CHAPTER 2: LITERATURE REVIEW

2.1 Solid Waste Management (SWM)

Solid waste management has become one of a major concern in environmental issues (Mazzanti & Zoboli, 2008). This is particularly true to urban areas where population is rapidly growing and amount of waste generated is increasing like never before (Kathiravale & Mohd Yunus, 2008). Current earth's population is 6.8 billion and it is estimated that almost half of this population lives in urban areas (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009). Waste generation increase proportionally to this population number and income, creating the needs of effective management (Mazzanti & Zoboli, 2008). Urbanization and industrialization leads to new lifestyles and behavior which also affects waste composition from mainly organic to synthetic material that last longer such as plastics and other packaging material (Idris et al., 2004). E-waste that barely existed before was generated as much as 20-50 metric tons a year (UNEP, 2006).

The management of waste become complex and the facilities provided cannot cope with the increasing demand and needs. Therefore, best approach need to be implemented immediately while considering environmental, social and economic aspects (Aye & Widjaya, 2006). The drivers of sustainable waste management were clarified by Agamuthu et al. (2009), which include human, economic, institutional and environment aspect. The study suggests that each driving group should be considered in local context as managing solid waste for a particular society may differ from the others.

For example, waste managers in Africa need to tackle some issues including, lack of data, insignificant financial resources, vast different of amount and waste types between urban and rural area, lack of technical and human resources, low level of awareness and cultural aversion towards waste (Couth & Trois, 2010). On the other hand, problems faced among Asian countries differ with two distinct groups; developed and developing countries. While some of the countries are having specific national policy on solid waste management, some others experience problems such as increasing urban population, scarcity of land, services coverage area, inadequate resources and technology, and so on (Shekdar, 2009).

The differences in managing solid waste not only vary between countries but also among areas in the same country. For instance, while Istanbul are having big improvement in their solid waste management with the establishment of transfer stations, sanitary landfills and methane recovery system, it does not reduce the problem in the Black Sea coast in Turkey. This is caused by the complex topography, weak administrative structures and the low local's income (Berkun et al., 2005).

Integrated Sustainable Waste Management (ISWM) system was then introduced in 1995 to improve earlier system that neglect unique characteristics of a given society, economy and environment (van de Klundert, 1999). For example, European countries had applied various system assessment tools and engineering models to create sustainable communities, manage resources efficiently, tapping innovation potential of the economy, ensuring prosperity, environmental protection and social cohesion in their SWM system (Pires et al., 2011). Asian countries had also given attention in building the national legal frameworks, managing institutional, technology, operational and financial aspects, and creating public awareness and participation (Shekdar, 2009).

The waste management system should be dynamic and continuous based on new insights and experiences (van de Klundert, 1999). For example, continuous assessment of current policy and regulatory framework of New Zealand indicated the lack of policies coordination, hazardous waste management, consistency, incentives and markets for recycled material, and cleaner production effort (Boyle, 2000). Thus, the improvement in policy is needed while it will also benefit the country. As an example, based from EU25 group, it was found that the generation of waste is increasing and is expected to continue for many years ahead. After the implementation of the new EU's policy in waste recovery and incineration, the amount of waste landfilled has been decreasing slowly (Mazzanti & Zoboli, 2008).

However, based from the data from developed countries, the actual amount of waste been landfilled is actually decreasing as more waste are incinerated, composted or recycled. Looking at the positive angle, Lomborg (1998) believed that area needed is sufficient to cater the total amount of waste generated by the world, but the problem is the location since nobody wants to stay near landfills. He also reported that air from incinerators and groundwater near landfills today are cleaner and safer. Therefore, solid waste generation can be considered more of a political or social issue than others (Lomborg, 1998).

A lot of literature has discussed current practices, challenges and future solutions on waste management such as those for India (Hazra & Goel, 2009), Portugal (Magrinho et al., 2006), Canada (Wagner & Arnold, 2008) and Malaysia (Agamuthu et al., 2009). These studies allow comparison to adopt the best practice wherever applicable.

2.1.1 Solid Waste Generation

Waste generation is the most important aspect to look at in order to have effective solid waste management system. The generation of waste varies considerably between countries based on the culture, public awareness and management (Hazra & Goel, 2009; Wagner & Arnold, 2008; Magrinho et al., 2006).

Generally, developed countries generate more waste than developing countries (Kathiravale & Mohd Yunus, 2008). Countries in Asian and African region produce waste in the range of 0.21-0.37 tons/ capita/ year, while European countries generate higher amount of waste with 0.38-0.64 tons/ capita/ year (Intergovernmental Panel on Climate Change [IPCC], 2006).

The generation of waste is also reported to be associated with the economic status of a country. In Asia, countries with higher GDP, namely Hong Kong and Japan were reported to generate more waste compared to developing countries such as India, Vietnam and Nepal (Table 2.1) (Shekdar, 2009). Waste composition from these countries also differs where rural areas often produce more organic waste and fewer recyclable items (Idris et al., 2004).

Table 2.1 Gross domestic index (GDP) and waste generation on selected Asian countries

Country	*GDP (PPP) per capita estimated for 2007(USD)*	*Waste generation (kg/capita/day)*
Hong Kong	37 385	2.25
Japan	33 010	1.1
Singapore	31 165	1.1
Taiwan	31 040	0.667
South Korea	23 331	1.0
Malaysia	12 702	0.5-0.8
Thailand	9426	1.1
China	8854	0.8
Philippines	5409	0.3-0.7
Indonesia	5096	0.8-1.0
Sri Lanka	5047	0.2-0.9
India	3794	0.3-0.6
Vietnam	3502	0.55
Lao PDR	2260	0.7
Nepal	1760	0.2-0.5

Source: Shekdar, 2009

Developed countries are experiencing high waste generation while developing countries always have problems with the implementation of the management system (Hazra & Goel, 2009; Bai & Sutanto, 2002). This includes weak enforcement, lack of technology and ineffective policy implementation (Agamuthu et al., 2009). In detail, these countries experience low and irregular collection of waste, uncontrolled of air and water pollution in open dumping area, the breeding of flies and vermin, and the mismanagement of scavenging activities (Latifah et al., 2009).

Looking at the waste generation trend of developed country, it is believed that other transition and developing countries will experienced the same. Until recently, the generation of waste is increasing and it is believed to continue rising. This is an issue of concern for authorities all over the world. It is believed that the amount of waste will continue to pile up the landfill and someday the land will not be able to receive anymore waste.

2.1.2 Solid Waste Disposal

Information on waste generation is important to determine the most suitable waste disposal options. Improper waste disposal may cause pollution. The main purpose in implementing best practice for solid waste management is to prevent pollution. Pollution is a threat to human and other living organism (Morra et al., 2009; Liu & Morton, 1998). It may also damage the ecosystem and disrupt the natural cycle and climate on earth (Raga et al., 2001). There are many disposal options available to suit the nature of waste and a country's preference and interest.

Economics and environmental aspects of waste disposal option are always the main issue in choosing the right technology (Aye & Widjaya, 2006; Daskalopoulos et al., 1997). Developed Asian countries such as Japan, South Korea and Singapore are on their way to eliminate landfilling while some other Asian countries still have problems with open dumping (Agamuthu & Fauziah, 2010; Shekdar, 2009; Bai & Sutanto, 2002).

Despite the development of many waste disposal option, landfills remain the most prominent system applied worldwide (Shekdar, 2009; Hamer, 2003). Although a lot of improvement had been possible in the landfilling system and the regulation on the type of waste that can be treated at landfill is stringent, most of landfills operated remain primitive (Hamer, 2003).

Ayomoh et al. (2008) had listed few problems related to improper landfill operation including, health deterioration, accidents, flood occurrences, pollution of surface and underground waters, unpleasant odor, pest infestation and gas explosion. Although the impacts from landfills are known, impacts from other alternative remain unanswered thus subject to critics (Hamer, 2003).

Incineration has been the choice for developed country as they have sufficient financial input and are looking into energy recovery from waste (Papageorgiou et al., 2009; Kleiss & Imura, 2006). Small country such as Singapore adopts incineration as their waste disposal option due to scarcity of land (Bai & Sutanto, 2002). Even that, incineration is also associated with some other risks. This includes the generation of carcinogenic and toxic compound. It will also produce end products which need further treatment where it is highly toxic, collectively known as dioxin (Hamer, 2003).

Some reported that the impacts from incineration are over-emphasized and the advancing technology had highly reduced the environmental impacts (Morselli et al., 2008; Hamer, 2003). However, many of the countries prefer waste minimization compared to waste treatment such as landfill or incineration (Bai & Sutanto, 2002; Boyle, 2000). Technology is advancing every day and chemical recycling of plastic wastes has also been made possible in these developed countries (Al-Salem et al., 2009).

Regardless of the technology chosen, each has its pros and cons. The information on each disposal option needs to be clarified to determine the suitable option for each particular country. Few tools had been used in the environmental evaluation including in determining best waste disposal option. For example, Life Cycle Assessment determined that the most economically feasible option for traditional market waste management in Indonesia is composting at a centralized plant, while biogas production option has the lowest environmental impact (Aye & Widjaya, 2006).

Other tools used to determine best waste disposal option includes multiple criteria analysis (MCA) and Cost-Benefit Analysis (CBA) (Chung and Poon, 1996). A SWPlan software particularly to calculate capital and management cost is also available to determine the best integrated technology in waste management (Fauziah & Agamuthu, 2007).

2.1.3 Solid Waste Management in Malaysia

In Malaysia, the Solid Waste Department of the Ministry of Housing and Local Government (MHLG) is the authorized body to manage issues regarding solid waste management. Below is the 6-step process of solid waste management in Malaysia (Figure 2.1):

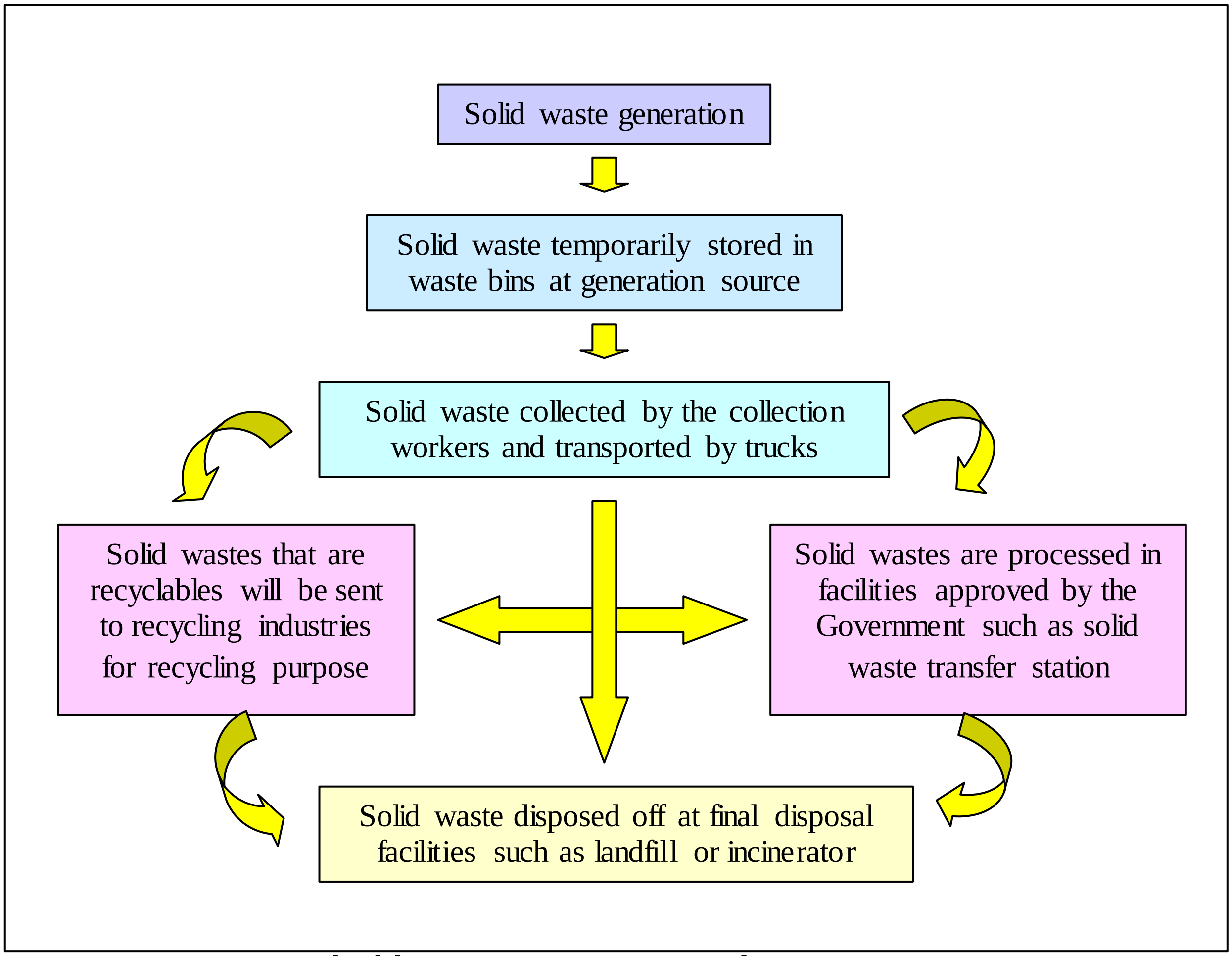

Figure 2.1: Processes of solid waste management in Malaysia
Source: Chong and Raihani, In: *IMPAK*, 2007

Earlier, the cleaning effort was done by the local authority until it was privatized to four private consortia in 1993 to improve efficiency (Agamuthu et al., 2009). After some years, it was unsuccessful to resolve solid waste problem but only managed to transfer the problem to other party (Agamuthu et al., 2009).

2.1.3 (a) Waste generation in Malaysia

Malaysia is a rapidly developing country that faces increasing amount of waste generation; as high as 91% over the past ten years, which current generation exceeds 31,000 tonnes per day (Agamuthu & Fauziah, 2010). This is beyond previous estimation where Malaysia was estimated to generate 31 000 tonnes of solid waste by the year 2020 (Latifah et al., 2009). This is due to the increase of waste generation rate from 0.5 kg/ca/day in 1980's to 1.3kg/ca/day in 2006 (Agamuthu et al., 2009).

Other study reported the per capita generation rate for Malaysian solid waste varies from 0.88 and 1.44 kg/ day depending on the rate of urbanization (Idris et al., 2004). Also, the amount of waste generated depends on the economic status of the inhabitants of the particular area (Agamuthu et al., 2009; Idris et al., 2004).

2.1.3 (b) Waste disposal in Malaysia

Solid waste disposal is one of the issues of concern in many developing countries (Idris et al., 2004). Currently, landfilling is the only method used for solid waste disposal in Malaysia (Agamuthu & Fauziah, 2010; Latifah et al., 2009). Currently, there are 166 dumps and only 8 sanitary landfills in Malaysia (Agamuthu et al., 2009).

Problems from landfills in Malaysia include odor, insufficient covering material, flies and other vermin infestations and smoke from open fires (Idris et al., 2004). The increasing amount of waste received by these landfill make it necessary to find other disposal option since constructing new landfills may be difficult due to the scarcity of land, increase of land price and demand for a better disposal system (Latifah et al., 2009).

2.1.3 (c) The Solid Waste and Public Cleansing Management (SWPCM) Act 2007

The ineffective solution in solid waste management in Malaysia had encouraged the government to further improve the management system by approving the Solid Waste and Public Cleansing Management (SWPCM) Act that has been reviewed since 1997 (Agamuthu et al., 2009). The objective of SWPCM Act 2007 is to improve and ensure high-quality services in solid waste management (Agamuthu et al., 2009). The implementation of the (SWPCM) Act will see the transfer of responsibility from Local Authorities to the federal government in managing solid waste in the country (Agamuthu et al., 2009; Latifah et al., 2009).

Major changes in solid waste management in Malaysia will be in terms of management funds, the payment mode, the waste separation system, improved enforcement and improvement in 3Rs (reduce, reuse and recycle) system (Agamuthu et al., 2009). Other area which is notable in the new Act is the strict punishment including RM10,000 (EURO 1980) to RM 100,000 (EURO 19,802) of fine and a jail sentence of up to five years for those found guilty of illegal dumping, storage and treatment (Latifah et al., 2009).

SWPCM Act 2007 will include the management of solid waste from commercial centers, public sites, construction sites, households, industrial zones, institutions, imported and others (Latifah et al., 2009). In general, the act is focusing on the management of waste at source. Monetary confinement will act upon those ‘found’ guilty, but it will be difficult to determine the culprit in the case of moving waste such as river or ocean dumping.

Currently in Malaysia, the management of this type of waste does not receive as much attention. It is treated separately where Department of Irrigation and Drainage (DID) and Department of Environment (DOE) is responsible for any pollution in river or marine ecosystem. Although direct ocean dumping is not common in Malaysia, urban runoffs and riverside dumps had contribute to debris found on rivers and finally on marine ecosystem (Rajah & Elias, 2006).

2.1.4 River and ocean dumping

River dumping usually involved waste from riverside houses, urban runoffs and storm drains. Ocean dumping includes materials such as demolition debris, sewage sludge, dredge materials, waste chemical and also garbage ("Ocean dumping", 2011). Most of the dumping activities are illegal while some are controlled and regulated.

Ocean dumping was a common practice before countries over the globe began to ban the activities in 1980s (Zou, 2009; Duxbury et al., 2000). Even after the prohibition, dumping into water bodies persist in the area where waste collection service is not received (Inanc et al., 2004).

In some regions, although there are designated dumping areas for slaughterhouse, hazardous and biomedical waste, the legislation are ineffective to curb illegal dumping onto water bodies (Inanc et al., 2004). To make it worse, waste previously dumped from ports and waterways had found their way back to the beaches years after the implementation of the legislation on ocean dumping (Duxbury et al., 2000).

Although direct dumping is prohibited, it was found that 80% of the total debris found in the river and ocean sourced from land-based activities ("Plastic debris: Rivers to sea", 2011). The amount of waste found on marine ecosystem can be minimized by controlling the amount of land-based charges ("Plastic debris: Rivers to sea", 2011). The management of solid waste on land will have impact to marine ecosystem, thus the understanding of the relationship is required to control marine pollution.

2.2 Marine Ecosystem

The earth is known as a system where living and non-living co-exist, dependant and interact with each other in exceedingly complex ways (Mann, 2000). About 75% of the total world area is water thus marine ecosystem definitely plays major roles in the earth system (Duxbury et al., 2000). Marine ecosystem consists of oceans, salt marshes, intertidal ecology, estuaries, mangroves, lagoons, coral reefs, deep sea and the sea floor ("Marine ecosystem", 2011).

2.2.1 Functions and roles of marine ecosystem

Marine ecosystem and the atmosphere are in contact over 75% of the Earth's surface in a continuous and dynamic manner (Duxbury et al., 2000). The interaction influenced occurrence of clouds, winds, storms, rain and fog over the earth; forming the weather and climate (Duxbury et al., 2000). Marine ecosystem has the capacity to control the earth surface temperature by heating or cooling processes; as a buffer for the whole system

(Duxbury et al., 2000). It is also involved in biogeochemical cycles including carbon, nitrogen and phosphorus cycle (Thurman & Trujillo, 2004).

The ocean is said to be the lungs of the earth by supplying 70% of the oxygen gas human breathe and taking carbon dioxide out of the atmosphere (Thurman & Trujillo, 2004). Other marine ecosystem such as estuaries acts as a filter for inland runoff while mangroves protect the coastline from waves thus prevents soil erosion (Mann, 2000). Marine ecosystem is the largest and prominent element on earth that has shaped political boundaries and human history (Thurman & Trujillo, 2004). Covering, as much as, 70% of the earth area, it is a home for thousands of species that is also important for human survival as food source (Mann, 2000).

The species found in the ecosystem varies in size; from microscopic bacteria and algae to the largest life form of blue whale (Thurman & Trujillo, 2004). As for recently, more than 250 000 marine species had been identified and the number is increasing everyday (Mann, 2000). In fact, it is estimated that 5 - 100 millions species have not been identified (Duxbury et al., 2000).

Within the vast area of marine ecosystem, most of the marine organisms can be found within the sunlit surface waters thus concentrated on the coastal area with high amount of primary production (Thurman & Trujillo, 2004; Mann, 2000). The high productivity of the marine ecosystem attracted large proportion of the world's human population (Mann, 2000). More than 60% of human population lives within 100 km of the coastline (Duxbury et al., 2000), where billions depend on marine ecosystem for their source of income including from fisheries and other associated industries (Mann, 2000).

Marine ecosystem has rich esthetic values thus offer famous recreational spot for tourist. Marine tourism is the fastest growing sector in global tourism industry and a major economic contributor for many small island countries. Other than that, this aquatic body also serves as a transporting medium between countries that connects all parts of the world; for tourism and also for other industries (Duxbury et al., 2000).

2.2.2 Human exploitation on the marine ecosystem

Concerns on the current state of marine ecosystem are rational since the destruction is uncontrollable. All types of marine ecosystem is experiencing human exploitation particularly from the destruction of mangroves area for aquaculture (Plate 2.1), waste loading in estuaries from inland development, and disturbance of coral reefs (Plate 2.2) and sandy beaches due to overexploitation in fishing (Plate 2.3) and recreational activities (Mann, 2000). Public protest over marine pollution continues but fails to leave a significant impact (Plate 2.4). Rapid population growth and recent advances in technology had both contributed to the depletion of marine resources such as marine fisheries and offshore petroleum deposits (Thurman & Trujillo, 2004).

Plate 2.1: Mangroves converted to aquaculture in Ecuador
(Source: http://blogs.nationalgeographic.com/blogs/news/chiefeditor/2010/07/atlas-of-mangroves.html, Retrieved: October 1, 2011)

Plate 2.2: Dead coral reefs in Malaysia's Tioman Island
(Source: http://surfspots-gps.com/great-barrier-reef-park-needs-vessel-tracking-system-implemented-to-avoid-disasters, Retrieved: October 1, 2011)

Plate 2.3: Over fishing in the Mediterranean water
(Source: http://www.greenpeace.org/mediterranean/photosvideos/photos/overfishing-in-the-mediterrane, Retrieved: October 1, 2011)

Plate 2.4 Esperanza flotilla protest over pollution from Lafayette's mine in Rapu-rapu.
(Source:http://weblog.greenpeace.org/makingwaves/archives/2006/08/rapu_rapu_lafayette_pollution.htm, Retrieved: October 1, 2011)

Although the marine ecosystem supplies the society with important resources, it is also the final destination of waste product (Thurman & Trujillo, 2004). As land become scarce, ocean dumping is increasingly important as the option for waste disposal (Thurman & Trujillo, 2004). The ecosystem is likely to be used as dumping area on the basis that the ocean are vast enough to dilute pollutants; with good solvent (water) and mixing mechanisms such as currents, waves and tides (Thurman & Trujillo, 2004). In addition, people believe that everything from the land will eventually end up in the ocean someday (NOAA, 2010).

Human depends on marine ecosystem for food, space, resources and so on. The importance of marine ecosystem is clear and undeniable yet unsustainable activities in extracting and using the resources had caused significant damages. Without any control, these disturbances will someday become a serious threat to our existence.

2.3 Marine Debris Pollution

Marine litter or commonly known as marine debris is 'any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment (NOAA, 2010). This definition is used by the USEPA for the implementation and requirement of their environmental regulations. However, the usage of the word 'persistent' is arguable since plastic material that is the most concerned type of marine debris is not always persistent. In this definition, natural debris such as driftwood is left out, whereas many studies do recognized them as marine debris (Claereboudt, 2004; Silva-Iñiguez & Fisher, 2003). However, the definition has been accepted worldwide including the UNEP (Ten Brink et al., 2009).

Marine debris is the most common term used in regards to solid waste found abandoned on any type of marine ecosystem. It is a broader term of marine litter that includes the impacts other than aesthetical point of view (Hall, 2002). Few different terms had been used which refers to marine debris, including beach debris, marine litter, beach litter, shore litter, and solid waste (ICC, 2010; Claereboudt, 2004; Moore et al., 2001; Madzena & Lasiak, 1997). Marine debris is the general terms, often used in many of the studies regardless the specific type of marine debris sampled.

Marine debris is a global problem which had impacted countries in terms of natural resources, wildlife, habitat and also human health and safety (NOAA, 2010). It later contributes to economic and social loss. The impact from marine debris had worsened in recent years due to the replacement of organic to synthetic materials as the most prevalent item found on marine ecosystem (NOAA, 2010). In International Coastal Cleanup 2010 report, marine debris is believed to be one of the worst pollution problems of lifetime (ICC, 2010). According to UNEP (UNEP, 2010); *"Marine debris is one of the most pervasive and solvable pollution problems plaguing the world's ocean and waterways"*

Although marine debris is a serious threat to the ecosystem, human have the ability to control and curb the problem. This is because it all began from human themselves. As quoted by Achin Steiner (UN Under-Secretary General and UNEP Executive Director), in International Coastal Clean-up 2010 report (ICC, 2010); *"Marine litter is symptomatic of a* *wider malaise: namely the wasteful use and persistent poor management of natural resources. The plastic bags, bottles, and other debris piling up in the oceans and seas could be dramatically reduced by improving waste reduction, waste management, and recycling initiatives"*.

Therefore, the change in behavior through education and supports from governments and corporations, nonprofits and scientists is able to prevent waste from our hands into the marine ecosystem (ICC, 2010). Therefore, the knowledge on marine debris including sources and impacts are important to be understood by everybody.

Marine debris may consist of any items. It includes smallest item such as cigarette butts to thousands pound of derelict fishing net (NOAA, 2010). These items may be deposited on beach or sea from all sorts of ways and sources. In general, marine debris is sourced from coastal or inland. Different activities in both areas may contribute to marine debris. It is estimated that 60-80% of marine debris were sourced from inland activities (ICC, 2010). However, there are studies that reported otherwise (Moore et al., 2001; Whiting, 1998).

There are numerous studies on marine debris from all parts of the world (Keller et al., 2010; Spengler & Costa, 2008; Ivar do Sul, 2007; Madzena & Lasiak, 1997). However, there are dissimilarities among studies of marine debris that minimize the possibility for comparison (Ryan et al., 2009). The differences include sampling protocols, units used and type of data reported in the studies.

For sampling protocols, many of marine debris studies only consider standing-stock (debris found on a particular time) while some observed the rate of accumulation following the previous clean-up (Ryan et al., 2009). There are studies that collect data from a single sampling event (Claereboudt, 2004; Moore et al., 2001; Whiting, 1998) while some considers the possible difference from spatial and temporal variations (Edyvane, 2004; Thornton & Jackson, 1998; Madzena & Lasiak, 1997).

Size of sampling area also differs where some studies sampled whole beaches while other collects litter only on fixed area or determined strandline (Ryan et al., 2009; Claereboudt, 2004; Moore et al., 2001). Other than that, there are studies that not only consider litter on beaches but also waste found in garbage bins (Ariza et al., 2008). The differences in sampling protocols contribute to different unit used to represent the debris found. There are studies that count the number of item found on sampling area while other studies look at mass (Ryan et al., 2009). Studies that use rate of accumulation recorded different unit which also include temporal unit such as ‘number of item/ day’, ‘g/ m^2/ day’, and so on (Ryan et al., 2009; Dameron et al., 2007).

Although marine debris covers wide range of litter types, most of information on debris is from monitoring studies of litter stranded on beaches (Ryan et al., 2009). Perhaps, debris on beach is the most studied because of its direct effect on users and tourism industry in general (Ivar do Sul & Costa, 2007). In addition, it could also due to the cost and technicality involve (Ryan et al., 2009).

Besides marine debris found on beaches, there are wider range of marine debris that is often neglected. Studies has looked on drifting, submerged, floating, benthic, and buried debris (Martinez et al., 2009; Thiel et al., 2003; Nagelkernen et al., 2001; Willoughby et al., 1997).

Sampling at sea provides data that considers the dynamic of marine ecosystem (Ryan et al., 2009). However, besides the complicated procedures, sea surveys are limited for standing-stock study and not accumulation rate (Ryan et al., 2009). It also often focuses on smaller range of debris. For example, floating debris may only cover lesser densities item such as plastics (Ryan et al., 2009). The differences between marine debris studies are mainly contributed by different goal and purpose. Studies may have different perspective although the method is similar. There are studies on debris that is a possible threat to beach ecosystem while other studies focused on the production of waste from recreational activities. Regardless of the objective of the studies, most provide a baseline data of marine debris for global comparison and future references.

2.3.1 Composition of Marine Debris

Marine debris may consist of any anthropogenic material such as plastics, bottles, cans, cloth, tires to fishing nets and cigarette butts. Each item may contribute to certain impact with some is more harmful than the other. The International Coastal Cleanup 2010 has come up with the 'Top ten marine debris item' list. Table 2.2 shows the most common type of marine debris found worldwide.

Table 2.2: Top ten marine debris item worldwide

Rank	*Debris item*	*Number of debris item*	*Percentage of total debris item (%)*
1	Cigarettes/ cigarette filters	2,189,252	21
2	Bags (plastic)	1,126,774	11
3	Food wrappers/ containers	943,233	9
4	Cups, lids	912,246	9
5	Beverage bottles (plastic)	883,737	9
6	Cups, plates, forks, knives, spoons	512,517	5
7	Beverage bottles (glass)	459,531	4
8	Beverage cans	457,631	4
9	Straws, stirrers	412,940	4
10	Bags (paper)	331,476	3
	Total	**10,239,538**	**100**

Source: International Coastal Cleanup (ICC, 2010)

From Table 2.2, cigarette and cigarette filters were recorded as the most abundant item found, nearly twice the number of plastic bags (ICC, 2010). Types of waste found during International Coastal Cleanup were listed in a more specific manner, where debris collected are categorized within five different sources, and divided between disposable and non-disposable. Result shows that 60% of the debris found was disposable and 73% of 'Top ten debris' found were from 'Shoreline and Recreational Activities' (ICC, 2010). International Coastal Cleanup is the biggest volunteer event related to beach health worldwide. However, it only acts as a snapshot of current estimates of marine ecosystem health at particular location, on a particular day, and by volunteers (ICC, 2010). The size of area covered, number of volunteers and types of sampling area (land/ underwater) are different between locations thus the result may not represent all beaches worldwide.

Scientific studies however, often cover smaller area and classify waste in more general groups. For example, these studies usually include cigarette butts as either 'organic waste' or 'others'. Therefore, the composition of waste between most of the studies differs from the International Coastal Cleanup report. Within these studies, plastics have been recorded to be the most abundant type of marine debris found worldwide (Bravo et al., 2009; Claereboudt, 2004; Derraik, 2002; Madzena & Lasiak, 1997). Despite their obvious negative impacts and low densities, plastics remain the most common anthropogenic marine debris found (Agamuthu, 2009; Bravo et al., 2009).

Plastics can be transported far from the source because of its low density compared to items such as glass or metal and lasts longer compared to other low density item such as paper (Ryan et al., 2010). In water, plastic also degrades slower due to fewer sunrays received and cooler temperatures (ICC, 2010). Light debris such as plastic travels far through space and time making it a global and not a local problem.

In a specific study of plastic debris, at least 33 out of 37 studies on marine debris worldwide had recorded plastic percentage of more than 50% (Table 2.3) (Derraik, 2002). Litter type, be it shoreline, beach or seabed, did not affect the percentages of plastic. It contributed 92% of debris found on the seabed of North East Atlantic, and also more than 90% of debris found on 50 beaches of South Africa (Derraik, 2002). Other study also recorded a significant amount of up to 99% abundance (Moore et al., 2001) while in other studies, plastics dominate the waste composition of 60 to 80% (Morishige et al., 2007; Claereboudt, 2004; Madzena & Lasiak, 1997).

Table 2.3: Plastic proportion among marine debris worldwide

Locality	Litter type	Percentage of debris items represented by plastics	Source
1992 International Coastal Cleanups	Shoreline	59	Anon (1990)
St.Lucia, Caribbean	Beach	51	Corbin and Singh (1993)
Dominica, Caribbean	Beach	36	Corbin and Singh (1993)
Curacao, Caribbean	Beach	40/64	Debrot et al. (1999)
Bay of Biscay, NE Atlantic	Seabed	92	Galgani et al (1995a)
NW Meditterranean	Seabed	77	Galgani et al. (1995b)
French Meditterranean Coast	Deep sea floor	>70	Galgani et al. (1996)
European coasts	Sea floor	>70	Galgani et al. (2000)
Caribbean coast of Panama	Shoreline	82	Garrity and Levings (1993)
Georgia, USA	Beach	57	Gilligan et al. (1992)
5 Meditterranean beaches	Beach	60-80	Golik (1997)
50 South African beaches	Beach	>90	Gregory and Ryan (1997)
88 sites in Tasmania	Beach	65	Gregory and Ryan (1997)
Argentina	Beach	37-72	Gregory and Ryan (1997)
9 Sub-Atlantic Islands	Beach	51-88	Gregory and Ryan (1997)
South Australia	Beach	62	Gregory and Ryan (1997)
Kodiak Is, Alaska	Seabed	47-56	Hess et al. (1999)
Tokyo Bay, Japan	Seabed	80-85	Kanehiro et al. (1995)
North Pacific Ocean	Surface waters	86	Laist (1987)
Mexico	Beach	60	Lara-Dominguez et al. (1994)
Transkei, South Africe	Beach	83	Madzena and Lasiak (1997)
National Parks in USA	Beach	88	Manski et al. (1991)
Meditterranean Sea	Surface waters	60-70	Morris (1980)
Cape Cod, USA	Beach/harbour	90	Ribic et al (1997)
4 North Atlantic harbors, USA	Harbour	73-92	Ribic et al. (1997)
Is. Beach State Park, New Jersey, USA	Beach	73	Ribic (1998)
Halifax Harbour, Canada	Beach	54	Ross et al. (1991)
Price Edward Is., Southern Ocean	Beach	88	Ryan (1987b)
Gough Is., Southern Ocean	Beach	84	Ryan (1987b)
Heard Is., Southern Ocean	Beach	51	Slip and Burton (1991)
Macquire Is., Southern Ocean	Beach	71	Slip and Burton (1991)
New Zealand	Beach	75	Smith and Tooker (1990)
Two gulfs in W. Greece	Seabed	79-83	Stefatos et al. (1999)
South German Bight	Beach	75	Vauk and Schrey (1987)
Bird Is., South Georgia, Southern Ocean	Beach	88[a]	Walker et al. (1997)
Fog Bay, N. Australia	Beach	32	Whiting (1998)
South Wales, UK	Beach	63	Williams and Tudor (2001)

Results are arranged in alphabetical orders by author

[a]76% of total consisted of synthetic line for long-line fisheries

Source: Derraik, 2002

Other marine debris frequently found includes metal and glass (Keller et al., 2010; Bravo et al., 2009). In many of the studies, although plastic is the most abundant item found, wood, metal and glass are sometimes considered more abundant on weight basis (Keller et al., 2010; Claereboudt, 2004). Plate 2.5-Plate 2.8 shows various types of debris found on beaches worldwide.

Plate 2.5 Debris on Alaskan rocky beach
(Source: http://seagrant.uaf.edu/news/08news/01-23-08marine-debris.html, Retrieved: October 1, 2011)

Plate 2.6: Bottles and other debris collected using traps
(Source: http://www.plasticdebris.org/, Retrieved: October 1, 2011)

Plate 2.7: Buoyant for fishing nets washed ashore in Laysan Island, Hawaiian Island. (Source: http://www.merosoch.com/2009/06/07/the-great-bamboo-story/, Retrieved: October 1, 2011)

Plate 2.8: Amount of fishing nets managed to be collected from North Pacific Ocean (Source: http://www.pifsc.noaa.gov/cred/img/mdr/DebrisPileOnMidway.jpg, Retrieved: October 1, 2011)

In these numerous studies of marine debris, different evaluation or units have been used including weight and number of item found, based on the objective of each study. Comparison is difficult, suggesting the need of a standard method. Many of the studies looked at number of item found in every meter or meter square (Bravo et al., 2009; Claereboudt, 2004; Madzena & Lasiak, 1997).

Results obtained vary between beaches around the world. An average of anthropogenic marine debris found on South East Pacific in Chile is 1.8 items m^{-2} (Bravo et al., 2009) similar with debris on the Gulf of Oman which is 1.79 item m^{-1} (Claereboudt, 2004). Other study recorded higher number of wastes such as in Transkei Coast of South Africa with 19.6 – 72.5 items found in every meter area (Madzena & Lasiak, 1997). Table 2.4 depicts marine debris densities on beaches throughout the world, as listed by Bravo et al. (2009).

Table 2.4: Densities of marine debris on beaches throughout the world

Country	**Number of surveyed beaches**	**Average densities (items m^{-2})**	**Reference**
Scotland	16	0.4	Velandes and Mocogni, 1999
Brazil	2	0.7	Araújo et al., 2006
Brazil	10	0.14	Oigman-Pszczol and Creed, 2007
Japan[a]	34	45000	Fujida and Sasaki, 2005
Japan[a]	18	3.4	Kusui and Noda, 2003
Russia	8	0.2	Kusui and Noda, 2003
Oman	11	~0.4	Claereboudt, 2004
Jordan	3	4.0	Abu-Hilal and An-Najjar, 2004
Panama	19	3.6	Garrity and Levings, 1993
Australia	1	0.5	Foster-Smith et al., 2007
Australia	6	0.1	Cunningham and Wilson, 2003
Pitcairn Island	2	0.2	Benton, 1995
Ireland	1	0.2	Benton, 1995
Indonesia	21	4.6	Evans et al., 1995
Chile	43	1.8	Bravo et al., 2009

[a] These studies counted individual pellets of fragmented Styrofoam, an item usually not counted in most other studies *Source*: Bravo et al., 2009

There is also a study looking at the amount of waste found in every km^2. The unit is more appropriate to be used in the study because it is actually looking at amount of benthic marine debris at different depth using bottom trawl surveys. In the study, marine debris found increased with depth ranging from 30 items km^{-2} to 128 items km^{-2} (Keller et al., 2010).

Other study using the same unit (number of item km^{-2}) is a study on floating marine debris (FMD) in Japan shores using moving vessel (Shiomoto & Kameda, 2005). For both example, total areas covered is larger and the probability to find debris is lower therefore 'items per km^2' is the most suitable unit.

Besides number of item, weight is often used to determine marine debris density too. Comparing the weight, wood and other heavier debris tends to dominate the waste composition perhaps from the presence of one particular bulky waste such as abandoned boat (Claereboudt, 2004). It is the cause of high proportion of fishing-related debris found when comparing the weight (Moore & Allen, 2000). Weight was chosen to represent waste abundant due to the large range of sizes that make it difficult to visualize the actual amount of waste found. Single plastic may not have the same impact with single driftwood found that make number of item an unsuitable unit to reflect marine debris pollution in an area. It shows the importance to determine the most suitable unit to represent different objectives and characteristics of the study.

2.3.2 Distribution of Marine Debris

The knowledge on marine debris sources allows us to overcome the problem through preventive action. Precautionary action should be the preference before treatment or cleaning efforts. To achieve this, it is important to understand the possible movement of marine debris before it is deposited and found. Floating material travels across the ocean, influenced by wind and sea currents (Figure 2.2) (ICC, 2010).

Figure 2.2: The ocean currents that impact marine debris movement.
Source:http://www.oceanconservancy.org/images/2010ICCReportRelease_pressPhotos/ICCcharts/globalSurfaceCurrentsW.jpg, Retrieved: October 1, 2010).

Debris with light weight such as plastics may be carried far from the origin thus harder to determine the source (NOAA, 2010). Little information can be found on the effect of wind and sea currents to waste distribution especially in South China Sea where this study is concerned. However, there are studies suggesting simpler method to determine the origin of debris which is from brand names, label or logos identified on the debris such as wrappers or bottles (Claereboudt, 2004). Although this method may not be accurate, it is common in marine distribution study (Madzena & Lasiak, 1997).

The distribution of debris on beach is affected by many interrelating factors. Physical characteristics of the beach profile with local wind and wave action control where the debris are cast ashore (Thornton & Jackson, 1998). For example, plastics were found abundant on wind-dominated area while heavier debris such as glass was observed to be abundant on wave-dominated area of the same beach (Thornton & Jackson, 1998).

In another study, more debris was found after periods of rough weather such as storms and rain (Ribic et al., 2010). The physical characteristics affecting debris accumulation is the evident when different composition of debris found on two different type of beach. Types of marine debris found between sandy beaches and rocky shores of a same area are at a different proportion. The debris is more abundant on rocky shores despite the remoteness of the area (Moore et al., 2001). However, the finding may be affected by the regular clean-up of higher usage shore and not based on beach type. This is agreeable in other study where a periodical regime of beach cleaning contributes to a lower density of waste found (Bravo et al., 2009).

The distribution of waste within months may also vary due to many factors. A study suggested that the amount of waste varies between seasons due to the intensity of beach usage and cleaning activities rather than the environmental factors (Ariza et al., 2008). Similarly, debris found on Transkei coast of South Africa also differs between months due to the low and high peak visiting period (Madzena & Lasiak, 1997). However, the natural impact of season is also possible where debris deposited during El-Niño is higher compared to La-Niña events; influenced by sea surface temperature (Morishige et al., 2007).

Considering spatial variation, the distribution of waste within the same beach indicated a significant trend. In a study, highest portion of waste was found at around 8 m from the high-water mark. It gets lesser ahead the water mark and approaching vegetation line (Claereboudt, 2004). However, this pattern may just reflect certain beaches. There is also a study which suggested that the highest density of debris was found in the upper zones of the beach, because of the present of most beach users within this part of the beach (Bravo et al., 2009). Type of waste found on the upper beach is mostly anthropogenic sourced while natural debris is mostly abundant near the water body and in smaller amounts (Ribic et al., 2010). It shows that man-made debris is significant on beaches.

2.3.3 Sources of Marine Debris

It is suggested that marine debris may be contributed from four main sources; recreational/ tourism, fisheries, shipping and sewage outfalls (Hall, 2002). Traditionally, these sources are classified into two categories which are land-based and sea-based sources. Jones (1995) suggested that sea-based sources include recreational boating and merchant ships while land-based sources include storm water drains and beachgoers. Based on the report on the International Coastal Cleanup 2010, sources of marine debris can be divided into 5 categories (Table 2.5).

Table 2.5: Sources of marine debris

Sources of marine debris	Percentage (%)
Shoreline and recreational activities	64
Smoking related activities	25
Ocean/ waterway activities	8
Dumping activities	2
Medical/ personal hygiene	1

Source: International Coastal Cleanup, 2010

The intensity of particular damage depends on the local inputs to the beach such as the large size of tourism industry, the high fishing activities or busy shipping lanes (Hall, 2002). However, there are other factors that may also affect the amount of debris found. A study of a main tourist attraction beach in Australia did not exhibit the highest amount of debris because of the presence of large number of litter bins (Frost & Cullen, 1997).

Activities held around the area often affect the composition and distribution of marine debris. Recreational beaches are polluted with debris such as plastics, cigarette butts, polystyrenes and glass bottles (Bravo et al., 2009; Willoughby et al., 1997). Other beaches with different usage are abundant with other types of marine debris. For instance, Kodiak Island in Alaska with frequent fishing activities was contaminated with debris such as plastic bait jars, fishing lines and crab pots (Hess et al., 1999).

In most of the studies conducted, major contributor to marine debris is land-based sourced (Silva-Iniguez & Fischer, 2003; Moore et al., 2001). However, this is not the case of some other isolated beaches where most of the debris is marine sourced (Moore et al., 2001; Whiting, 1998). In most of the cases, although waste is usually from land-based sources, debris from fisheries and maritime origins pose the greatest threat to ecosystem health which is influenced by the waste characteristics (Donohue et al., 2001).

2.3.4 Impact of Marine Debris

Marine debris abundance all over the globe affects human, wildlife and environment in many ways. Guidelines from United Nation Environment Program (UNEP) listed the impact of marine debris as loss of biodiversity, loss of ecosystem function, loss of revenue, loss of livelihoods and increase in the cost of maintenance and clean-ups (Ten Brink et al., 2009).

2.3.4.1 Loss of biodiversity

The main impact of marine debris is the entanglement and ingestion to wildlife. Entanglement and ingestion problem have affected many wildlife species and occurred frequently in many parts of the world. Most of the incident were caused by abandoned fishing-related item such as trawl netting and gillnets, and ‘ghost fishing’ (Donohue et al., 2001).

2.3.4.1 (a) Entanglement

Entanglement is a threat to wildlife because it may drown or irritate the animal. It also reduces their ability to move, to catch prey and avoid predators. In the case of lost gillnets, predators which were attracted to trapped animal can also get entangled with marine debris while catching their prey (Jones, 1995). All types of wildlife have been threatened from entangling material especially fishing related items (Good et al., 2010; Moore et al., 2009; Arnould & Croxall, 1995).

Bird's beck was found tied with ropes while catching its prey thus prevents the bird from eating (Plate 2.9). Nets entangled and irritate sea lions (Plate 2.10) and hinder turtle's movement (Plate 2.11). Bigger mammal such as whale is not excluded from the trap of abandoned nets (Plate 2.12). Some animals have to deal with the entangling material since they were young such as turtle in Plate 2.13.

Plate 2.9: A bird caught by marine debris
(Source: http://www.time.com/time/health/article/0,8599,1846014,00.html, Retrieved: October 1, 2011)

Plate 2.10: Unnecessary accessory for sea lion
(Source: http://marine-litter.gpa.unep.org/framework/region-1.htm,
Retrieved: October 1, 2011)

Plate 2.11: Turtle's growth distressed by a rope tightens the body.
(Source: http://aquascapeconservation.org/research/marine-debris/,
Retrieved: June 27, 2012)

Plate 2.12: Whale accidentally caught by net
(Source: http://www.fakr.noaa.gov/protectedresources/entanglement/whales.htm,
Retrieved: October 1, 2011)

Plate 2.13: Fishing nets nearly kill turtle hatchlings
(Source: http://turtlesoscaboverde.blogspot.com/2010_10_01_archive.html,
Retrieved: June 27, 2012)

In a study, it was found that the most common neck entangling material are packing bands (54%), rubber bands (30%), net (7%), rope (7%) and monofilament line (2%) (Raum-Suryan et al., 2009). Different types of entangling material were found on different types of animal. Boren et al. (2006) listed types of debris found entangling fur seals in the Kaikoura region of New Zealand as shown in Table 2.6.

Table 2.6: Types of debris found entangling fur seals:

	Debris type	**Number recorded**	**Proportion of total**
Main debris	Green trawl net	68	0.4198
	Blue packing tape	26	0.1605
	Other net	28	0.1728
	Other packing tape	24	0.1481
	Other	16	0.0988
“Others”	Rope	6	0.373
	Monofilament	3	0.1875
	Rubber ring	2	0.125
	Twine	1	0.0625
	Wire	2	0.125
	Fish hook	2	0.125

Source: Boren et al., 2006

From another study of recovered gillnets, 32 851 individuals from 13276 species of vertebrates, 22 species of fishes, 16 species of birds and 4 species of mammals were found dead or trapped by marine debris in Puget Island and Northwest Straits of USA since 2002 (Good et al., 2010).

All classes of wildlife cannot escape from the risks to be entangled. The most commonly found entangled were mammals including pinnipeds (Hanni & Pyle, 2000), sea lions (Raum-Suryan et al., 2009; Page et al., 2004) and seals (Boren et al., 2006; Arnould & Croxall, 1995). Other animals observed are birds (Moore et al., 2009) and fish (Sazima et al., 2002).

Local and international efforts are crucial in order to mitigate the problem. Campaigns held by the authority in South Georgia, UK for example, had successfully reduce the number of packing bands from fishing vessels thus significantly reduce the percentage of entanglement of Antarctic fur seals (Arnould & Croxall, 1995). However, there are also some failures in the effort to remove and reduce the debris. Cases of entanglement of Hawaiian monk seal in Northwestern Hawaiian Island since 1982 until 1998 did not lessen after the implementation of MARPOL Annex V 1989 (Henderson, 2001). Similar cases happen in South Australia. Despite of efforts from government and industries to reduce impact of fishing to non-target species, Australian sea lions and New Zealand fur seals continue to be trapped by lost fishing gear and other marine debris (Page et al., 2004).

2.3.4.1 (b) Ingestion

While bigger items entangled and threatened wildlife, smaller debris posed danger to other animals. Ingested material may harm the affected animal by damaging their digestive tract and reduce food intake (Jones, 1995). Often mistaken as food, debris was found to be ingested by small and even bigger animals. Plate 2.14 and Plate 2.15 illustrate the amount of debris found inside dead albatross chicks.

Plate 2.14: Dead Laysan albatross chick from ingestion of marine debris (Source: http://www.b-e-a-c-h.org/marine_debris.html, Retrieved: October 2, 2011)

Plate 2.15: Another albatross chick died from consuming too much plastic debris (Source: http://www.weareecofriendly.com/, Retrieved: October 2, 2011)

Turtles are one of the animals involved with debris ingestion. All dead green turtles in Southern Brazilian coast were found to have ingested debris (Tourinho et al., 2010). The death of both two stranded sea turtles (*Lepidochelys olivacea* and *Chelonia mydas*) along the coast of Paraíba, Brazil was also caused by the ingestion of hard plastics and plastic bags (Mascarenhas et al., 2004). However, in other study, loggerhead sea turtles (*Caretta caretta*) were found to be resistance to debris ingestion. Although different types of debris were found in 79.6% of the captured turtles, mortality is not the issue (Tomás et al., 2002). The actual cause of death was nutrition dilution (Tomás et al., 2002). Plate 2.16 shows some example of plastic debris found inside a stomach of a dead green turtle.

Plate 2.16: Sizes of plastic found in green turtle
(Source: http://www.seaturtle.org/imagelib/?cat=663&thumb=1,
Retrieved: October 2, 2011)

Tourinho et al. (2010) suggested that the occurrence of ingestion in turtles is not affected by the size or weight of the turtle. On the contrary, earlier study recorded significant increase of debris proportional to the size of sea turtles. However, the study suggested a further research to determine whether the resistant increases with size or age of the turtles (Tomás et al., 2002).

Besides turtles, other animals threatened by debris ingestion are seabirds and even bigger mammals. From 100 styrofoam and other macro spongious plastic debris found on Dutch coast, 80% showed peck marks of seabirds mistaken for cuttlebones as their calcium carbonate source (Cadée, 2002). Another 40% of seabirds in Southern Brazilian coast had ingested debris. However, one (Charadriiformes) of the three orders sampled was not contaminated with plastic debris (Tourinho et al., 2010). This result shows that debris is not a threat to all species probably due to different diet or feeding patterns.

Despite this, debris ingestion can also be fatal to big mammals such as sperm whale. Besides well documented entanglement events of this mammal, there were 2 sperm whales found dead from ruptured stomach, and emaciated and gastric impaction. This is caused by the presence of 134 different types of net, varying from the size of 10 – 16 cm^2 in both whales (Jacobsen et al., 2010).

Plastics are the most prevalent type of debris found to be ingested (Tourinho et al., 2010; Tomás et al., 2002; Bugoni et al., 2001). The ingested item are fishing-related items including lures (80%), longline gear (12%), hook and line (4%), spinners/spoon (2%) and bait hooks (2%) (Raum-Suryan et al., 2009). Among these debris, the most frequently ingested were white or colorless plastic pieces (Bugoni et al., 2001). In contrast, colors did not exhibit a significant different of debris chosen by seabirds (Tourinho et al., 2010).

2.3.4.2 Changes and destruction of ecosystem

In any addition to the environment, changes are unavoidable. Changes may be positive and it may also be negative. Marine debris especially man-made is unnecessary addition and mostly affects the environment negatively. The presence of marine debris may cause ecosystem disruptions. Many studies looked at the changes from the presence of marine debris to different habitats and organisms.

A study of biota in Ambon Bay, Eastern Indonesia suggested that marine litter affect the abundance of meiofauna, macrofauna and diatoms. Comparing sites of litter-covered with litter-free sediments, meiofauna and some of macrofauna (decapod crustacean and oligochates) were abundant on litter covered area while litter-free area was abundant with some other macrofauna (nereid and spionid polychaetes) and diatoms (Uneputty & Evans, 1997). The abundance of the organisms was a result of light availability and preferences for different organisms (Uneputty and Evans, 1997). This may be the case of some fishes and microinvertebrates in Californian deep seafloor habitat which use marine debris as their home (Watters et al., 2010).

Marine debris may also become a transport for encrusted and attached community when the debris is drifted to a new area hence becomes a competitor of the native species (Ten Brink et al., 2009). Besides, the usage of mechanical remover in many beaches cleaning process may also threaten the stability of some ecosystem by removing organic material from the area (Hall, 2002). Although the consequences of these situations are not certain, precaution is important as future outcome is unpredictable.

2.3.4.3 Loss of ecosystem function and revenues

The changes in environment will somehow affect the function of the ecosystem. Pollution from marine debris is known to contribute to biological, physical and social losses, followed by the economic cost (Ofiara & Seneca, 2006). For instance, plastics coated by shells and sand after some time will sink to the bottom and cause the anoxia and hypoxia area between water and sediments (Shahidul Islam & Tanaka, 2004). This is an example of the ecosystem changes that may alter the topographical and biological condition of the sea floor (Shahidul Islam & Tanaka, 2004).

Any changes particularly from marine debris may not just alter the physical appearance of the ecosystem but also the chemical and biological functions. Among the sectors that may be affected from marine debris pollution are tourism and fishing industries (Ofiara & Seneca, 2006).

Tourism had affected the environment adversely (Daby, 2003). A case study in Orange County, California estimated an economic loss of US$3.3 million per year to treat illnesses related to water contamination from two recreational beaches in the area (Dwight et al., 2005). The news of adverse health impact from polluted beaches may somehow affect public perception on other cleaner beaches in other area thus indirectly effects beach tourism industry in general (Ofiara & Seneca, 2006).

Recently, environmental quality of a beach is a significant value in holiday destination selection (Philips & House, 2009; Yaw Jr., 2005). Public demand has a great influence in beach conservation programs. Pressure from public forced the municipal cleaning provider to be more responsible (Araújo & Costa, 2007). Examples of public control over pollution prove that contaminated beach will reduce the number of visitors thus inflict a financial loss. This includes tourism revenues for surrounding community and dropped price of waterfront real-estate's value (Ofiara & Seneca, 2006).

Fisheries as well as tourism may also contribute to marine pollution. In some studies, fisheries was found to be the major contributor of marine debris (Hess et al., 1999; Jones, 1995) while it is also the most affected sector from marine pollution (Shahidul Islam & Tanaka, 2004). In terms of marine debris, it was recorded that the debris from fisheries floats across the water; entangle propellers and block the water cooling suction pipe thus resulting in engine failures (Cho, 2005).

In an interview, 92% of fishermen from Shetland had experienced problems related to marine debris accumulation (Hall, 2002). Marine debris may caused losses to fishermen in terms of time spent to clean debris from nets, avoidance of particular area to fish, damaged nets from large debris and the cost of employing divers to disentangle a fouled propeller (Hall, 2002). The removal of debris from propeller is time consuming and also expensive (Plate 2.17).

Plate 2.17: Entangled propeller
(Source: http://water.epa.gov/type/oceb/assessmonitor/debris/md_impacts.cfm,
Retrieved: October 2, 2011)

Besides impacts to fishermen and their vessels, marine debris had also reduced the production of shellfish and seaweed by 10-20% and 20-30% respectively (Cho, 2005). Marine debris affects this seafood industry by altering the habitat. To make it worst, news on unclean water also affect consumer's perception on other uncontaminated and safe seafood (Ofiara & Seneca, 2006).

2.3.4.4 Maintenance and clean-up cost

Apart from environmental damages and direct cost, marine debris indirectly cost the authorities and communities a considerable amount of money and efforts to restore the affected area. The esthetical value of an area is threatened while hazards are likely to occur, forcing the authorities and communities to bear costs in maintaining and cleaning the beach (Ten Brink et al., 2009). However, occasionally, costs in maintaining the ecosystem and removing marine debris is lower compared to the benefit it may gain ("Endoverfishing", 2011).

2.3.5 Efforts and benefits on marine debris removal

The impact from marine debris is very disturbing. However, most of the efforts been done so far is the physical removal of the debris (Dameron et al., 2007; Donohue et al., 2001). These removals usually focused on large debris item especially derelict fishing gear due to the impact and visibility (Morishige et al., 2007). For instance, debris removal carried out in Hawaiian Archipelago to protect the wildlife and coral reef ecosystem in the area by The National Marine Fisheries Service (NMFS) managed to remove 492 metric tonnes of derelict fishing gear (Dameron et al., 2007).

Many of marine debris and derelict fishing gear clean-up programs had benefited the economy. While Northwest Straits had been restored, $1.28 and $1.27 were gained in every dollar spent to remove crab pots and derelict fishing nets, respectively ("Endoverfishing", 2011). Abandoned gillnets removal event in Puget Sound, Washington recorded a benefit of $14.50 worth of crabs to the commercial fishery in every dollar used for the removal (Gilardi et al., 2010).

Unfortunately, debris removal is often temporary solution (Boland & Donohue, 2003). Beside physical efforts, it also cost a huge amount of money. For the alternative, a more comprehensive effort was done by the Korean government that implements 'A Practical Integrated System for Marine Debris' program. The program integrates four technologies including prevention, deep-water survey, removal, and treatment (recycling) (Plate 2.18). However, after a decade of development, public sector rather than private sector needs to maintain the environmental facilities due to the poor cost-benefit profile (Jung et al, 2010).

Marine debris removal may be costly, thus an innovative solution are needed. An incentive program carried out in Incheon, Korea that compensate fishermen to remove abandoned fishing gear successfully benefited both parties; the government and the fishermen. The fishermen were given US$ 5.00 per 40 L bag while the previous removal would cost the government at least US$ 48.00 per 40 L bag (Cho, 2009).

Plate 2.18: Floating debris containment boom, deep sea survey system, marine debris removal devices, thermal attraction system for volume reduction (*clockwise*)
Source: Jung et al, 2010.

The integrated system and the incentive program carried out in Korea illustrate the importance of government involvement in mitigating problems related to marine debris. Global and national policies on the issue will have significant impact to the current situation and benefited the interest groups.

2.3.6 Legislation related to Marine Debris

Malaysia currently does not have any legislation specifically for marine debris, although marine debris is acknowledged as one of the issue in the management of marine parks in Malaysia (Ministry of Natural Resources and Environment, 2010). Instead, Malaysia has a more general legislation which covers marine pollution. These include the Environmental Quality Act 1974, Merchant Shipping (Oil Pollution) Act 1994, Waters Act 1920 and Fisheries Act 1985.

Although legislation specifically for marine debris is absent in Malaysia, the country are supportive and has been involved in efforts to tackle marine debris presence in the beaches (ICC, 2010). NGOs and public have played a major role in the determination of water quality and other environmental issues in Malaysia. Therefore, it is important to acknowledge their influence in the quality of any marine ecosystem.

The most significant legislation related to marine debris is Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) implemented in 1989 that has been ratified by 70 nations (Henderson, 2001). The effort had successfully reduced the number of impacted marine mammal while some did not record significant changes (Henderson, 2001). Besides MARPOL, other international treaty related to marine debris is The London Convention which is the United Nation agreement to control ocean dumping (“Marine debris: European law”, 2010).

Besides these international treaties, most of the countries have a more general legislation and act including laws on clean water or marine pollution (NOAA, 2010). However, some countries do have specific legislation related to marine debris such as, Marine Plastic Pollution Research and Control Act and Marine Debris Research, Prevention and Reduction Act in United States (NOAA, 2010).

2.4 Public and marine pollution issue

2.4.1 Public involvement in environmental assessment and decision making

Public is the most affected group in every environmental decision made by the authoritive body. Therefore, their involvement in environmental assessment is a common practice in Europe and some other countries worldwide (González et al., 2008). Charnley & Engelbert (2005) suggested that the involvement of public in an environmental decision-making was driven by the demand of public to have greater role in a decision.

Although public involvement is recognized as one of important parts in environmental study, there are some concerned issues of the method (González et al., 2008). Sinclair & Diduck (1995) recognized the lack of knowledge and resources of the public to have a significant impact to their decision. The necessities in educating public and provide useful information was documented in many studies (Lai et al., 2011; González et al., 2008; Sinclair & Diduck, 1995).

Gonzalez et al. (2008) stated that public need to be informed thus providing technology-aided data such as GIS to public is an important step to educate and help them to make a better decision. This is proven in the case study of The Yuansantze Flood Diversion Works Project. At the beginning, public experienced problems in understanding the project, thus a communication barrier exist between public, engineers and the decision makers. However, after the implementation of 3D visualization, the project gained positive responds from the public (Lai et al., 2011).

As other environmental issues, public opinion in beach management is crucial. The attitude and action of public may determine the success of a beach program. Hence, it is important to include public or beach users' awareness, beliefs and attitude in the study.

2.4.2 Public attitude towards beach classification and policy

Public or beach user will act according to their beliefs and preferences. This is the basis in implementing classification of beaches cleanliness or the development of any policy. However, sometime beach user may not have the same interest as imagined by the implementing body.

In a study, the attitude of recreational users towards the European Water Framework Directive (WFD) was not as predicted. The users of recreational facilities were not highly constrained by the pollution and poor water quality, but more concern on their personal experiences and current situation. However, the mission of WFD to make sure that all water bodies are in 'good ecological status' by 2015 had slightly benefited coastal land-based activities that use water body as a backdrop such as cycling/ walking, and other water based activities such as angling and swimming (Ravensoft & Church, 2011).

Recognition of beach cleanliness had also experienced similar outcome. Nelson & Botteril (2002) reported that Green Coast Award that was designed to guide beach users in beach selection did not affect public decision in choosing certain beaches in Wales. However, although the award scheme is not well recognized by the public, the quality of beaches within the scheme had improved by having a very high environmental standard (Nelson & Botteril, 2002).

Nelson et al. (2000) also reported that beach award did not play major roles in beach selection criteria but, public have concerns over the distance of beach to their home (76%), facilities (40%) and the cost of the trip (33%). The study realized that criteria included in beach award scheme may not be the actual public demand. However, any development whether to facilitate users demand or to gain the beach award should be carefully considered. This is to prevent unnecessary damage to the beach features (Nelson et al, 2000).

2.4.3 Demographic, awareness and perceptions of public

Different range of age, gender, and economic status of beach user may have impact on their awareness and action. However, Nelson et al. (2000) reported that statistically, beach awards did not have influence towards gender and type of users, but have significant positive influence to older age user, employed users and housewives. Other study to determine the beach award awareness indicated similar result where older categories (age 45+) are more aware of the awards and recognized the importance of such scheme (Nelson & Botteril, 2002)

In a study to compare priorities of three different tourism market (surfing, ecotourism and family) found that different group of beach user have different priorities in choosing the beach to visit but share common concern over sewage treatment and regular removal of persistent marine debris (Philips & House, 2009). Thus, it is necessary that appropriate studies are conducted to identify the significant factors which may promote beach cleanliness and directly reduce impacts of marine debris.