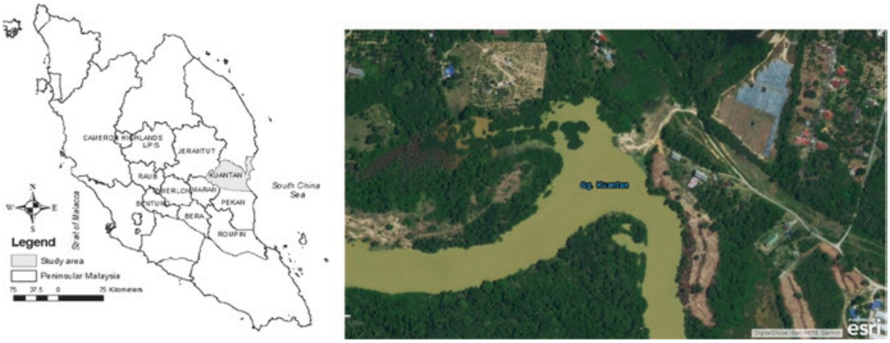


**Fig. 2.1** Map of Sungai Kuantan, Malaysia

## 2 Methods and Materials

### *2.1 Study Area*

Kuantan, Pahang is considered the Eastern Coast Peninsular Malaysia's social, economic, and commercial hub. (Kusin et al. 2016). Kuantan also becomes one of the hot spots for the production of bauxite in Malaysia. Bukit Goh is one of the large-scale bauxite minis located in Kuantan, Pahang. Sampling was carried out during the wet season and dry season (Fig. 2.1).

### *2.2 Sample Collection*

In June 2019 and December 2019, field sampling was performed. Total three different fish species samples were collected from Kuantan river located near bauxite mining in Bukit Goh, Kuantan. Fish samples were collected at 5 different stations along the rivers. The water samples were collected in polyethylene bottles and kept in icebox before bringing to the laboratory for further water quality analysis (APHA, 2017). The fish species were caught from each sampling stations by using fishing net. The fish were individually placed in polyethylene bags and immediately stored in icebox with ice. The fish were deep-frozen in the cool room at −20 °C until ready for analysis. The specimens were placed in an icebox before being sent for analysis to the laboratory (Kamaruzamaan et al. 2011).

### 2.3 Fish Samples Analysis

Acid digestion method (AOAC 2016) was performed to digest the fish samples. Each dried tissue was put in a test tube. 10 mL of 70% Nitric Acid ($HNO_3$) were added into each test tube and they were left overnight at room temperature. On the second day, the samples were digested for 2 h in 100 ° C block thermostat. Then, the samples were allowed to cool. The samples were returned to heat again at 100 °C for 1 h and they were left to cool. The digested solutions were filtered into a 25 mL volumetric flask using filter paper, and they were diluted to reach 25 mL with deionized water. After the digestion process was done, the samples were analyzed using Inductively Coupled Plasma-Mass Spectrometer (ICP-MS).

### 2.4 Heavy Metals Calculation

The content level of heavy metals in muscle samples was calculated by using the formula below (APHA 2005):

$$\begin{aligned} C &= A \times B / \text{weight of samples digested}\,(\text{kg}) \\ C &= \text{Actual concentration}\,(\text{mg/kg}) \\ A &= \text{Digested concentration}\,(ICP)(\text{mg/L}) \\ B &= \text{Volume digested}\,(\text{L}) \end{aligned} \tag{2.1}$$

### 2.5 Health Risk Assessment

Possible health risks from consumption of the dried fish and shellfish samples were assessed using the model equation developed by Agency for Toxic Substances and Disease Registry for fish consumption (ATSDR 2004).

The estimated daily intake (EDI) of heavy metals equation (Griboff et al. 2017):

$$EDI = \left( \left( C \times IRd \right) / BW \right) \tag{2.2}$$

where $C$ is the concentration of heavy metals in biological samples (mg/kg dw), IRd is daily average ingestion rate (123.56 g/day) per capita as recorded by Ahmed et al. (2016), and BW is the average body weight (59.23 kg). EDI was expressed as μg/kg bw/day.

Target hazard equation

$$THQ_{\text{non-carcinogenic}} = \left( EF \times ED \times IRd \times C \right) / \left( RfD \times BW \times AT \right) \tag{2.3}$$

where $THQ_{non\text{-}carcinogenic}$ is the target hazard quotient for non-carcinogenic risk, EF is exposure frequency (365 days/year), ED is the exposure duration (30 years old), IR is the ingestion rate (123.56 gday-1) *C* is the heavy metal concentration in aquatic products (mg/kg dw), RfD is the oral reference dose (μg/kg/day, 1 for Cd, 4 for Pb, 1500 for Cr, 40 for Cu, 20 for Ni, 300 for Zn, 140 for Mn, 0.3 for As) (Varol et al. 2017), BW is the average body weight (59.23 kg), and AT is the averaging exposure time for non-carcinogens effect (ED × 365 day/year). An averaging time of 365 days/year for 73 years (i.e., AT = 26845.75 days) was used to characterize lifetime exposure for cancer risk calculation (USEPA 2003). The exposed population is unlikely to sustain obvious adverse effects, when the HQ is <1. There is a potential health risk (Taweel et al. 2013), and related interventions and protective measurements should be taken when HQ is ≥1.

### *2.6 Statistical Analysis*

One-way variance analysis (ANOVA) was used to show significant differences in the concentration of heavy metals between different fishes. Using Microsoft Excel 2019, a statistical analysis was carried out.

## 3 Results and Discussion

### *3.1 Heavy Metals Levels in Freshwater Fish Muscle*

The concentration of heavy metals in the freshwater fishes in this study was determined on a dry weight basis as the values were more reliable and consistent compared to wet weight value (Pe'rez-Lo'pes et al. 2008).

In this study, a total of 30 fishes were caught from Kuantan river comprising three families and species. The distribution of the captured fish species is listed in Table 2.1. The Cyprinidae family included *Barbonymus gonionotus* (Lampam Jawa), *Barbonymus schwanenfeldii* (Lampam Sungai), and *Hampala macrolepidota* (Sebarau). Adult freshwater fishes were used in this study.

Heavy metals, namely, Al, Fe, Zn, Cu, Ni, As, Pb, and Cd, were assessed in each fish species' tissue using ICP-MS. The descriptive statistics of metals measured during the sampling period are shown in Table 2.1. Data of heavy metals distribution in tissue of all evaluated fish species showed that, heavy metals were accumulated in the fish tissues as follows: *Hampala macrolepidota*: Al > Fe > Zn > Cu > Ni > As > Cd > Pb; *Barbonymus schwanenfeldii*: Al > Fe > Zn > Cu > Ni > Pb > As > Cd; and *Barbonymus gonionotus*: Fe > Cu > Zn > Al > Pb > Ni > As > Cd.

**Table 2.1** longitude and latitude of sampling stations

| Station | Longitude and latitude |
|---|---|
| S1 | 3°51′27.0″N 103°12′27.0″E |
| S2 | 3°51′25.7″N 103°12′25.5″E |
| S3 | 3°51′24.7″N 103°12′24.1″E |
| S4 | 3°51′23.5″N 103°12′22.9″E |
| S5 | 3°51′22.7″N 103°12′21.9″E |

Additionally, the average concentrations of the 8 metals in fish samples were in the following order: Al > Fe > Zn > Cu > Ni > As > Pb > Cd. The average concentrations of Al, Fe, Zn, and Cd were the highest in *H.macroleidota*, which were 50.0 ± 8.335, 35.251 ± 1.802, 4.589 ± 3.803, and 0.0575 ± 0.01847 mg/kg, but still below the permissible limit under standard guidelines. Moreover, the average concentrations of Cu and Pb were the highest in *B.gonionotus*, which were 4.2356 ± 0.2352 and 0.6388 ± 0.1046 mg/kg, and Ni concentrations were the highest in *B. shwanenfeld*ii (0.3461 ± 0.357 mg/kg) and As in *H.macropelidota* (0.1778 ± 0.21 mg/kg), respectively, whereas the lowest concentration of Ni was in *H. macrolepidota* and As in *B. shwanenfeldii.*

In general, there are many organizations which function to set the safeguard public health limits of heavy metal concentration in fish (Rohasliney et al. 2014). Permissible limits of heavy metal contamination in Malaysia are determined by Malaysia Food regulations (MFR 1985). In this study, the heavy metal concentrations were also compared with limits specified by other international organizations, such as the FAO (2003) and WHO (1985).

As tabulated in Table 2.2, it was noted that the Fe content in all species of fish exceeded the permissible limits stated by the WHO (1983), which was 0.5 mg/L. However, the other seven heavy metals were under the WHO (1983) limits in all species. Metal accumulation in fish depends on pollution and may differ for various fish species living in the same water body (Jezierska & Witeska (2006).

In this study, it showed the concentration of Al was way higher than the other seven metals in most of the samples from all sampling sites. Results of this study showed a good agreement with report of (White and Rainbow 1982; Krantzberg and Stokes 1989; Kraak et al. 1994) stated various species of mollusc, crustacean and fish are able to regulate essential metals. The bioaccumulation of non-essential metals in the organisms depends on their concentrations in the environment. The higher the concentration of Al, the higher the bioaccumulation in species (Amiard et al. 1987).

Bioaccumulation of metals in an animal tissue is contributed by several factors: biotic ones such as body size and mass, age, sex, diet, metabolism, and position in the food web and abiotic factors such as salinity, distribution of metals in environment, temperature, and interaction with other metals. However, food is the factor that has the most influence on the accumulation of metals in animal tissues (Jakimska et al. 2011). Thus, different species may have different abilities in metal accumulation into

**Table 2.2** Bioconcentration (mg/kg) ± SD of heavy metals in muscle tissue of freshwater fishes in Kuantan river and permissible limit stated by authorities

| Species name | Al | Cu | Fe | Ni | Zn | As | Cd | Pb |
|---|---|---|---|---|---|---|---|---|
| *H. macrolepidota* | 50 ± 8.335 | 0.3569 ± 0.292 | 35.251 ± 1.8028 | 0.1844 ± 0.1842 | 4.5898 ± 3.8037 | 0.1778 ± 0.2099 | 0.0844 ± 0.1304 | 0.0575 ± 0.01847 |
| *B. schwanenfeldii* | 8.9488 ± 7.872 | 1.6746 ± 3.1254 | 8.9347 ± 7.71266 | 0.3461 ± 0.3573 | 2.5558 ± 0.9928 | 0.0709 ± 0.0407 | 0.0386 ± 0.06273 | 0.0757 ± 0.0626 |
| *B.gonionotus* | 1.5712 ± 1.7767 | 4.2356 ± 0.2352 | 4.658 ± 5.3512 | 0.2442 ± 0.35408 | 2.971 ± 1.8986 | 0.1039 ± 0.1456 | 0.0749 ± 0.0855 | 0.6388 ± 0.1046 |
| | Permissible limit stated by authorities | | | | | | | |
| WHO (1985) | – | 3.0 | 0.5 | 0.5–0.6 | 30 | 0.5 | 2.0 | 2.0 |
| FAO (2003) | – | – | – | – | – | – | 0.5 | 0.2 |
| MFR (1983) | – | 30 | 0.5 | – | – | 0.5 | 1.0 | – |

their tissue. Fish will accumulate metals in its tissue through absorption during respiration and breathing, and thus expose metals to humans via the food web.

## *3.2 Health Risk Assessment of Heavy Metals Exposure*

### 3.2.1 Hazard Quotient

Hazard Quotient (HQ) exceeding 1.0 is considered threatening human health. The calculated HQ of heavy metals in the fish species is given in Table 2.3. In this study, the mean concentrations of THQ in fishes were in order of As > Al > Pb > Cd > Fe > Ni > Zn > Cu. In the present study, As and Al both showed THQ values >1 in all fishes. According to New York State Department of Health, 2017, if the ratio of EDI of heavy metal to its RfD was equal to or less than the RfD, then the risk will be minimum.

Among the concerned heavy metals, it is Al whose permissible limit has yet not been established by any agency in the world and as well as Malaysia. The THQ level of Al for all species was higher than 1.00 and were as follows: *Hampala macrolepidota* (8.21), *Barbonymus schwanenfeldii* (4.33), and *Barbonymus gonionotus*

**Table 2.3** Health risk assessment of heavy metals exposure through fish ingestion

| Species name | Heavy metals | EDI | THQ | HI |
|---|---|---|---|---|
| *Hampala macrolepidota* | Cu | 0.0007 | 0.0186 | 34.1419 |
| | Al | 0.0410 | 8.2158 | |
| | Ni | 0.0003 | 0.0192 | |
| | Cd | 0.0001 | 0.1763 | |
| | Pb | 0.0001 | 0.8588 | |
| | As | 0.0003 | 8.1690 | |
| | Fe | 0.0500 | 0.0714 | |
| | Zn | 0.0095 | 0.0319 | |
| *Barbonymus schwanenfeldii* | Cu | 0.0005 | 0.0152 | 17.4422 |
| | Al | 0.0216 | 4.332 | |
| | Ni | 0.0007 | 0.0376 | |
| | Cd | 0.0001 | 0.0195 | |
| | Pb | 0.0001 | 0.7595 | |
| | As | 0.0001 | 12.251 | |
| | Fe | 0.0194 | 0.0265 | |
| | Zn | 0.0045 | 0.0147 | |
| *Barbonymus gonionotus* | Cu | 0.0004 | 0.0113 | 23.2306 |
| | Al | 0.0117 | 2.3584 | |
| | Ni | 0.0005 | 0.0267 | |
| | Cd | 0.0001 | 0.0107 | |
| | Pb | 0.0001 | 0.7948 | |
| | As | 0.0003 | 19.995 | |
| | Fe | 0.0127 | 0.0181 | |
| | Zn | 0.0043 | 0.0145 | |

(2.35). The highest THQ for Al was in *H.macrolepidota*. This may be attributed to the high Al contamination in the bauxite mining area where the fish live.

The as THQ from all species were also >1.00, which recorded as follows: *Hemibagrus nemurus* (4.88), *Hampala macrolepidota* (8.16), *Barbonymus schwanenfeldii* (12.25), and *Barbonymus gonionotus* (19.99). *B.gonionotus* had the highest THQ of As for ingestion on daily basis. The THQ for other evaluated elements was lower than 1 for people who eat fish seven times a week; based on the HQ cut-point. The calculated target hazard quotient for Arsenic indicates that the fishes are extremely contaminated, and it showed that all fishes can promote health risk due to As intoxication as the HQ values were greater than 1.0.

The HQ value is not only attributed to the extent of heavy metal content in the food, but is also influenced by the exposure frequency as well as the ingestion rate of the contaminated food (Ahdy 2007). Furthermore, the differences in oral reference dose of the respective metal may also affect the HQ value.

Although the Fe content in all analyzed species exceeded the permissible limits, only the HQ value of Al and As was greater than 1.0, which indicates the presence of adverse health effects due to Al and As intoxication. Upon consumption, the bioaccumulated heavy metals in the fishes' body can eventually transfer to humans (Han et al. 1994). As a result, there is a growing concern that metals accumulated in fish muscle can represent a health risk, especially for populations with high fish consumption rates (Burger and Gochfeld 2009; Díez et al. 2009; Liao and Ling 2003). THQ deal with individual heavy metal only, but generally food items contain more than one heavy metal as already seen in the case of fish muscle, six heavy metals were detected. So, it becomes mandatory to calculate the hazard index (HI). It is the numerical sum of all the metals.

### 3.2.2 Hazard Index

The cumulative effect of HQ of the respective heavy metals was indicated by the value of Target Hazard Index (THI). It was found that the THI values for all species were greater than 1.0. The THI value, in decreasing order, of the respective fishes begins with *Hampala macrolepidota* (34.14), *Barbonymus gonionotus* (23.23), and *Barbonymus schwanenfeldii* (17.44).

## 4 Conclusion

Overall, the total mean heavy metal concentration of all fish species in this study revealed an order of Al > Fe > Zn > Cu > Ni > As > Pb > Cd. Therefore, the results in this study demonstrated that fish species caught in the Kuantan River were contaminated with heavy metals. Nevertheless, the heavy metal concentration in the fish tissues, with the exception of Fe, did not exceed the MFA and WHO guidelines. Regular monitoring of heavy metal concentrations in fish tissue is necessary.

The present study also has shown that all selected species in the river seemed to experience high heavy metal contamination based on heavy metal levels determination in selected freshwater fishes. The Hazard Quotient for As in all species was more than 1.00, and for Al, the THQ was high in all specie*s*. The estimation of risk conducted in this study showed that adverse health effects may occur when consuming the local fish, mostly from the Kuantan river.

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# Chapter 3
# Determination of Nickel and Cadmium in Freshwater Fishes in Kuantan River and Riau River

**Nadzifah Yaakub and Wan Marlin Rohalin**

**Abstract** Nowadays, heavy metal pollution in Malaysia has become a major health concern in humans. Thus, this study was conducted to determine the level of cadmium (Cd) and nickel (Ni) in the muscle and gills of fishes collected from Kuantan river and Riau river. Field samplings were conducted between September and December 2017. Five different species of fishes: *Barbonymus gonionotus, Barbonymus schwanenfeldii, Hampala macrolepidota, Chitala chitala,* and *Hemibagrus nemurus* were digested by using acid digestion method and analyzed with Inductively Coupled Plasma-Mass Spectrometry (ICPMS). Concentration of Cd among species was in order of *H.macrolepidota* > *B.gonionotus* > *B.schwanenfeldii* > *C.chitala* > *H.nemurus,* whereas Ni level in fishes was: *C.chitala* > *H. macrolepidota* > *B. gonionotus* > *H. nemurus* > *B. schwanenfeldii*. Among all the species, *H. macrolepidota* from Kuantan river had the highest Cd in both muscle (0.1761 ± 0.0062 mg/kg) and gills (0.2938 ± 0.0066 mg/kg), whereas the highest Ni level in muscle was found in *C. chitala* from Kuantan river with (0.1473 ± 0.0755 mg/kg) and in gills of *B.gonionotus* (0.4544 ± 0.0470 mg/kg) from the same river, respectively. It was observed that there was a significant difference ($p < 0.05$) in Cd in muscle between species. Ni concentration in fishes was lower than the permissible limit (WHO, 1985) while the concentration of Cd was recorded high but still below the limits of World Health Organizations (WHO) 1985 and the Malaysian Food Act (MFA) 1983.

**Keywords** Heavy metals · Kuantan River · Riau River · Nickel · Cadmium

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## 1 Introduction

Metal contamination in the aquatic ecosystem is considered to be unsafe not only for aquatic organisms but also for terrestrial organisms including humans. Heavy metals are well-known environmental pollutants that cause serious health hazards to human beings (Jarup 2003). Fish can accumulate heavy metals through uptake from different organs depending on the affinity of such organs to accumulate heavy metals. As a consequence, different organs have different heavy metal concentrations (Perera et al. 2015).

Nickel (Ni) and cadmium (Cd) are heavy metals that can cause toxicity to humans. The main threats of heavy metals to humans are associated with exposure of heavy metals from industrial waste, mining activities, and agricultural activities into rivers. Kuantan river and Riau river have potentially high concentrations of heavy metals since they are located nearer to the largest bauxite mining site, which is in Bukit Goh, Pahang. Bauxite ores contain heavy metals such as aluminum, cadmium, nickel, chromium, lead, and arsenic, which are neurotoxic or carcinogenic toxicologically (Hussain et al. 2016). The heavy metals runoff will contaminate the rivers with heavy metals and accumulate into the fish through respiration and breathing.

The consumption of freshwater fish by a large portion of the population remain urgent due to toxic heavy metals bioaccumulation in the fish. It is important to determine the concentration of heavy metals in fishes in order to evaluate the possible risk of consumption for human health. Moreover, it also results in bioaccumulation of heavy metals in man using water from this river since its tributaries pass through populated residential areas, towns, industrial and agricultural sites.

The risk associated with the exposure to heavy metals present in fresh fish or fish products had aroused widespread concern in human health. The risk of Ni and Cd contamination in muscle has received attention for both aspects of food safety and human health as it is a common edible part of fish.

Currently, the information about Pahang river water quality and safety of fish consumption is still not enough with the rapid industrialization activities. Even some organizations had stopped the mining operation, but still, lots of companies continue bauxite mining activities illegally without being responsible for clean-up works. Due to public awareness that metal enrichment in aquaculture may pose a potential health risk, this work investigated the levels of Cd and Ni in freshwater fishes and water samples collected from Kuantan river and Riau river. These sampling sites were selected on the basis of likely variation in metal levels due to anthropogenic activities, namely bauxite mining.

## 2 Methods and Materials

### *2.1 Study Area*

Kuantan, Pahang is considered as the social, economic, and commercial hub for the East Coast Peninsular Malaysia. It is located at a latitude 30 45′ 0″ N and longitude of 102 30′ 0″ E (Kusin et al. 2016). Kuantan has also become one of the hot spots for the production of bauxite in Malaysia. Bukit Goh is one of the big scale bauxite mining, located in Kuantan, Pahang. Four sampling locations had been selected in Kuantan and Riau rivers. Sampling was carried out between February 2017 and May 2017.

### *2.2 Sample Collection*

Several experimental gill nets were set up and left for 48 h at each sampling location. Every 24 h each net was inspected from morning until afternoon. The gill net was placed on the river based on several factors according to the sampling location.

### *2.3 Sample Analysis*

The fish meat and gills were dissected and weighed for 10 grams per sample before being dried in the oven at 100 °C for 24 h. Samples were allowed to cool in a desiccator before the dry weights were taken. Acid digestion method was used to digest the meat samples based on the Association of Official Analytical Chemists (2016). Each sample was placed in the digestion tube and 10 ml of 69% of nitric acid was added before being left overnight at room temperature.

On the next day, the samples were digested at 100 °C for 2 h before cooling down for 1 h. After that, 2 ml of 30% hydrogen peroxide was added to each sample and heated for 1 h until a clear solution. Then, it was allowed to cool before solutions were filtered through filter paper into 25 ml of volumetric flask. Lastly, deionized water was added into the volumetric flask until the volume reach 25 ml. The concentration of heavy metals was determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

## 3 Results and Discussion

In this study, a total of 45 adult fishes were caught from Kuantan and Riau, comprising three families and five species. The distribution of captured fish species includes the Cyprinidae family, which were *Barbonymus gonionotus* (Lampam Jawa), *Barbonymus schwanenfeldii* (Lampam Sungai), and *Hampala macrolepidota* (Sebarau), while *Chitala chitala* (Belida) was from Notopteridae family and *Hemibagrus nemurus* (Baung) from Bagridae family. The findings regarding the levels of Cd and Ni found in the muscles and gills of the freshwater fishes collected from Kuantan and Riau rivers are presented in Tables 3.1 and 3.2.

As tabulated in Table 3.2, it was reported that the mean concentration of Cd in muscle and gills of freshwater species was in the following order: *H.macrolepidota* > *B.gonionotus* > *B.schwanenfeldii* > *C.chitala* > *H.nemurus*. The highest Cd level in muscle was observed in *H. macrolepidota* from Kuantan river (0.1761 ± 0.0062 mg/kg) and the least value of Cd was found in muscle of *H.nemurus* from Riau river (0.0004 ± 0.0002 mg/kg). *H.macrolepidota* had Cd level above established limits set by USFDA (1993), EC (2001), and FAO (2012); however, it was still below the WHO (1985) and MFA (1983) limits.

Therefore, *H.macrolepidota* collected for consumption from Kuantan river may pose adverse health risks of Cd intoxication in the human population. *H. macrolepidota* is a type of fish that inhabits the bottom layer of rivers and hunts for pellets, shrimp, bloodworms, or small insects. Mohsin and Ambak (1991) and Amundsen et al. (1997) had reported that carnivores could accumulate higher metal concentrations.

This statement is in agreement with the result that showed the highest concentration in this species. Whereas, *H.nemurus* from Riau river had the lowest Cd concentration with 0.0004 ± 0.0002 mg/kg in muscle and 0.0044 ± 0.0028 mg/kg in gills, respectively. Cd levels in *B.gonionotus*, *B.schwanenfeldii, C.chitala*, and *H.nemurus* were all below the established safe limits, and this species did not show a sign of danger since the concentration from all rivers was still far from the danger limit.

**Table 3.1** List of local fishes caught from Kuantan river and Riau river

| Species | Length (cm) | Weight (g) | No. of samples |
|---|---|---|---|
| *Barbonymus gonionotus* | 24.0–26.0 | 600–800 | 9 |
| *Barbonymus schwanenfeldii* | 20.0–24.0 | 200–600 | 9 |
| *Hampala macrolepidota* | 18.0–20.0 | 150–200 | 9 |
| *Chitala chitala* | 30.0–45.0 | 500–800 | 9 |
| *Hemibagrus nemurus* | 24.0–32.0 | 400–600 | 9 |

**Table 3.2** Mean concentration of cadmium (mg/kg) ± SD in muscle and gills of individual species collected from selected rivers

| Location | Kuantan River | | Riau River | |
|---|---|---|---|---|
| Species | Muscle | Gill | Muscle | Gill |
| *Barbonymus gonionotus* | 0.0122 ± 0.0095 | 0.0422 ± 0.0078 | 0.0004 ± 0.0003 | 0.0134 ± 0.0147 |
| *Barbonymus schwanenfeldii* | 0.0056 ± 0.0024 | 0.0643 ± 0.0021 | 0.0005 ± 0.0001 | 0.0355 ± 0.0003 |
| *Hampala macrolepidota* | 0.1761 ± 0.0062 | 0.2938 ± 0.0066 | 0.0184 ± 0.0032 | 0.0749 ± 0.0052 |
| *Chitala chitala* | 0.0022 ± 0.0021 | 0.0510 ± 0.023 | 0.0006 ± 0.0029 | 0.0314 ± 0.0199 |
| *Hemibagrus nemurus* | 0.0005 ± 0.0223 | 0.0032 ± 0.0048 | 0.0004 ± 0.0002 | 0.0044 ± 0.0028 |

**Table 3.3** Mean concentration of nicke (mg/kg) ± SD in muscle and gills of individual species collected from selected rivers

| Location | Kuantan River | | Riau River | |
|---|---|---|---|---|
| Species | Muscle | Gill | Muscle | Gill |
| *Barbonymus gonionotus* | 0.0620 ± 0.0227 | 0.4544 ± 0.0470 | 0.0208 ± 0.0040 | 0.1139 ± 0.0511 |
| *Barbonymus schwanenfeldii* | 0.0216 ± 0.0019 | 0.3028 ± 0.0028 | 0.0124 ± 0.0041 | 0.2373 ± 0.0001 |
| *Hampala macrolepidota* | 0.0916 ± 0.0341 | 0.6805 ± 0.0241 | 0.0255 ± 0.0041 | 0.0747 ± 0.0143 |
| *Chitala chitala* | 0.0946 ± 0.0182 | 0.1831 ± 0.1921 | 0.0239 ± 0.0052 | 0.1360 ± 0.0022 |
| *Hemibagus nemurus* | 0.0291 ± 0.0056 | 0.0848 ± 0.0166 | 0.0180 ± 0.0008 | 0.0795 ± 0.0107 |

Cd is a nonessential heavy metal that can affect the kidneys and causes symptoms of chronic toxicity, such as the impairment of kidney function, poor reproductive capacity, hypertension, tumors, and hepatic dysfunction when ingested in high doses (Waalkes 2000). As Cd is the second product of mining activities, it could likely be discharged into the river in high concentrations, which would eventually accumulate in fishes (May et al. 2001). It also carries water from Lembing river, which is located near the Tin Ore Mining Industry.

According to Table 3.3, the levels of Ni were recorded in the range of 0.0216–0.0946 mg/kg in muscle and 0.0848–0.6845 mg/kg in gills. Mean concentration of Ni in muscle of freshwater species was in the following order: *C. chitala* > *H. macrolepidota* > *B. gonionotus* > *H. nemurus* > *B. schwanenfeldii*, meanwhile, in gills, it was in the following order: *B. schwanenfeldii.* > *H. macrolepidota* > *B. gonionotus* > *C. chitala* > *H. nemurus.* The highest Ni concentration in muscle was in *C. chitala* from Kuantan river with value of 0.0946 ± 0.0182 mg/kg. Whereas, *B. schwanenfeldii* from Riau river showed the lowest Ni level in muscle (0.0124 ± 0.0041 mg/kg) and *H. macrolepidota* had the lowest Ni in gills (0.0747 ± 0.0143 mg/kg). This result proved that the accumulation of heavy metals is varying in different species. However, the Ni level in freshwater fishes in all rivers was still below the permissible limit set by the World Health Organization (1985) and the Food and Agriculture Organization (2003). Low concentration of Ni will not cause adverse effects on animals and human health since it is essential for growing (Bharagava 2017).

Differences of value between the current study and previous study determined the toxicity of the area and may give harmful to human society and community through ingestion and consumption. A previous report shows that there were three different fish species that have been studied along the Kelantan river (Hashim et al. 2014). The study reported that *B. gonionotus* from Kelantan river had maximum concentration of Cd 0.061 ± 0.076 mg/kg and *B. schwanenfeldii* with 0.100 ± 0.15 mg/kg. It also had reported maximum Ni concentration obtained from freshwater fishes in Kelantan River was 0.024 ± 0.037, 0.262 ± 0.024, and 0.056 ± 0.069 mg/kg, respectively, for *H. macrolepidota, C. chitala*, and *H. nemurus*. However, accumulation of Ni in *C. chitala* was reported lower than this present study.

**Table 3.4** The permissible limit of heavy metal cadmium (Cd) and nickel (Ni) in fish (mg/kg) by organizations

| | Cd | Ni |
|---|---|---|
| EC (2001) | 0.05–0.10 | – |
| WHO (1985) | 2.00 | 0.50–0.60 |
| FAO (2012) | 0.05 | 0.40 |
| MFA (1983) | 1.00 | – |
| USFDA (1993) | 0.01–0.21 | – |

Fish are known to accumulate Ni in different tissues when exposed to elevated levels in their environment (Nussey et al. 2000; Obasohan and Oronsaye 2004). Lung inflammation and damage to the nasal cavity have been observed in fish exposed to Ni compounds. Ni is either proven to be or is strongly suspected to be essential in trace amounts, yet toxic in higher doses. Contact with Ni compounds (both soluble and insoluble) and ingestion of polluted fish as well as drinking water can cause a variety of adverse effects on human health (Table 3.4).

In this study, it is also reported that Ni level was higher compared to Cd in fishes from both the rivers. These observations may be due to the surrounding ecosystem status, as the sampling sites were nearby the bauxite mining area and nickel was present abundantly in the water environment, which may lead to a high probability to contribute high level of Ni in fish. High Ni concentration in fish might also be the result of effluent discharge received from households and the agriculture industry as Kuantan is the main river in Pahang. All these factors are the main contributors to the finding, which showed high Cd and Ni concentrations in freshwater fishes which originated from Kuantan river.

This study showed that both Cd and Ni levels in fish were higher in Kuantan river compared to Riau river. This might be due to the water flow of river was carried from upstream to downstream start from Kuantan to Riau river. By receiving industrial effluents generated by upstream, freshwater fish in Kuantan have a tendency to accumulate higher Cd and Ni in muscle tissue. A previous study shows that heavy metal content in aquatic organisms may be affected by their habitats and different ecosystems (Fidan et al. 2008).

In addition, it was found that the Cd and Ni concentration in gills was much higher than in muscle tissue. This statement is in agreement with Yeşilbudak and Erdem (2014), who mentioned that Cd was prone to be accumulated in gill compared to muscle tissue as gill is a metabolically active and readily available organ analyzed for biomonitoring. According to Mansor (2017), Cd concentration in muscle tissue of fish collected from Kelantan river was reported at 0.0181–0.0304 mg/kg, while Baharom and Ishak (2015) reported the Ni concentration at 0.058–0.072 mg/kg. Moreover, this study recorded that Cd found in gill showed the highest concentration compared to muscle tissue.

Gills have a tendency to accumulate high heavy metals as they had a large surface area for straightforward and persistent contact with contaminants in the water

(Olgunoglu et al. 2015; Yilmaz 2003). Cd accumulation in gill of freshwater fish in Kelantan was ranged 0.0275–0.0335 mg/kg reported by Mansor (2017) which was lower than this study.

## 4 Conclusion

In conclusion, the accumulation of non-essential metal (Cd) and essential metal (Ni) had been varying in each species. Among species, *H. macrolepidota* was detected with the highest Cd concentration in muscle tissue (0.1761 ± 0.0062 mg/kg), and the least Cd concentration was detected in *H. nemurus* (0.0013 ± 0.0258 mg/kg). Ni concentration was detected the highest in *C. chitala* muscle (0.1473 ± 0.0755 mg/kg) and the least detected in *B. schwanenfeldii* (0.0562 ± 0.0066). Cd and Ni concentration in gills was obtained higher compared to muscle.

Cd level in gill was detected highest in *H. macrolepidota* (0.1250 ± 0.0047 mg/kg), while Ni was highest in gills of *B. schwanenfeldii* (0.2810 ± 0.0044 mg/kg). In conclusion, Ni concentration in fishes was below the permissible limit stipulated by the World Health Organizations (WHO) (1985) and the Food and Agriculture Organizations (2012), and even though the concentration of Cd was recorded high, it was still below the limits of WHO (1985) and the Malaysian Food Act (MFA) 1983.

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# Chapter 4
# Tourism Sustainability: Perspectives on Past Works, Issues and Future Research Opportunities

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**Abstract** The emergence of tourism as one of the crucial contributors to global economic performance has led to the proliferation of studies on the sector's link to the concept of sustainability. It is a well-established knowledge that tourism lays its foundation on the environment to build infrastructure, facilities and services to develop a tourist destination. As the destination becomes competitive, the tourism sector has the responsibility to minimise its footprint that would lead to degradation of the environment. This is difficult to achieve as finding the right balance between environmental limits and sectoral development is further complicated by the dynamism of tourism and a multitude of other variables, such as the complexities of host communities, destination lifecycles and also the uncertainty and instability of the global economy along with emerging trends in tourism. Specifically, challenges in tourism sustainability are bountiful. This chapter unearths the contemporaneous issues that range from the quality of indicators, formulation and implementation of policies, poor relations among stakeholders to the lack of awareness on environmental sustainability. Considering the extent of challenges that beleaguers the sustainability concept as a whole, this chapter provides three main research opportunities on pro-environmental behaviours, policymaking and sustainability communication for future commentators, industry practitioners and policymakers. It is hoped that this will provide a strong foundation for more empirical works on tourism sustainability, further reducing the gap of inherent contradictions between sustainability and development.

**Keywords** Tourism sustainability · Tourism development · Environmental sustainability · Challenges · Issues · Future opportunities

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## 1 Introduction

The development of the tourism industry in terms of economy places it as one of the most remarkable industries of the current era. Tourism has retained its position among the world's largest and fastest-growing industries in the world, indicated by the 4% increase in international tourist arrivals in the previous year, of almost 1.5 billion people travelling worldwide (United Nations World Tourism Organisation (UNWTO 2020). Before the current outbreak of the coronavirus disease (COVID-19), the tourism sector was seen as the primary economic driver for many countries. However, this rapid growth has raised concerns regarding the impacts of the industry towards the environment. These include the depletion of natural resources, air pollution, physical damage to ecosystems, deforestation and loss of landscape (Bhuiyan et al. 2018). The connection between tourism and the environment especially is significant since tourism activities are highly dependent on the quality of the environment (Avcikurt et al. 2015).

Data from the EU Eurobarometer survey in 2016 for the European Union indicated that nature and landscape continue to be the main factors influencing tourists' choice of holiday destinations, while the quality of nature is among the reasons for revisits (Halleux, 2017). This is likely due to the intention of most tourists seeking pleasant destinations to relieve pressure and psychological stress (Ritchie and Crouch 2003). Indeed, this intention could be among the important elements in the decision-making process for tourists which consequently affects the competitiveness of a particular destination (Becken et al. 2017).

From this perspective, it is, therefore, necessary to consider the possibilities of sustainable development in the tourism sector, to offset the global environmental changes caused by humans travelling for the purpose of leisure (Räikkönen et al. 2019). Implementing sustainable development demands proper tourism infrastructure and site traffic planning to address any negative environmental impacts (Ólafsdóttir and Haraldsson 2019).

It is highly probable that sustainable development through the sustainable use of natural resources will create opportunities for the current and future generations to experience a better life as a fundamental sense of well-being (Räikkönen et al. 2019). This is particularly because environmental sustainability emphasises the conserving and managing of resources that are non-renewable and in limited supply (Goeldner and Ritchie 2007; Sunlu 2003). Given the circumstances, tourism destinations need to consider implementing environmental sustainability in order to maintain essential ecological processes and conserve natural heritage and biodiversity (United Nations Environment Programme (UNEP) & UNWTO 2005). Therefore, the following section will review past studies on sustainable tourism and its implementation in the tourism industry. Challenges of tourism environment sustainability will then be discussed. Finally, future research opportunities in tourism environment sustainability will be presented.

## 2 Results and Discussion

### *2.1 A Glance into Past Studies*

The release of the Brundtland Report by the World Commission on Environment and Development (as cited in Bramwell and Lane 2011) caught the attention of many scholars with the term "sustainable tourism." It was defined as the ability of a destination to meet the needs of existing generations without compromising the needs of future generations. Sustainable tourism was then represented by Bramwell and Lane (1993) as a model for economic development with emphasis on the quality of life of local communities, supporting tourist experiences and sustaining the environment of tourism destinations. Since then, the growing number of studies on this particular topic are mostly identified based on three "pillars" of sustainable tourism policies as introduced by the United Nations' Environment Programme (UNEP) and World Tourism Organisation (UNWTO). These pillars or elements consist of environmental, social, and economic (Della Corte et al. 2019). Figure 4.1 depicts the amount of literature on sustainable tourism development from 1992 to 2019. The graph shows the amount started to increase beginning 2007.

As reported by Della Corte et al. (2019), the first period (1992–2008) has a cumulative 22 papers capturing the sustainability pillar of environment, where the scope of studies extends to the contextual settings of protected areas. The advent of 2003 has seen the concept expanding to include community involvement by

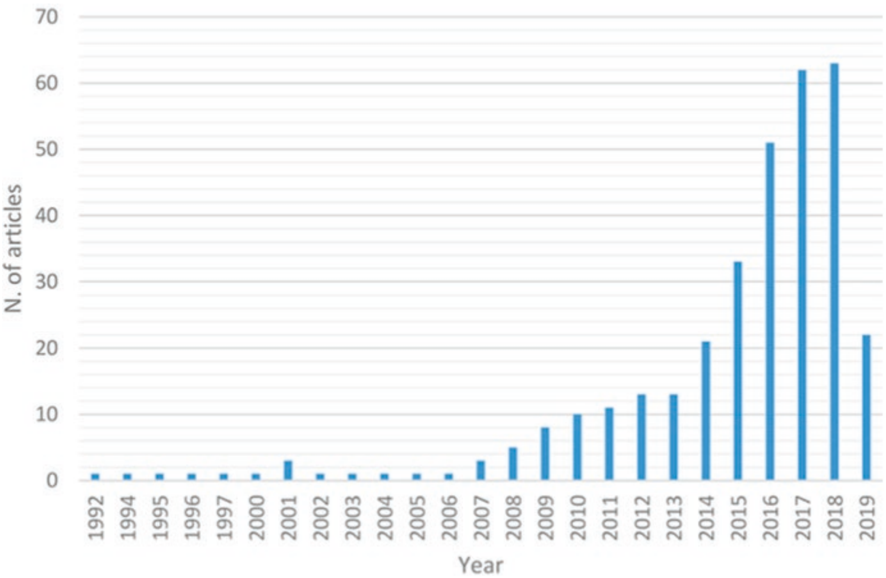


**Fig. 4.1** Annual trajectory of sustainable tourism development literature. (Data from "Sustainable Tourism in the Open Innovation Realm: A Bibliometric Analysis" by Della Corte et al. 2019, p. 6)

emphasising on the community as the host and their important role in sustainable development. Further studies started to address sustainable tourism development based on specific topics such as sustainable accessibility for transportation (Bertolini et al. 2005; De Vasconcellos 2005). It was also the beginning of sustainable tourism being explored comprehensively from different perspectives. A sharp increase was recorded in the second period (2009–2014) where a total of 76 papers on tourism sustainability were published (Della Corte et al. 2019). Interesting prospects were identified among the studies on the relationship between sustainable tourism with food and beverages production, management as well as experience. These include local food as a sustainable tourism experience (Sims 2009), food chains among two countries (Neves 2010), environmentally friendly production practices in winemaking (Schmit et al. 2013) and the use of technology for sustainable practices (Okumus 2013). The literature available shows the broad implications of sustainable development through the impact of identifying the raw materials for food productions towards the foundation of finished products. Moreover, studies on eco-tourism were also investigated on the basis of environmental planning activities (Gunter et al. 2018).

For the last 5 years and specifically in the beginning of 2017, many tourism scholars have emphasised the urgency of sustainable tourism development as an increasing number of tourist arrivals globally bring about challenges to practice environmental sustainability (Yoopetch and Nimsai 2019; Della Corte et al. 2019). From 2015 to 2019 scholars have contributed 231 pieces of literature and this period is considered to be the most productive period (Della Corte et al. 2019). The studies on sustainable development have theoretically strayed from traditional topics to more extensive findings from different standpoints. In particular, the tourism industry is one of the industries that is rapidly evolving with the latest trends following tourist demand. Therefore, in this digital era, tourism has been at the forefront of digital innovation at an exponential rate. Many scholars grasped the opportunity to investigate sustainable development as part of the digital revolution and embedded it as a sustainable marketing tool (Sharma et al. 2016; Trunfio and Della Lucia 2019). The engagement among stakeholders through digital platforms also creates opportunities for sustainable development (Liu et al. 2015). Apart from this, studies on sustainable tourism have taken on the approach of exploring the relationship with specific sectors, such as hotels, through "green" practices (Amin and Tarun 2019; Pham et al. 2019). Green hotels are basically hotels that carry out sustainable practices such as energy conservation, environmental protection and sustainable management through recycling, reusing and resource-saving (Hsiao et al. 2014). Societal awareness of sustainable development has driven the increase in the amount of literature on sustainable tourism. According to Liu et al. (2017), through this increase, the narrative of sustainable tourism is enhanced through deeper understanding of different perspectives of sustainability.

## 2.2 Challenges in Tourism Environment Sustainability

The concept of sustainable tourism has gained a foothold and continues to grow to become a significant topic of discussion among industry practitioners, governments, academics and policymakers. However, this concept can be a paradox, where the rapid growth of tourism will be detrimental to the environment, creating confusion on what should be deemed as a success or a failure. Often understood in economic terms, this sectoral growth that prioritises tourism development over any other dimension such as sustainability has contributed to the clear contradiction when analysing the concept (Räikkönen et al. 2019). In fact, the nature of tourism in terms of the dynamism, instability and unpredictability of the sectoral economic development strategy can be linked to the fragility of the environment settings and sensitivity of the local culture (Van Zyl 2005; Reddy 2008). Given the complexity of these interrelationships, the importance of consistent performance of tourism destinations from the sustainability standpoint is heightened (Asmelash and Kumar 2019; Ghoochani et al. 2020; Jurigova´ and Lencse´sova´ 2015). This notion is vital considering that traditionally, performance measurement has been through the utilisation of economic and financial dimensions (Luo 2018) as global tourism has grown exponentially.

With the world seeing the emergence of tourism as a major industry in the global economy, this has subsequently led to the industry being constantly pressured by the opposite agendas of sustaining the environment and cultural heritage while supporting development activities and increasing profit (Fenton-Keane 2015). As environment sustainability forms the basis of all sustainability, tourist destinations rely on the usage of the natural resources that involves the development of tourism infrastructure, facilities and activities for tourists (Brundtland et al. 1987; Ghoochani et al. 2020; Hopwood et al. 2005). In other words, the environment has become a tool for tourism activities, through which it is transformed for resource management; with the massive growth of the tourism sector, this may yield a potential threat to nature and local communities (Andria et al. 2020; Räikkönen et al. 2019). Owing to this, assessment tools are important in identifying and tracking the development activities if environmental sustainability is truly the goal (Toelkes 2018; Zaei and Zaei 2013).

Sustainability indicators are one of the few examples of assessment tools, as suggested by numerous commentators regarding steps to evaluate tourism destinations (see the works of Asmelash and Kumar 2019; Cernat and Gourdon 2012; Guijt and Moiseev 2001; Huang and Coelho 2017). To distinguish a good sustainability indicator, it needs to possess certain characteristics, namely reliability, clarity, simplicity and flexibility in practice (Waas et al. 2014). Nevertheless, it is not an easy feat to produce a sustainability indicator with such qualities, as documented via criticisms in various literature. For instance, there are commentators that are pessimistic on the utilisation of quantitative-based indicators as they are considered to be error-prone and can be misleading especially in terms of results interpretations (Ghoochani et al. 2020). This can be seen especially in their inability to “capture” the unique characteristics of each destination or reflect the complex interrelationships between the environment, economy and socio-cultural issues (referring to the works of Gkoumas 2019). Besides this, the tendency to oversimplify indicators in examining the complex interrelationships between the environment and socio-cultural issues in the context of local tourism development can raise issues of data reliability (Font and Harris 2004).

Serious questions also need to be raised on the applicability of such indicators to all types of destinations. This highlights the need for universally accepted sustainability indicators which can be used for general tourism practices and measures. The application of the sustainability concept into practice through various schemes or systems will be problematic due to the diverse interests of different actors or local stakeholders, its theoretical vagueness and inappropriate utilisations of methodology (Bramwell 2013). Likewise, criticisms can also be seen in the context of formulations and implementations of tourism policies or standards that are aimed to preserve and protect the environment. Policies or standards are considered a suitable and rational approach for tourism development and management to control the level of tourism performance and environmental health, through the elimination of environmental impacts of tourism development as well as by improving the quality of the local tourism industry and competitiveness of the destination (Andria et al. 2020; Font and Harris 2004).

However, it is difficult to balance the environmental limits and tourism development owing to the complexity of the variables involved such as the constant transformation of the tourism system, the socio-cultural complexities of host communities, the dynamics of destination lifecycles and also the uncertainty and instability of the global economy along with the emerging trends in tourism (Casagrandi and Rinaldi 2002; Farrell and Twining-Ward 2004; Faulkner and Russell 1997). Combining these issues with the low capacity of policy domain to manage the conflict of interests and priorities of those in tourism will further make it difficult to apply sustainability in the governance of a local destination (Bramwell 2013). As mentioned by Hall (2011), the practical achievements and concrete results of policies at every level on local development have not been positive, irrespective of the growing awareness on the importance of environmental sustainability. Apart from the applicability of the policies, it is crucial to highlight that majority of commentators often exclude insights into the opinions of local tourism professionals on sustainability especially in the context of national and regional governance (Gkoumas 2019; Vellecco and Mancino 2010). For this reason, Jamal and Watt (2013) proposed that a "performative approach" should be employed in governing the tourism sector and sustainability, as the process should involve sizeable well-informed civic society and active citizens in the decision-making.

In reality, raising environmental sustainability awareness, however, has proved to be challenging as the rate and scale of adopting green practices, for instance, vary considerably. It is postulated that these variations are due to the contextually driven movement, and can differ across geographical spaces, as countries show different attributes of national-specific social, cultural, legal and regulations (Marano and Kostova 2016; Williams and Aguilera 2008). Looking at the European context, for example, it is revealed that the majority of hoteliers, restaurateurs, travel agents and a few of the car rental entrepreneurs and yacht company managers feel that the implementation of environmental sustainable tourism is the main responsibility of the central governments and local administration authorities (Gkoumas 2019). Despite this, they are in agreement that it is their social responsibility to foster environmental sustainability. This is different in the context of the Asian setting where there are some tour operators who claim to be involved in the sustainability program, even though the actual situation demonstrates that they are just promoting it without actually implementing any substantial practices (Sood 2011). As for the accommodation sub-sector, it is concluded that lodging enterprises from developing regions are less committed to employing green practices compared to their counterparts in developed countries (Kim et al. 2017). Considering the differences in the few given examples, it is unfair to make a concrete conclusion since there is still insufficient knowledge in comparative research on the differences in going green between; (1) Western and Eastern countries, and (2) developing and developed settings.

Nevertheless, it is unfair to portray the local tourism operators as being against the essential ideas of environmental sustainability as they are hindered by a multitude of barriers. As stated by Li and Liu (2020), the lack of awareness, knowledge, skills, support from stakeholders, financial resources, time and green supplies were identified as among the barriers faced by the tourism organisations to adopt green practices. Not limiting these barriers to tourism operators only, it appears that tourists also demonstrated low environmental awareness and showed no interest in the preservation of the environment or the sustainable use of the destination's resources (Gkoumas 2019). From the demographic perspective, it is notable that the level of factual environmental knowledge especially among the young people is often found to be relatively low and inconsistent (Rickinson 2001; Vicente-Molina et al. 2013). As for the adults, the challenge is more on whether their knowledge will encourage environmental attitudes and behaviours towards conservation and sustainability (Malka et al. 2009).

### *2.3 Future Research Opportunities in Tourism Environment Sustainability*

The enforcement of plans and strategies to reduce the impacts of ecological degradation from tourism activities is essential in order to overcome the challenges of implementing tourism environment sustainability. As such, it is necessary to identify and incorporate the findings derived from new research opportunities to achieve efficient sustainable tourism growth. The main concern is to foresee the impetus of tourism in protecting destinations. Based on the work by Haulot (1985), there are two essential questions that are still relevant to this day on the issues pertaining to environment sustainable development; (1) What exactly is the environment expected by a someone on holiday? (2) How does that person influence the environment?

One of the directions Haulot (1985) provides in addressing the two questions is the evaluation of tourists' pro-environmental behaviour. This evaluation requires a "person on holiday" or also known as the tourist, visitor, traveller, backpacker or jetsetter within the setting. The terms reflect clear evidence of mass tourism movement – this brings large segments of people from one place to another. As stated in the previous section, the more tourists at one site, the more the damage is caused to the environment. The idea of pro-environmental behaviour helps to educate tourists to be sensitive in protecting destinations and reduce environmental damage mainly caused by humans. There are a few instances in past literature that is worth highlighting and can be further explored and expanded by fellow researchers in the field. One such example is the work produced by Imran et al. (2014). They inserted several elements to evaluate tourists' pro-environmental behaviour, including values, social or personal norms and concerns about environmental matters.

Another example by Park et al. (2018) goes in a different direction through the integration of two established theoretical models in the field of study in order to determine a more comprehensive view on the pro-environmental behaviour by looking into tourists' decision-making process. The two models comprise the Norm Activation Model (NAM) and Value-Belief-Norm (VBN). Specifically, the NAM model examines three environmental variables; (1) awareness of consequences, (2) ascription of responsibility and (3) personal norms; to describe pro-environmental behaviours in terms of personal and social norms, moral motivations and perceived behavioural control (De Groot and Steg 2009; Schwartz 1977; Steg and De Groot 2010; Bamberg and Möser 2007; Bamberg and Schmidt 2003). As for the VBN model, it includes the causal or hierarchical relationship which looks into the impacts of significant elements of values, beliefs, moral obligations, new environmental paradigms, awareness of consequences, ascription of responsibility and personal norms on the pro-environmental behaviours (Stern 2000; Stern et al. 1999).

The integration of both models reflects the importance of identifying the intrinsic and extrinsic characteristics of humans (tourists) and the environment, as one of the crucial steps and elements for destination tourism stakeholders to create strategies to tackle environmental concerns based on human-nature relationships. Thus, tourists' pro-environmental data on values and personal norms can be visualised as individual awareness of the negative consequences of environmental problems in which they become more responsible in alleviating adverse consequences and become morally obligated to adopt pro-environmental behaviours at the destinations (Steg et al. 2005). Apart from this, the future of sustainable tourism and environment can also be implemented through a transformative role of tourism stakeholders in a collaboration.

A collaborative approach or network collaboration is an effective tool to minimise potential economic and socio-cultural problems and to reduce environmental negative impacts. As reported by UNWTO (2015), tourism is one of the industries that have a unique and subtle capacity to control and sustain natural resources – from environmental preservation, promotion, and cultural appreciation and understanding among people. Thus, network collaboration from the multiplicity and heterogeneity of stakeholders, including Small and Medium-Sized Enterprises (SMEs), tourism agencies, local producers, accommodation and transport providers, which co-exist alongside destination governance is important in achieving the sustainable goals. Destination governance involves tourism planning, policy and decision-making, collective stakeholder collaboration and execution, and is aimed at improving stakeholder and destination performance (Pechlaner et al. 2012; Padurean 2010; Beritelli et al. 2007). However, it is important to bear in mind that the focus of future policymaking must change from economic growth to growth that does not undermine the tourism carrying capacity and subsequently lead to the degradation of environment (Guo et al. 2019). In fact, sustainable tourism policies should incorporate indicators that are specifically developed for synergies among the local public and private enterprises. This is important to encourage mutual understanding at every level of the destination stakeholders, which is especially vital in terms of feasibility and domain capacity of national environmental policies.

Thus, future considerations for tourism planning and policymaking should emphasise the element of shared responsibility among the public, private and hybrid tourism stakeholders. This shared responsibility is vital since sustainable tourism policies cannot be just limited on the balance and coordination between tourism sub-sectors, as traditional tourism problem-solving paradigms and methods cannot effectively address all the challenges mentioned in the previous section (Guo et al. 2019). This is because the development of tourist destinations is prone to spillover effects in pursuing economic growth, which heightens the importance of decision-makers integrating the potential impact of various developments that are not directly related to tourism (Collins 1999). Therefore, innovative approaches are required to go beyond the limits of learning from past policies as well as the tools and concepts of policymaking and directly address what matters the most, which is the systemic (e.g. supply chain) and institutional impacts from the cross-sectoral perspectives (Guo et al. 2019).

## 3 Conclusion

Finally, effective sustainability communication should be further explored as one of the significant future directions of destination marketing and method of raising tourist awareness on sustainable tourism development. It is part of a contemporary tourism process to ensure consumers are aware of the availability of sustainable travel products, to inform consumers on how these offerings meet their needs and comply with sustainability criteria, and ultimately to stimulate pro-sustainable purchases (Tölkes 2018). Moreover, Tölkes (2018) found that the studies on sustainability communication mostly focused on specific green hotel contexts or sustainable destinations.

Given the nature of the focus, it is important to understand that the future of sustainability communication is about the implementation of substantial management and monitoring of two-ways activities that would allow and preserve the development and environment conservation. In order to increase awareness of sustainable tourism, effective communication should be embedded in four distinctive phases of the tourist experience – pre-consumption experience, purchase experience, core consumption, and nostalgia experience (Tiago et al. 2020). In this context, technologies or the role of Information and Communication Technologies (ICTs) can be the tool to facilitate a symbiotic connection between tourists and a destination, where it can improve and add value to the competitiveness of the destination (Ramos et al. 2020). As technological advancement is always a part of the significant elements of tourism development, further innovative works should be encouraged for better-integrated planning of tourism environment sustainability especially within the spheres of policies, designation of products and services as well as tourist experiences.

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# Chapter 5
# Overview on Particulate Matter Emissions at Construction Site: Story in Malaysia

**Fatthir Iftiaz Ismail, Mohd Armi Abu Samah, Mohd Shukri Mohd Aris, and Siti Rohana Mohd Yatim**

**Abstract** Deterioration of air quality especially in Malaysia has now become an issue in the global environment. The increase of construction projects in Malaysia is due to the growth of population, and rapid urbanization is the main factor contributing to the highest industrial air pollution sources by the state from the year 2010 to 2015. One of the pollutants involved in the cause of air pollution especially in Malaysia is from particulate matter (PM) emission. The emission of PM in Malaysia comes from three primary sources, which are mobile, stationary, and open burning sources. In the year 2000–2015, the estimated percentage of annual PM emission accumulated in Malaysia is 7% for every year of air pollution sources. Consequently, this distribution of PM in the atmosphere produced by human activities can cause serious problems such as radiation balance of the Earth, change in the cloud formation, contribution to global warming, reduced visibility, and worst affect the human health, especially the construction workers and public due to the inhalation of small particles that induces an inflammatory reaction in the airways and subsequent induction of systemic inflammation and coagulation disturbances.

**Keywords** Particulate matter · Construction · Air pollution · Particulate pollution

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## 1 Introduction

Airborne particulate matter (PM) around us is generated from two important sources: natural (e.g., sea sprays, entrained dust, and fires) and manmade activities (e.g., construction, road transport, combustion, industry, and minerals extraction), which are known to have significant impacts on the environment and human health (Environment Agency 2013). Basically, particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets (Mohd Zin et al. 2008). Meanwhile, suspended particulate is a complex mixture of particles that may be solid, liquid or both, suspended in the air and consisting of organic and inorganic substances (Yuwona et al. 2014).

Particulate matter can be divided into three categories: inhalable coarse particles, fine particles, and ultra-fine particles. Coarse particles are defined as those having an aerodynamic diameter larger than 2.5 μm ($PM_{2.5}$) and smaller than 10 μm aerodynamic diameter ($PM_{10}$). Fine particles are those having an aerodynamic diameter less than 2.5 μm, and ultra-fine particles are those less than 100 nm in diameter (Lee 2010). From these categories, coarse particles are less harmful to public health than fine particles ($PM_{2.5}$) (Bari and Kindzierski 2016). The common parameters used to determine the concentration of particulate matter are based on the particulate mass concentration (Dominick et al. 2015). Besides, meteorological factors also contribute to the amount of particulate matter in the region. Higher concentrations of particulate matter have been recorded during the dry season, predominantly during the El Nino/Southern Oscillation (ENSO) events (Shaadan et al. 2015).

Inter-comparison studies of major Asian cities in most cases shown the excessive of USEPA 24-h and annual standards with high levels of $PM_{10}$ and $PM_{2.5}$ in those cities especially during the dry season (Tahir et al. 2013). China is one of the countries experiencing rapid urban population growth, and industrialization produces large quantities of particulate matter and contributes to the particulate-bound pollutant contents of road dust (Zhao et al. 2016). Similarly, Malaysia has also undergone rapid urban growth, which affected local and regional air pollution from three main sources of air pollutants, which are mobile (motor vehicles), stationary (construction works and industrial waste incinerators), and transboundary sources (Dominick et al. 2012). Klang Valley is one of the most economic and developed areas regarding growth of urbanization, population, and industrial activities that are constantly exposed to the problem of air quality (Azmi et al. 2010). Besides, $PM_{10}$ has been recognized as an important atmospheric pollutant in Klang Valley, Malaysia (Juneng et al. 2011). The emission of $PM_{10}$ in Klang Valley is due to its rapid transformation into a wide urban region during the last decade of the twentieth century, and it contributed to environmental issues particularly, air pollution (Abdullah et al. 2012).

As a consequence, particulate matter can cause serious problems in the environment, such as change in the radiation balance of the Earth, change in cloud formation, contribution to global warming, and reduced visibility. The levels of $PM_{10}$ concentration in Malaysia comply with the Malaysia Ambient Air Quality Guidelines (Table 5.1) (Jabatan Environment 2015).

**Table 5.1** Malaysia Ambient Air Quality Guidelines (DOE 2015)

| Pollutant | Averaging time | ppm | (µg/m³) |
|---|---|---|---|
| Ozone | 1 h | 0.10 | 200 |
| | 8 h | 0.06 | 120 |
| Carbon monoxide | 1 h | 30.0 | 35[a] |
| | 8 h | 9.0 | 10[a] |
| Nitrogen dioxide | 1 h | 0.17 | 320 |
| | 24 h | 0.04 | |
| Sulphur dioxide | 1 h | 0.13 | 350 |
| | 24 h | 0.04 | 105 |
| Particulate matter ($PM_{10}$) | 24 h | | 150 |
| | 12 months | | 50 |
| Total suspended particulate (TSP) | 24 h | | 260 |
| | 12 months | | 90 |

Note: [a]mg/m³

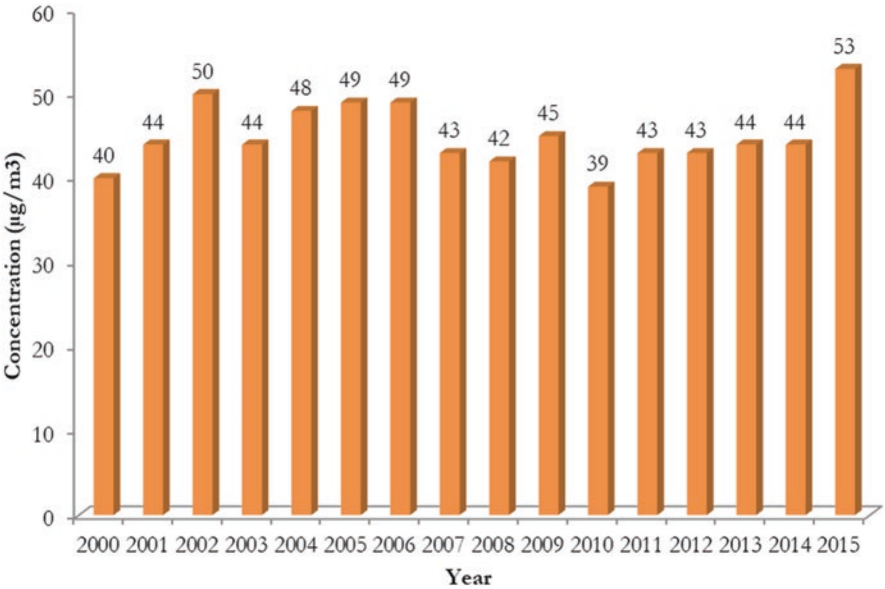



**Fig. 5.1** Annual average concentration of $PM_{10}$ in Malaysia from 2010 to 2015. (DOE 2015)

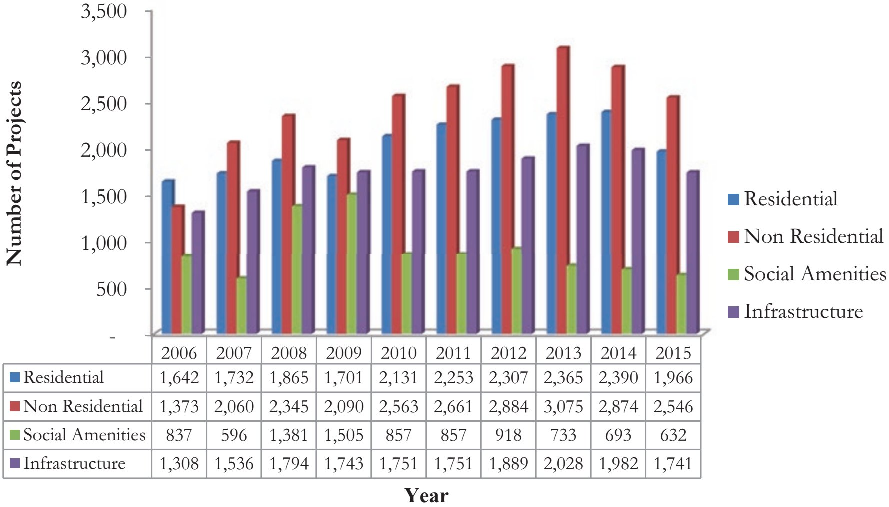
The trends of annual average concentration of $PM_{10}$ in Malaysia from the year 2010 to 2015 (Fig. 5.1) show slight fluctuation for every year, and from the year 2010 until 2014, it did not exceed the guidelines. However, in the year 2015, the annual average value of $PM_{10}$ in the ambient air was 53 µg/m³, which exceeded the Malaysia Ambient Air Quality Guidelines, and it is recorded as the highest concentration of $PM_{10}$ in 5 years.

## 2 Construction Activities and Particulate Matter

Generally, construction work includes designing, manufacturing, technology, material and workmanship, and services for the purpose of construction (CIDB 2011). In Malaysia, four main sectors of the construction industry are identified as residential buildings (houses and condominiums), nonresidential buildings (warehouse and industrial buildings), civil engineering (bridges and highways), and special trade sectors (electrical and plumbing), which are actively working towards achieving a high-income status by 2020 (Olanrewaju and Aziz 2015). The rapid construction development, especially in urban areas, will impact the ambient air quality by the generation of fugitive particulate matter (fPM) from construction dust in the dry arid land at the site which is a frequent product of soil erosion from winds (Hassan et al. 2016). For many activities that result in fugitive dust emissions, the dust emission is strongly dependent on the material or soil moisture content because moisture tends to promote particles to clog together, preventing particles from becoming airborne (EEA 2016).

Moreover, construction dust is a major source of particles and contributes greatly to the $PM_{10}$ and $PM_{2.5}$ in the atmospheric environment (Yongjie et al. 2016). Construction activities have the potential to generate a substantial amount of air pollution, such as exhaust emissions of particulate matter (PM) and oxides of nitrogen (NOx), fugitive particulate matter dust, evaporative emissions of reactive organic gases, and exhaust emissions of greenhouse gases such as carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) (SMAQM 2009). The performing of construction dust from construction and demolition activities, it also becomes the largest contributor of the street dust which suspends into the air under influence of human activities and wind action.

Building and road construction, such as land clearing, drilling, blasting, ground excavation, cut and fill operations (i.e., earthmoving), and construction of a particular facility, itself are the two examples of construction activities with high dust emissions potential, which varies substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions (USEPA 2016). Also, the construction activities involving excavation, loading, and transport of soil by an excavator and several dump trucks have been recognized as dynamic sources for the input of particulate particles and hazardous trace gasses into the atmosphere (Faber et al. 2015). Other activities related to building construction that act as the main contributor of particulate emission are involved the earthmoving operation, truck loading, and dumping (Muleski et al. 2005). Previously, prior research on environmental impacts of construction works was more focused on raw materials, its manufacturing and operational phase of the facility which is related to the global warming potential of pavement based on eight components such as materials extraction and production, transportation, onsite equipment, traffic delays, carbonation, lighting, albedo, and rolling resistance (Ma et al. 2016). Thus, the latest research now highlights particulate emissions during the




| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 1,642 | 1,732 | 1,865 | 1,701 | 2,131 | 2,253 | 2,307 | 2,365 | 2,390 | 1,966 |
| Non Residential | 1,373 | 2,060 | 2,345 | 2,090 | 2,563 | 2,661 | 2,884 | 3,075 | 2,874 | 2,546 |
| Social Amenities | 837 | 596 | 1,381 | 1,505 | 857 | 857 | 918 | 733 | 693 | 632 |
| Infrastructure | 1,308 | 1,536 | 1,794 | 1,743 | 1,751 | 1,751 | 1,889 | 2,028 | 1,982 | 1,741 |

**Fig. 5.2** Number of projects in Malaysia, 2006–2016. (CIDB 2016)

construction and mainly due to the operation of onsite heavy construction equipment (Waris et al. n.d.).

The exposure of human population to PM originating from construction-related activities is expected to increase because of the recurring infrastructure developments that accompany the exploding urbanization occurring around the world (Li et al. 2015a, b). Recently, the latest statistics on the construction industry in Malaysia from the year 2014 to 2015 is recorded from 7939 projects to 7013 projects (CIDB 2016). Besides, the nonresidential sector is recorded as the highest ranking of the construction projects in Malaysia from the year 2006–2015 (Fig. 5.2) with 24,471 projects, followed by residential sector with 20,352 projects, and the third ranking is infrastructure sector with 17,523 projects. The lowest number of projects is under the sector of social amenities with 9009 projects from the year 2006 to 2015.

The construction industry generates a variety of different wastes which affected to the serious environmental impacts especially air pollution is regarding lacking implementing environmental management in the stage of construction, type of construction work and construction practices on site (Muhwezi et al. 2012). The high environmental impacts also caused by the sources of construction processes (i.e., waste generation, energy consumption, and resource depletion), emissions from onsite construction equipment account for more than 50% of the total impacts, emissions from equipment (power-driven by diesel engines such as non-road construction equipment, machinery, and vehicles) (Waris et al. n.d.). The pollutant of PM is produced from the source of construction operations and building demolition (Araujo et al. 2014). Besides, similar research claimed that construction procedure such as grinding activities proved to produce a high level of particulates (Wu et al. 2016).

**Table 5.2** Number of construction projects year 2015 (CIDB 2016)

| States | No. of projects |
|---|---|
| Johor | 1110 |
| Selangor | 1472 |
| Wilayah Persekutuan | 637 |
| Sabah | 381 |
| Sarawak | 509 |
| Negeri Sembilan | 442 |
| Perak | 451 |
| Pulau Pinang | 507 |
| Pahang | 481 |
| Terengganu | 273 |
| Melaka | 275 |
| Kedah | 295 |
| Kelantan | 139 |
| Perlis | 41 |

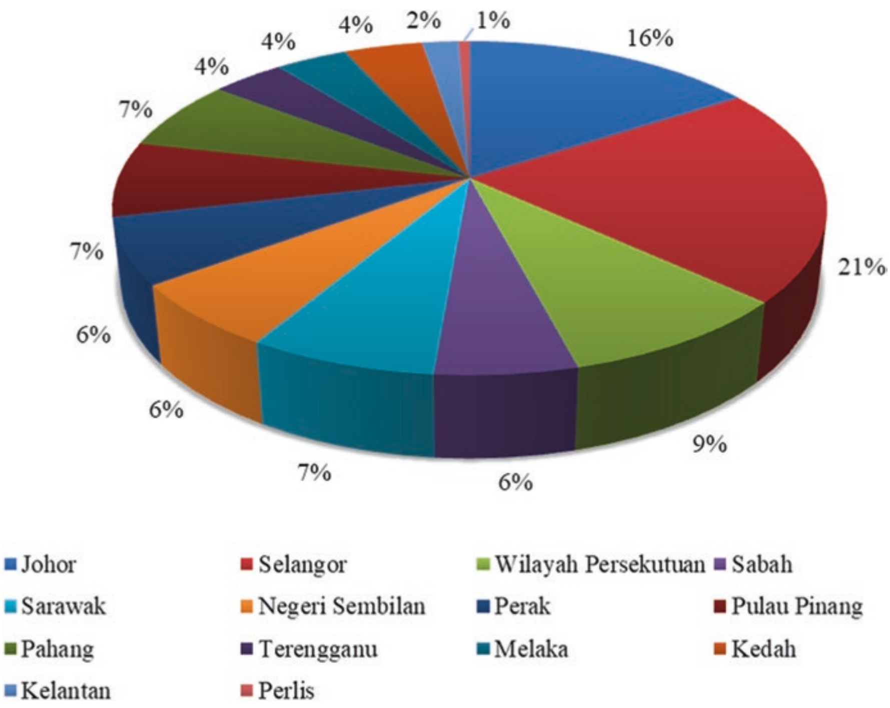



**Fig. 5.3** Percentage of industrial air pollution sources by states in Malaysia in the year 2015. (DOE 2015)

**Table 5.3** Average of rainfall in Peninsular Malaysia in the year 2015 (DIDM 2017)

| Month | Average of rainfall (mm) |
|---|---|
| January | 136.5 |
| February | 52.6 |
| March | 93.0 |
| April | 210.4 |
| May | 189.2 |
| June | 138.3 |
| July | 160.4 |
| August | 194 |
| September | 212 |
| October | 216 |
| November | 318 |
| December | 198 |

Therefore, by considering the negative impact of PM on the atmosphere, the evaluation for PMs emission from construction activities should be conducted especially when standards for PM are exceeded, and control plans are required (Sinesi et al. 2018). The rise in the number of constructions of new buildings impact the air quality and the matter related to the construction has become an important issue. The statement is proved based on the total number of construction projects for every state in Malaysia in the year 2015 (Table 5.2) affected the percentage of industrial air pollution sources by states in Malaysia year 2015 (Fig. 5.3). The states of Selangor are the highest undergoing construction project, and the result is parallel to the most polluted of air quality in Malaysia with 2%. The state of Perlis is undergoing the least number of Malaysia construction projects in 2015, and it is significant to the lowest percentage of industrial air pollution sources with 1%.

## 3 The Relationship Between Meteorological Condition and Particulate Matter Emissions in Malaysia

Trends of air pollution not only depend on the emission of certain pollutants but also on the meteorological condition in the area of interest, such as at construction sites (Barmpadimos et al. 2011). The defining of pollutant levels is based on the factors of meteorological in the transport and diffusion stage of the air pollution cycle such as wind speed, precipitation, and mixing height is well recognized for a given rate of pollutant emission (Bhaskar and Mehta 2010). It is also estimated the volume and variability of pollution are largely affected by meteorological conditions, which can have an effect on both dilution and concentration of pollutants (Olszowski 2016). Additionally, photochemical reactions depend upon favorable temperature, relative humidity, and solar radiation. Also, the accumulation and transport of particles are closely related to the synoptic system and atmospheric circulation (Li et al. 2015a, b).

Rainfall acts as a remover for atmospheric particulates and moisture restricts the possibility of resuspended soil particulate by making the soil humid (Owoade et al. 2012). Thus, the effect of precipitation scavenging effect on the reduction of gaseous and particulate pollutants specifically with a diameter below 10 μm, such as $PM_{10}$ during the wet season is greatly reduced (Kim et al. 2014). In Peninsular Malaysia (Table 5.3), the month of November is recorded as a maximum average of rainfall while February is the minimum average of rainfall in the year 2015. The highest average in November is due to the northeast monsoon or rainy season, which started in Malaysia at the end of last October. Most of the areas in Peninsular Malaysia that received more rainfall are Penang, Perak, Pahang north, south Kelantan, and Selangor by adding the percentage of anomalies from 20% to 60% (MMD n.d.). However, the month of February is in the final phase of the northeast monsoon, which recorded less rainfall. Most areas in the north and west of Peninsular Malaysia, such as Perlis, Kedah, Penang, Perak, and Selangor, recorded a reduction in rainfall from 40% to 60% below the average and the amount of rainfall is below 100 mm (MMD n.d.).

The previous study proved the rainfall removal efficiency for total suspended particles (TSP) (Guo et al. 2016), and it is shown from the agrometeorology data and mean of $PM_{10}$ based on the region in Peninsular Malaysia in the year 2010 (Fig. 5.5). Agrometeorology data (Fig. 5.4) represent 10 days rainfall average in Peninsular Malaysia for the third decade for every month from the year 1981 to 2010. Generally, all regions in Peninsular Malaysia, involving north, east, central, and south Malaysia, have experienced optimum quantity of rainfall with 50–100 mm from March to September. Also, the states of Perlis, several places in Negeri Sembilan, and Terengganu were recorded as the driest places with the least average of rainfall (0–20 mm). Heavy rain occurred mostly in the north and east region of the Peninsular region in the months of October until December. The concentration of PM was collected at selected station. In the central region, the location is chosen at Sek. Men. Perempuan Raja Zarina, Klang; the station for the east region is Sek. Keb. Chabang Tiga, Kuala Selangor; while the north region is located at Sek. Men. Pegoh 4, Ipoh; and the location station in the south region is at Sek. Men. Teknik Tuanku Jaafar, Seremban. According to Fig. 5.5, the highest concentration of $PM_{10}$ was recorded from January to May.

## 4 Effects of Particulate Matter on the Construction Workers

Workers in cement plants are exposed to airborne particulate matter (dust) generated from cement and raw materials during the production of cement exposed to cement-containing dust, although in lower concentrations (Nordby et al. 2016). According to an article by Scroll published in November 2016, construction workers in India are highly exposed to cement (contains chromium and metal) and

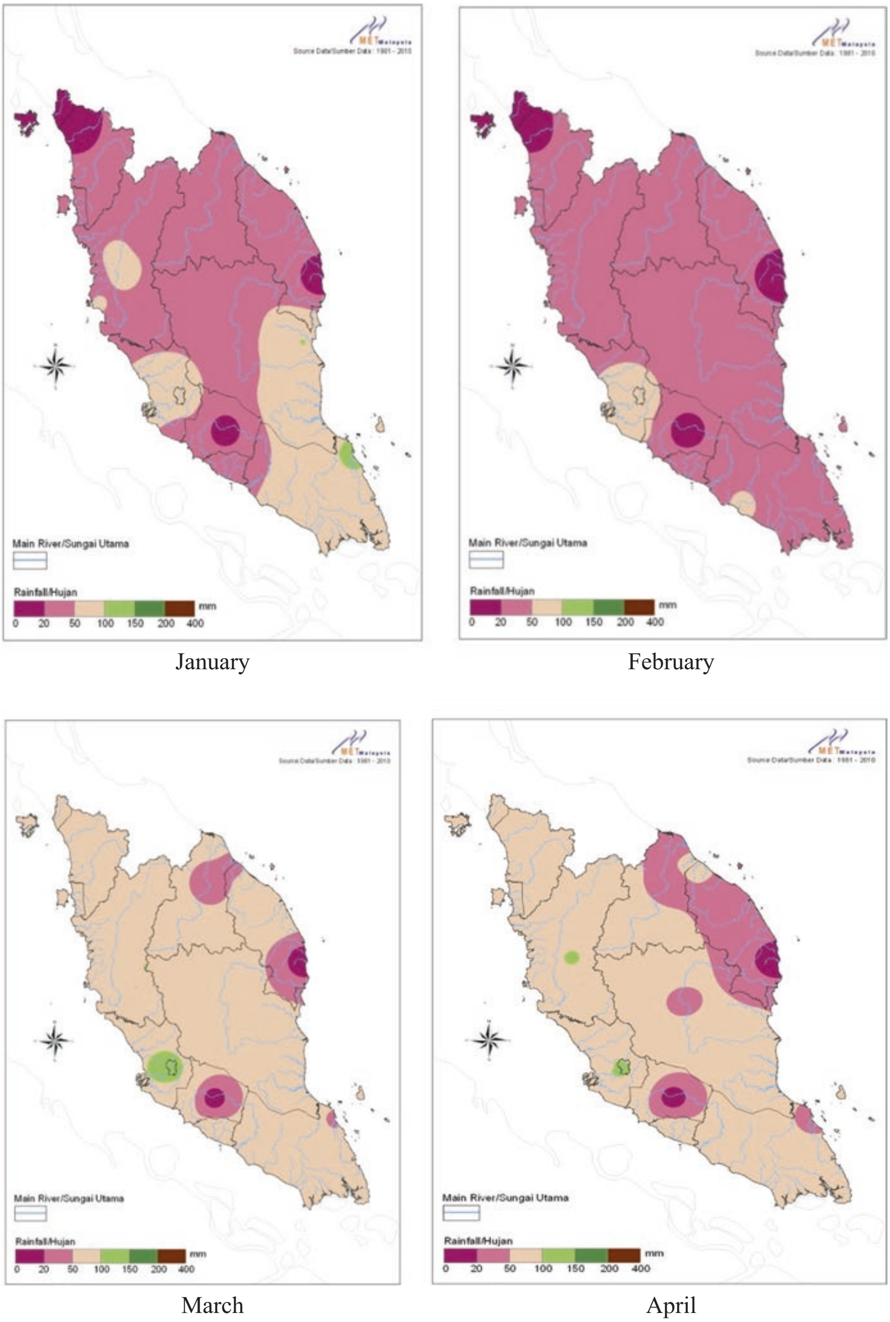
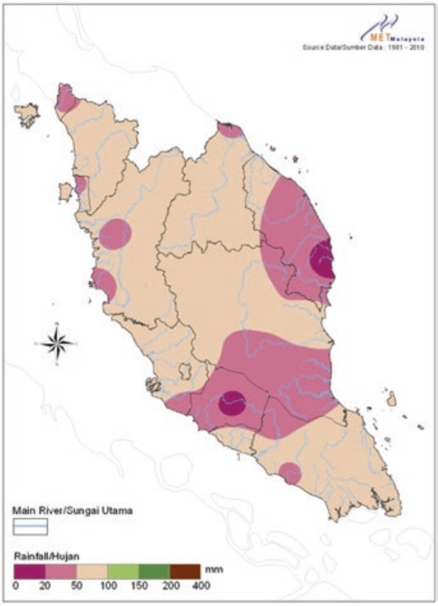
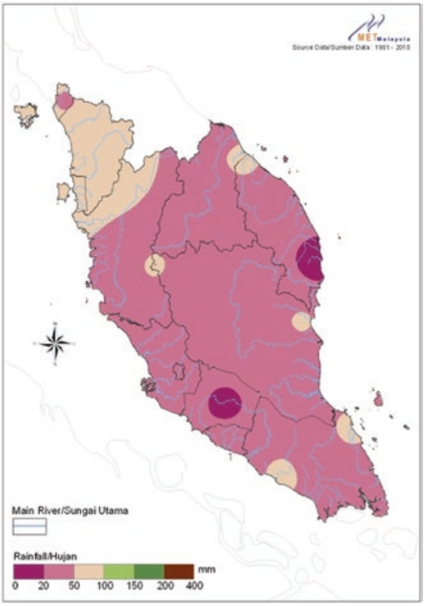


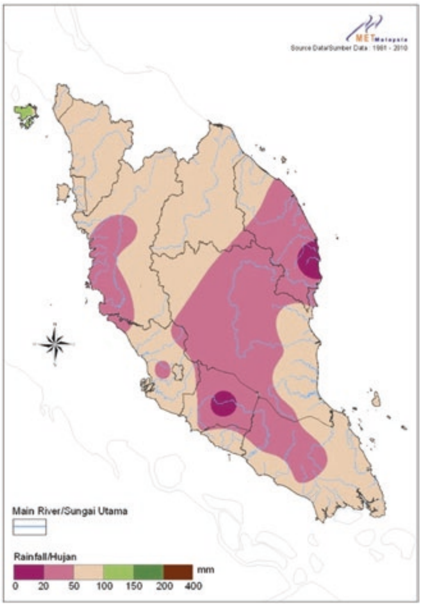

**Fig. 5.4** 10 days rainfall average for the third decade (21–30) from 1981 to 2010. (MMD n.d.)



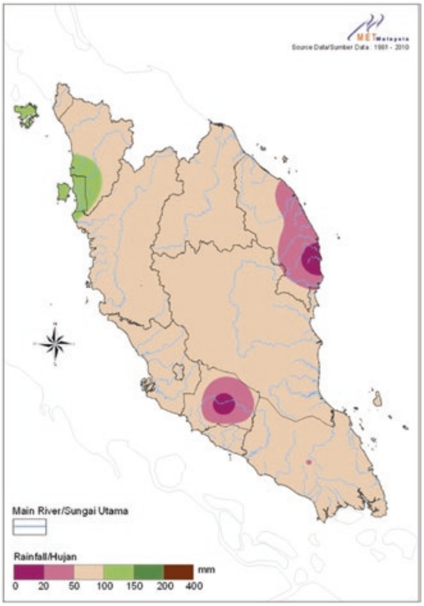

May




June

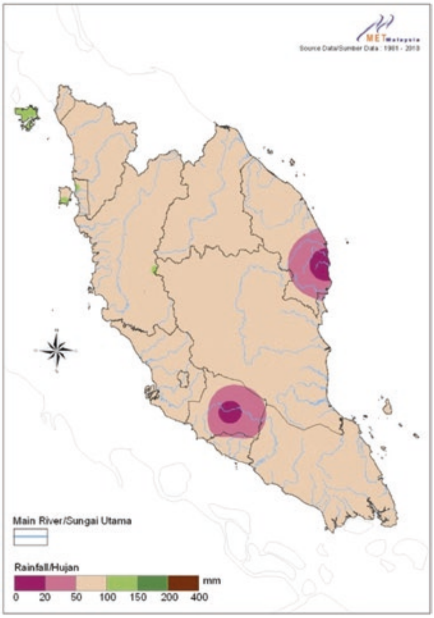



July

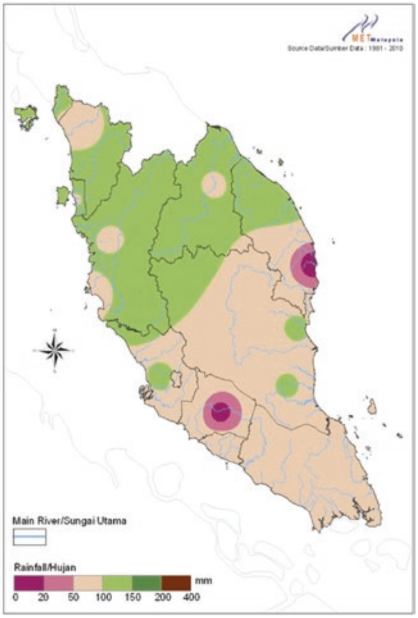



August

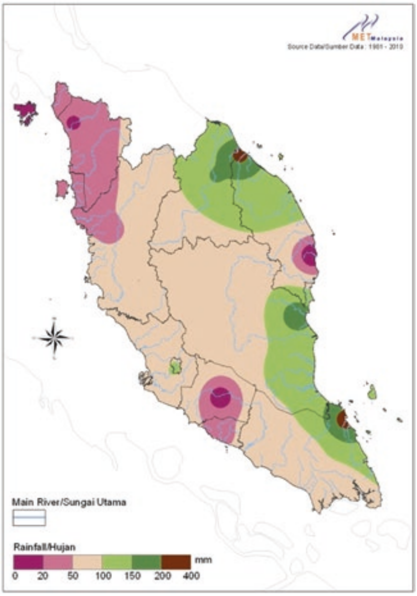
**Fig. 5.4** (continued)



September



October



December

**Fig. 5.4** (continued)

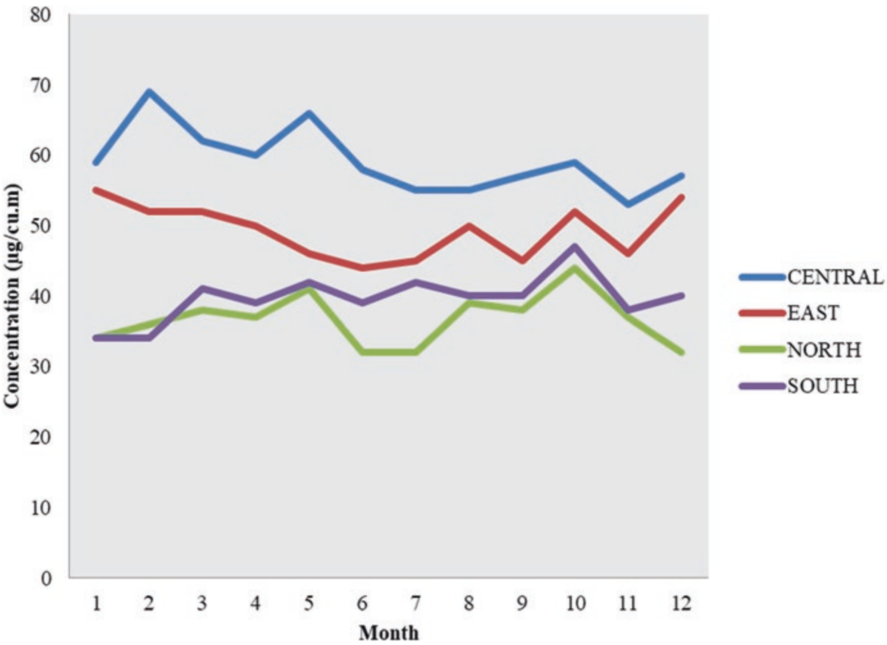



**Fig. 5.5** Mean of $PM_{10}$ based on the region in Peninsular Malaysia in the year 2010

construction dust enter the lungs and damage the alveolar macrophage and form the first line of defense in lungs and cause fibrosis (Yadav 2016). Likewise, hazardous respirable dust like steel dust, cement dust, black carbon, and rubber that are occupationally exposed were associated with acute and chronic health effects especially on the respiratory system and lung function performance (Masngut et al. 2015). Research also claimed that the continued exposure to dust particles at such sites accelerates the decline in lung functions (Sumana et al. 2015). The construction workers also were exposed to PM with tiny particles in the air with the shape of dust, soot, fly ash, wood smoke, sulfate aerosols, and diesel exhaust particles which trigger respiratory problems including bronchitis, emphysema, and asthma (Mabahwi et al. 2014). The inhalation of small particles induces an inflammatory reaction in the airways and subsequent induction of systemic inflammation and coagulation disturbances, and associates between ambient particulate air pollution and disturbances of the cardiac autonomic nervous system where there are changes in heart rate variability associated with ambient particulate air pollution (Torén et al. 2007).

Besides, the US Bureau of Labor Statistics (BLS) reported that 41% of construction workers had an abnormal pulmonary function and 1.4% of them suffered beryllium sensitivity (BeS) (Beryllium Network 2016). Consequentially, the adverse impact on the construction workers' health is caused by high exposure to PM due to the poor management at construction sites such as adopting materials, techniques of performing task, and safety and health practices (Ofori 2000).

## 5 Relationship Between Particulate Matter and Public Effects

Exposure to tiny particles present in indoor and outdoor air pollution causes about 2 million death per year (Gozzi et al. 2016). The large quantities of particulate matter emission generated from activities at construction sites could be inhaled by on-site workers and people living in the nearby neighborhood, causing serious impact on human health (Azarmi and Kumar 2016). These particulates will penetrate into sensitive regions of the respiratory system and can lead to increase in mortality and hospital admissions (Qureshi et al. 2015). Besides that, particulate matter is a very small particle that can be carried deep into the lungs and can cause inflammation and worsen the heart and lung disease risks. Aerosols like particulate matter also render harmful effects on human health, mostly lung and eye diseases, as a major component of the air pollution ($PM_{10}$ and $PM_{2.5}$) and degradation of visibility (Kanniah et al. 2016). This is also proved by other research where ultrafine particles penetrate the pulmonary alveolus causing breathing problems (Amaral et al. 2015). Numerous scientific studies have linked particulate pollution exposure to a variety of problems, including increased respiratory symptoms (such as irritation of the airways, coughing, or difficulty in breathing), decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease, and the people with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure. However, healthy people may experience temporary symptoms from exposure to elevated levels of particulates pollution (Mohddin and Aminuddin 2014).

In Malaysia, statistic shows that only one case related to Malaysian construction safety and health issues in 1961–2011 was caused by gaseous fumes and vapor (Chong and Low 2015). Although the health issues related to construction workers are low, it still has to be given equal attention as another incident due to the chronic term effect is proven by previous research. Therefore, it is necessary to cancel mass actions for people who are sensitive to air pollution which makes the construction site as a certain type of objects unprofitable in the area (Sanzhapov et al. 2016).

## 6 Conclusions

Based on all information and data received, particulate matter emission is an important contributor to air pollution due to the human activities, especially construction activities involving land clearing, drilling, blasting, ground excavation, and cut and fill operations, which generally produce abundant particulate matter. Basically, the factors of meteorological such as rainfall, temperature, relative humidity and solar radiation also taking on the role of particulate dispersion which can affect the human health. However, there is limited information regarding the research, specifically

PM emission from construction activities at the construction sites in Malaysia. Therefore, a further comprehensive study is required to determine the specific concentration of PM at the construction sites to reduce health effects on human surroundings.

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# Chapter 6
# The Contribution of Polluter Pays Principle (PPP) Approach on Environmental Pollution Reduction and Health Risk for Municipal Solid Waste (MSW)

**Mohd Filza Ikmal Irozi, Sharifah Norkhadijah Syed Ismail, Sarva Mangala Praveena, Aida Soraya Shamsuddin, and Nazri Che Dom**

**Abstract** This study estimated the contribution of the polluter pays principle (PPP) on the reduction of environmental pollution and health risk for municipal solid waste (MSW). Data of MSW volume disposed (tonnes) in the landfill from 2011 to 2017 were obtained from the respective agency. The level of GHG emission ($CH_4$, $CO_2$), leachate production, heavy metals, on-methane organic compound (NMOC), and health risks were calculated using the mathematical equation for three PPPs implementation scenarios. The average volume of waste disposed in the landfill was 199,593.48 ± 16,094.14 tonnes/year. The volume has increased by 29.4%, from 14,912.80 ± 821.17 tonnes/month in 2011 to 19,300.47 ± 829.44 tonnes/month in 2017. Prediction on waste composition was made based on the average percentage

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provided by the National Solid Waste Management Department (NSWMD). Food waste dominates in household waste composition (57,472.94 ± 4634.30 tonnes/year) followed by institutional, commercial, and industrial waste composition (21935.32 ± 1768.75 tonnes/year). The emission of $CH_4$ and $CO^2$ in scenario 1 were 6058.96 tonnes/year and 151,473.88 tonnes/year, in scenario 2 were 5193.39 tonnes/year and 145,414.93 tonnes/year, and in scenario 3 were 4327.83 tonnes/year and 121,179.11 tonnes/year; respectively. The volume of leachate produced in scenario 1, scenario 2, and scenario 3 were 29,340.24 $m^3$, 25,148.78 $m^3$, and 20,957.32 $m^3$, respectively. The total heavy metals production in leachate in scenario 1, scenario 2, and scenario 3 were 1.26 kg/year, 1.08 kg/year, and 0.901 kg/year, respectively. The total production of non-methane organic compounds (NMOCs) in scenario 1, scenario 2 and scenario 3 were 2.93E-01 $m^3$, 2.52 E-01 $m^3$, and 2.09E-01 $m^3$, respectively. The implementation of PPP has the potential to reduce environmental pollution and health risk by reducing the total waste disposed in the landfill.

**Keywords** Landfill · Municipal Solid Waste (MSW) · Polluter Pays Principle (PPP) · Health Risk

## 1 Introduction

In developing countries such as Malaysia, management of solid waste continues to be a major challenge reflected in the increasingly growing urban population and the high generation of solid waste (Abas and Wee 2014; Boateng et al. 2019). Statistics have shown that the population in urban area has increased more than 50% in the last decades in Malaysia, hence leading to the tremendous increase in solid waste generation (Abd Manaf et al. 2009; Masron et al. 2012). According to Bashir et al. (2020), waste generation has increased from 0.5 kg/capita/day in the 1980s to 1.3 kg/capita/day in 2009. On average, Malaysia had an increase of 2% of municipal solid waste (MSW) generation annually and is expected to reach 3% due to continuous rural to urban migration and economic growth. There are now 33,130 tonnes/day of solid waste management in Malaysia and is expected to reach 49,670 tonnes/day by 2030 (Bashir et al. 2020). Based on the US EPA's definition, MSW is waste consisting of everyday items from homes; institutions such as schools and hospitals; and commercial sources such as restaurants. Examples of MSW are product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. The overall solid waste composition in Malaysia is dominated by MSW with 64% and the remaining consists of industrial, commercial, and construction wastes (EA-SWMC 2009). Food/organic waste dominates the MSW (45%), followed by plastics (13–24%), diapers (12%), papers (7–9%), glass (3–6%), metals (3–6%), textile (3%) and others (Bashir et al. 2020).

Today, the compositions of MSW have changed from mainly organic (putrescible) to more inorganic (not easily putrescible), namely packaging materials, plastics, and paper that are complex in nature as a result of the rapid development and changing lifestyle in growing cities (Abdul Jalil 2010). Most of the collected MSW (about 89% of waste) were disposed of in the landfills throughout Malaysia (NSWMD 2013). The use of landfills as the primary disposal method is due to their considerable advantages, such as low technological barriers and economic efficiency (Boateng et al. 2019). However, the use of landfills in managing solid waste was associated with many problems, such as land scarcity and environmental pollution, such as air pollution (unpleasant odour, risk of fire, green-house gases emission), soil pollution (complex mixed waste to contaminate topsoil), and water pollution (leachate contaminate surface water and groundwater), which can impact human health (Shekdar 2009; Srivastara and Singhvi 2015; Chadar and Chadar 2017; Bashir et al. 2020). There is a serious need to manage the MSW in a proper way to minimize the negative impacts on the environment and human health. One of the approaches in waste management is the use of an economic instrument. The aim of an economic instrument is to persuade waste producers to divert waste from landfill or incineration towards material recovery, in order to optimize the use of resources while contributing to the costs of the waste management service (Morlok et al. 2017). One of the examples of economic instruments is "Pay-As-You-Throw" (PAYT), which is also known as unit pricing and differential and variable rate or variable fee charge systems (Morlok et al. 2017). PAYT applies the polluter-pays principle (PPP), and it stands as an international guideline for environmental policy stipulating that the person or firm who damages the environment must bear the cost of such damage (Luppi et al. 2012). The implementation of the PAYT to local authorities is to support and optimize waste management policy and improve the situation of urban waste generation by increasing waste separation and recycling (Habil and Bilitewski 2008). PAYT is a strategy in which customers are provided with an economic signal to reduce the waste they throw away, because garbage bills increase with the volume or weight of the waste they dispose of (Skumatz 2008).

The main objective of the study is to analyze the level of GHG, non-methane organic compounds (NMOCs) emission, heavy metals, and health risk from municipal solid waste landfilling practice. A similar analysis was done to the data under three different PPP implementation scenarios for municipal solid waste. This study is intended to elaborate the contribution of PPP implementation towards the variable.

## 2 Materials and Methodology

### *2.1 Study Location*

This study was conducted in Malaysia, situated in the Southeast Asia region. A district in Selangor state (Peninsular Malaysia) was selected as the study area known as Klang (Fig. 6.1). Based on a 2010 census, the total population in this area was 861,189 (changed + 2.36% every year) with area covered 672 $km^2$ and density of 1374/$km^2$. According to the National Solid Waste Management Department, NSWMD (2013), the study area is the major waste generator in the country with

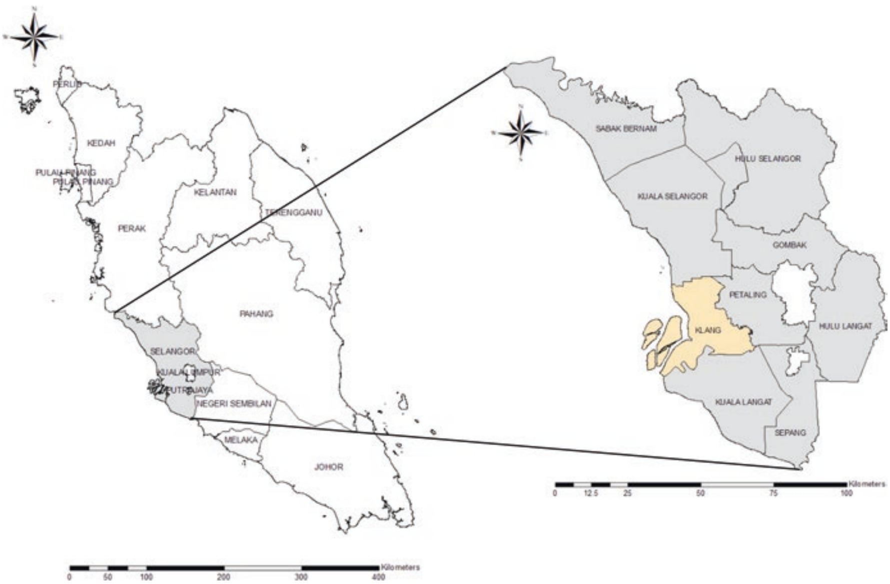


**Fig. 6.1** Location of the study area

1.35 kg/capita/day or 9702 metric tonne/day. The solid waste management services in this area are conducted three times a week for residential areas and daily for commercial and trash bins. Public cleaning services and lawn mowing and roadside perimeter drain cleaning are performed twice a month. The collected waste was disposed of in the sanitary landfill located 20 km to the North West of Kuala Lumpur. The landfill total area is 52 ha including six phases for waste disposal and was designed to receive approximately 2050 tonnes of waste per day within a 10-year lifespan operation started from 2007 (Abushammala et al. 2014).

## *2.2 Data Collection*

The secondary data of the volume of MSW were collected from 2011 to 2017. The datasets obtained the volume of solid waste that has been disposed of in the landfill by month and year. The fractions of MSW were separated into sources of waste (i.e. household, commercial, and institutional, and industrial) and compositions (food and organic, plastics, paper, diapers, garden, etc.), and the percentage was estimated based on literature data on the fractions of MSW from the NSWMD (2013).

## *2.3 Greenhouse Gas (GHG) Emission from Landfill*

Methane ($CH_4$) and carbon dioxide ($CO_2$) are the main constituents of landfill gases (LFG) (Feuyit et al. 2019). They are generated during the putrefaction of waste in the landfill and can contribute to global warming (Latake et al. 2015). The $CH_4$ emission was calculated based on the waste deposited in the landfill by using Eqs. (6.1) and (6.2).

$$\mathrm{DOC} = \sum\left(0.15\mathrm{F} + 0.20\mathrm{G} + 0.40\mathrm{P} + 0.43\mathrm{W} + 0.24\mathrm{T} + 0.24\mathrm{D} + 0.0\mathrm{O}\right) \quad (6.1)$$

The degradable organic carbon (DOC) was calculated by using Eq. (6.1), where the default carbon content value for food waste, garden waste, paper and tetra pak, wood, textile, diapers, and other waste (rubber, leather, plastics, metal, glass) is 0.15, 0.20, 0.40, 0.43, 0.24, 0.24, and 0.0 (IPCC 2006). F is the fraction of food waste in MSW, G is the fraction of garden waste in MSW, P is the fraction of paper waste in MSW, W is the fraction of wood in MSW, T is the fraction of textile in MSW, D is the fraction of diapers in MSW and O is the fraction of other waste in MSW (NSWMD 2013). Thus, $CH_4$ gases emission was calculated by using Eq. (6.2):

$$\mathrm{CH4\ \ emission}\left(\mathrm{tonne}\right) = \Sigma i\left(\mathrm{MSWT} \times \mathrm{MSWF} \times \mathrm{MCF} \times \mathrm{DOC} \times \mathrm{F}\right) \times \frac{16}{12} \quad (6.2)$$

MSWT is the total of municipal solid waste disposed of in the landfills (tonne). The fraction of MSW (MSWF) is 0.8. According to Zhang et al. (2010), Malaysia disposed 80% of waste in the landfills. MCF is methane correction factor, and it ranges from 0.4 to 1.0; the value 0.6 can be used for Malaysia's landfills (Johari et al. 2012). The degradable organic carbon (DOC) will be calculated by using Eq. (6.1). The degradable organic carbon fraction (DOCF) is 0.77 (Johari et al. 2012). The default value for Fraction (F) is 0.5 where landfill approximately generates 50% of methane gases (IPCC 2006). The $CO_2$ equivalent was calculated by using the following equation (Eq. 6.3):

$$\mathrm{The\ \ total\ \ carbon\ \ dioxide\ \ equivalent}\ \left(\mathrm{tonne}\right) = \sum\left(\mathrm{TCH4} \times 25\right) \quad (6.3)$$

The total carbon dioxide equivalent ($TCO_2$) is defined as 100-year global warming potential (GWP) factors by multiplying the estimated total of $CH_4$ emission ($TCH_4$) by 25 as $CH_4$ gases has 25 times more GWP than $CO_2$ (IPCC 2006).

**Table 6.1** The default concentration of landfill gas (NMOCs) and sulphides

| Compound | Concentration (ppmv) |
|---|---|
| *NMOCs* | |
| Acrylonitrile | 6.33 |
| Carbon disulphide | 0.58 |
| Carbon tetrachloride | 0.004 |
| Carbonyl sulphide | 0.49 |
| Chlorobenzene | 0.25 |
| Chloroethane | 1.25 |
| Chloroform | 0.03 |
| Dichlorobenzene | 0.21 |
| Dichloromethane | 14.3 |
| Ethylbenzene | 4.61 |
| *Sulfides* | |
| Hydrogen sulphide | 35.5 |

Source: US EPA (1997)

## *2.4 Non-methane Organic Compounds (NMOCs) Emission*

The decomposition process in the landfill will produce landfill gas (LFG), which contains NMOCs (Yucekaya 2014). The exposure to NMOCs causes potential health risks, such as respiratory problems and cancer (Macklin et al. 2011). The landfill gas constituents of NMOCs were calculated by using Eq. (6.4) (US EPA 2005);

$$\text{NMOC emission} = \Sigma p\left(1.82 \times \text{TCH4} \times \left(\text{CP}/10\hat{\ }6\right)\right) \tag{6.4}$$

The NMOCs were calculated in $m^3$ per year ($m^3$-year) unit. The emissions of NMOCs were calculated based on the total volume of methane gases produced from Eqs. (6.1) and (6.2). The total volume of $TCH_4$ (tonnes) was converted to $m^3$, in which 1 tonne = $0.42m^3$. P refers to the type of NMOCs that were considered in this study as shown in Table 6.1. The multiplication factor of 1.82 was used in the calculation assuming that approximately 55% of landfill gas is $CH_4$ and 45% is $CO_2$ and other constituents produced in the landfill. The CP is the default value for each compound P as shown in Table 6.1, and the 1 × 10ˆ6 is the conversion unit of ppmv to $m^3$.

## *2.5 Heavy Metal in Leachate Production*

Leachate production was calculated by using Eq. 6.5 (KPKT 2015);

$$\text{Volume of leachate} = \Sigma(\text{MSWT} \times 0.21) \tag{6.5}$$

The volume of leachate (VL) was calculated in ($m^3$) unit. The MSWT is the total waste disposed of in the landfill (tonne) and 0.21 refers to one tonne of waste that will generate 0.21 $m^3$ of leachate (KPKT 2015).

Landfill leachate is one of the major anthropogenic heavy metal sources in nature. The risk of heavy metal contamination is due to the consumption of food and water that contain the element of heavy metals. The bioaccumulation of heavy metals in the body will cause chronic health effects such as cancer. The quantity of heavy metal released from the leachate was calculated by using Eq. (6.6):

$$\text{Heavy metal quantity} = \Sigma h(\text{VL} \times ch) \tag{6.6}$$

The heavy metal quantity (HQ) was calculated in kg per year (kg-year) unit, and *h* refers to the type of heavy metals that were calculated in this study, such as Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn). VL is the total volume of leachate produced in $m^3$ and was calculated from Eq. 6.5. The concentration (C) is the average of heavy metal concentration (kg-$m^3$) in the landfill leachate which the average value from a case study of Malaysia landfill leachate characteristics was used to estimate the emission per year (Cd = 2.00E-06; Cr = 6.00E-06; Cu = 5.00E-06; Pb = 1.50E-05; Zn = 1.50E-05) (Agamuthu and Fauziah 2010).

## 2.6 Health Risk Evaluation

The health risk assessment was conducted to identify the potential health risk of inhalation exposure to the NMOCs from the landfill. The health risk assessment will be conducted among adult men, adult women, and the child community in the study area. From a toxicological point of view, acrylonitrile, carbon tetrachloride, chloroform, and dichloromethane were classified as carcinogen agents. However, acrylonitrile, carbon tetrachloride, and dichloromethane were also classified as non-carcinogen agents. Hence, these compounds were calculated for cancer risk and non-cancer risk. Other compounds such as carbon disulphide, chloroethane, ethylbenzene, and hydrogen sulphide have not been classified as carcinogen agents by the International Agency for Research on Cancer (IARC), while they have important non-carcinogenic toxic potentials. The health risk assessment will be calculated by using Eq. (6.7) (US EPA 2009).

$$\text{EHE}i = \Sigma i\left(\frac{\text{C}i \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}\right) \tag{6.7}$$

EHE*i* is the exposure to pollutant P (Table 6.1). *i* is the type of pollutant compound, P and C*i* is the concentration of NMOCs calculated from Eq. (6.4). The default value of inhalation rate (IR) for long-term exposure varies for adult men, adult women, and children, which are 8395 $m^3$/year, 7665 $m^3$/year, and 5475 $m^3$/year, respectively (WHO/IPCS 1994, WHO 1999). The exposure frequency (EF) is 1 year (365 days). The exposure duration (ED) is the lifespan of the landfill which is 20 years (Ministry of Housing and Local Government (KPKT) 2015). The average body weight (BW) for adult men is 66.56 kg, while for adult women it is 58.44 kg (Azmi et al. 2009). The average body weight (BW) for a child of 31.8 kg was used (US EPA 2009). The averaging time (AT) for non-carcinogenic effect is equal to the exposure duration (ED), while for carcinogenic effect, the averaging time for adult men is 72.7 years, while for adult women is 77.6 years (DOSM 2019).

The lifetime cancer risk (LCR) for carcinogenic risk was calculated by using Eq. (6.8);

$$\text{LCR} = \Sigma i\left(\text{EHE} \times \text{URF}\right) \tag{6.8}$$

where EHE is the inhalation exposure to pollutant, and URF is the inhalation unit risk factor that was obtained from the Integrated Risk Information System (IRIS), US EPA. The CR values $>10^{-6}$ indicate that potential carcinogenic effects may occur, whereas CR values $\leq 10^{-6}$ represent an admissible level (Feuyit et al. 2019).

For non-cancer risk induced by inhalation of NMOCs, hazard quotient (HQ) was used by using Eq. (6.9)

$$\text{Hazard Quotient} = \Sigma i\left(\text{EHE} / \text{RfC}\right) \tag{6.9}$$

The inhalation reference concentration (RfC) for non-carcinogenic risk was obtained from the Integrated Risk Information System (IRIS), US EPA. HQ values below 1.0 indicate that the pollutant under investigation is not likely to cause health impairment, whereas HQ values above 1.0 indicate risk levels that are likely to damage health (Feuyit et al. 2019).

## *2.7 PPP Implementation Scenarios*

Three different scenarios of MSW disposal method were created based on the literature review (Table 6.2). Scenario 1 consists of 70% of landfilling activity, 20% of recycling, 5% of incineration, and 5% of composting activity. In scenario 2, 60% of the waste has been landfilled, 20% of recycling, 10% of incineration, and 10% of

**Table 6.2** Scenario of MSW disposal method

| Disposal method | Scenario 1 (%) | Scenario 2 (%) | Scenario 3 (%) |
|---|---|---|---|
| Landfill | 70 | 60 | 50 |
| Recycle | 20 | 20 | 25 |
| Incineration | 5 | 10 | 15 |
| Composing | 5 | 10 | 10 |

the waste has been composted. In scenario 3, 50% of the MSW has been estimated landfilled, 25% of recycling, 15% of incineration, and 10% has been composted. The emission from the landfill has been estimated by using a mathematical equation, while for recycle, incineration, and composting, the avoidance of emission has been estimated by using the same equation.

# 3 Results

## *3.1 Total Volume of MSW Disposed in the Sanitary Landfill*

Table 6.3 shows the volume of solid waste disposed in the landfill from 2011 to 2017. The volume of waste that has been disposed of shown an increasing pattern. The highest volume of solid waste disposed of was in 2017 (231,605 tonnes/year) with the mean ± SD of 19,300.47 ± 829.44 tonnes/year.

**Table 6.3** The total volume of solid waste disposed of in Jeram landfill (2011–2017)

| Month/ year | Solid waste disposed of in Jeram landfill (tonnes/year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 14,857.88 | 18,141.89 | 17,752.05 | 17,509.88 | 16,599.55 | 15,592.51 | 21,225.60 |
| February | 13,643.14 | 16,073.45 | 15,898.69 | 14,435.70 | 14,987.17 | 14,661.38 | 17,968.04 |
| March | 14,946.38 | 16,816.00 | 16,327.37 | 15,255.97 | 16,434.41 | 15,058.41 | 19,976.91 |
| April | 14,635.24 | 16,395.24 | 16,368.96 | 15,898.36 | 15,827.07 | 15,032.03 | 18,552.34 |
| May | 14,293.91 | 16,908.78 | 16,570.20 | 16,425.29 | 15,857.25 | 16,013.09 | 19,320.88 |
| June | 14,152.00 | 15,620.39 | 15,234.33 | 16,566.55 | 16,168.70 | 15,260.63 | 18,991.99 |
| July | 15,212.24 | 16,466.87 | 17,595.90 | 17,116.36 | 16,235.22 | 16,917.88 | 18,995.75 |
| August | 15,985.03 | 15,383.99 | 16,757.09 | 16,024.48 | 16,044.96 | 19,371.41 | 19,264.74 |
| September | 14,467.28 | 15,378.63 | 16,344.14 | 15,686.28 | 15,301.52 | 17,548.19 | 18,528.3 |
| October | 14,843.00 | 16,001.95 | 16,962.07 | 16,689.30 | 15,931.96 | 19,087.59 | 19,683.97 |
| November | 15,206.47 | 17,000.18 | 16,245.01 | 15,728.03 | 16,262.52 | 18,844.31 | 19,468.67 |
| December | 16,710.99 | 18,183.34 | 17,079.04 | 16,842.80 | 16,184.52 | 19,688.31 | 19,628.44 |
| *Total per year* | 178,953.56 | 198,370.71 | 199,134.85 | 194,179.00 | 191,834.85 | 203,075.74 | 231,605.63 |
| Min | 13,643.14 | 15,378.63 | 15,234.33 | 14,435.70 | 14,987.17 | 14,661.38 | 17,968.04 |
| Max | 16,710.99 | 18,183.34 | 17,752.05 | 17,509.88 | 16,599.55 | 19,688.31 | 21,225.60 |
| Mean | 14,912.80 | 16,530.89 | 16,594.57 | 16,181.58 | 15,986.24 | 16,922.98 | 19,300.47 |
| SD | 821.17 | 941.65 | 699.41 | 852.89 | 457.59 | 1905.46 | 829.44 |

## 3.2 MSW Compositions

Since no data for waste volume by composition were obtained, this study made an estimation based on the percentage provided by the National Solid Waste Department (NSWD) (2013). The volume in Table 6.4 was estimated at the percentage as follow; food waste (44.3%), plastic (11.7%), paper (9.4%), diapers (11.7), garden waste (5.9%), glass (3.5%), metal (2.2%), textile (3.9%), Tetra Pak (1.4), rubber (2.1%), leather (0.3%), wood (1.4%), households hazardous waste (HHW) (1.5%), and others (0.7%) (NSWMD 2013). A similar approach was used for waste composition data for institutional, commercial, and industrial in Table 6.5.

## 3.3 Greenhouse Gas (GHG) Emission, Leachate Production, Heavy Metals, and Non-methane Organic Compound (NMOC) from Landfilling Practice

Table 6.6 highlights the estimated emission of greenhouse gases (i.e. $CH_4$ and $CO_2$), leachate production, heavy metals, and NMOC from the total volume of waste disposed in landfill. The mean ± SD of methane gases emission was 8655.65 ± 697.95 tonnes/year and 216,391.26 ± 17,448.63 tonnes/year of carbon dioxide equivalent.

The mean ± SD of estimated production of leachate was 41,914.63 ± 3379.77$m^3$. There were five heavy metals elements considered in this study as Cd, Cr, Cu, Pb, and Zn. Pb (6.29E-01 ± 0.05 kg) and Zn (6.29E-01 ± 0.05 kg) were at the highest emission in leachate compared to other heavy metals. Other elements such as Cd (8.38E-02 ± 0.01 kg), Cr (2.51E-01 ± 0.02 kg), and Cu (2.10E-01 ± 0.02 kg) were determined at lower rate. The estimated emission of NMOC was determined as high for hydrogen sulphide with the mean and SD of 2.35E-01 ± 1.89E-02 $m^3$.

## 3.4 Health Risk

Table 6.7 shows the lifetime cancer risk (LCR) for carcinogenic risk compounds from the NMOC, such as acrylonitrile, carbon tetrachloride, chloroform, and dichloromethane. The LCR for each compound was within an acceptable range. The hazard quotient (HQ) for non-carcinogenic risk compounds such as acrylonitrile, carbon disulphide, carbon tetrachloride, chloroethane, dichloromethane, ethylbenzene, and hydrogen sulphide. The HQ for each compound was within an acceptable range.

**Table 6.4** Volume of household waste (tonnes/year) by its composition

| | Volume of waste (tonnes/year) | | | | | | | Statistic | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of waste | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Min | Max | Mean | SD |
| Food waste | 51,529.68 | 57,120.85 | 57,340.88 | 55,913.84 | 55,238.85 | 58,475.66 | 66,690.84 | 51,529.68 | 66,690.84 | 57,472.94 | 4634.31 |
| Plastics | 13,609.42 | 15,086.09 | 15,144.21 | 14,767.31 | 14,589.04 | 15,443.91 | 17,613.61 | 13,609.42 | 17,613.61 | 15,179.08 | 1223.96 |
| Paper | 10,934.06 | 12,120.45 | 12,167.14 | 11,864.34 | 11,721.11 | 12,407.93 | 14,151.10 | 10,934.06 | 14,151.10 | 12,195.16 | 983.35 |
| Diapers | 13,609.42 | 15,086.09 | 15,144.21 | 14,767.31 | 14,589.04 | 15,443.91 | 17,613.61 | 13,609.42 | 17,613.61 | 15,179.08 | 1223.96 |
| Garden waste | 6862.87 | 7607.52 | 7636.82 | 7446.76 | 7356.87 | 7787.95 | 8882.08 | 6862.87 | 8882.08 | 7654.41 | 617.21 |
| Glass | 4071.19 | 4512.93 | 4530.32 | 4417.57 | 4364.24 | 4619.97 | 5269.03 | 4071.19 | 5269.03 | 4540.75 | 366.14 |
| Metal | 2559.04 | 2836.70 | 2847.63 | 2776.76 | 2743.24 | 2903.98 | 3311.96 | 2559.04 | 3311.96 | 2854.19 | 230.15 |
| Textiles | 4536.47 | 5028.70 | 5048.07 | 4922.44 | 4863.01 | 5147.97 | 5871.20 | 4536.47 | 5871.20 | 5059.69 | 407.99 |
| Tetra Pak | 1628.48 | 1805.17 | 1812.13 | 1767.03 | 1745.70 | 1847.99 | 2107.61 | 1628.48 | 2107.61 | 1816.30 | 146.46 |
| Rubber | 2442.72 | 2707.76 | 2718.19 | 2650.54 | 2618.55 | 2771.98 | 3161.42 | 2442.72 | 3161.42 | 2724.45 | 219.69 |
| Leather | 348.96 | 386.82 | 388.31 | 378.65 | 374.08 | 396.00 | 451.63 | 348.96 | 451.63 | 389.21 | 31.38 |
| Wood | 1628.48 | 1805.17 | 1812.13 | 1767.03 | 1745.70 | 1847.99 | 2107.61 | 1628.48 | 2107.61 | 1816.30 | 146.46 |
| HHW | 1744.80 | 1934.11 | 1941.56 | 1893.25 | 1870.39 | 1979.99 | 2258.15 | 1744.80 | 2258.15 | 1946.04 | 156.92 |
| Others | 814.24 | 902.59 | 906.06 | 883.51 | 872.85 | 923.99 | 1053.81 | 814.24 | 1053.81 | 908.15 | 73.23 |

**Estimated based on Klang valley household waste compositions**: Food waste (44.3%), Plastic (11.7%), Paper (9.4%), Diapers (11.7), Garden waste (5.9%), Glass (3.5%), Metal (2.2%), Textile (3.9%), Tetra Pak (1.4), Rubber (2.1%), Leather (0.3%), Wood (1.4%), Households hazardous waste, HHW (1.5%), Others (0.7%) (NSWMD 2013)

**Table 6.5** Volume of institutional, commercial, and industrial waste (tonnes/year) by its composition

| | Volume of waste (tonnes/year) | | | | | | | Statistic | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of waste | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Min | Max | Mean | SD |
| Food waste | 19,667.00 | 21,800.94 | 21,884.92 | 21,340.27 | 21,082.65 | 22,318.02 | 25,453.46 | 19,667.00 | 25,453.46 | 21,935.32 | 1768.75 |
| Plastics | 16,222.14 | 17,982.30 | 18,051.57 | 17,602.33 | 17,389.83 | 18,408.82 | 20,995.05 | 16,222.14 | 20,995.05 | 18,093.15 | 1458.93 |
| Paper | 12,839.92 | 14,233.10 | 14,287.93 | 13,932.34 | 13,764.15 | 14,570.68 | 16,617.70 | 12,839.92 | 16,617.70 | 14,320.83 | 1154.75 |
| Diapers | 501.07 | 555.44 | 557.58 | 543.70 | 537.14 | 568.61 | 648.50 | 501.07 | 648.50 | 558.86 | 45.06 |
| Garden waste | 1753.75 | 1944.03 | 1951.52 | 1902.95 | 1879.98 | 1990.14 | 2269.74 | 1753.75 | 2269.74 | 1956.02 | 157.72 |
| Glass | 2004.28 | 2221.75 | 2230.31 | 2174.80 | 2148.55 | 2274.45 | 2593.98 | 2004.28 | 2593.98 | 2235.45 | 180.25 |
| Metal | 3069.05 | 3402.06 | 3415.16 | 3330.17 | 3289.97 | 3482.75 | 3972.04 | 3069.05 | 3972.04 | 3423.03 | 276.01 |
| Textiles | 1377.94 | 1527.45 | 1533.34 | 1495.18 | 1477.13 | 1563.68 | 1783.36 | 1377.94 | 1783.36 | 1536.87 | 123.92 |
| Tetra Pak | 1879.01 | 2082.89 | 2090.92 | 2038.88 | 2014.27 | 2132.30 | 2431.86 | 1879.01 | 2431.86 | 2095.73 | 168.99 |
| Rubber | 1002.14 | 1110.88 | 1115.16 | 1087.40 | 1074.28 | 1137.22 | 1296.99 | 1002.14 | 1296.99 | 1117.72 | 90.13 |
| Leather | 313.17 | 347.15 | 348.49 | 339.81 | 335.71 | 355.38 | 405.31 | 313.17 | 405.31 | 349.29 | 28.16 |
| Wood | 939.51 | 1041.45 | 1045.46 | 1019.44 | 1007.13 | 1066.15 | 1215.93 | 939.51 | 1215.93 | 1047.87 | 84.49 |
| HHW | 688.97 | 763.73 | 766.67 | 747.59 | 738.56 | 781.84 | 891.68 | 688.97 | 891.68 | 768.43 | 61.96 |
| Others | 375.80 | 416.58 | 418.18 | 407.78 | 402.85 | 426.46 | 486.37 | 375.80 | 486.37 | 419.15 | 33.80 |

**Malaysia Institutional, Commercial, and Industrial Waste Compositions**: Food waste (31.4%), Plastic (25.9%), Paper (20.5%), Diapers (0.8), Garden waste (2.8%), Glass (3.2%), Metal (4.9%), Textile (2.2%), Tetra Pak (3.0), Rubber (1.6%), Leather (0.5%), Wood (1.5%), Households hazardous waste, HHW (1.1%), Others (0.6%) (NSWMD 2013)

**Table 6.6** The emission of greenhouse gases ($CH_4$, $CO_2$) and environmental pollution of the current waste landfilling practice

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | Min | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total volume of waste (tonnes/year) | 178,953.56 | 198,370.71 | 199,134.85 | 194,179.00 | 191,834.85 | 203,075.74 | 231,605.63 | 1,397,154.34 | 178,953.56 | 231,605.63 | 199,593.48 | 16094.14 |
| *GHG gases* | | | | | | | | | | | | |
| $CH_4$ (t) | 7760.57 | 8602.62 | 8635.76 | 8420.84 | 8319.19 | 8806.66 | 10,043.90 | 60,589.55 | 7760.57 | 10,043.90 | 8655.65 | 697.95 |
| $CO_2$ (t) | 194,014.29 | 215,065.59 | 215,894.04 | 210,521.10 | 207,979.67 | 220,166.59 | 251,097.56 | 1,514,738.85 | 194,014.29 | 251,097.56 | 216,391.26 | 17,448.63 |
| Leachate ($m^3$) | 37,580.25 | 41,657.85 | 41,818.32 | 40,777.59 | 40,285.32 | 42,645.91 | 48,637.18 | 293,402.41 | 37,580.25 | 48,637.18 | 41,914.63 | 3379.77 |
| *Heavy metals(kg)* | | | | | | | | | | | | |
| Cadmium (Cd) | 7.52E-02 | 8.33E-02 | 8.36E-02 | 8.16E-02 | 8.06E-02 | 8.53E-02 | 9.73E-02 | 5.87E-01 | 7.52E-02 | 9.73E-02 | 8.38E-02 | 0.01 |
| Chromium (Cr) | 2.25E-01 | 2.50E-01 | 2.51E-01 | 2.45E-01 | 2.42E-01 | 2.56E-01 | 2.92E-01 | 1.76E+00 | 2.25E-01 | 2.92E-01 | 2.51E-01 | 0.02 |
| Copper (Cu) | 1.88E-01 | 2.08E-01 | 2.09E-01 | 2.04E-01 | 2.01E-01 | 2.13E-01 | 2.43E-01 | 1.47E+00 | 1.88E-01 | 2.43E-01 | 2.10E-01 | 0.02 |
| Lead (Pb) | 5.64E-01 | 6.25E-01 | 6.27E-01 | 6.12E-01 | 6.04E-01 | 6.40E-01 | 7.30E-01 | 4.40E+00 | 5.64E-01 | 7.30E-01 | 6.29E-01 | 0.05 |
| Zinc (Zn) | 5.64E-01 | 6.25E-01 | 6.27E-01 | 6.12E-01 | 6.04E-01 | 6.40E-01 | 7.30E-01 | 4.40E+00 | 5.64E-01 | 7.30E-01 | 6.29E-01 | 0.05 |
| *NMOC ($m^3$)* | | | | | | | | | | | | |
| Acrylonitrile | 3.76E-02 | 4.16E-02 | 4.18E-02 | 4.07E-02 | 4.03E-02 | 4.26E-02 | 4.86E-02 | 2.93E-01 | 3.76E-02 | 4.86E-02 | 4.19E-02 | 3.38E-03 |
| Carbon disulphide | 3.44E-03 | 3.81E-03 | 3.83E-03 | 3.73E-03 | 3.69E-03 | 3.90E-03 | 4.45E-03 | 2.69E-02 | 3.44E-03 | 4.45E-03 | 3.84E-03 | 3.09E-04 |
| Carbon tetrachloride | 2.37E-05 | 2.63E-05 | 2.64E-05 | 2.57E-05 | 2.54E-05 | 2.69E-05 | 3.07E-05 | 1.85E-04 | 2.37E-05 | 3.07E-05 | 2.65E-05 | 2.13E-06 |
| Carbonyl sulphide | 2.91E-03 | 3.22E-03 | 3.23E-03 | 3.15E-03 | 3.12E-03 | 3.30E-03 | 3.76E-03 | 2.27E-02 | 2.91E-03 | 3.76E-03 | 3.24E-03 | 2.61E-04 |

(continued)

**Table 6.6** (continued)

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | Min | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorobenzene | 1.48E-03 | 1.64E-03 | 1.65E-03 | 1.61E-03 | 1.59E-03 | 1.68E-03 | 1.92E-03 | 1.16E-02 | 1.48E-03 | 1.92E-03 | 1.65E-03 | 1.33E-04 |
| Chloroethane | 7.42E-03 | 8.22E-03 | 8.25E-03 | 8.05E-03 | 7.95E-03 | 8.41E-03 | 9.60E-03 | 5.79E-02 | 7.42E-03 | 9.60E-03 | 8.27E-03 | 6.67E-04 |
| Chloroform | 1.78E-04 | 1.97E-04 | 1.98E-04 | 1.93E-04 | 1.91E-04 | 2.02E-04 | 2.30E-04 | 1.39E-03 | 1.78E-04 | 2.30E-04 | 1.98E-04 | 1.60E-05 |
| Dichloromethane | 8.48E-02 | 9.40E-02 | 9.44E-02 | 9.20E-02 | 9.09E-02 | 9.63E-02 | 1.10E-01 | 6.62E-01 | 8.48E-02 | 1.10E-01 | 9.46E-02 | 7.63E-03 |
| Ethylbenzene | 2.73E-02 | 3.03E-02 | 3.04E-02 | 2.97E-02 | 2.93E-02 | 3.10E-02 | 3.54E-02 | 2.14E-01 | 2.73E-02 | 3.54E-02 | 3.05E-02 | 2.46E-03 |
| Hydrogen sulphide ($H_2S$) | 2.11E-01 | 2.33E-01 | 2.34E-01 | 2.29E-01 | 2.26E-01 | 2.39E-01 | 2.73E-01 | 1.64E+00 | 2.11E-01 | 2.73E-01 | 2.35E-01 | 1.89E-02 |

**Table 6.7** The carcinogenic and non-carcinogenic health risk of NMOCs

| | Carcinogenic risk (Lifetime cancer risk, LCR) | | |
|---|---|---|---|
| Non-methane organic compound (NMOCs) | Adult women | Adult men | Child |
| Acrylonitrile | 3.74E-13 | 3.59E-13 | 4.90E-13 |
| Carbon tetrachloride | 2.08E-17 | 2.00E-17 | 2.73E-17 |
| Chloroform | 5.99E-16 | 5.76E-16 | 7.86E-16 |
| Dichloromethane | 1.24E-16 | 1.19E-16 | 1.63E-16 |
| | *Non-carcinogenic health risk (Hazard quotient, HQ)* | | |
| Acrylonitrile | 2.83E-09 | 2.91E-09 | 1.44E-08 |
| Carbon disulphide | 9.08E-08 | 9.32E-08 | 4.62E-07 |
| Carbon tetrachloride | 8.95E-11 | 9.18E-11 | 4.56E-10 |
| Chloroethane | 2.80E-06 | 2.87E-06 | 1.42E-05 |
| Dichloromethane | 1.92E-06 | 1.97E-06 | 9.77E-06 |
| Ethylbenzene | 1.03E-05 | 1.06E-05 | 5.25E-05 |
| Hydrogen sulphide | 1.59E-08 | 1.63E-08 | 8.09E-08 |

## *3.5 Greenhouse Gas (GHG) Emission, Leachate Production, Heavy Metals, and Non-methane Organic Compound (NMOC) from Polluter Pay Principle practice*

Table 6.8 shows the greenhouse gases (GHG) emission, leachate production, heavy metals, and NMOC from polluter pay principle implementation scenarios in the study area. The emission of $CH_4$ and $CO_2$ equivalent from scenario 1 was 6058.96 tonnes/year and 151,473.88 tonne/year, respectively. It was the highest estimated emission compared to other scenarios since the percentage of waste disposed of in the landfill was the highest at this scenario at 70%. The levels of $CH_4$ and $CO_2$ show a decreasing trend as the percentage of waste disposed of in the landfill decreased from each scenario. As the percentage of recycling rate, incineration, and composting increased (from scenarios 1 to 3), the levels of greenhouse gases from the environment also increase.

The reduction of $CH_4$ and $CO_2$ equivalent from recycle in scenario 3 was the highest at −2163.91 tonnes/year and −60,589.55 tonnes/year, respectively, compared to other scenarios with 25% of the waste recycled.

The highest estimated leachate production was 29,340.24 $m^3$ from scenario 1. The reduction of leachate production was the highest in scenario 3, which is −10,478.66 $m^3$. Pb and Zn had shown the highest production and reduction of heavy metals in scenario 1 and scenario 3.

The estimated emission and reduction of NMOCs of PPP implementation scenario highlighted the highest estimated emission of hydrogen sulphide from landfill scenario 1 was 1.64E-01 $m^3$. The reduction of NMOCs (hydrogen sulphide) from recycle in scenario 3 was −5.87E-02 $m^3$. It was the highest estimated reduction of NMOCs compared to other scenarios, with 25% of the total waste being estimated recycled.

**Table 6.8** The emission and avoidance of greenhouse gases ($CH_4$, $CO_2$) and environmental pollution of PPP implementation scenarios in the study area

| | Scenario 1 | | | | Scenario 2 | | | | Scenario 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landfill (70%) | Recycle (20%) | Incineration (5%) | Composting (5%) | Landfill (60%) | Recycle (20%) | Incineration (10%) | Composting (10%) | Landfill (50%) | Recycle (25%) | Incineration (15%) | Composting (10%) |
| *Volume of waste (tonnes/year)* | 139,715.43 | −39,918.70 | −9979.67 | −9979.67 | 119,756.09 | −39,918.70 | −19,959.35 | −19,959.35 | 99,796.74 | −49,898.37 | −29,939.02 | −19,959.35 |
| *GHG gases* | | | | | | | | | | | | |
| $CH_4$ (t) | 6058.96 | −1731.13 | −432.78 | −432.78 | 5193.39 | −1731.13 | −865.57 | −865.57 | 4327.83 | −2163.91 | −1298.35 | −865.57 |
| $CO_2$ (t) | 151,473.88 | −48,471.64 | −12,117.91 | −12,117.91 | 145,414.93 | −48,471.64 | −24,235.82 | −24,235.82 | 121,179.11 | −60,589.55 | −36,353.73 | −24,235.82 |
| Leachate ($m^3$) | 29,340.24 | −8382.93 | −2095.73 | −2095.73 | 25,148.78 | −8382.93 | −4191.46 | −4191.46 | 20,957.32 | −10,478.66 | −6287.19 | −4191.46 |
| *Heavy metals(kg)* | | | | | | | | | | | | |
| Cadmium (Cd) | 5.87E-02 | −1.68E-02 | −4.19E-03 | −4.19E-03 | 5.03E-02 | −1.68E-02 | −8.38E-03 | −8.38E-03 | 4.19E-02 | −2.10E-02 | −1.26E-02 | −8.38E-03 |
| Chromium (Cr) | 1.76E-01 | −5.03E-02 | −1.26E-02 | −1.26E-02 | 1.51E-01 | −5.03E-02 | −2.51E-02 | −2.51E-02 | 1.26E-01 | −6.29E-02 | −3.77E-02 | −2.51E-02 |
| Copper (Cu) | 1.47E-01 | −4.19E-02 | −1.05E-02 | −1.05E-02 | 1.26E-01 | −4.19E-02 | −2.10E-02 | −2.10E-02 | 1.05E-01 | −5.24E-02 | −3.14E-02 | −2.10E-02 |
| Lead (Pb) | 4.40E-01 | −1.26E-01 | −3.14E-02 | −3.14E-02 | 3.77E-01 | −1.26E-01 | −6.29E-02 | −6.29E-02 | 3.14E-01 | −1.57E-01 | −9.43E-02 | −6.29E-02 |
| Zinc (Zn) | 4.40E-01 | −1.26E-01 | −3.14E-02 | −3.14E-02 | 3.77E-01 | −1.26E-01 | −6.29E-02 | −6.29E-02 | 3.14E-01 | −1.57E-01 | −9.43E-02 | −6.29E-02 |
| *NMOC ($m^3$)* | | | | | | | | | | | | |
| Acrylonitrile | 2.93E-02 | −8.38E-03 | −2.09E-03 | −2.09E-03 | 2.51E-02 | −8.38E-03 | −4.19E-03 | −4.19E-03 | 2.09E-02 | −1.05E-02 | −6.28E-03 | −4.19E-03 |
| Carbon disulphide | 2.69E-03 | −7.67E-04 | −1.92E-04 | −1.92E-04 | 2.30E-03 | −7.67E-04 | −3.84E-04 | −3.84E-04 | 1.92E-03 | −9.59E-04 | −5.76E-04 | −3.84E-04 |
| Carbon tetrachloride | 1.85E-05 | −5.29E-06 | −1.32E-06 | −1.32E-06 | 1.59E-05 | −5.29E-06 | −2.65E-06 | −2.65E-06 | 1.32E-05 | −6.62E-06 | −3.97E-06 | −2.65E-06 |
| Carbonyl sulphide | 2.27E-03 | −6.48E-04 | −1.62E-04 | −1.62E-04 | 1.95E-03 | −6.48E-04 | −3.24E-04 | −3.24E-04 | 1.62E-03 | −8.11E-04 | −4.86E-04 | −3.24E-04 |
| Chlorobenzene | 1.16E-03 | −3.31E-04 | −8.27E-05 | −8.27E-05 | 9.92E-04 | −3.31E-04 | −1.65E-04 | −1.65E-04 | 8.27E-04 | −4.14E-04 | −2.48E-04 | −1.65E-04 |
| Chloroethane | 5.79E-03 | −1.65E-03 | −4.14E-04 | −4.14E-04 | 4.96E-03 | −1.65E-03 | −8.27E-04 | −8.27E-04 | 4.14E-03 | −2.07E-03 | −1.24E-03 | −8.27E-04 |
| Chloroform | 1.39E-04 | −3.97E-05 | −9.92E-06 | −9.92E-06 | 1.19E-04 | −3.97E-05 | −1.98E-05 | −1.98E-05 | 9.92E-05 | −4.96E-05 | −2.98E-05 | −1.98E-05 |
| Dichloromethane | 6.62E-02 | −1.89E-02 | −4.73E-03 | −4.73E-03 | 5.68E-02 | −1.89E-02 | −9.46E-03 | −9.46E-03 | 4.73E-02 | −2.37E-02 | −1.42E-02 | −9.46E-03 |

| | Scenario 1 | | | | Scenario 2 | | | | Scenario 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landfill (70%) | Recycle (20%) | Incineration (5%) | Composting (5%) | Landfill (60%) | Recycle (20%) | Incineration (10%) | Composting (10%) | Landfill (50%) | Recycle (25%) | Incineration (15%) | Composting (10%) |
| Ethylbenzene | 2.14E-02 | −6.10E-03 | −1.53E-03 | −1.53E-03 | 1.83E-02 | −6.10E-03 | −3.05E-03 | −3.05E-03 | 1.53E-02 | −7.63E-03 | −4.58E-03 | −3.05E-03 |
| Hydrogen sulphide ($H_2S$) | 1.64E-01 | −4.70E-02 | −1.17E-02 | −1.17E-02 | 1.41E-01 | −4.70E-02 | −2.35E-02 | −2.35E-02 | 1.17E-01 | −5.87E-02 | −3.52E-02 | −2.35E-02 |

# 4 Discussion

The volume of MSW has shown an increasing pattern from 2011 to 2017. It has increased by 29.4% due to several factors such as rapid growth of populations, lifestyle changes, and rising community standards. These factors lead to increasing solid waste generation from households and institutional, commercial, and industrial sectors, which will lead to increasing solid waste in landfills. Furthermore, Malaysia is highly dependent on the landfill as the main disposal method with 89% of the total solid waste was disposed of using this method (NSWMD 2013). The population in this study area has been reported to produce more waste compared to other regions in Malaysia with 1.35 kg/capita/day (NSWMD 2013). Furthermore, waste segregation activity was not made compulsory in the study area. Based on the national survey of waste generation, the recycling rate in the study area was the lowest (9.4%) compared to other cities in Malaysia, such as Kuantan (18.4%), Kota Bahru (15.7%), and Sibu (15.6%) (NSWMD 2013). This is one of the factors that lead to increasing solid waste ending up in the landfills.

Food waste is a major type of waste with the fraction of 44.3% from households and 31.4% from institutional, commercial, and industrial sectors. Food waste production in Malaysia had reached 15,000 tonnes per day, and almost 70% of the food waste end up in landfills (Abd Ghafar 2017). The food waste estimation from household is higher compared to institutional, commercial, and industrial sectors because of the daily activity of the population in the area. The increasing Malaysian population contributes to the increasing amount of food waste due to economic development, population growth, and urbanization, which is to fulfil the demands of the population. The changes in eating habits, improvement of living standards, and rapid urbanization also contributes to the increasing of waste.

The estimated emission of greenhouse gases ($CH_4$, $CO_2$-eq) increased with the increasing waste in the landfill. The disposals of solid waste in the landfill were recognized as the major contributor of greenhouse gases emissions (Ishigaki et al. 2011). The deposited wastes in the landfill that contain highly organic material (food, paper, wood, garden waste) will undergo decomposition process by microbes under anaerobic conditions and will produce $CH_4$, $CO_2$, and other gases compound (Muda 2016). Landfill generates 50% of methane and 45% of carbon dioxide. It also produces NMOC from the biodegradation process that can contribute to global warming. Global warming can cause climate change that will affect the population by heavy precipitation, heat waves in susceptible areas, drought, food, water, and vector-borne diseases and malnutritions (Hoornweg and Bhada-Tata 2012).

The emission of non-methane organic compounds due to isposal of waste in the landfill can affect human health. The highest emission of NMOCs is hydrogen sulphide compared to other gases. However, health risk posed by hydrogen sulphide was minimal as landfills only emit a trace amount of NMOCs to the atmosphere during the decomposition process compared to methane and carbon dioxide (Pazoki et al. 2015). The lifetime cancer risk (LCR) for carcinogenic risk compounds (acrylonitrile, carbon tetrachloride, chloroform, and dichloromethane) was also within an acceptable range. Furthermore, the hazard quotient (HQ) for non-carcinogenic risk compounds (acrylonitrile, carbon disulphide, carbon tetrachloride, chloroethane, dichloromethane, ethylbenzene, and hydrogen sulphide) is also within an acceptable range. According to Chalvatzaki and Lazaridis (2010), the decomposition process of waste in the landfill usually produced less than 1% of NMOCs. NMOCs are contained in biogas in a small percentage of 2% together with other organic air pollutants that are also harmful and smelly. Despite their small concentration in the biogas emitted from the landfill, it can give risk to public health in the general population because of the harmful and toxic gases containing unpleasant odour in regions adjacent to landfills.

The $CH_4$ and $CO_2$ emissions that were released from the decomposition process of MSW in the landfill can contribute to global warming. The high concentration of GHG can cause a reduction in outgoing infrared radiation, thus the earth's climate must change in order to restore the balance between incoming and outgoing radiation. The climatic change leads to global warming of the earth's surface and the lower atmosphere as warming up is the simplest way for the climate to release the energy. Global warming can increase the temperature of the earth. A small change in temperature rise can cause many other changes, such as cloud cover and wind patterns (Latake et al. 2015). Based on complex climate models, the "Intergovernmental Panel on Climate Change" in their third assessment report has forecast that global mean surface temperature will increase by 1.4–5.8 °C by the end of 2100. $CH_4$ generation in the landfill usually begins between 6 and 12 months of burying the waste in the landfill and rises on its peak after the closure of the landfill. This methane generation trend then started to fall gradually after 30–50 years, which can vary according to the site-specific conditions. These gases could affect receptors up to the minimum distance of 3.5 km. The high concentration of these components was due to anaerobic microbial degradation of organic compounds, during which excessive concentrations of $CH_4$ are released and it also depends on the composition of the landfilled waste. Due to the high quantity of organic waste in the landfill, $CH_4$ generation will further increase over time (Iqbal et al. 2019).

The disposal of waste in the landfill cause production of leachate and heavy metal content in the leachate. The estimated production of leachate and heavy metal content was consistently high with the increased volume of waste in the landfill. The disposal of waste in landfills will produce leachate due to percolation of rainwater through waste dumps (Prabpai et al. 2009). Heavy metal is one of the most hazardous components in the leachate. The disposal of the residual waste in the landfill will produce leachate containing heavy metals such as Hg, Cd, Cu, Zn, Pb, and Fe (Vasanthi et al. 2008). Heavy metal contaminations occur due to the subsequent migration of leachate from and within the landfill's waste cell (Agamuthu and Fauziah 2010). Fauziah and Agamuthu (2012) stated that the negative impacts of MSW landfill on the environment cause a wide range of concerns such as increase in the risk of explosion, odour problem, and contamination of leachate that contain heavy metals in soil and groundwater. In their study revealed that one of the most hazardous components in leachate is heavy metals. Furthermore, landfills especially in Asia contain high concentration of heavy metals in leachate from closed and active landfills (Emenike et al. 2011). This has become a great concern of leachate pollution in the water because it can result in potential bioaccumulation of the pollutants (Mn, Cu, Zn, Fe, Cr, Al) in aquatic organisms and humans (Fauziah et al. 2013) .

Morling (2010) stated that the heavy metal concentration is significantly higher in younger leachate where it is in acidic phase and can give threat to the environment. However, the estimation of heavy metals in the leachate in this study was observed to be of low concentrations compared to the previous study. In my opinion, it could be due to the difference in total waste that has been disposed in the landfill. Furthermore, the estimation of leachate production in the landfill did not exceed the acceptable conditions for discharge of leachate in Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. The application of PPP has the potential in reducing environmental pollution and health risk for MSW by avoiding landfilling and initiating recycle, composting, and incineration. The implementation of PAYT in the United States has led to the diversion of perhaps 6.5 million tonnes of MSW per year (4.6–8.3 million tonnes) that would otherwise have been landfilled (Skumatz and Freeman 2006). Lee and Paik (2011) also reported the same finding as after implementation of unit pricing system, the recycling rate has increased steadily up to 59.8% in 2008 while landfill has decreased down to 20.3% in Korea. It has shown that PPP has the potential to reduce environmental pollution and health risk for MSW. PPP is a waste management scheme and PAYT is one of the approaches applied in this principle (Morlok et al. 2017). The aim of economic approach is to promote material recovery among waste producers (Morlok et al. 2017). Some municipalities have adopted PAYT programs to educate the residents on the cost of waste disposal and promote community efforts towards waste reduction.

## 5 Conclusion

This study was carried out to determine the contribution of PPP on the reduction of environmental pollution and health risk for municipal solid waste. In conclusion, the volume of waste disposed of in the landfill has increased over the years. This has also caused the rise of GHG emission, leachate production, heavy metals and NMOC. However, the increase in NMOCs does not produce significant health risk as the emission was too minimal. The implementation of PPP under different scenarios has the potential to reduce the GHG emission and environmental pollution by enhancing recycle, incineration, and composting as the alternatives to avoid landfilling practise. The level of GHG emission ($CH_4$, $CO_2$), environmental pollution, and health risk from the PPP scenario showed some in the reduction of landfilling impact on the environment and human health.

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# Chapter 7
# General Overview on Cellulose and Cellulose Nanocrystals: Properties, Extraction, Application, and Sustainable Development

**Wan Hazman Danial, Raihan Mohd Taib, Mohd Armi Abu Samah, and Zaiton Abdul Majid**

**Abstract** This chapter describes the general overview on cellulose and cellulose nanocrystals (CNCs). Structure and properties of cellulose and CNCs are fundamentally discussed in detail. A brief discussion on various techniques and methods of extraction of cellulose and CNCs from a myriad range of precursors such as plants and waste materials are also presented and the applications of cellulose and CNCs in a multitude of fields are described. The sustainable development associated with cellulose and nanocellulose material is also highlighted.

**Keywords** Cellulose · Cellulose nanocrystals · Properties · Extraction · Application

## 1 Introduction

Cellulose is the most abundant natural polymer in the biosphere, with ~$1.5 \times 10^{12}$ tons of production and decomposition globally per year, comparable to the main resource of planetary reserves which are fossils and minerals (Rojas 2016). In addition to the ever-strong scientific interest in cellulose, the utilization of cellulose as a

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renewable and biodegradable raw material in various applications is one of the initiated and revolving solutions in order to face the current industrial challenge of environmental and recycling problems. Various modification procedures on the flexible structuring of cellulose, both through physical and chemical methods, has enabled its utilization in diverse applications like building and coating materials, fillers, papers, textiles, laminates, optical films, absorption media, viscosity regulators, and even advanced functional materials (Rojas 2016).

Cellulose, known to be the most abundant and naturally occurring organic polymer, is composed of two anhydroglucose rings as the repeating unit structure, which is covalently linked together by β 1-4 glycosidic bond. A linear chain of cellulose may be comprised of more than ten thousand repeating units depending on its source material. Its linear configuration and parallel multiple stacking of the cellulose chain are due to the formation of interchain hydrogen bonding between the hydroxyl groups and oxygen on adjacent ring molecules (Moon et al. 2011). This intermolecular hydrogen bonding, including van der Waals interaction in the cellulose chain, produced elementary fibrils which are then further assembled to form larger microfibrils. Cellulose structures within the fibrils, usually consisting of two different cellulose chain arrangements, are ordered and disordered and the extraction of only the ordered segments, results in the production of high crystalline cellulose, or so-called cellulose nanocrystals (CNCs) (Lin et al. 2012).

CNCs are rod-like particles which resemble needles or are spherical in appearance and are usually produced from the cellulose source materials including wood, plant fibers, and waste materials like office paper and pineapple peels using stages of treatments while microcrystalline cellulose (MCC) or micro-fibrillated cellulose can directly be subjected to acid hydrolysis with controlled conditions. CNCs had most of their amorphous regions removed through acid hydrolysis and are highly crystalline. The diameter and length of the CNCs range between 3–5 nm and 50–500 nm, respectively (Moon et al. 2011) but are dependent on the materials used as cellulose source. CNCs are otherwise referred to as cellulose whiskers, cellulose nano-whiskers or just simply nanocrystalline cellulose, where they are all present in the previous literatures and are acceptable. CNCs are comparatively akin to MCC which have a rigid rod-like structure and a high aspect ratio with a higher degree of hydroxyl side groups that can facilitate surface functionalization except that the size ranged in nano-scale. Besides their inherent renewability and sustainability, CNCs also possess impressive mechanical properties due to their high crystallinity (Meng and Wang 2019; Xie et al. 2018). CNCs are significantly nanoscale in size, and show birefringence and liquid crystalline properties (Hastuti et al. 2018; Moon et al. 2011). The fascinating characteristics of CNCs render them suitable to be an ideal material on its own and also showed excellent compatibality in nanocomposites for a wide range of applications.

## 2 Structure and Properties of Cellulose and CNCs

Cellulose is composed of linear chains of D-glucose which is linked by ß-1,4-glycosidic bonds with the degree of polymerization from 10,000 in wood fiber to 1000 in bleached kraft pulps. A single unit of D-anhydroglucopyranose contains hydroxyl (-OH) groups at carbon atoms located at the 2, 3, and 6 positions that can perform the typical reactions known to exhibit experimental results similar to primary and secondary alcohols. The molecular structure endows cellulose the characteristics and properties of hydrophilicity, chirality, degradability, and extensive chemical variability. Figure 7.1 shows the general structure of cellulose.

The cellulose chain branches with polar -OH groups and these groups form many hydrogen bonds with other OH groups on nearby chains, thus assembling the chains. The chains also group-arranged regularly in places to form stable and firm crystalline regions that enhance the bundled chains with high stability and strength. Cellulose has a strong tendency to connect through intra- and inter-molecular hydrogen bonds between the hydroxyl groups on these linear cellulose chains stiffening, thus providing a rigid longitudinal straight chain. This promotes aggregation into a crystalline structure and bestows on cellulose a variety of morphologies and partially crystalline fiber structures.

Crystalline structures of cellulose polymorphs include Cellulose I, II, III, and IV, where each was well investigated. Native cellulose, or cellulose I, is the crystalline cellulose which is produced naturally from a range of organisms, such as plants, bacteria, tunicates, etc. Cellulose I has thermodynamically a less stable structure, which consists of two polymorphs (triclinic (Iα) and monoclinic structure (Iβ)) and can be possibly converted into cellulose II or III structures. The most stable structure is Cellulose II, which consists of monoclinic structures and can be produced from cellulose I by two processes: (1) regeneration, which involved the dissolution of cellulose I in an appropriate solvent followed by re-precipitation or (2) mercerization, which involved the treatment of cellulose fibers in aqueous sodium hydroxide by a swelling process to yield cellulose II (Klemm et al. 2005). Cellulose III can

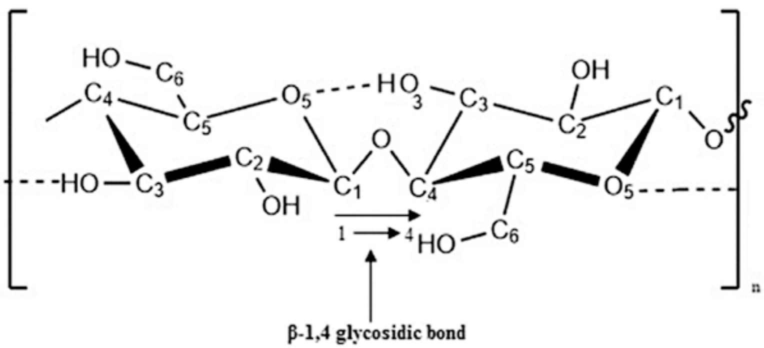


**Fig. 7.1** General structure of cellulose

be obtained from cellulose I or II through a reversible process of liquid ammonia treatments while cellulose IV can be prepared by thermal treatment of cellulose III in glycerol.

The interaction of hydrogen bonding present in the cellulose crystal structure has a significant contribution to the properties and stability of these polymorphs (Moon et al. 2011). Theoretical calculations and modeling of the hydrogen bonding networks in cellulose structure are been briefly discussed (Nishiyama et al. 2008). Theoretical evaluation suggests that the presence of intramolecular hydrogen bonding within Iα and Iβ structures gives an unexpectedly high axial elasticity and Young's Modulus (Eichhorn and Davies 2006; Tashiro and Kobayashi 1991). Higher intermolecular hydrogen bonding presence in the Iβ structure and weaker strength of hydrogen bonding in Iα have contributed to higher stability of Iβ and lower Iα stability, respectively (Nishiyama et al. 2002; Watanabe et al. 2007).

CNCs have many desirable physical and chemical properties, such as their relatively low density, high surface area, high tensile strength, high stiffness of Young's modulus, and an abundance of surface hydroxyl groups. These hydroxyl groups on the surface offer a facile platform for chemical modification, which may enable conversion into other functional groups like carboxylic acid, amine, aldehyde, or thiol groups (Ferreira et al. 2018). They could then be further modified for selective applications like grafting smaller molecules such as metal nanoparticles or biomarkers and give assistance in the formation of larger macromolecules like polymers and protein. Their stiffness and biocompatibility function very well for bone regeneration as tissue scaffolds and when loaded with bioactive molecules, the scheduled release of drugs after implantation could improve the outcome of such medical treatments (Grishkewich et al. 2017). Antimicrobial products could be formulated due to the colloidal stability and enormous surface area of CNCs, and active antimicrobial agents could be formulated and delivered to inhibit the growth of pathogenic organisms.

The isolation of CNCs can be achieved from various cellulose source materials and may require different extraction techniques. Therefore, the morphology and geometrical dimensions of CNCs vary depending on the materials and processing. A number of reports were written on the geometrical range of the CNCs extracted from various sources such as wood, plant, cotton, bacteria, sisal, and tunicate. It was reported that CNCs produced from tunicate have the largest aspect ratios (~100) while other sources generally produced CNCs with lengths and diameters that ranged between 50–500 nm and 5–50 nm respectively. The CNCs generally consisted of rod-like morphology although some reported on spherical CNCs (Wang et al. 2007). The morphology and geometrical analysis of CNCs can be investigated using imaging analysis such as transmission electron microscopy (TEM), field-emission scanning electron microscopy (FESEM), and atomic force microscopy (AFM).

Due to the small geometrical dimensions and limited techniques to characterize and manipulate individual CNCs, the direct measurements and quantitative mechanical analysis of CNCs is a great challenge and extremely difficult. However, the chronology of crystal modulus analysis as reviewed from literature is discussed here. In 1936, Meyer and Lotmar (1936) performed a theoretical calculation of the bond stiffness constants via spectroscopic measurements and obtained a value of 120 GPa for crystal modulus of cellulose (Meyer and Lotmar 1936). However, Meyer and Lotmar used an inaccurate structure of cellulose, which was then corrected by Lyons (1959), and obtained a value of 180 GPa (Lyons 1959). Mathematical expressions for bond angle bending used by Lyons were however incorrect and revised by Treloar (1960), who obtained a value of 56 GPa (Treloar 1960). Nevertheless, Treloar's cellulose structure might possibly lack intrachain hydrogen bonding which gave a very low crystal modulus value. In 1962, Sakurada et al. (1962) pioneered an experimental analysis of cellulose crystal modulus using X-ray diffraction of deformed fibers bundles and obtained a value of 138 GPa (Sakurada et al. 1962). Inspired from their work, many attempts at using X-ray diffraction were carried out (Nishino et al. 1995) and combined with the theoretical calculations (Marhöfer et al. 1996; Tashiro and Kobayashi 1991) obtained values of crystal modulus ranging between 100 and 160 GPa. By using the inelastic X-ray scattering (IXS) technique, Diddens et al. (2008) reported a cellulose crystal modulus value of 220 GPa (Diddens et al. 2008). On the other hand, the Raman spectroscopy technique was employed by Šturcová et al. (2005) for CNCs stiffness measurement and obtained a value of 143 GPa (Šturcová et al. 2005). Similar work using Raman spectroscopy technique was carried out by Rusli and Eichhorn (2008) but obtained a value of 105 Gpa, and the sourced CNCs were from cotton. In addition, the elastic modulus of 150.7 GPa was obtained via AFM technique for stiffness measurement of CNCs produced from tunicate (Shinichiro Iwamoto et al. 2009).

The thermal properties of the CNCs could be determined with thermogravimetric analysis (TGA) and the typical onset of thermal degradation ranged between 200 °C and 300 °C. Petersson et al. (2007) reported on a set of TGA analyses of freeze-dried MCC, CNCs, and modified CNCs (with surfactant). The thermal degradation onset for MCC and CNCs was found to be around 300 °C and 260 °C, respectively (Moon et al. 2011). However, the thermal degradation onset could be altered if the CNCs were subjected to surface modification or functionalization. For instance, Roman and Winter (2004) reported on the effects of sulfate groups in CNCs produced by sulphuric acid hydrolysis, which could significantly reduce the thermal stability. The linear thermal expansion coefficient of crystalline cellulose was approximately $10^{-7}$ $K^{-1}$, which is comparable to the value of carbon fibers but much lower than most metals.

The CNCs suspension exhibited a shear thinning behavior with concentration dependence as it increased with an increase of concentrations of CNCs in the suspension resulting from rheological properties (Liu et al. 2011). At low shear rates, the suspension of CNCs showed an unusual shear thinning behavior at higher concentration but the concentration dependence fell at higher shear rates (Moon et al. 2011). Such shear thinning behavior occurred due to alignment of the CNCs' rod-like shape which facilitated their flow properties. The effects of different acid treatments on the rheological properties were investigated and it was found that hydrochloric acid-treated suspensions showed greater shear thinning behavior and was thixotropic at high concentrations while sulphuric acid-treated suspensions showed no time-dependant behavior in viscosity (Araki et al. 1998). Further investigations showed that the influence of surface charge was responsible for this behavior of viscosity (Araki et al. 1999).

It is already known that CNCs suspension displayed a birefringent and liquid crystalline behavior at sufficiently high concentrations similar to other asymmetric rod-like particles owing to their chain stiffness (Klemm et al. 2005). Besides this, the stiff rigid-rod structures combined with high aspect ratio of CNCs could lead to nematic behavior where the rods are aligned at certain conditions. Lyotropic behavior could also be observed due to strong interactions between the individual CNCs, yet it was easily dispersed (Habibi et al. 2010). On the other hand, the CNCs derived from sulphuric acid hydrolysis showed a chiral nematic or cholesteric phase, where the CNCs aligned parallel to each other along a perpendicular axis director. The chiral nematic phase was induced by a helical twist of the cellulose crystallite which is analogous to screw-like rods (Holt et al. 2010). This resulted in macroscopic birefringent of individual domains due to optical band gaps, which were observed as fingerprint patterns (for chiral nematic) of the anisotropic phase through crossed polarizers optical microscope (Moon et al. 2011). However, different functionalizations, such as sulfonated or non-sulfonated CNCs might show different liquid crystalline behaviors (Lin et al. 2012). Sulphuric acid hydrolysis of CNCs also produced a chiral nematic phase while hydrochloric acid hydrolysis CNCs with post-sulphation treatment showed birefringent glassy phase (Fleming et al. 2000).

## 3 Extraction of Cellulose and CNCs

The extraction method of cellulose can be divided into two categories namely mechanical and chemical, which are both applicable in producing micro to nano-scale size particles. The mechanical techniques comprise of grinding, homogenization, ball-milling, twin-screwing extrusion, cryocrushing, high-intensity ultrasonication, and microfluidization, while the chemical method involves alkali and bleaching treatments. The variety of cellulose source materials may require different pretreatment and extraction processes depending on the matrix material.

In the mechanical approach that is usually used in the extraction of microfibrillated cellulose, high shear processes could be used to transversely cleave along the longitudinal axis of the fibrillar cellulose structure (Moon et al. 2011). Briefly, the mechanical techniques require the usage of mechanical equipment specified for the tasks, such as a grinder system for fibrillation process (Kargarzadeh et al. 2017). This process is conducted by passing the cellulose slurry through alternating static and rotating grindstones at a given rate. With the force applied during the process, the cell walls structure may degrade forming micro to nano-scale size fibrils. The advantages of the grinding method are high efficiency, large capacity, low energy consumption, and less inclined to cause material clogging (Kargarzadeh et al. 2017). Hassan et al. (2012) were able to obtain nanofibers from bagasse and rice straw while Iwamoto et al. (2005) used this method with plant pulps and obtained similar results. However, the strong mechanical force in the grinding process may contribute an extensive fiber damage.

The homogenization technique involves forcing the suspension through a very narrow vent or opening using a piston with high pressure (Jonoobi et al. 2015). The mechanism behind the homogenization process induces cavitation and shockwaves, which agitate up the fibrillar structure of the cellulose (Kargarzadeh et al. 2017). A variety of cellulosic material, like wood pulp (Siddiqui et al. 2010), cotton (Wang et al. 2015), and kapok husk (Tan and Chou 2020), were subjected to this method. This technique has positively shown better outcomes than grinding as the fiber size can be controlled and reduced by regulating the pressure, which influence the shear forces, turbulent flow, and interparticle collisions (Xie et al. 2018). The number of homogenization cycles and the applied pressure greatly affect the extent of the fibrillation process where the higher the pressure applied, the higher the efficiency of the agitation per pass through the machine.

The ball milling process can be used to isolate the cellulose by subjecting the fiber suspension into high-energy collision between balls made of metal, ceramic, or zirconia in a hollow cylindrical rotating container. The technique influences the macroscopic and microscopic properties of cellulose, such as structure, crystallinity, morphology, and thermal stability of the resulting material (Piras et al. 2019). This method was practically used on eucalyptus biomass (Ferreira et al. 2018), bamboo pulp, kraft fibers (Zeng et al. 2020), and even on commercial cellulose in order to obtain a refine fiber structure (Kang et al. 2018). This method can be considered as an eco-friendly method to obtain the cellulose and when combined with acid hydrolysis, it can further enhance cellulose production (Zeng et al. 2020). Besides that, twin-screw extruders are also commonly used in the modern industry. They were traditionally used for forming polymers and composites due to higher availability as compared to homogenization or disintegration systems (Ho et al. 2015). The process involves the interaction of the screws and a barrel container to extrude the intended product. Gamon et al. (2013) employed this method using Miscanthus and bamboo fibers whereby the bamboo fibers showed better fiber separation as compared to Miscanthus fibers.

Cryocrushing is a mechanical fibrillation method for prefrozen cellulose. In this process, water-swollen cellulose fibers are frozen in liquid nitrogen before getting crushed (Kargarzadeh et al. 2017). The high impact from the pressure exerted by the ice crystals forces the frozen cellulosic fibers to break down the cell walls and thus allow producing nanofibers (Frone et al. 2011). The cryocrushed fibers can be uniformly dispersed in water using a disintegrator. This procedure can be applicable to numerous cellulose sources and can be used before homogenization as a fiber pretreatment procedure, such as reported by Wang and Sain (2006), who conducted on soybeans. However, the downside of the cryocrushing method is that it has a low productivity rate due to high energy consumption during the process and is considered expensive.

On the other hand, high-intensity ultrasonication is a mechanical treatment that is usually used for cell disruption in an aqueous medium. This treatment generates efficient cavitation caused by the formation, expansion, and implosion of microscopic gas bubbles during the process of the water molecules absorbing ultrasonic energy (Kargarzadeh et al. 2017). The hydrodynamic forces of the ultrasound on the pulp intensely cause the cellulose fibers to defibrillate (Chen et al. 2011). Many cellulosic sources including flax (Qua et al. 2011), bamboo pulp (Hu et al. 2017), rice straw (Dinh Vu et al. 2017), and banana peel (Khawas and Deka 2016) have been reported employing the ultrasonication method. The results showed that a mixture of both micro and nano-sized fibrils can be obtained. The ultrasonication of these cellulose samples produces fibrils with diameter ranging widely within the distribution from smallest 20 nm to several microns.

A microfluidizer is another instrument that can be used for micro and nano-sized cellulose isolation and it operates at a constant shear (Kargarzadeh et al. 2017). The fluid slurry is pumped through a z-shaped chamber through which the pulp slurry accelerates to high velocities. Positioned within the chamber are microchannels that are specially designed with a fixed-geometry, where the pulp slurry reaches a high shear force. The preferred shear and impact forces are generated when the slurry stream strikes the wear-resistant surfaces (Missoum et al. 2013). Ferrer et al. (2012) employed the technique on three different types of empty oil palm fruit bunch which all produced nano-sized fibers and exhibited significantly better properties as compared to bleached-treated fibers.

The chemical procedure for the isolation of cellulose is classified into two steps, which are alkaline and bleaching treatment. This treatment involves immersion of the fiber material in a known concentration of aqueous sodium hydroxide (NaOH) at a given temperature and time duration (Ouarhim et al. 2018), and most of the alkaline treatment conducted by previous studies used NaOH with not more than 10% concentration. Orue et al. (2017) investigated the usage of 2% and 7.5% NaOH on office paper for cellulose extraction and revealed that lengths of cellulose were obtained. As for the bleaching treatment, which is usually carried out after the alkaline treatment, the material can be bleached or scourged to remove the final traces of lignin and other impurities, without affecting the cellulose polymorphism or crystallinity. After the bleaching process, nearly completely white cellulose can be obtained. Some examples of the bleaching agents that can be used include hydrogen peroxide ($H_2O_2$) (Hafemann et al. 2019), sodium chlorite ($NaClO_2$) (Draman et al. 2016), and sodium hypochlorite (NaClO) (Hu et al. 2017). Among the bleaching agents, sodium chlorite is mostly preferred followed by sodium hypochlorite. However, some attempted to employ non-chlorinated oxidizing agents for the bleaching treatment, as reported by Hafemann et al. (2019), mainly using $H_2O_2$ with the addition of NaOH and magnesium sulfate ($MgSO_4$).

CNCs are mostly extracted by the hydrolysis method. This faction is further classified into five categories which include the hydrolysis using mineral acids, solid acids, gaseous acids, hydrolysis with metal salt catalyst, and enzymatic hydrolysis whereby the most favorable method is the former, which used sulphuric acid ($H_2SO_4$). The method uses known concentrations of acids to remove the amorphous region resulting in the isolation of crystalline cellulose particles. Further filtration, washing, and rinsing steps were needed to remove free any remaining acids. Rod-like CNCs would be obtained through this acid hydrolysis and the reaction might result in various crystalline shapes of different widths and lengths. It is reported that acidic cation exchange resin as a solid catalyst in combination with high-power disintegration can also be implemented to overcome certain problems like high consumption of chemicals and energy (Liu et al. 2014). Liu et al. (2014) found that the resultant CNCs showed a significantly higher thermal stability than the CNCs prepared using hydrolysis with $H_2SO_4$. Besides, the hydrolysis using solid acid can be less corrosive, safer, and straightforward recovery of the solid acid (Jonoobi et al. 2015). The third category, in the presence of an acidic gas, wet cellulose with a moisture content of up to 80% can hydrolyzed. The gaseous acid reacts with the moisture of the material when absorbed by the cellulose fibers. As a result, a high level of acid concentration is created. This increases the rate of hydrolysis of the amorphous regions and the exposed interfibril links. Various types of gaseous acids can be used in this procedure and this method can avoid time-consuming and environmentally hazardous steps that are originally required for the former mineral acid hydrolysis. Furthermore, only considerable amounts of water are needed and the recycling of acid becomes easier and the dialysis step may not be necessary. This method also yields bigger amounts of CNCs as the cellulose feedstock loss during the acidic gaseous hydrolysis process is lower.

The fourth catgeroy of hydrolysis method is hydrolysis with metal salt catalyst where a transition metal-based catalyst presents a viable yet selective and controllable hydrolysis process with mild acidity. It was reported that the catalyst diffuses into the amorphous regions of cellulose and further promotes the cleavage of glycosidic bonds between cellulose chains into smaller dimensions (Li et al. 2015). In addition, the ultrasonic-assisted treatment or the acidic presence inside the medium may facilitate and improve the accessibility of metal ions for the hydrolysis process (Li et al. 2015). Yahya et al. (2015) revealed that the CNCs extracted via 40% $H_2SO_4$ hydrolysis had lower aspect ratio as compared to CNCs produced using nickel-catalyzed reaction. This shows that the nickel-based inorganic salt can also be efficient in controlling the size of the CNCs.

The fifth category of hydrolysis involves non-acidic conditions. The previous studies on the use of enzymatic hydrolysis for the extraction of CNCs focused primarily on the preparation of micro and nano-sized fibrils without external assistance. Filson et al. (2009) reported the preparation of CNCs from recycled pulp using hydrolysis with endoglucanase enzyme inside a microwave. The results revealed that microwave heating promotes faster nanoparticle production with higher yield when compared to conventional heating. Siqueira et al. (2010) also reported on enzymatic hydrolysis combined with mechanical shearing to produce nanoparticles from sisal pulp. It is reported that depending on the treatment conditions, a mixture of CNCs and micro-sized fibrils can be produced in the obtained suspensions (Kargarzadeh et al. 2017).

### 3.1 Extraction of Cellulose and CNCs from Plant and Waste Material

In order to obtain or isolate cellulose from plant-based material, most works employ chemical procedures of pretreatment, alkali treatment, and bleach treatment. The procedures of pretreatment, alkali, and bleach treatment may require different concentrations of alkali or bleaching solutions while some skipped the pretreatment step to avoid extensive use of chemicals. The pretreatments may consist of mechanical, non-mechanical, or a combination of both such as soxhlet extraction for wood and leaves (Cullen and Macfarlane 2005), argan press cake (Hu et al. 2017), and sugarcane bagasse (Kumar et al. 2020) or purification by pre-steaming in a digester and refining with hot water of the waste plant materials (Kopania et al. 2012) or boiling and filtration followed by addition of low concentration of HCl to the residue for fruit and vegetable pomaces (Szymanska-Chargot et al. 2017) or cleaning with detergent for waste cotton cloth (Wang et al. 2017). Some pretreatments may have a more sophisticated method of dewaxing, reflux followed by filtration, methanol wash and drying for kapok fiber and pineapple leaf (Draman et al. 2016) or mild acid hydrolysis of 0.4% $H_2SO_4$ followed by chlorination with 3.5% NaClO for Tò leaf (Bolio-López et al. 2015) or just a simple wash either with distilled water under ultrasonic wave (Wang et al. 2019) or hot water (Thambiraj and Ravi Shankaran 2017). The pretreatment process is mainly aimed to remove the non-cellulosic components of biomass (Kopania et al. 2012) or prepare the material for alkali treatment (Madureira et al. 2018).

The next step involves alkali treatment which mostly used sodium hydroxide as the main reagent albeit some that utilized potassium hydroxide, KOH such as reported by Kumar et al. (2014). The alkali treatment is able to increase the amount of cellulose in the sample by removing the most non-cellulosic part of the material, such as pectin, waxes, hemicelluloses, oils, and other impurities, including lignin contained in the fiber (Kopania et al. 2012). This process can also be considered one of the delignification processes (Dussán et al. 2014) as lignin can be partly removed during this particular step.

The final step and major delignification process before obtaining cellulose, or similarly known as cellulose fibers, is bleaching treatment. This step is where the bleaching or oxidizing agent removes the remaining lignin (Kopania et al. 2012; Madureira et al. 2018). Hafemann et al. (2019) also stated that it was during the bleaching process that the lignin almost totally removed. The bleaching process further purifies the cellulose content by removal of the remaining unwanted compositions of lignin, hemicellulose, leaving behind the α-cellulose that can be either utilized for various applications or reacted through acid hydrolysis to obtain CNCs.

CNCs acquisition can be achieved from various cellulose source materials and may require different extraction techniques. Therefore, the morphology and geometrical dimensions of CNCs products vary depending on the materials and process. Previous reports of sources include sugarcane bagasse (Kumar et al. 2014), grass waste (Danial et al. 2020), oil palm empty fruit bunch (Hastuti et al. 2018), cotton cloth waste (Wang et al. 2017), office paper waste (Hanafiah et al. 2019), tea leaf waste (Rahman et al. 2017), old newspaper (Danial et al. 2015a, b), pineapple peel (Madureira et al. 2018), Pueraria root (Wang et al. 2019), and royal palm tree agro-industrial waste (Hafemann et al. 2019).

Briefly, the cellulose can be further subjected to acid hydrolysis mainly with sulphuric acid (Danial et al. 2020), hydrochloric acid (HCl) (Hastuti et al. 2018), or a mixture of HCl and $H_2SO_4$ (Wang et al. 2017) or phosphoric acid $H_2PO_4$ (Wang et al. 2019). These acids were varied in concentrations of with mainly 64% for $H_2SO_4$ and with predetermined ratio of material to acid solution. The unique and exceptional properties of CNCs make it an ideal material to be considered for utilization in a wide range of applications of material science. The capability to perform surface modifications of the CNCs has enabled them to exhibit their specified duties as advanced functional nanomaterials which can be applied in numerous fields including and not limited to, biomedical, membranes, polymers, environmental, food agriculture, and gel nanomaterials. These fields of applications depend on the properties, surface functionalization, extraction, and material processing of the CNCs. The geometrical range of the CNCs extracted from plant material like sugarcane bagasse, tea leaf waste and eucalyptus fibers give the diameter of nanocrystals a wide range of distribution and the size of most of the nanocrystals are within the range of 250–480 nm in length and 20–60 nm in diameter. The same can be seen from waste materials like cotton cloth waste and office paper waste and where the length and diameter measured to be within the range of 17–470 nm and 2–35 nm, respectively. It can be noted that different source of precursor or materials provides different values of CNCs dimension.

## 4 Application of Cellulose and CNCs

Cellulose is the most abundant organic compound in the world, mostly sourced from plants, and can also be isolated from waste materials like wastepaper (Danial et al. 2015a, b). It is the most structural component in herbal cells and tissues and naturally consists of a long polymer chain that indirectly plays a significant role in human food cycle and a diverse range of industrial applications. This polymer is a resourceful material in multiple industrial fields expanding from wood and paper, fibers and clothes, veterinary foods, cosmetics to pharmaceutical industries as excipients (Shokri and Adibkia 2013). Cellulose also can exist as semi-synthetic derivatives which are substantially used in cosmetic, biomedical, and pharmaceutical industries. Cellulose derivatives namely cellulose ethers and cellulose esters are two major classes, each having different mechanical and physicochemical properties. These polymers are broadly used in healthcare products, biomedical appliances and the formulation of dosage for drug-related activities (Xie et al. 2018).

These compounds play an active and significant role in various pharmaceutical sectors such as controlling the release matrices and osmotic drug delivery systems, bioadhesives and mucoadhesives, thickening agents in compression tablets, as compressibility enhancers as well as functions as stabilizers, granules and tablets as binders, semisolid preparations as gelling agents, and many other applications (Hu et al. 2017; Shokri and Adibkia 2013; Xie et al. 2018). These polymeric materials have also been used as filler, taste masker, free-flowing agents, and pressure-sensitive adhesives in transdermal patches. Another sector where cellulose greatly influences is the wastewater treatment application (Sulaiman et al. 2019; Yu et al. 2016). Biosorption mechanisms of cellulose and cellulose derivatives have been reported to be an effective and efficient alternative to take over the former conventional technologies (Shojaeiarani et al. 2019; Shokri and Adibkia 2013). The hydroxyl functional groups in cellulose act as the main key to produce better absorbent materials (Sulaiman et al. 2019).

CNCs is a suitable nanomaterial for a wide range of applications such as biosensing, synthesis of antimicrobial and medical materials, enzyme immobilization, green catalysis, synthesis of drug carrier in therapeutic and diagnostic medicine (Ünlü 2015). These advantageous nanomaterials serve as a potential drug delivery enhancer due to their properties of smaller size yet large surface area, hydrophilicity, and biocompatibility (Thambiraj and Ravi Shankaran 2017). Due to their exceptional large surface area and possibility of acquiring negative charge during hydrolysis, large quantities of drugs can be attached to the surface of these materials with the potential for optimal control of dosing. The abundant surface hydroxyl groups present in nanocrystals provide sites for surface modification with a range of chemical groups.

Surface modification can be used to modulate the loading and release of drugs that are commonly not attached to cellulose, such as nonionized or hydrophobic drugs. CNCs-based aerogels are also receiving growing interest in biomedical and pharmaceutical applications due to their open pore structure and high surface area, which can provide enhanced drug bioavailability and better drug-loading capacity (Prakash Menon et al. 2017). Highly porous nanocellulose aerogel scaffolds were reported to attain sustained drug release, which also revealed new possibilities as carriers for controlled drug delivery (Grishkewich et al. 2017). The production of CNCs aerogel has also been reported using wastepaper as the source material (Danial et al. 2015a, b).

The practical application of CNCs for other fields can be classified into two major categories which are;

(a) Polymer nanocomposites where CNCs is the reinforcing agent and
(b) Functionalized or nonfunctionalized premade CNCs

As a result of their distinctive properties, premade CNCs have the capability to being used in a diversity application ranging from products such as nanopaper (Meng and Wang 2019), barrier membrane or films (Lei et al. 2018), and pH sensors (Xie et al. 2018). A polymer nanocomposite is a composition material composed mainly of the polymer phase and is enhanced with a nanomaterial reinforcement. These polymer nanocomposites exhibit exceptional properties because of their nano-sized dimensions and the increased surface area of the reinforcing material (Ferreira et al. 2018).

In the area of polymer nanocomposites, CNCs are also used as nanofillers (Zhou and Wu 2012) with a defined morphology to provide sufficient strength and modulus. Both natural and synthetic polymers are used to synthesize nanocomposites. These natural polymers, namely starch (Gaaz et al. 2015), natural rubber (Mariano et al. 2016), chitosan (Yadav et al. 2020), soy protein (Qin et al. 2019), and gelatin (Leite et al. 2020) have previously been used in the preparation of nanocomposites. Similarly, synthetic polymers such as polyvinyl alcohol (PVA) (Kang et al. 2018), polyvinyl chloride (PVC) (Rojas 2016), polyetherimide (PEI) (Lee et al. 2020), polyethylene (Sapkota et al. 2017), polypropylene (Bagheriasl et al. 2015), and polyurethane (Yuwawech et al. 2017) have also been used. The main hurdle in getting better and exceptional performance depends on securing a homogeneous dispersion of nanocrystals within the polymer composite and a good interaction between the filler and the base material. Good dispersibility of the CNCs inside the polymer composite is a precondition to enable it to achieve better properties, as a nonhomogeneous dispersion of the filler in the polymer composition impacts negatively on the final mechanical properties of the nanocomposite material.

Furthermore, in certain cases, better dispersion of CNCs leads to the formation of a widely spread network of nanocrystals within the polymer nanocomposite, which also contributes to improvement in the properties of polymer nanocomposites. These types of nanocomposites are used for making water repellents, flat yet flexible panel displays, biomimetic foams, fortified and high-security papers (Prakash Menon et al. 2017). They are also useful for various biomedical applications such as tissue engineering basing stages, patches that are able to cover and heal wounds, and hydrogels which can be applied for clinical and pharmacological purposes (Shojaeiarani et al. 2019; Xie et al. 2018).

Assessing the possibility of chemical modifications such as fluorescent labeling and the biocompatibility of CNCs, they are prospectively applicable as biomedical applications like biosensors, fluorescence bioassays, bioimaging, and so on. Fluorescently labeled CNCs allow facile investigation towards interaction between CNCs and living cells in vivo with fluorescence techniques (Chen et al. 2019). CNCs are also capable of enhancing nanocomposites with high functionality for applications like ultrathin film-coating materials (Kang et al. 2018). CNCs can also be used to stabilize nanoparticles with specific functionality to perform specific applications. In addition, they can be used as precursors for biocatalysts or biomarkers to extend the activity of active compounds to higher temperatures and undesirable pH conditions, as well as prolong their shelf life. In the field of wastewater treatment, the application of CNCs towards waste and toxic contaminants removal has also emerged (Köse et al. 2020; Sulaiman et al. 2019). Their exquisitely large surface area is important in designing and developing efficient bio-adsorbents that optimally and efficiently remove toxic impurities (Köse et al. 2020). They can impart strength to membranes for filtration applications (Bai et al. 2019) and their ability to be destabilized by contaminants makes them efficient water treatment flocculants (Morantes et al. 2019).

In the energy sector, CNCs offer various advantages in fabricating composites and devices. Their ability to form percolating networks enhances and improves the transport of electrons and charges. For example, in supercapacitors application, the large surface area of the CNCs improves charge storage, while the porous structures make them an ideal material to be used as separators in batteries. The utilization of CNCs as substrates in organic electronics has also been developed. CNCs-reinforced polymer nanocomposites are also used in developing textiles, fibers, membranes, supercapacitors, batteries, electroactive polymers, and sensors and actuators that detect electromechanical responses (Prakash Menon et al. 2017). One perceivable futuristic area of application of CNCs-containing polymer nanocomposites is the field of biodegradable packaging materials. The incorporation of CNCs can significantly improve mechanical performance, thermal stability, and barrier and optical properties due to their improved crystallinity and better interfacial interaction.

## 5 Sustainable Development of Cellulose and CNC Materials

In recent times, the need for sustainable development and environmentally friendly material is necessary to reduce waste and toxic residues. Therefore, the usage of cellulose as biodegradable, renewable, and flexible material in various applications can be employed to allow sustainable consumption and development. For instance, it was recently reported that the cellulose nanomaterial has been used as substrate and sensing layer for biodegradable moisture sensors (Rivadeneyra et al. 2021). The sensor was developed via a one-step fabrication technique based on screen printing thus avoiding any additional processing. This technique and cellulose nanomaterial application ensure the advancement of sensor development through sustainability and offers cost-effective, reproducible, fast, and can be adaptable to green-electronics industry.

On top of that, cellulose is known as the most abundant natural biopolymer which can be found in agricrultural crops, trees, and biomass waste and can be harvested from renewable resources. The biomass waste which comes from a broad range of sources is an important and unique source for numerous bioproducts relevant in various fields and industries. Substantial attention and initiatives to recycle, reuse and recover biomass waste have been devoted by various communities of academia, government agencies, and industries. Therefore, the cellulose material may offer a unique technological influence due to the sustainability potential and also combined with interesting functional properties such as mechanical, thermal, optical, and fluidic. The uses of cellulose materials have been explored in various materials fabrication including thin films, membranes, gel nanomaterials, and composites (Li et al. 2021). Besides, various strategies and preparation methods of utilizing nanocellulose from diverse biomass wastes and its applications for high value-added products have also been reported (Yu et al. 2021).

Cellulose or nanocellulose material has been regarded as an important material towards environmental sustainability, and the increased demand for cellulose nanomaterials has been accentuated by the continuous increase of industrial production of nanocellulose. It is expected that the demand will be further increased due to the emerging and broadening applications of nanocellulose combined with the development of environmentally sustainable products incorporated by cellulose or nanocellulose materials. For instance, it was reported that cellulose materials as a natural polymer might serve as a potential candidate to replace plastics and synthetic polymers (Dhali et al. 2021). Plastics, or synthetic polymers, are anthropogenic chemicals and undeniably have a negative impact on natural habitats. Plastic waste has accumulated as a result of the ongoing disposal of long-life plastics, causing substantial degradation of both aquatic and terrestrial environments. Therefore, the need for environmentally sustainable products made from renewable energy has focused on cellulose material.

Due to exponential increase in waste generation from textile cotton wastes, Rizal et al. (2021) reported an in-depth study of CNCs extraction from cotton waste to mitigate the ineffective processing mechanism and environmental impact towards the development of advanced functional materials for a wide range of applications (Rizal et al. 2021). The isolation techniques and applications of the cotton waste CNCs have been comprehensively studied, and the sustainable cotton-based CNCs provide significant improvement in the reinforced matrix for packaging and biomedical applications. On the other hand, the nanocellulose material has been considered as second-generation renewable resources potentially function as a better alternative for petroleum-based products (Rajinipriya et al. 2018). The nanocellulose material including CNCs has received remarkable attention due to the low density, sustainable, high mechanical, renewable, and biodregradable properties. Besides, the nanocellulose has also become topical and interesting in the field of sustainable materials (Rajinipriya et al. 2018) especially towards agricultural and industrial waste utilization, and industrial developments.

## 6 Conclusion

The intriguing and engineered properties of cellulose or CNCs make it an ideal material to be considered for a wide range of applications in material science. The utilization of surface modifications of CNCs has led to their special usages as advanced functional nanomaterials which can be utilized in niche fields of applications including, but not limited to, biomedical, membranes, polymers, environmental, and aerogel. These fields of applications depend on the properties, functionalization, extraction, and material processing of the CNCs. In general, there is a myriad range (mainly plants) of sources to extract cellulose to produce cellulose-based materials. The variety of cellulose source materials may require different pretreatment and extraction processes depending on the matrix material. The production method and precursor selection may also directly influence the significant environmental management in terms of proper waste valorization for the production of value-added products, adapting waste to wealth initiative. The selection of the method of extraction and processing in turn determines the quality, scalability, and applicability of the cellulose and CNCs. The manipulation of cellulose and CNCs as biodegradable, renewable, and flexible material in various applications allows sustainable consumption and development and unique technological appeal.

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# Chapter 8
# Strengthening Wildlife Protection Law in Malaysia to Deter Poaching

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**Abstract** In Malaysia, the Federal Constitution allows Sabah and Sarawak to have their own jurisdiction, and federal intervention is limited in certain aspects including matters related to biodiversity. Therefore, wildlife protection laws, in particular anti-poaching laws governing Peninsular Malaysia, Sabah and Sarawak are different depending on its own legislative discretion, which has caused inconsistency in terms of penalties against wrongdoers. Although Malaysia has implemented laws against poaching, some wildlife is still facing the threat of extinction as they are given different levels of protection under different legislations. More effective approaches should be taken by the legislative body to review the existing law on wildlife and to recommend necessary amendments to the existing laws. In our study, we utilized qualitative methodology with analytical and comparative approaches in our comparison of the existing wildlife protection law in Malaysia with jurisdiction

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in other countries in Asia to obtain insights to overcome and combat the increasingly serious problem of poaching.

**Keywords** Wildlife · Anti-poaching · Punishment · Extinction · Jurisdiction

## 1 Introduction

Malaysia is rich in biodiversity. However, some wildlife species such as tiger, rhinoceros, elephant, turtles and orangutan are facing extinction. Therefore, policy and law are one of the alternatives to save our wildlife from extinction. In Malaysia, the Federal Constitution allows Sabah and Sarawak to have their own jurisdiction, and federal intervention is limited to biodiversity matters. Therefore, wildlife protection law, in particular anti-poaching law governing Peninsular Malaysia, Sabah and Sarawak are different depending on their own legislative discretion, which has caused inconsistency in terms of penalty against poachers. The territorial jurisdiction of laws made by the state governments and federal government are stated in Article 73:

> In exercising the legislative powers conferred on it by this Constitution, (a) Parliament may make law for the whole or any part of the federation and law having effect outside as well as within the federation; and (b) the legislature of a state may make laws for the whole or any part of that state.

The subject matter of legislative jurisdiction for state governments and the federal government is based on Article 74, which shall be read together with the 9th Schedule of the Malaysia Federal Constitution. Article 74, 'Subject matter of federal and state law' states that:

> Parliament may make laws with respect to any of the matters enumerated in the Federal List (First List of the Ninth Schedule) or the Concurrent List (Third List of Ninth Schedule) and the legislature of a state may make laws with respect to any of the matters enumerated in the State List (Second List of Ninth Schedule) or the Concurrent List.

Based on the above provision, only the federal government can make laws on subject matters mentioned in the Federal List (the First List) and only states may make laws on subject matters enumerated under the State List (the Second List) and residuary matter. In the case of Mamat bin Daud & Ors v. The Government of Malaysia, it was held that if the federal government passes a law on a matter stated under the State List or residuary matter, the law may be declared void on the ground of ultra vires (excess of jurisdiction), and vice versa. Under the Federal Constitution, protection of wildlife falls under Concurrent List and forests affair is under the State List. Therefore, this chapter analyzes and scrutinizes the existing wildlife protection law in Peninsular Malaysia, Sabah and Sarawak to identify the lacuna of existing law to deter poaching in Malaysia.

## 2 Problem Statement

The existing laws in Peninsular Malaysia, Sabah and Sarawak have listed down the maximum imprisonment of each offence committed by the accused. However, all the wildlife protection laws, in particular the anti-poaching law which consisted of the Wildlife Conservation Act 2010, Wild Life Protection Ordinance 1998, and Wildlife Conservation Enactment 1997, have failed to list down the minimum imprisonment period for each offence. In addition, judges have raised concerns in determining the adequate imprisonment period to be imposed on the accused once they are found guilty.

## 3 Research Objective

The research objective was to identify the lacuna of wildlife protection law in Malaysia.

## 4 Research Motivation

This study is essential to improve the wildlife protection law found in Malaysia which will help to deter poaching in Malaysia.

## 5 Literature Review

Malaysia is considered a leader among Southeast Asian countries with regard to conservation legislation and program; it was among the first ASEAN countries to develop a national conservation legislation to sign CITES and develop a national conservation strategy (Mohd-Azlan 2014). In Malaysia, there are three major wildlife conservation legislations, namely the Wildlife Conservation Act 2010 (applies to Peninsular Malaysia only), the Wild Life Protection Ordinance 1998 (applies to Sarawak only) and the Wildlife Conservation Enactment 1997 (applies to Sabah only). The act, ordinance and enactment impose different fines, penalty and imprisonment in regard to the same offence committed in different states. Therefore, the location of the crime committed will determine which act, ordinance or enactment to be applied. The wildlife categories in the act, ordinance and enactment may be different based on the respective state legislative body.

Protected area boundaries have not been enforceable due to inadequate government resources, weak management capacities, remote sites and ineffective legal systems. Many protected areas have been proposed on lands or in waters that are legally or customarily owned and managed by local people where it has often been impractical, illegal, or impossible to declare. In Southeast Asia where remote populations endure structural social and economic inequities, protected areas have often further restricted the livelihood options of people who are destitute. It has been socio-politically difficult to spend money on protecting biodiversity while local people's needs increase. Alternatively, it seems plausible to suggest that managing the existing protected areas with increased efficiency with additional protection to the wildlife through upgrading the legislation. An alarming rate of habitat destruction and various threats to wildlife has heightened the need to review and compare the existing conservation policies and legislation in Malaysia (Mohd-Azlan 2014).

Conversion of natural forest and hunting causes an immediate threat to wildlife in many parts of Southeast Asia, especially in Malaysia (Koh and Sodhi 2010). This has probably contributed to the increasing trend in the number of species being categorized as endangered by the IUCN. In addition to this, the number of endangered species involved in illegal trade in Peninsular Malaysia seems to increase at an alarming rate. From 1996 to 2010, various wildlife species and their derivatives have been confiscated by the Department of Wildlife and National Park (DWNP) in Peninsular Malaysia alone. This includes 80,124 individuals of wildlife (mostly monitor lizards and pangolins), 15,121.3 kg of meat (mostly wild boar, deer, bear and pangolin), 802,376 kg of skin (mostly from civets, monitor lizards, pangolins and pythons), 5 kg of feathers (mostly argus pheasant), 152.2 edible birds' nests, over 10,000 turtle eggs and 1012.8 kg of pangolins' scales. During this period, 52,188 cases (includes technical cases) have been reported by the department. Similar information is not available for Sabah and Sarawak but it is expected the figures can be much more compared to Peninsular Malaysia (Mohd-Azlan 2014).

Therefore, according the government should look more frequently at its wildlife trade laws to deal with new situations as they arise. In general, the Sarawak Wild Life Protection Ordinance 1998 is the most undemanding wildlife protection legislation when compared to Peninsular Malaysia and Sabah. It appears outdated and inferior even when compared to the old Protection of Wildlife Act 1972 (Mohd-Azlan 2014). In order to keep up with the current wildlife conservation status locally and globally, Sarawak needs to review the Wildlife Protection Ordinance immediately to cover loopholes and provide additional protection to Sarawak's wildlife, especially the globally threatened species (Mohd-Azlan and Engkamat 2013). During the Training-the-Judges program held on 10–13 July 2017 in the Judicial and Legal Training Institute (ILKAP), a majority of session court judges had raised their concern on the difficulty in giving judgment especially with the absence of minimum imprisonment in the act, ordinance and enactment. Members of the Sabah state assembly unanimously supported the bill for several amendments to the Sabah's Wildlife Conservation Enactment 1997, which, among others, set a higher minimum and maximum penalties for various offences including wildlife poaching and trafficking (Malay Mail Online 2016). According to the Sabah Tourism, Culture and Environmental Minister, Datuk Seri Masidi Manjun:

> The Wildlife Conservation Enactment 1997 has been enforced for almost 20 years but the penalties have never been reviewed. It is time for the amendments to take place in order to better prevent wildlife poachers from disrespecting and not fearing our laws.

As such, there is a need to review the existing wildlife protection legislations in Malaysia in order to promote a nationalized strategy to ameliorate the shortcoming (Mohd-Azlan 2014).

## 6 Methodology

Qualitative methodology with analytical, historical and comparative approaches was used in this research.

## 7 Results and Discussion

According to the annual report of DWNP, 41 poaching cases were reported from 2011 to 2015. The following graph (Fig. 8.1) shows the increment of poaching cases in Peninsular Malaysia from year 2011 to 2015.

The highest number of poaching cases was reported in 2015. A total of 18 cases were reported, which is equal to a 44.44% increment from year 2014. In 2014, a 50% increase in poaching cases was reported from 2013, which indicated the weaknesses of the Wildlife Conservation Act 2010. From 4 cases in the year 2011–18 cases in the year 2015, the reported cases increased by 77.77%. This increase of reported cases needs to be taken into consideration by the legislative body.

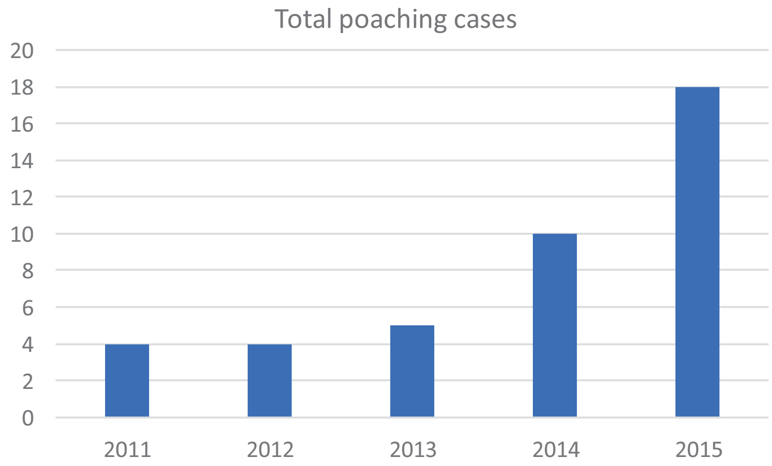


**Fig. 8.1** Poaching cases reported from 2011 to 2015

In the Training-the Judges program held on 10–13 July 2017, session court judges raised the issue of difficulty in giving imprisonment sentences especially in the absence of minimum imprisonment period in the act, ordinance and enactment. Therefore, we have referred to wildlife protection laws, in particular anti-poaching laws, from other jurisdictions in order to make some recommendations to improve the existing law. Cambodia, Laos, Philippines, Burma and Thailand have been identified as subject states.

We have scrutinized the existing anti-poaching law in Malaysia and have identified 3 specific laws in Peninsular Malaysia, Sabah and Sarawak. The respective laws are the Wildlife Conservation Act 2010 (Peninsular Malaysia), the Wildlife Conservation Enactment 1997 (Sabah) and the Wild Life Protection Ordinance 1998 (Sarawak). The following schedule summarizes the minimum and maximum fine depending on the type of offences and maximum imprisonment period imposed by each act, ordinance and enactment Table 8.1.

**Table 8.1** Comparison of penalties under the three different legislations

| | WCA 2010 [Peninsular Malaysia] | WCE 1997 [Sabah] | WLPO 1998 [Sarawak] |
|---|---|---|---|
| **Fine** | ≥RM10,000 – [*not less than*] ≤RM500,000 [*not exceeding*] | ≤RM1,000 – ≤RM50,000 [*a fine of*] [*RM100,000: Corporate body*] | ≤RM1,000 – ≤50,000 [*a fine of*] |
| **Imprisonment** | 10 years | 5 years | 5 years |
| **Hunting** | Allowed with license – listed animals | Allowed with license- listed animals | Not allowed on listed animals (including CITIES I & II) |
| **Fine for killing a totally protected species** | ≤RM 100,000 or imprisonment ≤ 3 years / both | Imprisonment ≥ 6 months [*not less than*] ≤5 years (in possession – to a fine of RM50,000 or to imprisonment for 5 years or both | RM25000 and imprisonment for 2 years |
| **Killing charismatic animals** | (Serow, Gaur, Rhino, tiger, leopard, clouded leopard, false gharial) Fine ≥ RM100,000 & ≤ RM 500,000 & with imprisonment for a term ≤5 years. [*not exceeding*] | N/A | (Rhinoceros) fine of RM50,000 and imprisonment for 5 years Orangutan or proboscis monkey, imprisonment for 2 years and a fine of RM30,000 |
| **Maximum imprisonment [for each offence]** | Yes | Yes | Yes |
| **Minimum imprisonment [for each offence]** | No | No | No |

**Table 8.2** Imprisonment for wildlife-related crimes in Southeast Asian countries

| | Cambodia | Laos | Philippines | Myanmar | Thailand |
|---|---|---|---|---|---|
| **Legislation** | Law of Forestry 2003 | Wildlife & Aquatic Law 2007 | Wildlife Resources Conservation & Protection Act 2001 | The Protection of Wildlife & Conservation of Natural Areas Law (1994) | Wildlife Preservation & Protection Act 1992 |
| **Imprisonment** | 1 month – 10 years | 3 months – 5 years | 5 days – 12 years | ≤7 years [*may extend to*] | ≤7 years [*Not exceeding*] |
| **Maximum imprisonment** | Yes | Yes | Yes | Yes | Yes |
| **Minimum imprisonment** | Yes | Yes | Yes | No | No |

From the critical analysis, it can be summarized that under the act, ordinance and enactment, minimum and maximum fine has been passed in each offence. Under the WCA 2010, the minimum fine is RM10,000, with a maximum fine not exceeding RM500,000. For Sabah, WEC 1997 imposes a minimum fine of RM1000 and maximum fine of RM50,000. However, for corporate bodies found guilty of the wildlife crime, the maximum fine imposed is RM100,000. While in Sarawak, the minimum fine for wildlife crime is a fine of RM1000 and the maximum fine is RM50,000. Under the same act, ordinance and enactment, imprisonment for the wildlife crime committed will also be imposed. However, all of these act, ordinance and enactment only impose the maximum imprisonment period without stating the minimum imprisonment period for any of the offence.

This has created difficulty for the judges in sentencing, especially when dealing with the imprisonment period to be imposed against the poachers. Therefore, we have looked into the legislation of other jurisdictions (Table 8.2):

Five Southeast Asian countries were selected, based on the comprehensiveness of wildlife protection laws in the subject countries. From the critical analysis, three of the five subject countries have passed the minimum imprisonment period to deter poaching. Under the Law of Forestry 2002, Cambodia has a minimum imprisonment of 1 month. Laos' Wildlife and Aquatic Law 2007 has a minimum imprisonment of 3 months while the Philippines' Wildlife Resources Conservation and Protection Act 2001 has a minimum imprisonment of 5 days. However, Myanmar and Thailand have not passed any minimum period of imprisonment. In Cambodia, the maximum imprisonment year for wildlife crime is 10 years while Laos' maximum imprisonment is 5 years and the Philippines is 12 years. For Myanmar and Thailand, the maximum imprisonment may extend to 7 years.

## 8 Conclusion

Based on the critical analysis, it is advisable that the minimum imprisonment period be added to Malaysia's Wildlife Conservation Act 2010 (Peninsular Malaysia), Wild Life Protection Ordinance 1998 (Sarawak) and Wildlife Conservation Enactment 1997 (Sabah) to resolve judges uncertainty as to the appropriate period of imprisonment and at the same time to standardize the sentencing. As stated by the Sabah Tourism, Culture and Environmental Minister, Datuk Seri Masidi Manjun, the Wildlife Conservation Enactment 1997 has been enforced for almost 20 years and it is time for the amendments to take place in order to better prevent wildlife poachers. Azlan and Engkamat also raised the same concern about Sarawak's Wild Life Protection Ordinance 1998 which needs immediate review to cover loopholes and provide additional protection to Sarawak's wildlife especially the globally threatened species. Therefore, a revision of the existing wildlife poaching law is necessary and it is recommended that the minimum period of imprisonment be considered by the legislative body in order to deter wildlife crimes such as poaching more effectively.

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# Chapter 9
# Lifting of Corporate Veil in Wildlife Crime: The Lacuna of Law in Malaysia

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**Abstract** It is a well-known law that a company and its members are separate legal entities. Therefore, members which include the board of directors and shareholders will not be liable for the company's liability. However, the courts are ready to lift up the corporate veil in criminal cases. In wildlife crime, lifting up of corporate veil is important to attribute the act of the criminal to the company by using "direct mind and will" test. However, to charge the right person (director, manager or shareholders) for the wildlife crime committed by the company has caused difficulty to the court. Therefore, this study has been conducted to identify the lacuna of law related to wildlife crime committed by the body corporate and the right person to be charged for the company's wildlife crime and to propose a solution to the problems which have been identified. Qualitative methodology with analytical, historical and comparative approaches were used in this study. Results indicate that the existing laws are very general as to who to be charged for the company's wildlife crime, and it has caused the real offender to escape from justice.

**Keywords** Lifting · Corporate · Veil · Wildlife · Crime

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# 1 Introduction

In Malaysia, corporate bodies have contributed to the increase in wildlife crime. Although in most cases, individual person has been convicted for wildlife crime, some cases, especially smuggling, have reported the involvement of a corporate body. When dealing with the corporate body, Company Act 2016 is relevant in determining whether a director of the corporate body will be charged for the wildlife crime committed by the corporate body. Section 16(5) of Malaysia Company Act 1965 stated:

> On and from the date of incorporation specified in the certificate of incorporation but subject to this act the subscribers to the memorandum together with such other persons as may from time to time become members of the company shall be body corporate by the name contained in the memorandum capable forthwith of exercising all the functions of an incorporated company and of suing and being sued and having perpetual succession and common seal with power to hold land but with such liability on the part of the members to contribute to the assets of the company in the event of its being wound up as is provided by this Act.

Once incorporated, a company becomes a legal person with a legal personality separate from its members. As a legal person, the company would be able to enter into contracts and bring an action to sue in its own name. It is also capable of owing property and continues to exist despite any changes to its membership. It is, however, an artificial person, having no physical body and therefore requires human agents to act on its behalf (Aiman and Effendy 2015).

Even though Company Act 1965 has been replaced by Company Act 2016, the principle of separate legal entity under Section 16(5) is still applicable. Section 21(1) of Company Act 2016 reads as follows:

> S. 21(1) A company shall be capable of exercising all the functions of a body corporate and have the full capacity to carry on or undertake any business or activity including –

(a) to sue and be sued;
(b) to acquire, own, hold, develop or dispose of any property; and
(c) to do any act which it may do or to enter into transactions.

Additionally, Section 20 of Company Act 2016 states:

> “A company incorporated under this Act is a body corporate and shall –

(a) have legal personality separate from that of its members; and
(b) continue in existence until it is removed from the register.

Both Section 21(1) and Section 20 of the Company Act 2016 are parallel with Section 16(5) Company Act 1965, and the principle of separate legal entity is still applicable under the Company Act 2016. Therefore, this study has been conducted to identify the lacuna of law in deterring wildlife crime against the director of a company in Malaysia.

## 2 Problem Statement

Under Malaysian legislations, a corporate body can be convicted for corporate crimes against wildlife. However, the real offender has often escaped from the wildlife crime he masterminds because of the lacuna of the existing law. Therefore, a thorough study has been conducted to overcome this serious problem which weakening the wildlife protection law.

## 3 Research Objective

The research objective was to identify the lacuna of law related to wildlife crimes committed by a corporate body.

## 4 Research Motivation

This study will be essential to improve the wildlife protection law in particular corporate wildlife crime.

## 5 Literature Review

In the eyes of law, a company is an independent legal person separate and distinct from its individual members or directors. In Re Sheffield & South Sheffield Yorkshire Permanent Building Society, in Liquidation, it was held that a company is a "legal persona just as much as an individual. A company once created by the law can only be destroyed by the process of the law".

In the case of *Salomon v Salomon & Co Ltd*, Mr. Salomon sold his sole trader business to a company. The company was owned and controlled by his family, and Mr. Salomon was the majority shareholder. In addition to the issue of shares, the purchase price was secured by debentures issued to Mr. Salomon. An independent lender also made secured loans to the company. When the company was wound up, nothing was left for the unsecured creditors. The liquidator argued that Mr. Salomon had breached his fiduciary duty as promoter by selling his business to the company he created at an excessive price. At first instance, the court rejected the liquidator's argument, since the failure of the business could be attributed to the strikes in the boot trade, rather than breach of fiduciary duty. The liquidator then claimed that the debentures held by Mr. Salomon should not get priority over unsecured creditors. It was held in the lower court that Mr. Salomon, as agent, was bound to indemnify the company for the debts it had incurred. Mr. Salomon appealed to the English Court of Appeal. This court held that Mr. Salomon was not an agent for the company, but trustee for the company, and that Mr. Salomon and his company should not have the privileges of incorporation. Mr. Salomon appealed to the House of Lords. The House of Lords held that even though Mr. Salomon operated as a one-man company, upon incorporation a separate legal entity had been created and that it had the legal capacity to trade and incur debts separately from its directors or members.

The principle of separate legal entity is well accepted by judicial body in Malaysia. In Goh Hooi Yin v. Lim Teong Ghee & Ors, It was said by Arulanandom J. that it was incumbent on Malaysian courts to abide by the doctrine as laid down by the English court unless there were compelling reasons not to do so. In Abdul Aziz bin Atan & Ors v. Ladang Rengo Malay Estate Sdn. Bhd, it was held that even if all the shares in a company were transferred from the existing member to another person, the transfer would not change the company to another entity. In Yap Sing Hock & Anor v. Public Prosecutor, it was held by the Supreme Court that the independent legal entity concept applied to criminal offences.

Based on Section 21(1) and Section 20 of Company Act 2016 and the decided cases, if the company committed wildlife crime, the company will be liable without involving its members. However, in case of corporate liability for crimes, as a legal person, the company would be able to incur its own obligation and may be liable for crimes. For a person to be held liable for a crime, two elements are generally required: mens rea (intention) and actus reus (the conduct/act that is stated to be an offence or a crime). The main challenge for imposing criminal liability on a company is establishing or determining who is the human agent whose conduct and mental state should be attributed to the company (Aiman and Effendy 2015).

Where a crime requires proof of mens rea, the courts will apply the directing mind and will" test to ascertain whose mental state should be considered to make the company liable for the crime. The director, the CEO (chief executive officer) and other senior executives (based on the directing mind and will" test of *Tesco Supermarket Ltd v Nattrass*) or any other person who is to be regarded as the controller of the company for that particular purposes or situation (based on Meridian Global Funds). However, the "directing mind and will" test is only applicable to determine whether an act by a particular person will cause his company liable for the crime committed by him. And while most of the decided cases have been unwilling to treat the directing mind as intrusion on the doctrine of separate legal entity, the directing theory tends to precisely do just that, thereby blurring the distinction between a company and its senior officers and directors (LawTeacher).

Therefore, this research has looked into the lifting of the corporate veil in wildlife crime and identified the lacuna of law in convicting a director of a company.

## 6 Methodology

Qualitative methodology with analytical, historical and comparative approaches was used in this research.

## 7 Result and Discussion

During the Strengthening Capacity for Environmental Law in Malaysia Judiciary: Train-the –Judges Program (TTJ) program, which was held from 10 to 13 July 2017 at the Judicial and Legal Training Institute (ILKAP), one of the concerns of session court judges was the lacuna of law in determining who should be liable for the company's wildlife crime. Recent development has shown the tendency of the company directors or top management to send any of their workers to the court without involving themselves in a trial. In some cases, the offenders were found guilty and sentenced to imprisonment. The judges raised the concern on the lacuna of the existing law and the right person to be convicted and sentenced if the company committed a wildlife crime.

In Peninsular Malaysia, Section 124(1) Wildlife Conservation Act 2010 states:

> Section 124(1) where a body corporate commits an offence under this Act or any of its subsidiary legislation, any person who at the time of the commission of the offence was a chief executive officer, director, manager, secretary or other similar officer of the body corporate or was purporting to act in any such capacity or was in any manner or to any extent responsible for the management of any of the affairs of the body corporate or was assisting in such management –

(a) may be charged severally or jointly in the same proceedings with the body corporate; and
(b) where the body corporate is found guilty of the offence, shall be deemed to be guilty of that offence unless, having regard to the nature of his functions in that capacity and to all circumstances, he proves –

(i) that the offence was committed without his knowledge, consent or connivance; and
(ii) that he took all reasonable precautions and had exercised due diligence to prevent the commission of the offence.

> (2) Where any person would be liable under this Act or any of its subsidiary legislation to any punishment or penalty for any act, omission, neglect or default, he shall be liable to the same punishment or penalty for every such act, omission, neglect or default of any employee or agent of his, or of the employee of such agent, if such act, omission, neglect or default was committed –

(a) by his employee in the course of his employment;
(b) by the agent when acting on his behalf; or
(c) by the employee of such agent in the course of his employment by such agent in the course of his employment by such agent or otherwise on behalf of the agent.

Section 124 clearly lifts the corporate veil and goes against the chief executive officer, director, manager, secretary or other similar officer of the body corporate, and he may be charged severally or jointly in the same proceeding with the body corporate. If the body corporate is found guilty of the wildlife offence, he (the chief executive officer, director, manager, secretary or other similar officer) shall be deemed to be guilty of the same offence, except if he is able to prove that the offence was committed without his knowledge and he has taken reasonable precautions to prevent the commission of the crime. The court applies a strict liability approach on the offender. If the body corporate is found guilty, directly the offender will also be guilty for the same offence until he is proven not guilty.

In Sabah, Section 99 of the Wildlife Conservation Enactment 1997 states:

> "where any offence against this Enactment has been committed by a company or any member of a membership, firm or business, society or association of persons, each director or officer of that company or any other member of the partnership or other person concerned with the management of such partnership, form or business, society or association of persons, shall be liable for such offence, unless he proves to the satisfaction of the Court that –

(a) he has used due diligence to secure compliance with this Enactment; and
(b) such offence was committed without his knowledge or consent".

Section 99 of the WCE 1997 is similar to Section 124(1) WCA 2010 in the sense that Section 99 also lifted up the corporate veil, and strict liability has also been imposed on the director, officer or any other member or any person concerned with the management to prove not guilty of the offence convicted by the company or partnership.

However, Sarawak's Wild Life Protection Ordinance 1998 does not emphasise the term "body corporate." The only term mentioned under the ordinance are any person and whoever. However, the researcher is of the opinion that Sarawak's Wild Life Protection Ordinance 1998 is applicable to individual person rather than body corporate. There is no single section in the act that reflects the offence committed by the body corporate. Therefore, it is questionable as to the applicability of this particular act to the body corporate and its effect on the directors and members of the company.

Section 45 of International Trade in Endangered Species 2008 states:

> "45. Where a body corporate commits an offence under this Act, any person who at the time of the commission of the offence was a director, manager, secretary or other similar officer of the body corporate or was purporting to act in any such capacity or was in any manner or to any extent responsible for the management of any of the affairs of the body corporate or was assisting in such management –

(a) may be charged severally or jointly in the same proceedings with the body corporate; and
(b) where the body corporate is found to have committed the offence, shall be deemed to commit that offence unless, having regard to the nature of his functions in that capacity and to all circumstances, he proves –

(i) that the offence was committed without his knowledge, consent or connivance; and
(ii) that he took all reasonable precaution and had exercised due diligence to prevent the commission of the offence.

Section 45 of the INTESA and Section 124(1) of the WCA are similar in a way that strict liability will be imposed against the offender (the director, manager, secretary or officer) until he is proven not guilty. If the body corporate is found guilty, the director, manager, secretary or officer will directly be convicted. The below schedule summarises the wildlife crime charges impose upon the body corporate (Table 9.1).

**Table 9.1** Charge against body corporate for wildlife crime

| | WCA 2010 [Penisular Malaysia] | WCE 1997 [Sabah] | WLPO 1998 [Sarawak] | INTESA 2008 [whole Malaysia] |
|---|---|---|---|---|
| **Sections** | 124 | 99 | N/A | 45 & 46 |
| **Term** | Offence committed by body corporate | Liability of members of companies and firms | Any person/ Whoever | Offence committed by body corporate |

### *7.1 "Directing Mind and Will" Test as a Guideline to Judges in Determining Who Should Be Charged*

One method of ascribing liability to a company is by ascertaining who is the "directing mind and will" of a company. A Company can be held liable if the person committing the wrongdoing is its "directing mind and will". This concept was laid down in *Lennard's Carrying Co. Ltd v Asiatic Petroleum Co. Ltf.*, where the House of Lords held that the major shareholders' negligence for navigating the ship can be attributed to the company so as to make the company liable. The test formulated determined:

> who is really the directing mind and will of the corporation, the very ego and centre of the personality of the corporation. That person may be under the direction of the shareholders in general meeting; that person may be the board of directors itself, or it may be, and is in some companies it is so, that that person has an authority coordinate with the board of directors given to him under the articles of association, and is appointed by the general meeting of the company, and can only be removed by the general meeting of the company.

In *HL Bolton (Engineering) Co. Ltd v TJ Graham & Sons Ltd*, the company was held to have the intention to occupy certain premises through the conduct of the managers. This was because the board of directors had only met once a year and had left the management to the manager. Denning LJ said:

> A company may in many ways be likened to a human body. It has a brain and nerve centre which controls what it does. It also has hands which hold the tools and act in accordance with directions from the centre. Some of the people in the company are mere servants and agents who are nothing more than hands to do the work and cannot be said to represent the mind or will. Others are directors and managers who represent the directing mind and will of the company, and control what it does. The state of mind of these managers is the state of mind of the company and is treated by the law as such… whether [the] intention [of a particular company officer or officers] is the company's intention depends on the nature of the matter under consideration, the relative position of the officer or agent and the other relevant facts and circumstances of the case.

Both Lennard and HL Bolton laid down the proposition that the law treats directors primarily as the directing mind and will of the company. In addition to directors, the directing mind and will of the company can be the CEO and other senior executives.

However, employees who occupy subordinate position and who carry out the orders of persons who are in control of the company cannot be considered as the company's "directing mind and will", and the employee's mental state will not be attributed to the company. This was decided in *Tesco Supermarket Ltd v Nattras*. At one of the company's stores, the store had run out of the packages of the products on special offer. One of the employees had stocked products which were not on offer on the shelves and had not informed the branch manager. The branch manager had not detected the discrepancies between the price as advertised and the products which were on the store's shelves. The House of Lord held that the branch manager was not the company's "directing mind and will" and the company could rely on the defence that the offence was due to the conduct of another person. The House of Lords held that:

> Normally the board of director, the managing director and perhaps other superior officers of the company carry out the function of management and speak and act as the company. Their subordinates do not. They carry out orders from above and it can make no difference that they are given some measure of discretion.

The same test may be used by the judges to determine who to be charged for the company's crime against wildlife. The researcher will not discuss the application of "directing mind and will" test to prove the attribution of the wrongdoer to the company because it is a well-known test. The researcher is focusing on the proposed "directing mind and will" test to be applied to wildlife crime committed by the corporate body in order to determine who [director, manager, secretary or officer] to be charged together with the company for company's wildlife crime.

The *ratio decidendi* given by Lennard, HL Bolton, and Tesco Supermarkets Ltd perfectly laid down the direction to the judges as to who shall be responsible for wildlife crime committed by the company. Based on the "directing minds and will" test, whoever represents the directing mind and will of the company shall be charged under WCA 2010, WCE 1997 or INTESA 2008 and strict liability approach shall be imposed as the offender until he is proven not guilty. The judges shall apply this "directing mind and will" test in wildlife crime by the company in order to determine that no one [director, manager, secretary or officer] will escape from the wildlife crime he is committed (Fig. 9.1).

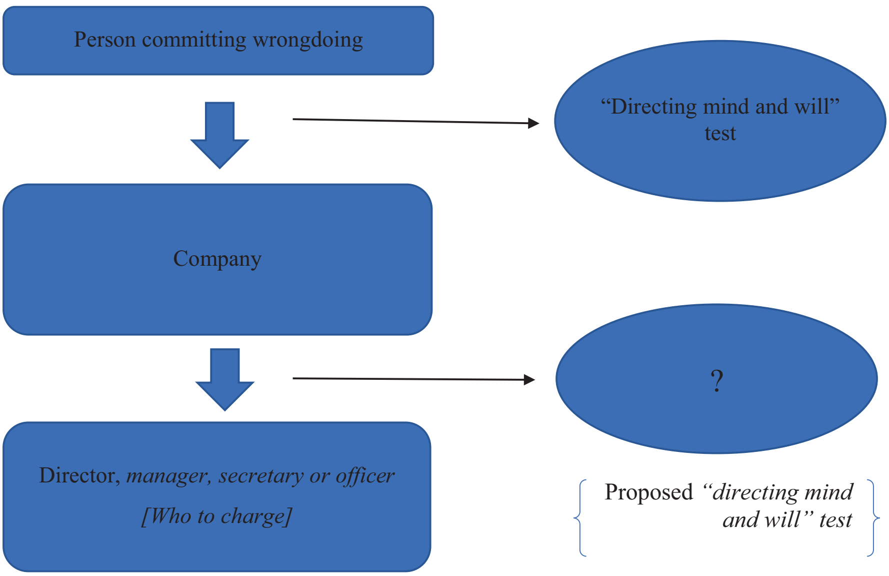


**Fig. 9.1** Flowchart for the study

## 8 Suggestion and Conclusion

Based on the above discussion, it is urged that Sarawak's legislation body should review its Wild Life Protection Ordinance 1997 to incorporate offence committed by a body corporate. It is concluded that under the Wildlife Conservation Act 2010, Wildlife Conservation Enactment 1997, and International Trade in Endangered Species, the body corporate will be liable for corporate wildlife crime and the courts are ready to lift up the corporate veil in order to determine the right person to be charged together with the company.

However, as stated by the researcher, the judges have raised their concern as to the right person to be charged and may be convicted. Therefore, the researcher proposes that "directing mind and will" test together with strict liability approach to be applied in determining the right person to be charged together with the company for wildlife crime. It is hoped that amendment to Sarawak's Wild Life Protection Ordinance 1997 will be done in the future to include offence committed by a body corporate, and the proposed "directing mind and will" test will be applied to determine the right person to be charged together with the company in order to strengthen the wildlife protection law in Malaysia.

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