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Management of Marine Debris from Ships in Compliance to MARPOL 73/78 Annex V

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Management of Marine Debris from Ships in Compliance to MARPOL 73/78 Annex V

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been dully acknowledged.

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Julyus Melvin Mobilik
13010036

8 January 2016

I dedicate this study to my parents,

Mr. Julius Mobilik and Mdm. Mariana Norman...

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ABSTRACT

Marine debris is widely distributed at the ocean surface and coastal area, but their specific sources, quantities and distribution remain uncertain. Although, studies have been conducted to estimate the quantity of debris along the Malaysian beaches, marine sources especially from the shipborne garbage was not extensive. In addition, the large number of vessels using Malacca Straits as an important trading route may produce pressure on the marine environment, particularly garbage accumulated on the vessels navigating within Malaysian Territorial Water. Therefore, this study was designed to investigate marine debris abundance in Malaysia marine environment from shipborne garbage source. This study adopted a standard method of beach marine debris survey and shipborne garbage survey to assess the types, amount, categories and sources of debris on eight public beaches and five ports in Malaysia. Beach marine debris study was conducted during the northeast monsoon (NEM), southwest monsoon (SWM) and intermediate monsoon (IM) seasons at Pandan, Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru, Kosuhoi, Saujana and Batu Rakit beaches. A total of 46,141 items (961 item/km) weighing 2,120 kg (44.2 kg/km) were collected and categorized during six surveys conducted at the beaches between October 2012 and August 2014. Debris accumulation was more abundant during SWM, while, plastic category (88.48%) dominating debris items collected at this study. Debris abundance stranded on the beaches can be attributed to urban proximity. As for shipborne garbage survey, 115 vessels were selected at Kuching (25 vessels), Bintulu (20 vessels), Kota Kinabalu (20 vessels), Sandakan (14 vessels) and Klang (36 vessels) ports en route through Malacca Straits. A total of 20,895 items (182 item/vessel) weighing at 6,316.1 kg (54.9 kg/vessel) were collected and categorized during surveys conducted on the vessels between October 2012 and October 2014. Sandakan port accumulated the highest mean shipborne garbage item (SGI) at 197 item/vessel, whereas, Kota Kinabalu port accumulated the highest mean shipborne garbage

weight (SGW) at 64.0 kg/vessel. Shipborne garbage abundance is influenced by number of crews and vessels' gross tonnage. As for shipborne garbage accumulation according to ship type, bulk carrier vessels accumulated the highest mean SGI (212 item/vessel) and SGW (63.8 kg/vessel). The low percentage of vessels equipped with garbage processing equipment (33.33%), may resulting the high percentage of plastic category (63.75%) ending in the marine environment. Although, many factors contributed to the marine debris abundance, human-generated debris was found to be the major source of the marine debris problem in this study. The presence of debris items associated with shipping activities found on the beaches indicated not all vessels comply with the new revised Annex V of the MARPOL 73/78. Therefore, promulgating awareness and educate the general public on pathway of marine debris needs to be collaborated with public participation to instill consciousness through environmental education. In addition, comprehensive and long-term monitoring along Malaysian coastline is paramount to identifying marine debris point source. Thus, specifying and implementing strategic solution besides determining priorities to ensure total eradication of illegal discharge at sea and understanding marine debris abundance relationship against dynamic climate conditions. This effort may be small but the impact as a result of this action will reduce the amount waste dispose of at sea tremendously.

Pengurusan Debri Marin dari Kapal dalam Pematuhan MARPOL 73/78 Lampiran V

ABSTRAK

Debri marin diagih secara meluas di permukaan laut dan kawasan pantai, tetapi punca sumber, kuantiti dan pengagihan debri marin masih kurang jelas. Walaupun terdapat banyak kajian yang menyeluruh telah dijalankan untuk menganggarkan kuantiti sampah sepanjang pantai di Malaysia, punca sumber marin daripada sisa sampah kapal belum meluas. Di samping itu, jumlah kapal menggunakan Selat Melaka sebagai laluan perdagangan penting boleh menghasilkan tekanan ke atas persekitaran laut, terutamanya kapal yang membawa sisa sampah ke dalam kawasan perairan Malaysia (MTW). Oleh itu, kajian ini di reka bentuk untuk menyiasat kuantiti debri marin di persekitaran pantai di Malaysia, terutama sisa sampah dari sumber kapal. Kajian ini mengguna pakai kaedah baku kajian pantai debri marin dan kajian sisa sampah kapal untuk menilai jenis, jumlah, kategori dan sumber sisa debri marin di lapan pantai awam dan lima pelabuhan di Malaysia. Kajian debri marin di pantai dijalankan semasa musim monson timur laut (NEM), monsun barat daya (SWM) dan monsun perantaraan (IM) di pantai-pantai Pandan, Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru, Kosuhoi, Saujana and Batu Rakit. Sejumlah 46,141 item (961 item/km) yang mempunyai berat keseluruhan sebanyak 2,120 kg (44.2 kg/km) telah dikutip dan dikategorikan semasa enam pensampelan yang dijalankan pada setiap pantai antara Oktober 2012 dan Ogos 2014. Jumlah item debri marin lebih banyak dikutip semasa musim SWM, manakala, item debri marin daripada kategori plastik (88.48%) adalah paling banyak terkumpul di pantai kajian. Pengumpulan debri marin di pantai di pengaruhi oleh jarak daripada bandar. Bagi kajian sisa sampah kapal, sebanyak 115 buah kapal telah terpilih di pelabuhan-pelabuhan Kuching (25 kapal), Bintulu (20 kapal), Kota Kinabalu (20 kapal), Sandakan (14 kapal) dan Klang (36 kapal) yang menggunakan Selat Melaka sebagai laluan perjalanan. Sejumlah 20,895 item (182 item/kapal) sisa sampah kapal yang mempunyai berat

6,316.1 kg (54.9 kg/kapal) telah dikutip dan dikategorikan semasa pensampelan di atas kapal di antara Oktober 2012 dan Oktober 2014. Pelabuhan Sandakan mengumpul purata item sampah kapal (SGI) tertinggi pada 197 item/kapal, manakala, pelabuhan Kota Kinabalu mengumpul purata berat sampah kapal (SGW) tertinggi pada 64.0 kg/kapal. Pengumpulan sampah kapal di pengaruhi oleh jumlah anak kapal dan berat kasar kapal. Kapal jenis pukal mengumpul purata SGI (212 item/kapal) dan SGW (63.8 kg/kapal) paling tinggi. Peratusan kapal dilengkapi dengan alat memproses sisa sampah yang rendah (33.33%), mungkin akan menyebabkan kategori plastik (63.75%) yang tinggi berakhir di laut. Walaupun terdapat banyak faktor menyumbang kepada kuantiti debri marin, faktor sikap manusia didapati menjadi punca utama kepada masalah tersebut. Kehadiran sisa sampah aktiviti perkapalan di pantai, menunjukkan tidak semua kapal mematuhi keperluan terkini Lampiran V MARPOL 73/78. Oleh itu, kempen mendidik masyarakat mengenai laluan debri marin di persekitaran marin perlu melibatkan penyertaan orang ramai untuk memupuk kesedaran melalui pendidikan alam sekitar. Tambahan daripada itu, terdapat keperluan pemantauan secara komprehensif dan jangka panjang di sepanjang pantai Malaysia untuk mengenal pasti punca dari sumber marin secara spesifik. Ini seterusnya memudahkan penetapan keutamaan dan memperkenalkan penyelesaian strategik untuk membasmi pembuangan sampah secara haram di laut, selain memahami perhubungan terhadap kajicuaca yang dinamik. Usaha-usaha ini mungkin kecil tetapi kesan akibat daripada tindakan ini akan mengurangkan tindakan membuang sampah ke laut.

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LIST ABBREVIATIONS

3R	- Reduce, Reuse, Recycle
BDI	- Beach Debris Item
BDW	- Beach Debris Weight
BGW	- Black Grey White classification
CPB	- Clear plastic bottles
DWT	- Deadweight tonnage
EAN	- European Article Number
EF	- Excess factor
EGW	- Estimate Garbage Weight
EPA	- Environmental Protection Agency
GGR	- Garbage Generation Rate
GMP	- Garbage Management Plan
GPS	- Global Positioning System
GRB	- Garbage Record Book
GRT	- Gross Tonnage
ICC	- International Coastal Cleanup
IM	- Intermediate Monsoon
IMO	- International Maritime Organization
IOC	- International Ocean Conservancy
IPO	- Input-Process-Output
ISM	- International Safety Management
JGESAMP	- Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
JLM	- Jabatan Laut Malaysia
km	- kilometer
km/h	- kilometer/hour
km^2	- kilometer square
LA21	- Local Agenda 21
LC	- Langmuir Circulation
LNG	- Liquefied natural gas vessel
LPG	- liquefied petroleum gas vessel
m	- meter
MARPOL 73/78	- International Convention for the Prevention of Pollution from Ship 73/78
MEPC	- Marine Environment Protection Committee
MMD	- Malaysia Meteorological Department
MOU	- Memorandum of Understanding
MT	- Metric Tonnes
MTW	- Malaysia Territorial Water
NEM	- Northeast Monsoon
NGO	- Non-Governmental Organization
Nm^{-2}	- newton/square meter
nmi	- Nautical mile
NOAA	- National Oceanic and Atmospheric Administration
PSC	- Port State Control
PSCO	- Port State Control Officer
PVC	- Polyvinyl chloride
R&D	- Research and Development
REI	- Relative Exposure Index

Ro-Ro	- Roll-on/Roll-off vessels designed to transport wheeled cargo
SGI	- Shipborne Garbage Item
SGW	- Shipborne Garbage Weight
SWM	- Southwest Monsoon
TSS	- Traffic Separation Scheme
UNEP	- United Nations Environment Programme
USM	- Universiti Sains Malaysia
VOS	- Voluntary Observation Ship

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The characteristic of the coastal area has attracted the development of residential, commercial, recreational area and with its aesthetic value (Valavanidis & Vlachogianni, 2012; Walker *et al.*, 2006; Kamaruddin, 1998; Vandermeulen, 1998), therefore, have inculcated the coastal zone as highly economic importance and attraction. Given the concentration of development along the coastal area a connection between development and pollution, it is important to involve multi disciplinary approach to ensure minimum pollution of marine environment.

The marine debris has created a significant problem affecting the oceans, coastlines, beaches and seafloors (Williams *et al.*, 2005). Marine debris which is also term as marine litter or solid waste (Allsopp *et al.*, 2006; United Nations Environment Programme (UNEP), 2005), poses potential threats and hazards to the abundance of marine life (Laist, 1987). These debris includes plastic bags, six pack rings, tar, styrofoam, glass and other materials that can pose danger to human and marine wildlife (Mascarenhas *et al.*, 2004; Bugoni *et al.*, 2001). In general, plastics are considered as a destructive material to the ocean life, degrading extremely slowly due to their polymeric nature and intended durability in the ocean (Webb *et al.*, 2012; O'Brine & Thompson, 2010; Hetherington *et al.*, 2005). It was not until the 1970's, that plastic was perceived as a widespread marine pollutant or recognized as a threat to marine species (Azzarello & Van Vleet, 1987). With increased knowledge of mechanical effects on marine life, marine debris is established as an ocean pollutant (Laist, 1987). Rubbish in the marine environment could derive from marine source such as discharge deliberately from ships, platform, fishing vessels; and land-based sources such as runoff, blown by wind or recreational litter left on beaches (Ryan *et al.*, 2009; Ribic, 1998; Coe & Rogers, 1997; Dixon & Dixon, 1981).

Malaysia has coastline stretches of about 4,800 km (Department of Irrigation and Drainage, 2012). The coastlines and associated coastal zone areas are precious national asset for marine bio-production including fishes, crustacean, bivalves and other marine wildlife. In addition, it provides facilities to connect with international global trade demands. Malaysia particularly Sarawak coastline has variable characters and contains valuable natural resources, including lagoon, mangrove forest, mudflats, swamps, rocky cliffs, sandy beaches and coral reefs (Hassan *et al.*, 2007). Due to rapid development occurring in coastal zone, there is an increase of environmental concern among the public. Beaches in Malaysia are suffering serious pollution due to either natural cause or human impact (Gasim *et al.*, 2013; Khairunnisa *et al.*, 2012; Ngah *et al.*, 2012; Husin *et al.*, 2007; Hassan *et al.*, 2007; Chan *et al.*, 1996). Studies suggested that there is a direct correlation between population rate, urbanization and desirable quality of cleanliness (Abdullah *et al.*, 2012; Khairunnisa *et al.*, 2012; Manaf *et al.*, 2009; Hassan *et al.*, 2007; Sheavly, 2005a). Thus, littering has become a major problem among urban population in Malaysia which produces between 1.25 and 1.70 kg/person/day (Ismail, 2014; Manaf *et al.*, 2009; Saeed *et al.*, 2009). Despite mitigation action from the Ministry of Urban Wellbeing, Housing and Local Government, population in the urban areas should take pride and be more responsible towards the environment.

Marine pollution can derive from many sources, however, ship generated waste is of particular concern (National Research Council (NRC), 1995). From the shipping industry perspective, pollution in the oceans has been recognized an environmental concerns that may caused a significant threat to marine life (Abdulla, 2010). The International Convention for the Prevention of Pollution from Ship 73/78 (MARPOL 73/78) is the primary international treaty governing ship generated waste (International Maritime Organization (IMO), 2012a), include 169 countries representing approximately 99% of the vessel gross tonnage distributed across the world (IMO, 2014b). Similar to other international conventions, MARPOL 73/78 must be translated into domestic legislation to comply with MARPOL 73/78 mandate upon signing the convention.

MARPOL 73/78 defines several classes of wastes and sets separate requirements for the disposal of each waste (IMO, 2012b). Of these, oil (Annex I) and garbage (Annex V) are the most common and make up the majority of waste tonnage. Depending on the nature of the waste, MARPOL 73/78 determines whether it may be discharged into the ocean or discharge on land once the vessel enters the port. These restrictions apply wherever vessels from member countries of MARPOL 73/78 travel. Although the convention obligates the ship owners to provide accurate records of garbage disposal to coastal authorities, the conformity to maintain the records without illegally altering discharge practices is difficult (Ninaber, 1997). In the face of such challenges, compliance with MARPOL 73/78 is not universal. Inadequate reception facilities, high costs of disposal, and other factors may lead some crews to illegally discharge their ships' waste (Ball, 1999) particularly in the Malaysian waters. The probability of detecting such illegal dumping in the vastness of the Malaysian water is very low. Unless proper disposal is desirable to the ship, illegal discharge will continue.

The amounts and types of garbage discharge overboard before the ratification of Annex V of the MARPOL 73/78 are unknown (NRC, 1995). Furthermore, garbage input generated from land and other maritime industries wastes transported through offshore winds, rivers, and coastal runoff makes ship garbage identification difficult (Lu *et al.*, 2013; Bird, 1996).

However, possible way to estimate shipborne garbage is monitoring a particular debris types at a selected sampling area (Ribic, 1998). Shipborne garbage especially plastic-based materials may be a reliable indicator to identify ships' discarded garbage on beach isolated from recreational activities and potential land-based debris influences (UNEP, 2005).

Malaysia as an important water gateway from east to west for transportation of goods by vessels (Khalid, 2006), accumulation of marine debris can be critical especially at heavy maritime traffic area (Walker *et al.*, 1997) in Malacca Straits. In addition to LNG, LPG, Ro-Ro (Car carrier), tug boats, barges and tanker vessels, there are many commercial vessels frequently visiting ports in Malaysia. These vessels include container, bulk carrier and general cargo vessels that transport goods and resources to markets around the world besides importing necessary goods. These ships generate waste under all of the annexes of MARPOL 73/78.

1.2 Problem statement

The presence of marine debris in marine environment can be associated with human activities (Sheavly & Register, 2007), and has been established as pollution problem globally (Sheavly, 2005a; Derraik, 2002). Marine environment particularly beaches around the world are littered with numerous type of solid waste especially plastics-based materials. Factors determining accumulation of debris on beaches include location, beach usage and human activities (Corbin & Singh, 1993). In addition, indirect factors such as natural beach physiographic, slope, exposure and environmental factors (prevailing winds and ocean currents) also influence the transportation of the debris items (Thornton & Jackson, 1998; Frost & Cullen, 1997).

Although awareness of the solid waste pollution problem has grown in Malaysia, systematic observations have not been extensive to document the marine debris pollution satisfactorily (Agamuthu *et al.*, 2012). Studies on marine debris in Malaysia have been conducted but limited to Teluk Kemang, Pasir Panjang, Pandan, Pasir Pandak, Temasyah, Tg. Lobang and Terengganu beaches during the northeast monsoon (NEM) season (Fauziah *et al.*, 2015; Khairunnisa *et al.*, 2012; Hassan & Mobilik, 2012; Chan *et al.*, 1996). Studies have shown that fragmentation and deposition of debris items increased with storms and rain events (Golik & Gertner, 1992; Vauk & Schrey, 1987). However, submerged debris through coastal morphology changes may consequently underestimate total amount of debris reaching the shore (Williams & Tudor, 2001). Since Malaysia is influenced by different monsoon seasons, this study examines marine debris accumulation during NEM, intermediate monsoon (IM) and southwest monsoon (SWM) seasons to determine the relationship of debris stranded on the beach with shipborne garbage.

Studies has shown that stranded debris on beaches derive from people who leave their rubbish on the beach, discard of unwanted garbage by fishermen or people living in the urban area directly into rivers or the sea (Abdullah *et al.*, 2012; Ribic *et al.*, 2012; Kershaw *et al.*, 2011; Sheavly, 2005a). However, in areas adjacent to shipping lanes, rubbish found can also be associated with shipping activities where by convenience rubbish is thrown overboard rather than discharged at ports (Walker *et al.*, 2006; Vauk & Schrey, 1987; Horsman, 1982). Rusli (2012) estimated that 150,000 vessels will utilize Malacca Straits in 2020 as transiting route to transport goods to/from Japan, India, Europe and other parts of the world. With this high volume of vessels, the concentrations of debris in shipping lanes could also be high (Galgani *et al.*, 1995). Since vessels in the shipping lanes navigate from this strait to Japan or China is within Malaysia Territorial Water (MTW), those vessels may contribute to the marine debris accumulation. The MARPOL 73/78 Annex V elaborated the type of debris that may accumulate on a vessel according to garbage categories (IMO, 2012b). Although, disposal of shipborne garbage is allowed according to MARPOL 73/78 requirements, through the ocean dynamics the debris may ensemble to the shores (Hassan & Mobilik, 2012; Garcon *et al.*, 2010; Ribic *et al.*, 2010; Frost & Cullen, 1997; Vauk & Schrey, 1987; Neumann, 1966).

Other studies (Ryan *et al.*, 2009; Allsopp *et al.*, 2006; Palabıyık, 2003; Nawadra *et al.*, 2002; UNEP, 2001; Rees & Pond, 1995; Pruter, 1987; Vauk & Schrey, 1987; Dixon & Dixon, 1981) highlighted that vessels may contribute to debris accumulation on beaches. However, those study only estimated shipborne garbage, limited to passenger and general cargo vessels (Johnson, 2008; Butt, 2007; Polglaze, 2003; Minooee & Rickman, 1999; Horsman, 1982). The shipborne garbage information can only be available from port reception facilities when vessel discharges garbage at port (Carpenter & Macgill, 2005; Ball, 1999; Gregory, 1999). However, this does not give a clear picture of the actual shipborne garbage since every disposal is a cost to the vessels' operation, calculated based on the volume sent to port. Thus, there is a possibility of garbage illegally discharge to sea before arriving at the port. Although monitoring protocol for shipborne garbage has not yet been well-defined, systematic efforts have been conducted to accurately estimate shipborne garbage sources (Derraik, 2002; Miller & Echols, 1993, 1994; Ribic *et al.*, 1992; Vauk & Schrey, 1987; Dixon & Dixon, 1981). Up to March 2013, there is no record or study conducted to identify shipborne garbage or vessel discharges garbage into port facilities in Malaysia.

1.3 Objectives

The general aim of this study is to investigate the marine debris abundance at the beaches and on the vessel, consequently examine garbage accumulation relationship from shipborne garbage source as shown in Diagram 1. The specific objectives for this study were to:

(1) assess spatio-temporal marine debris abundance across the eight study sites during NEM, SWM and IM periods;

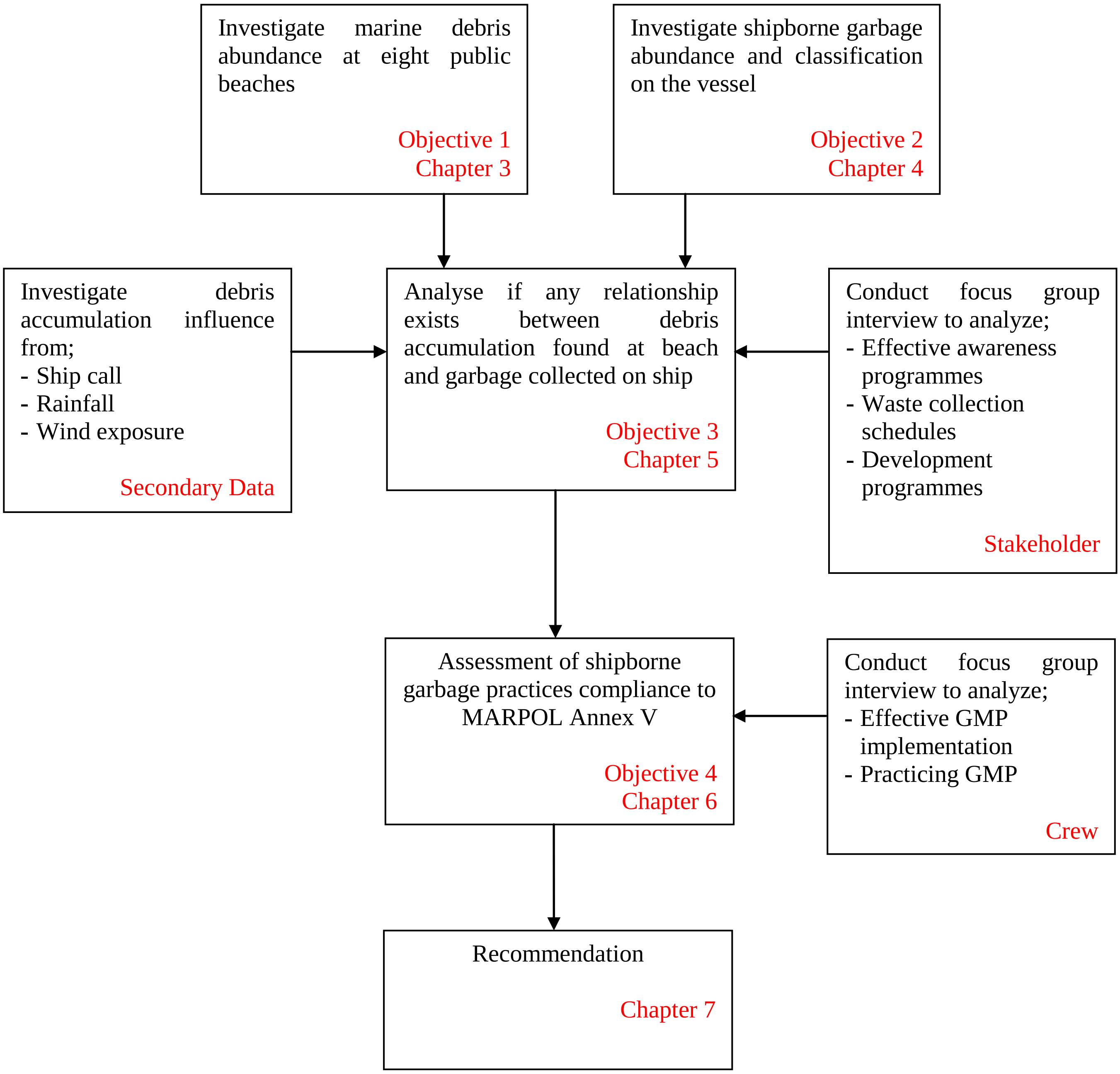
(2) determine the abundance and classification of shipborne garbage on container, bulk carrier and general cargo vessels at five study ports in Malaysia;

(3) analyze debris accumulation relationships between debris found at beach and ship surveys.

(4) assess shipborne garbage practices on the vessel in relation to MARPOL 73/78 Annex V;

The degree of pollution from ship has been well acknowledged, however, shipborne generated waste has not been studied in depth. In addition, Malacca Straits is one of the busiest sea routes, connecting the eastern and the western countries. Increasing volume if sea transport around Malaysia may increase the shipborne garbage generated waste pollution in MTW. Therefore, this study is carried out to get an overall picture of shipborne garbage generated wastes that is most likely stranded at public beaches in Malaysia. Upon having this information, strategic mitigation and prevention plan can be developed to ensure illegal discharge practices from vessel navigating within MTW are totally eliminated. In addition, this study can be used as a baseline for future reference for a more complete data set.

Diagram 1: Theoretical framework of the study



CHAPTER 2

LITERATURE REVIEW

2.1 Marine pollution

The ocean is a natural asset for the marine inhabitants as well as human. The marine ecosystem is the largest system on the planet, and the coastal areas have attracted 70% of the human population who dwell within 60 km of the areas (Jha, 2004). Surrounding Malaysians' rich biodiversity marine ecosystem are sandy white beaches, islands and coastal village which are resources for ecotourism (Hassan, 2008; Ching, 1998). In addition, 1,659 km^2 of Malaysian coastal area is covered with mangrove which provides between 30-40% of protein source (Spalding *et al.*, 1997). Mangrove and coral reef provide natural protection against shoreline erosion and flooding as a result of river discharge (Spalding *et al.*, 1997). Besides sources of seafood and habitats for marine life, the ocean is used as a mode of transporting material and goods using ships. The sea transport industry has a significant importance towards the development of major cities in Malaysia such as Port Klang, Kota Kinabalu, Kuching, Bintulu, Pasir Gudang and Penang (Gasim *et al.*, 2013).

There are many arguments and a lot of confusion about the exact definition of pollution as the ecological knowledge on marine environment. Webster dictionary define pollution as an introduction of contaminants into the natural environment that causes adverse change. Pollution is broadly known as measurable amounts of harmful substances generated from human by-products, either chemical or physical (Gasim *et al.*, 2013; Islam & Tanaka, 2004; West, 2004). According to Ross (1995), there are three types of pollution that may affect marine environment, namely:

a. substances which directly destroy the organisms within the polluted area (e.g. pesticide, hydrofluoric acid and methyl alcohol),

b. substances which alter the physical and chemical properties of the environment and thus favor a particular type of organism (e.g. rubbish or debris),
c. substances which are dangerous to higher forms of life such as human but are relatively harmless to lower forms of life (e.g. lead and mercury).

However, the recommended term by United Nations Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution (JGESAMP) has been widely used to define pollution of the marine environment as the introduction by man, directly or indirectly, of substances or energy into the marine environment, resulting in such deleterious effects such as harm to living resources, hazards to human health, hindrance to marine activities including fisheries, impairment of quality for use of seawater, and reduction of amenities (Clark, 2001). In addition, Borja *et al.* (2011) stressed that marine pollution effects can be applied at molecular and cellular levels in the natural environment, physiological processes in organs and organisms, behavior of individuals or populations; or habitats and ecosystems.

Although the oceans vastness has the capacity to absorb, dilute or remove pollutants (Trujillo & Thurman, 2005), excessive amount of wastes discharge will be a burden to oceans as it still have limited ability to disperse all the wastes (Sverdrup & Armbrust, 2009). There are various types of pollution known to deteriorate marine environment, however substances which can have severe deleterious effects on marine biota particularly in coastal ecosystems are oil, heavy metals, synthetic organic chemicals, sediment, sewage, waste heat, introduced species and solid waste (Garrison, 2005; Kennish, 1994). The increasing pollution rate is threatening ocean health by contaminating ecosystems with chemicals, sewage, invasive species (e,g. *Vibrio cholerae*), persistent organic pollutants (POP's), siltation, pesticides, marine litter, heavy metals and a range of other impacts including destruction of coastal and marine habitats (Todd *et al.*, 2010; Rios *et al.*, 2007; Bellwood *et al.*, 2004; Nyström *et al.*, 2000; McCook, 1999).

Domestic and industrial development also creates common form of pollution with the ability to alter natural physical, chemical and biological balance of seawater (Sheavly, 2005b; Thurman & Trujillo, 2004; Ross, 1995) including sewage and eutrophication pollution which become apparent when excess nitrogen and phosphorus are released into marine water from wastewater treatment plants or factory effluent (Clark, 2001). It stimulates the growth of some marine species which is detrimental to other species (Garrison, 2005). Sediments generated from harbor works, dredging or other maritime construction also contribute to eutrophication but in general this pollution change water quality, reduce light penetration and photosynthetic activity that can cause smothering of bottom dwelling species and impairing fish spawning (Wilson, 1988; Beer, 1983). In addition, heavy metals are toxic to aquatic organisms and human when they are above threshold availability (Tajam & Kamal, 2013; Kanakaraju *et al.*, 2008; Husin *et al.*, 2007). This is proven in the case of severe mercury poisoning in Minimata Bay, Japan (Nemerow, 1985).

General public associates marine pollution with oil pollution since every oil spill incident attracted the most publicity (Szepes, 2013; Hall, 2000). Oil spills occurrence are the result of loading or unloading accidents, collisions, tankers running aground and routine transportation activities that can destroy large quantities of marine organisms and devastate ecological effects (Trujillo & Thurman, 2005; Clark, 2001). Three most significant oil spills ever recorded were the sinking of the *Amoco Cadiz*, the grounding of the *Exxon Valdez,* and the 1991 Persian Gulf War oil spill (Szepes, 2013; Sverdrup & Armbrust, 2009; Law & Hii, 2006). However, other pollution could also originate from ships including bunker fuel, paint on ship's hull, exhaust pollution from ships' engine, chemical as cleaning agent, garbage, food residue and untreated sewage. Recent studies (Gregory, 2009; Barnes, 2002) has indicated foreign marine organism in ships' ballast tank compartments or barnacles clinging to the ships' hull may invade and cause destruction to local marine species and the environment.

Pollution by solid waste represents the latest pollutant in the marine environment. Although, disposal of solid waste into the oceans already existed long ago, serious effect to the marine environment has only recently been acknowledged (Jambeck *et al.*, 2015; Derraik, 2002; Stefatos *et al.*, 1999). The oceans can assimilate degradable organic and inorganic substances, but unassimilated materials such as synthetic material will accumulate and remain unchanged in marine environment (Cole *et al.*, 2011; Polglaze, 2003; Kennish, 1994; Park & O'Connor, 1981). The dumping of solid wastes such as plastics, metals, wood products, glass, cloths and others that originated from land-based and sea-based; in the ocean has been common practice around the world (Sverdrup & Armbrust, 2009; Horsman, 1982). Conversely, many nations still dump solid waste into the oceans to avoid expensive costs of building plants and cleaning up process of solid waste, even though, they knew that the discharge of waste materials in the marine environment is the wrong solution (Butt, 2007; Duxbury *et al.*, 2002; Ball, 1999).

2.2 Marine debris pollution

Light weighted, highly buoyant and easily blown around are rubbish characteristics. Such rubbish becomes marine debris when stranded on the marine environment, while the slow degradation processes indicates the duration that debris will be in the marine environment (Environmental Protection Agency (EPA), 1999). Marine debris referred to the solid waste or marine litter that has inevitably been introduced into the marine environment which may be present in the oceans and on beaches (Allsopp *et al.*, 2006; UNEP, 2005). Marine debris is also often termed as marine or beach litter (Cheshire *et al.*, 2009; Barnes, 2002; Derraik, 2002). Marine debris is always difficult to control as it became one of the pervasive marine pollutants whose impacts have been underestimated (Stefatos *et al.*, 1999). During natural disaster events such as tsunami and typhoon, significant amount of debris may enter the marine environment (Brown *et al.*, 2011). The presence of marine debris in marine environment creates degradation of the modern environment due to plastics' non-degradable ability (Gasim *et al.*, 2013; Khairunnisa *et al.*, 2012; Dixon & Dixon, 1981). Accumulation of marine debris can be critical especially at heavy vessel traffic region or areas highly exposed to ocean currents which can naturally cause debris accumulation (Ribic *et al.*, 2010; Walker *et al.*, 1997, 2006). Over the years, extensive study and monitoring programs have been conducted to identify the distribution, composition and state of pollution caused by marine debris in order to overcome this growing problem (Jambeck *et al.*, 2015; Barasarathi *et al.*, 2014; Jayasiri *et al.*, 2013; Ribic *et al.*, 2010, 2012; Ryan *et al.*, 2009; Sheavly, 2007; Abu-Hilal & Al-Najjar, 2004; Derraik, 2002; Ryan & Moloney, 1993; Ribic & Bledsoe, 1990; Dixon & Dixon, 1981).

2.2.1 Definition of marine debris

Marine debris has been an international discussed issue and a threat to the marine environment (Jambeck *et al.*, 2015; IMO, 2012c; Barnes *et al.*, 2009; JGESAMP, 2009; Sheavly, 2007; Derraik, 2002; NRC, 1995). Coe & Rogers (1997) define marine debris as any manufactured or processed solid waste material that enters the marine environment from any source. Kiessling & Hamilton (2001) has given marine debris a wider scope definition including any human-generated waste, leachates from landfill and spoil from dredging operations that enters the marine environment. Nevertheless, researchers have not yet concluded a specific definition on marine debris. However, the Interagency Marine Debris Coordinating Committee has introduced a formal definition for marine debris and the Marine Debris Research, Prevention and Reduction Act in the US dated September 29, 2005 supported the creation of a formal definition as any manmade object discarded, disposed of, or abandoned that enters the coastal or marine environment (NOAA Marine Debris Program, 2011). It may enter directly from a vessel, aircraft, platform, or other man made structure, or indirectly when washed out to sea via rivers, streams and storm drains. In addition, IMO which regulates maritime industry and establishes uniform international regulation addressing the garbage pollution prevention from ships define garbage as all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes from MARPOL 73/78 (IMO, 2012b). Therefore, this study defines marine debris as any foreign objects present in the marine ecosystem, which could be harmful to marine ecosystems, wildlife and humans.

2.2.2 Pathways of marine debris into the environment

Accumulation of marine debris can be found in all major oceans (Thiel *et al.*, 2013; Barnes, 2002) and has raised a global concern on marine environment pollution (UNEP, 2005). Most marine debris material is light weight, has low density and is buoyant which makes it easy to be transported across oceans polluting beaches environment including remote islands (Cózar *et al.*, 2014; Thiel *et al.*, 2013; Gregory, 2009; Barnes, 2002). Studies had estimated 80% of marine debris entered through land, wind, current or discarded deliberately, while 20% were from maritime activities (Allsopp *et al.*, 2006; Leous & Parry, 2005; U.S. Commission on Ocean Policy, 2004). The proportion of plastic-based debris was reported to vary between 60% and 80% from the total marine debris (Derraik, 2002; UNEP, 2001; Gregory & Ryan, 1997), thus, it dominating the total debris items in the marine environment (Jambeck *et al.*, 2015; UNEP, 2005; Coe & Rogers, 1997). The combination of distribution, point source input, visibility and oceanographic factor describe the abundance of plastic material increase with distance compared to more dense material, as well as degrades slowly in the marine environment. Thus, explains significant temporal and spatial variability in marine debris accumulation.

Therefore, there is a need to understand debris sources and sinks dynamic relationship in marine debris monitoring (Browne *et al.*, 2011; Ryan *et al.*, 2009). Studies have shown that the amount of debris and other pollutants will increase after rain events (Gasim *et al.*, 2013; Silva-Cavalcanti *et al.*, 2009; Pickard & Emery, 2007; Golik & Gertner, 1992). Thus, runoff flows along the ground in the urban area can pick up rubbish including, but not limited to, debris and other pollutants, as the water flows through the urban environment and into rivers and storm drains (Gasim *et al.*, 2013; Waters *et al.*, 2011; Mackenzie & Masten, 2009). Unlike sanitary sewer system, storm water system collected is not treated and flows directly into river system. According to Neumann (1966), quoted by Hall (2000), once rubbish enter into the ocean, the pathways of floating material at the ocean surface are influenced by the wind, tide and current. The total load of land-based debris decreases towards off-shore while ship-based debris increased (Pichel *et al.*, 2007) as revealed in debris loads at the U.S. Pacific coast which were influenced by El Niño Southern Oscillation cycle (Ribic *et al.*, 2012). Therefore, marine debris movement has a significant relationship with debris sink on beaches, in coastal waters and in the open ocean.

2.2.2.1 Oceanography processes

The climate system are determined by sea level pressure, winds, clouds and temperature (Comiso, 2010). Each parameter exercises an important role in the ocean physical processes. The air dynamic pressure in the atmosphere affects oceans circulation which determines weather and climate conditions. Therefore, ocean circulation is due to changes in density and wind stress (Pinet, 2009; Pickard & Emery, 2007; Stowe, 1987). Ocean circulation pattern can be divided into two; thermohaline circulation and wind-driven circulation. Thermohaline circulation or thermohaline conveyor belt is the movement of water when there is a change in water density (Figure 1). This circulation pattern moves colder water at deep water currents, while, warmer water at the surface currents around the globe.

Figure 1: Ocean circulation conveyor belt (Source: www.ncdc.noaa.gov)

In contrast, wind-driven circulation is a horizontal circulation. As shown in Figure 2, the ocean surface moves parallel with the prevailing blowing winds (Pickard & Emery, 2007; Stowe, 1987). Eventually, these pattern creates large circular patterns, also known as gyres (Pinet, 2009). Northern Hemisphere circular patterns move clockwise, while anti clockwise in the Southern Hemisphere.

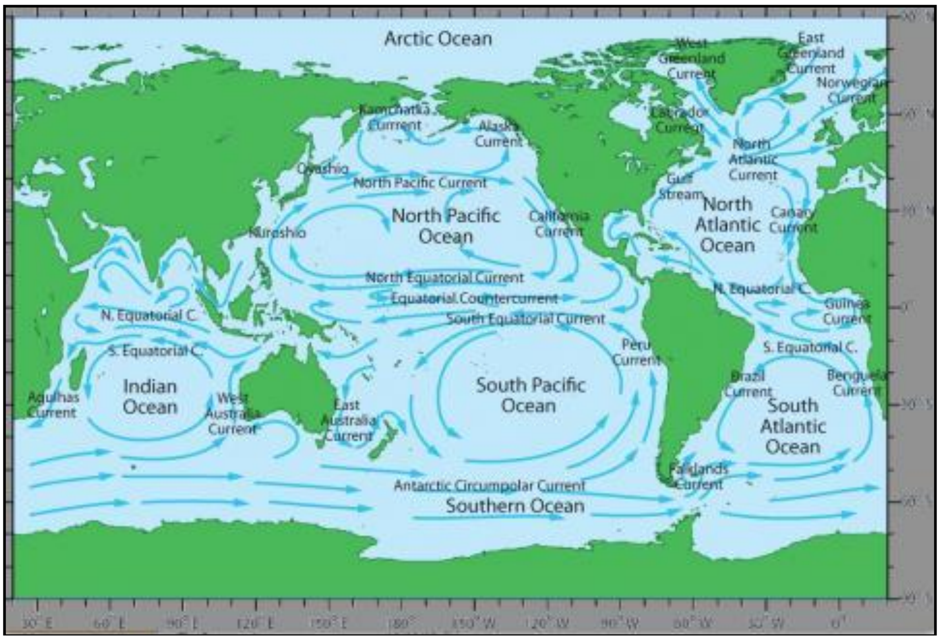


Figure 2: Major ocean wind-driven circulation (Source: www.climatescience.org.au)

As wind blows a long period of time, the motion is transferred downwards into the water column (Pickard & Emery, 2007). The sea water surface layer flows 45^{o} to the right of the wind direction (Figure 3). Through frictional drag, the underlying layer of water body will be in motion. As a result of the Coriolis deflection and eddy friction, the current is flowing slower than the layer immediately above it and farther to the right. This resulting flow pattern is called the Ekman Spiral. Ekman calculated a net transport of 90^{o} to the right (at Northern Hemisphere) over the wind-driven spiral.

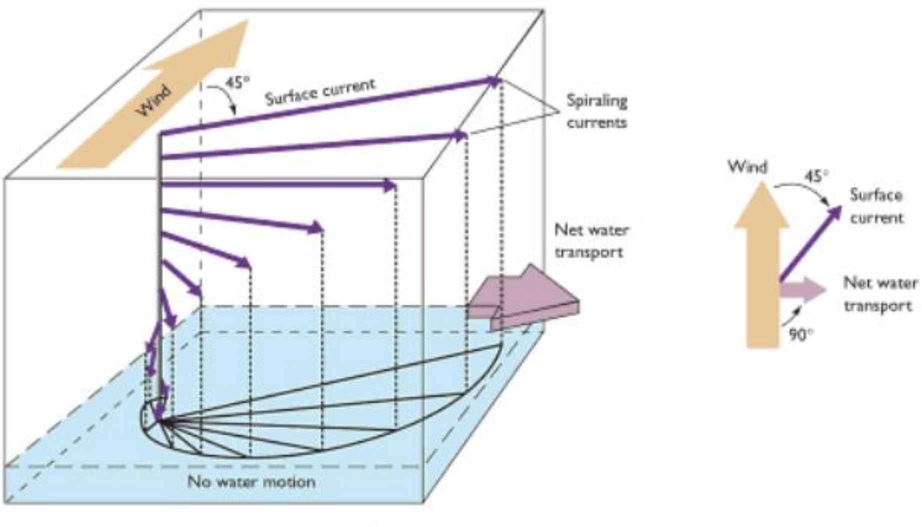


Figure 3: Ekman spiral in the Northern Hemisphere (Source: Pinet, 2009)

When wind blows steadily on the ocean surface, a slow rotating circular pattern phenomenon take place called Langmuir Circulation (LC). LC can be observed quite frequently in lakes and oceans by the occurrence of long parallel lines or streaks of flotsam at the surface resulting from relatively low (3 m/s) wind speeds (Pickard & Emery, 2007). As shown in Figure 4, the circular rotation motion has the same direction as the wind. As the circular motion reaches the ocean surface, buoyant material concentrates along the two rotation motion meet forming a surface streak and moves along the wind direction (Tejada-Martínez *et al.*, 2012; Thorpe, 2004; Barstow, 1983). However, this circulation only forms 10-20 minutes in the open sea of wind speed more than 3 m/s (Pickard & Emery, 2007).

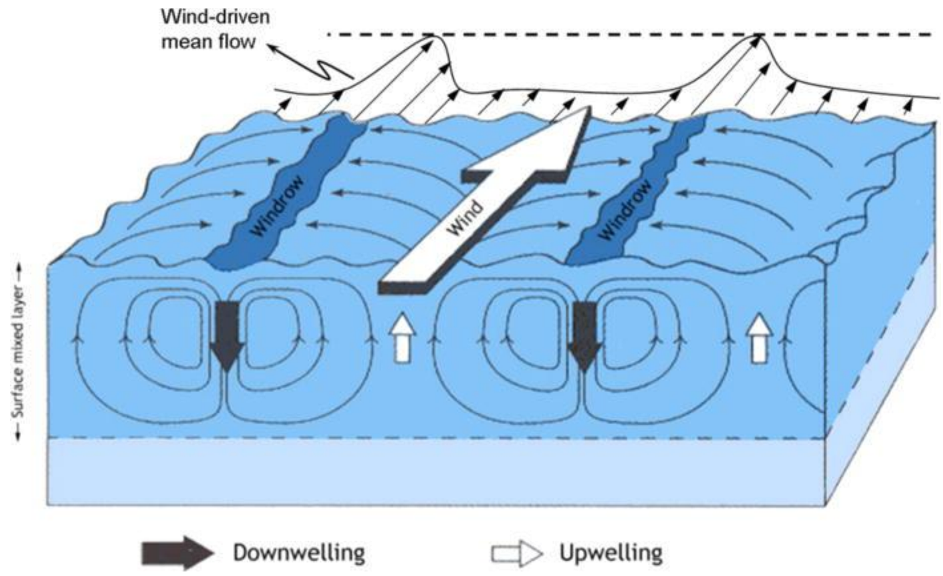


Figure 4: Schematic of idealized Langmuir Circulation (Source: Tejada-Martínez *et al.*, 2012)

2.2.2.2 Monsoon characteristics

A monsoon phenomenon is a wind pattern circulation related to different specific heats of land and water; and influence of wind convergence near the equator called intertropical convergence zone (ITCZ) (Segar, 2012; Garrison, 2005). Air flows from a high to a low pressure system (Segar, 2012; Camerlengo *et al.*, 1998). As a result of this, tropical air (high pressure) moves to Asia continent (low pressure) during northern summer (Figure 5a). Condensation and formation of clouds occur from continuous heating of the land. Southeast trade wind deflected southwesterly direction upon crossing the equator into the northern hemisphere due to Coriolis effects. During northern winter, the land cools more rapidly than the ocean, consequently dry wind (high pressure) moves seawards (low pressure) northeastly direction (Figure 5b). The direction of both the northeast and the southwest monsoon winds is thus explained.

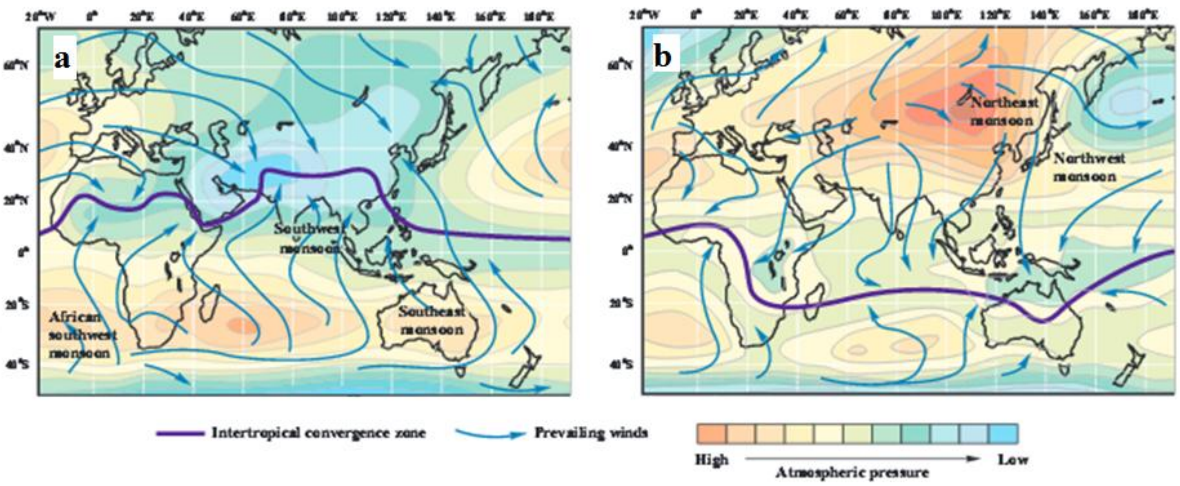


Figure 5: Indian Ocean monsoon winds during a) Northern summer (SWM) and b) Northern winter (NEM) (Source: Segar, 2012)

Malaysian and Indonesian archipelagos are the most obvious regions affected by the seasonally reversing winds (Brown *et al.*, 1989). In Malaysia, changes in the direction and speed of the air-streams across Southern South China Sea lead to the division of the year, into four seasons; northeast monsoon (NEM) (November-March), southwest monsoon (SWM) (late May-early September) and two transitional periods known as intermediate monsoon (IM) (April-early May and late September-October) (Camerlengo *et al.*, 1998; Cheang, 1987).

A study by Wyrtki (1961), quoted by Akhir (2012), data obtained from ship drift and prevailing wind by the Hydrographic Office of the U.S. Navy illustrated opposite current movement when monsoon season changes (Figure 6). During the NEM, the circulation on the shelf is directed southward (Figure 6a), while the SWM reverses the flowing direction (Figure

6b). This result shows that NEM (0.3 Nm^{-2}) winds stress is stronger compared to a weaker one during SWM (0.1 Nm^{-2}) period, whereas the current speed along the Malaysia coast flows with the maximum speed of 1 m/s and 0.4 m/s during NEM and SWM respectively (Akhir, 2012). NEM period brings heavy rain to the northeast coast of Sabah, while, wind speed can reach up to 15.4 km/h along the east coast states of Peninsular Malaysia and 3.5 m wave height. Unlike SWM, prevailing wind flows below 7.7 km/h with 2.5 m waves high. During IM period, rain may occur at almost any hour of the day with regards to location, in contrast to the more regular afternoons rains commonly found during the NEM period.

a

b

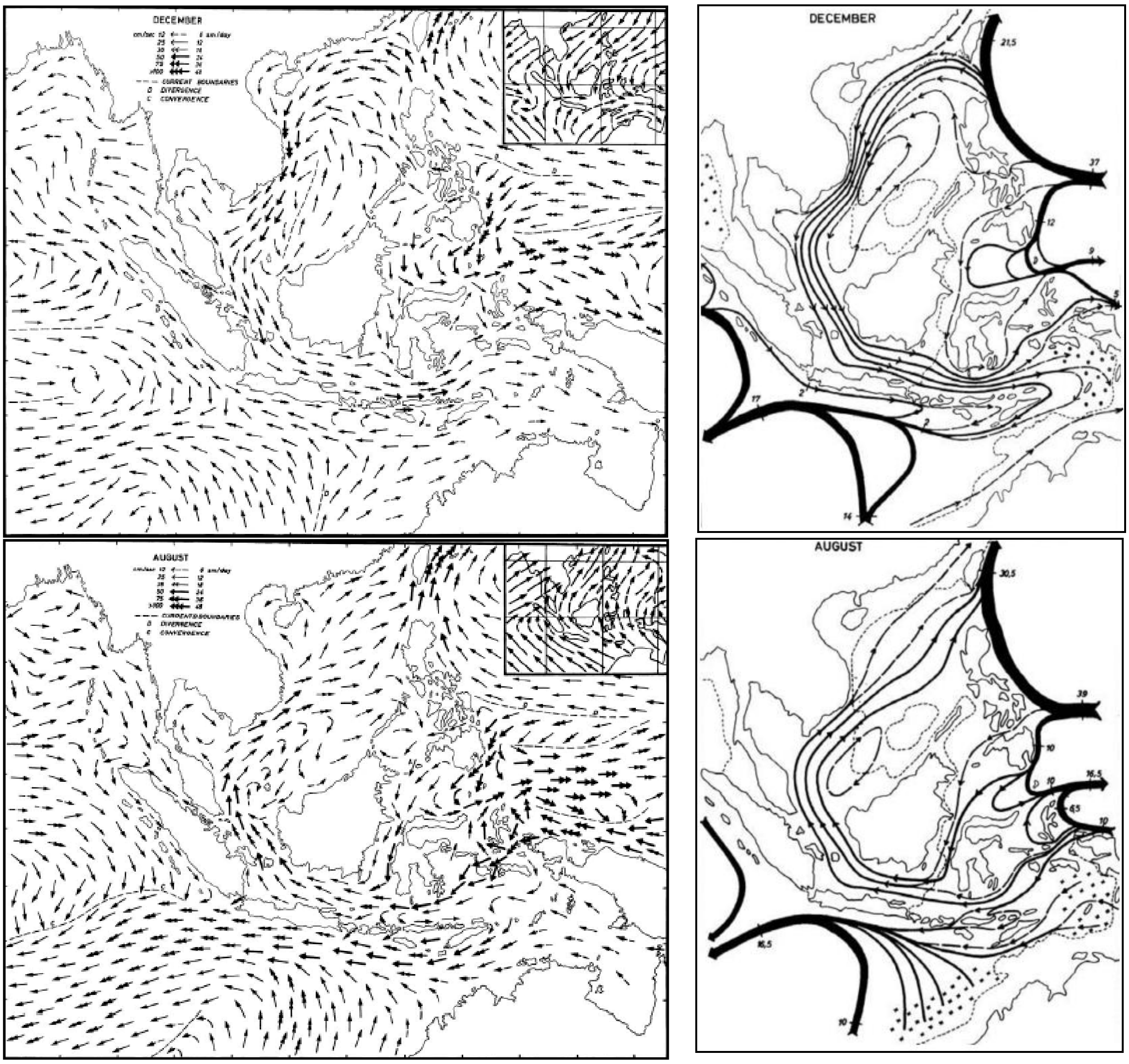


Figure 6: Observational surface circulation during a) NEM period and b) SWM period (Source: Wyrtki, 1961)

Malaysia annual mean rainfall is 3,419 mm with maximum rainfall coinciding the NEM period and minimum rainfall occurs during IM period (Malaysian Meteorological Department (MMD), 2010; Camerlengo & Somchit, 2000; Camerlengo *et al.*, 1998). Monsoon precipitation supplies a large volume of fresh water, discharge runoff from the river into the ocean and along the coast, indicated by reduced salinity and sediment in the water (Waters *et al.*, 2011; Niitsuma & Naidu, 2009; Pickard & Emery, 2007).

2.2.3 Marine debris around the world

Many studies (Jambeck *et al.*, 2015; Irwin, 2012; Zheng *et al.*, 2005; Derraik, 2002; Rees & Pond, 1995) investigating debris abundance in the marine environment, discovered debris is ubiquitous especially at ocean surface and along coastlines. Marine debris studies have concentrated on floating debris (Cózar *et al.*, 2014; Ryan *et al.*, 2009; Lattin *et al.*, 2002), stranded debris along the coastline (Kuo & Huang, 2014; Hassan & Mobilik, 2012; Ribic *et al.*, 2010, 2012; Slavin *et al.*, 2012; Frias *et al.*, 2011; Zhou *et al.*, 2011; Golik & Gertner, 1992) and seafloor debris (Keller *et al.*, 2010; Watters *et al.*, 2010; Williams *et al.*, 2005; Katsanevakis & Katsarou, 2004).

Generally, the marine debris has a decrease trend which lowest quantities are found towards the poles (Barnes & Milner, 2005; Otley & Ingham, 2003; Barnes, 2002). Using satellite data analyzing floating debris trends movement with ocean currents and winds, it was found that debris accumulation is most abundant at the Northern Hemisphere mid latitudes (Sebille *et al.*, 2012; Kubota *et al.*, 2005; Barnes, 2002). Other studies (Leite *et al.*, 2014; Khairunnisa *et al.*, 2012; Abdullah *et al.*, 2012; Ribic *et al.*, 2012; Defeo *et al.*, 2009; Sheavly, 2005a) suggested that proximity to urban centers, industrial and recreational areas may influence the type and amount of debris present along the coastlines. However, higher debris accumulation can be found at location adjacent with shipping lanes, fishing areas and around oceanic convergence zones (Todd *et al.*, 2010; Carpenter & Macgill, 2001; Galgani *et al.*, 1995; Vauk & Schrey, 1987).

Plastic-based materials known to respond slowly to degradation processes, thus have dominated the larger proportion of marine debris found in marine environment (Jambeck *et al.*, 2015). Studies also shown that total debris quantities have doubled in the Indonesian Island beaches (Willoughby *et al.*, 1997) and the United Kingdom's inshore zone (Barnes, 2002). Although efforts to improve marine debris pollution have been implemented since 20 years ago, continuous input of these materials has worsen the marine environmental condition (Barnes *et al.*, 2009; Pichel *et al.*, 2007; UNEP, 2005; Barnes, 2002).

Northern Atlantic Ocean and Europe

Barnes & Milner (2005) had established that debris densities along North Atlantic shores in the years between 1984 and 2001, varied between 0.15 and 12.5 items/m^2. The density of debris off the coast of Edinburgh has double to 0.8 items/m^2 within 10 years (Velander & Mocogni, 1998).

Mediterranean

Barnes & Milner (2005) concluded that debris densities along five Mediterranean countries coastlines were between 6.4 and 231 items/m. Along the coastline of Greece, plastic material density was between 0 and 251 items/km^2 (Katsanevakis & Katsarou, 2004). The most abundant debris items in the Mediterranean was plastic material which represent 75% of the total beach litter (UNEP, 2005). Vauk & Schrey (1987) recorded that ship contributed 141 item/m waste from ships along the shipping route at German Bight beach.

Middle East

Marine debris studies at the coast of Omani (Claereboudt, 2004) and Gulf of Aqaba (Abu-Hilal & Al-Najjar, 2004) found fishing-related debris as the most abundant representing 25% of the total debris accumulated ranging from 0.43 to 6.01 items/m. In the same study, local source origin ranged between 2 and 5 items/m^2.

Southern Atlantic

A scientific review by Otley & Ingham (2003) shows debris decreasing trend accumulation towards the pole in the Southern Hemisphere of 332 item/km at survey locations below 50° S and 68 items/km at survey location greater than 50° S. A study at Southern Ocean island beaches at Tristan da Cunha, Inaccessible and Gough (Ryan, 1987) reported total debris of 0.019 to 2.3 items/m. Common debris item found were plastic bottles, small plastic fragments from broken plastic bottles, and small pieces of expanded polystyrene (Slip & Burton, 1990). However, Falkland Islands adjacent to a fishing port accumulated 42% of fishing related debris (Otley & Ingham, 2003).

Southern Ocean and Antarctica

Although, the presence of debris items in the Oceanic Island of the Southern Ocean is generally lower compared to coastline along Northern Atlantic (Barnes & Milner, 2005), most of these Oceanic Islands are uninhabited (Barnes & Milner, 2005; Convey *et al.*, 2002). Data compiled by Barnes & Milner (2005) analyzed total debris surveyed in the Ocean Island ranging between 0.006 to 2.43 items/m, where 40 to 86% of the items collected were plastic-based material. The most common debris items observed were plastic bottles, plastic containers, fishing floats and polystyrene fragments (Convey *et al.*, 2002; Walker *et al.*, 1997).

United State

Marine debris accumulation along Hawaii Islands beaches were larger compared to U.S. Northern Pacific coast due to the effect of the Central Pacific Gyre (Ribic *et al.*, 2010). According to Ribic *et al.* (2012), average debris accumulated in Hawaii was 267 items/km, 139 items/km in California Bight and 56 items/km in North Pacific Coast. In the same study, it was found that general-source debris items were associated with urban proximities and they comprised 30 to 40% of the total items in all regions. Orange County beaches (Moore *et al.*, 2001) accumulated 99% of plastic-based materials debris items, while derelict trawl nets were commonly found on Alaskan beaches (Allsopp *et al.*, 2006). These materials may poses threat to marine life when washed back into the sea.

South America

Debris densities averaged 14.6 items/km along beaches in Costa dos Conqueiros region, Brazil (Santos *et al.*, 2005). Plastic bottles made up of 35% of the total debris proportion. In comparison, a total of 1.3 item/m^2 (13,900 item/km) was collected in the north coast of Rio Grande do Sul (Portz *et al.*, 2011). Plastic debris accumulated 42% of the total debris items. In addition, debris originated from land-based source was 68% while ocean-based source was only 7%. Both studies suggested that debris on beaches in the region could originate from ships garbage disposed at sea.

Caribbean

Along the Caribbean coast of Panama, the average density of debris items was reported 3.6 items/m^2 (Garrity & Levings, 1993). The study found debris item abundance associated with fast-food packaging including plastic packaging and styrofoam. However, debris abundance ranging between 19 and 253 items/m along beaches at the island of Curaçao and those debris accumulation may have been influenced by northeast winds (Debrot *et al.*, 1999).

Australia

Northern Australia accumulated more than 2,000 items/km debris along the beaches (White, 2006; Kiessling & Hamilton, 2001; Whiting, 1998). In comparison, beach surveys along New South Wales was between 256.6 and 2,664 items/km (Taffs & Cullen, 2005; Cunningham & Wilson, 2003; Frost & Cullen, 1997). While Southern Australia accumulated between 1.9 and 13.2 items/km (Slavin *et al.*, 2012; Edyvane *et al.*, 2004). These results show decreasing trend when the lowest quantities were found towards the South Australia. Debris density was the highest on the northern Australia and this could be influenced by oceanographic factors (Garcon *et al.*, 2010; Edyvane *et al.*, 2004; Frost & Cullen, 1997). These studies found that plastics-based material from land-based origin contributed between 77 and 86% from the total debris items. The most plastics-based material found were plastic bottles, soft drink tetra-pack cartons, water bottle lids and seal caps. Although, proximity to urban areas was the main source of litters along beaches (Taffs & Cullen, 2005; Frost & Cullen, 1997), the awareness among general public has shown a reduction in debris accumulation on the Australian beaches (Slavin *et al.*, 2012). However, debris from ocean sources shows no sign of reduction. The abundance of ocean source debris from commercial fishing, merchant shipping and recreational boaters represented 85% of the total ocean source debris at Fog Bay, Northern Australia (Whiting, 1998). In 2004, a total of 406 derelict fishing nets collected weighing at 880 kg were of foreign origin (White, 2006). South Australia received the same fate as maritime activities source were present in Tasmania (Jones, 1995) and Great Australian Bight (Edyvane *et al.*, 2004).

Sea of Japan

A study on 18 beaches along western Japan, resulted a mean number of debris items of 341 items/m^2 (Kusui & Noda, 2003). The most abundant type of debris was plastic, representing 80% of the total debris item collected. In Hiroshima Bay, average density of debris items was 44,521.3 item/m^2 of which foamed plastic fragment accounted for 99.5% of the total debris items collected (Fujieda & Sasaki, 2005). The study observed the presence of stranded floats, used mooring buoys and unwanted fenders along the 48.6 km coastlines.

Indonesia

Uneputty & Evans (1997a) and Willoughby *et al.* (1997) reported that debris pollution on Jakarta Bay and islands on the northwest in the Java Sea shorelines had increased between 1985 and 1995. The mean total debris on the 23 islands shoreline at the Jakarta Bay ranged between 0 to 29.1 items/m (Willoughby *et al.*, 1997). Plastic-based material represented 80% of the total debris items, which includes plastic bags, polystyrene blocks and discarded footwear. Other studies along Ambon Bay beaches, Eastern Indonesia, reported a mean total debris of 8.6 items/m^2 (Uneputty & Evans, 1997b; Evans *et al.*, 1995). These studies have concluded that Jakarta city is a major source of debris.

Malaysia

The study of a comparison between recreational (Teluk Kemang) and fishing (Pasir Panjang) beaches in Port Dickson showed that plastic-based objects were the highest accumulated at 64% and 46% respectively (Khairunnisa *et al.*, 2012). The results showed that less rubbish found on recreational beach was due to the availability of rubbish bins and regular schedule rubbish collection. The study at Pandan, Pasir Pandak, Temasyah and Tg. Lobang beaches has also shown that plastic-based objects were the highest accumulated and

Asia continent made up about 93.18% of all the identified debris (Hassan & Mobilik, 2012). The most common debris items were plastic water bottles, shampoo bottles, skin care products and motor oil containers and they made up 34.01% of all items being allocated to marine origin.

2.2.4 Category of marine debris

Beach survey is an established monitoring technique to evaluate the general trend of marine debris distribution, composition and types of debris items stranded on beaches (Cheshire *et al.*, 2009; Derraik, 2002; Ribic *et al.*, 1992; Dixon & Dixon, 1981). A beach survey can determine the rates of floating debris loss from the ocean, and predict the surface transport of marine debris such as winds or waves activity (Shiber & Barrales-Rienda, 1991; Shiber, 1989). Therefore, investigating debris item quantities on the beaches can be systematic, continuous, representative or random (Cheshire *et al.*, 2009; Gregory & Andrady, 2003; Ribic *et al.*, 1992; Dixon & Dixon, 1981). According to Frost & Cullen (1997) marine debris composition are important to determine:

a. the types and amount of debris accumulated,
b. debris deposition rate over time,
c. the sources of the debris,
d. debris deposition to relative beach usage.

To identify the different marine debris dispersed and deposited, debris may be classified according to size (Lippiatt *et al.*, 2013; Ribic *et al.*, 1992). The classification may identify wildlife impacts as well as type of survey approaches that may be practical to be used. Debris classification is as follow; small (<2.5 cm), medium (<10 cm), large (<1 m) and very large debris (>1 m). The limit 2.5 cm was determined according to MARPOL 73/78 Annex V regulations material released from ships capable of passing through a filter openings no greater than 2.5 cm (Ribic *et al.*, 1992). Medium and large debris categories has a larger surface areas, therefore have a greater probability to interrupt a habitat. Furthermore, larger debris is heavier and may be present in continuous surveys if not removed from the site. Having a record and location of these items will minimize repetition during each survey.

Since individual debris can contribute certain impact to marine environment, studies have identified individual debris objects which are then grouped into major categories (Cheshire *et al.*, 2009; Derraik, 2002; Ribic, 1998; Wace, 1995; Willoughby, 1986). The debris objects are organized according to material, usage or combination of the two. Although, other studies (Lippiatt *et al.*, 2013; Barnes *et al.*, 2009; Sheavly, 2007; Walker *et al.*, 2006; Willoughby, 1986) had developed categories that reflected specific study objectives, the general groupings used have been similar. Ribic *et al.* (1992) has classified marine debris into six main categories: plastic, rubber, metal, glass, timber and cloth. Each category was further sorted into objects associated type of product material. The complete list can be referred to Appendix A.

Table 1 shows composition of debris items collected during marine debris surveys. During the Orange County beach surveys, plastics were the major type of marine debris, followed by wood, metal, glass and rubber (Moore *et al.*, 2001). Similarly, plastic items were the most frequently found items (58%) at Curaco beach; followed by wood and glass at 17% and 15% respectively (Debrot *et al.*, 1999). However, plastic items accumulation in the South East Asia region was even higher at 80% (Khairunnisa *et al.*, 2012; Hassan & Mobilik, 2012; Willoughby *et al.*, 1997). Nevertheless, marine debris studies has indicated that plastic is the major component of man-made debris compared to other debris items both in terms of number and weight.

Table 1: Comparison of various studies beach debris item (item/km) and weight (kg/km) according to debris categories

Study site (source)	Abundance	Composition					
		Plastic	Rubber	Metal	Glass	Wood	Cloth
Orange County, California (Moore *et al*., 2001)	Item	69,216	537	1,175	1,110	1,396	297
	Weight	214	19	68	44	103	33
Port Dickson (Khairunnisa *et al*., 2012)	Item	1055	35	25	60	5	40
	Weight	8	85	1	4	1	8
Indonesia Island (Willoughby *et al.*, 1997)	Item	4,743	1,014	139	21	-	-
	Weight	*Items weight was not consider in this study*					
Sarawak (Hassan & Mobilik, 2012)	Item	1,569	47	46	43	82	13
	Weight	29	12	5	9	20	2
Yos Sudarso Bay, Indonesia (Nash, 1992)	Item	459	210	15	13	7	1
	Weight	*Items weight was not consider in this study*					
South Australia (Edyvane *et al*., 2004)	Item	46	-	13	50	-	-
	Weight	*Total weight for all categories was 8 kg/km*					
Curaco, Venezuela (Debrot *et al*., 1999)	Item	4,832	284	257	1,308	1,449	181
	Weight	92	125	107	66	710	28

2.3 Sources of marine debris

The presence of debris in the marine environment has an increasing trend in terms of quantities stranded on the beach environment (Laglbauer *et al.*, 2014; Jayasiri *et al.*, 2013; Ribic *et al.*, 2010, 2012; Caldwell *et al.*, 2009; Ryan *et al.*, 2009; Hassan *et al.*, 2007; Walker *et al.*, 2006; Santos *et al.*, 2005; Edyvane *et al.*, 2004; Barnes, 2002). Debris in the marine environment may derive from rivers runoff, drains, wind, improper sewage systems, rubbish left on beaches or discharge illegally at sea (Ryan *et al.*, 2009; Ribic, 1998; Coe & Rogers, 1997; Dixon & Dixon, 1981). Therefore, to quantify amount of debris in the marine environment, it is important to measure the debris sources (Ryan *et al.*, 2009). Ribic *et al.*, (2012) and Wace (1995) suggested three debris sources which can be associated with the debris objects as shown in Table 2. Common source referred to debris objects that could originate from either terrestrial (land-based) or marine (ocean-based) sources.

Table 2: Debris objects according to debris sources (Source: Ribic *et al.*, 2012; Wace, 1995)

Marine	Terrestrial	Common
Aerosol cans	Aluminum cans	Clear plastic bottles
Baskets and buckets	Baby care items (including disposable nappies, milk bottles and milk formula spoons)	Colored plastic bottles
Cigarette lighters	Cardboard drink cartons	Glass bottles
Fishing line	Children's toys	Toothbrush
Fishing nets	Cloth and clothing	Hairbrushes
Foam insulation	Food wrappers	Plastic bottle tops
Foam packaging	Medical waste	Foam cups
Salt bags	Paper and cardboard	Footwear (rubber thongs)
Gloves	Shopping bags	
Hard hats	Six pack rings	
Ice bags	Steel food cans	
Light globes/tubes		
Lures		
Net floats and buoys		
Oil bottles		
Pallet wrappers		
Ropes		
Scrubbing brushes		
Steel drums		
Strapping bands		
Other (Fuel pumps, Potable water filters)		

2.3.1 Land-based sources

The pathway of debris from land-based or terrestrial sources are wind-blown, deliberately discharged into the sea or washes into the sea, including littering, solid waste disposal at landfills, urban storm drain discharges, combined sewer overflows and small medium industries activities (Gasim *et al.*, 2013; Leous & Parry, 2005; Nash, 1992). Although debris can be transported by wind (Cózar *et al.*, 2014), most terrestrial debris are carried by water through rivers and storm-water discharge (Waters *et al.*, 2011). During heavy rains, urban runoff flows into storm drains eventually discharge into streams, rivers or the ocean (Waters *et al.*, 2011; UNEP, 2005). Therefore, any floating rubbish or debris from the urban or housing areas may be carried during runoff then find ways to enter river and the ocean (Griffith *et al.*, 2010; Wright *et al.*, 2009).

Inadequate coverage of landfills located along the coastal areas or near to rivers may result in debris accumulation in the marine environment, since light weighted material are easily blown into rivers and the ocean (Uneputty & Evans, 1997a, 1997b). In addition, garbage collected or transported may easily be blown by wind and could end up in the marine environment (Manaf *et al.*, 2009; Tadesse, 2004). Eventually, river and ocean will be polluted by garbage from nearby runoff or landfills (Nollkaemper, 1994; Nash, 1992).

According to Sheavly (2005b) wastewater treatment system handling capacity may be exceeded during heavy rains. Plastic fragments smaller than 10 mm can easily move into municipal sewers system which discharge into marine environment (O'Hara *et al.*, 1998). Therefore, overflow of unprocessed sewage will mix with storm water which is discharged into rivers or oceans. Unprocessed sewage waste which has been the main source of plastic items in the USA (Nollkaemper, 1994), includes condoms, tampon applicators, syringes and street litter.

Littering can be considered the most common form of solid waste pollution (Thiel *et al.*, 2013; Slavin *et al.*, 2012; Roca *et al.*, 2009; Jędrzejczak, 2004). Beach litter in particular has a significant impact on wildlife and clean up can be costly (Tudor & Williams, 2008). Beach visitor carelessly leave litter at the beach area which will remain on the beach or is carried offshore by wind and currents, adding to debris in the ocean (Moore *et al.*, 2001). These litters include items such as plastic bottles, food packaging, beverage containers, plastic shopping bags, cigarette butts and plastic beach toys.

2.3.2 Ocean-based sources

Ocean-based or marine sources originate from commercial shipping, fishing vessels, fish farming, cruise liners, military fleets, research vessels, passenger ferries, offshore oil and gas platforms and service vessels and recreational boats (Sheavly, 2005b). Plastic materials are widely used in the maritime activities especially in fishing equipment gears, ships' operation and galley wastes (Cho, 2009; Palabıyık, 2003). The increase usage of highly visible non-biodegradable products are illegally discharged and washed along the shoreline including large and buoyant plastics material (Portz *et al.*, 2011; Walker *et al.*, 2006; Fujieda & Sasaki, 2005; Edyvane *et al.*, 2004; Convey *et al.*, 2002; Frost & Cullen, 1997).

The concerns about marine source debris in marine environments largely focused on ships (Ryan *et al.*, 2009; Vauk & Schrey, 1987). Although shipborne garbage discharge at sea has been prohibited since 1973, ignorance to the international convention resulted in debris accumulation at sea instead of properly discharged to shore facilities (Carpenter & Macgill, 2005; Palabıyık & Altunbas, 2004; Polglaze, 2003; Vauk & Schrey, 1987). Areas where commercial fishing is concentrated, discarded fishing gear could be a major source of debris on many beaches (Hong *et al.*, 2014; Otley & Ingham, 2003; Walker *et al.*, 1997; Jones, 1995; Johnson, 1994). Other studies (White, 2006; Barnes & Milner, 2005; Convey *et al.*, 2002; Gregory, 1999; Ryan & Moloney, 1993) have shown marine sources as the most abundant on remote location. Allsopp *et al.*(2006) has identified 46% from the total marine debris on the beach originating from shipping activities, while, Vauk & Schrey (1987) identified 99.2% shipping debris items at German Bight beach.

Although, vessels may contribute to debris accumulation on beaches, estimating shipborne generated garbage is very imprecise and subject to sampling method besides considering vast variability. Before MARPOL 73/78 was fully enforced, studies (Rees & Pond, 1995; Pruter, 1987; Dixon & Dixon, 1981) assessing shipborne garbage waste only presented an estimation of waste discharge at sea. Studies of shipborne garbage on passenger ship (Johnson, 2008; Butt, 2007; Minooee & Rickman, 1999) and general cargo vessel (Sarinas *et al.*, 2012; Horsman, 1982) had been used to estimate total input of litter into the marine environment. However, the information can be misinterpreted as each vessel type has different in terms of size, trading route, crew composition, waste generated and garbage management practices. Horsman (1982) estimated each crew member discharge 0.2 cardboard boxes item; 0.3 plastic items; 0.2 bottles and 3.2 tins per day, whereas, Palabıyık (2003) estimated each crew generates 3 kg of domestic and operational waste per day. A synthesis analysis by Nawadra *et al.* (2002), estimated that each crew could generate between 0.5 to 4.65 kg/person/day of garbage taking into consideration all type of vessels. Although, the port reception facilities data can be a reliable source to estimate total shipborne garbage (Ohlenschlager & Gordiani, 2012; Carpenter & Macgill, 2005; Ball, 1999), formal amount to determine estimated shipborne garbage that contributes to the accumulation of debris in the environment since MARPOL 73/78 Annex V came into force is still unavailable.

Ships are loaded with cargo meeting shipping schedules, catering to avid international demand for consumers and other goods (Asariotis *et al.*, 2013; Desa *et al.*, 2012; Khalid & Tang, 2010; Chua *et al.*, 2000). These vessels are subjected to accidents and groundings which can cause loss of cargo at sea leading to additional input of waste to the seas (Keller *et al.*, 2010; Mouat *et al.*, 2010; Carpenter & Macgill, 2005; Negri *et al.*, 2002). In search of fragments of Malaysian passenger flight MH370 which has been missing since March 2014 in the Southern Indian Ocean, there were numerous reports of claiming debris of the aircraft which later turned up to be pieces of trash and steel containers. This has focused world attention on the vastness of the ocean and in the process, reflects the discharge of operational and cargo waste at sea. World Shipping Council (2011) estimates between 350 and 675 containers lost each year. Although, the numbers are relatively small, any loss containers and cargoes in the ocean could pose hazard to the environment. Nevertheless, there is little information on the relationship between debris from ship and the presence of similar debris on the beaches (Ryan *et al.*, 2009; Vauk & Schrey, 1987), nor it is clear what is the fate of all the rubbish from the ocean (Sarinas *et al.*, 2012; Thompson *et al.*, 2004; Horsman, 1982). The combination of multi point-source inputs and oceanographic influences, the spreading of debris lead to great temporal and spatial litter loads variability in the marine environment (Portz *et al.*, 2011; Ryan *et al.*, 2009). Thus, this study explores relationship between shipborne garbage and marine debris abundance on the beaches in Malaysia.

2.4 Impacts of marine debris

Marine debris is widely known to cause injuries to wildlife and humans (Mouat *et al.*, 2010; Derraik, 2002). Despite the negative impact of marine debris, there are also positive effects as a result of stranded debris on the beaches (Thanh *et al.*, 2011; Saeed *et al.*, 2009). Stranded debris along the beaches can be collected such as aluminum cans, glass bottles and plastic bottles then recycled. The recycling effort can be an additional source of income especially for coastal villagers. Nevertheless, marine debris still represents a significant problem that needs to be dealt with great urgency. Studies have estimated plastic beverage bottles and disposable diapers takes 450 years to degrade in the marine environment, while plastic shopping bags takes 20 years (Hetherington *et al.*, 2005). The situation becomes more apparent when degraded plastics transforms into plastic dust, consumed by marine filter feeders which accumulates toxins (Gregory, 1996) and is eventually consumed by human.

Therefore, marine debris causes more harm than good towards the marine environment and human.

2.4.1 Human health and safety

Debris items found on beaches including broken glass bottles, used medicine strips, syringes and fishing line can be hazardous and pose health risk and human safety. Floating or submerged debris can become entangled by swimmers, divers and snorkelers. This situation may affect human health and safety concerns besides affecting tourism industry (Abdullah *et al.*, 2012). When a person steps on a broken glass or had a cut from sharp metal edge pieces, serious injury can occur and that can spoil the whole visit to the beach. Used medical waste, disposable nappies and other personal hygiene waste are sewage related waste which enters the marine environment through unsatisfactory sewage treatment systems (UNEP, 2009; Sheavly & Register, 2007). The presence of these items may attract pathogenic pollutants such as streptococci, fecal coliform, and other bacterial contamination (UNEP, 2009; Wright *et al.*, 2009; West, 2004; Minooee & Rickman, 1999), which may result in contamination of the surrounding area including water. A person in contact with water contaminated with these microorganisms may suffer infectious sickness including hepatitis, diarrhea, bacillary dysentery, skin rashes, typhoid and cholera.

2.4.2 Entanglement and ingestion

The knowledge on the impact of plastics pollution towards marine wildlife has been well documented (Pham *et al.*, 2014; Verlis *et al.*, 2014; Lavers *et al.*, 2013; Rodríguez *et al.*, 2013; Good *et al.*, 2010; Cho, 2009; Raum-Suryan *et al.*, 2009; Pichel *et al.*, 2007; Boren *et al.*, 2006; Derraik, 2002; Bugoni *et al.*, 2001; Blight & Burger, 1997; Azzarello & Van Vleet, 1987). A large number of marine animals become victim to entangle or ingestion of plastic material. Plastic has been found in the stomach of manatees, fish, birds, dolphin and whales (UNEP, 2001; Blight & Burger, 1997). Marine wildlife especially the turtle frequently mistaken plastic bag floating in the sea for a jellyfish (Galgani *et al.*, 2014; Moore, 2008; Mascarenhas *et al.*, 2004). Although, there are many forms of debris posing threat to marine wildlife, entanglement is the most threatening (Sheavly & Register, 2007). Entanglement have been affected 136 marine species, including six species of sea turtles, 51 species of seabirds, and 32 species of marine mammals (Marine Mammal Commission, 1996). Debris items that can cause these serious threats towards marine wildlife include monofilament line, fishing nets and ropes, six-pack rings, and packing strapping bands. When debris entangles around the limbs, it will reduce mobility to feed and some do suffocate to death.

2.4.3 Aesthetic and economic impacts

Natural aesthetic beaches encourage tourism and coastal community economy (Mouat *et al.*, 2010). Therefore, natural and originality of the beach can be unpleasant having stranded debris around the beach area. Marine debris is not only unpleasant and dangerous but could deplete the livelihood of coastal community that rely beach patrons to support their economic trade (Abdullah *et al.*, 2012). In addition, it discourages tourists and local communities from involving in coastal activities, such as visiting, recreational fishing, boating, swimming or picnicking.

2.5 Legal setting

The influence of human activities introduced pollutant into the environment. Environmental stewardship as well as enforcement and penalties are essential to pollution prevention effort which may lead to the reduction of pollution problems. In Malaysia, the legislation on land and at sea related to pollution including litter and debris has been in place. The current laws relevant to the marine debris issue in Malaysia are as follow.

2.5.1 International law

2.5.1.1 International Convention for the Prevention of Pollution from Ships 73/78

The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) (IMO, 2012a) is the main convention governing prevention of pollution of the marine environment by vessels from operational or accidental causes. The IMO also manages the convention, which provides a comprehensive approach to deal with ocean dumping by creating international guidelines to prevent ship pollution. This convention categorizes waste into six annexes (Table 3). A country that becomes a party to MARPOL 73/78 is mandatory to accept Annex I /II of the convention, whereas, Annex III, IV, V, and VI are to be accepted on a voluntary basis. Malaysia has ratified Annex I/II, III, VI, V and VI, enabling instrument are the Merchant Shipping Ordinance, 1952 and Environment Quality Act, 1974 (Jabatan Laut Malaysia (JLM), 2014; Mustafa, 2011; Law & Hii, 2006).

Table 3: Summary MARPOL 73/78 Annexes (Source: IMO, 2014b)

Annex	Groups of materials	Entry into force	Country ratify	World tonnage (%)
I	Oil	1 October 1983	150	99
II	Noxious Liquid Substances	1 October 1983	150	99
III	Harmful Substances in Packaged Form	1 July 1992	133	96
IV	Sewage	27 September 2003	124	82
V	Garbage	31 December 1988	139	97
VI	Air Pollution	19 May 2005	56	46

Annex V is of particular importance to the maritime community (shipping, oil platforms, fishers, boaters, and cruise lines), because it prohibits disposal of plastic at sea and regulates disposal of other garbage at sea (IMO, 2012b). However, the revised Annex V which has been enforced since 1 January 2013, exempt under specific requirements of food waste, animal carcasses, cargo residues contained in wash water and environmental friendly cleaning agents. To cite a vessel for illegally discharging garbage or plastics into the sea, an individual must see the event and report, or provide sound evidence, that an act of discharging of garbage has occurred. As a result, many pollution violations go unreported or are never fully pursued due to lack of evidence. Garbage discharge regulations do not apply when the discharge of garbage from a ship is a necessary action for the purpose of securing the safety of a ship and those on board or saving life at sea as explain in Regulation 7.1.1 of the MARPOL 73/78 Annex V. In such cases an entry should be made in the Garbage Record Book (GRB), or in the ship's official log-book for ships of less than 400 gross tonnages.

According to the revised MARPOL 73/78 Annex V, shipboard generated garbage is grouped into the following categories: (1) Plastic, (2) Food waste, (3) Domestic wastes, (4) Cooking oil, (5) Incinerator waste, (6) Operational waste, (7) Cargo residues, (8) Animal carcasses and (9) Fishing gear. In cases garbage is mixed with other garbage which has different discharge requirements, a more stringent requirement shall apply. For example, if a vessel is sailing within a special area and has mixed comminuted food waste with other garbage material that is not comminuted then according to the revised MARPOL 73/78 Annex V regulations the vessel should not discharge the food waste mixture to the sea. A simplified overview of the discharge provisions of the revised MARPOL 73/78 Annex V is presented in Table 4

2.5.1.2 Convention of the Prevention of Marine Pollution by Dumping of Wastes and other Matter

This convention was established to control pollution of the sea by dumping of wastes which could create hazards to human health or to harm living resources and marine life, to damage amenities, and to interfere with other legitimate uses of the sea. This convention

Table 4: Waste Discharging Regulations (Source: IMO, 2012c)

Type of garbage	Ships outside special areas	Ships within special areas	Offshore platforms (more than 12 nm from land) and all ships within 500 m of such platforms
Food waste comminuted or ground	Discharge permitted ≥3 nm from the nearest land, en route and as far as practicable	Discharge permitted ≥12 nm from the nearest land, en route and as far as practicable	Discharge permitted
Food waste not comminuted or ground	Discharge permitted ≥12 nm from the nearest land, en route and as far as practicable	Discharge prohibited	Discharge prohibited
Cargo residues [1] not contained in wash water	Discharge permitted ≥12 nm from the nearest land, en route and as far as practicable	Discharge prohibited	Discharge prohibited
Cargo residues [1] contained in wash water		Discharge permitted ≥12 nm from the nearest land, en route, as far as practicable and subject to two additional conditions [2]	Discharge prohibited
Cleaning agents and additives [1] contained in cargo hold wash water	Discharge permitted	Discharge permitted ≥12 nm from the nearest land, en route, as far as practicable and subject to two additional conditions [2]	Discharge prohibited
Cleaning agents and additives [1] in deck and external surfaces wash water		Discharge permitted	Discharge prohibited
Carcasses of animals carried on board as cargo and which died during the voyage	Discharge permitted as far from the nearest land as possible and en route	Discharge prohibited	Discharge prohibited
All other garbage including plastics, synthetic ropes, fishing gear, plastic garbage bags, incinerator ashes, clinkers, cooking oil, floating dunnage, lining and packing materials, paper, rags, glass, metal, bottles, crockery and similar refuse	Discharge prohibited	Discharge prohibited	Discharge prohibited
Mixed garbage	When garbage is mixed with or contaminated by other substances prohibited from discharge or having different discharge requirements, the more stringent requirements shall apply		

1 Substances not harmful to marine environment.
2 Discharge shall only be allowed if both the port of departure and the next port of destination are within the special area

administered under the United Nations by the IMO, also known as the London Convention (LC 72), was adopted on 29 December 1972 in London and entered into force on 30 August 1975. In addition, Part XII (Articles 192-237) of the 1982 United Nations Convention on the Law of the Sea (UNCLOS) in particular, concerns the Protection and Preservation of the Marine Environment. This treaty established permitting requirements for the disposal of wastes into the sea and functions as the global instrument to control marine pollution from dumping dredge spoils, sewage sludge and other types of land-based wastes, including rivers, estuaries, pipelines and outfall structures; from seabed activities subject to national jurisdiction; from activities in a designated area, that is, the seabed, ocean floor and subsoil thereof, beyond the limits of national jurisdiction; from vessels; by dumping; and from or through the atmosphere (Kershaw *et al.*, 2011). This convention contains three Annexes: dumping of matter listed in Annex I is prohibited; dumping of matter listed in Annex II is allowable only by special permit; dumping of matter listed in annex III is allowable only by general permit. Malaysia has yet to ratify this Convention.

2.5.1.3 The Basel Convention

The Basel Convention (1992) is a policy that was created during a treaty negotiation under the guidance of the United Nations. The intention is to prevent nations from transporting waste to other nations for disposal if this transfer will result in the waste being disposed of improperly. The Basel Convention is different from MARPOL 73/78 and LC 72, which deals with waste disposal rather than transportation. The Basel Convention allows for international shipments of hazardous waste under very specific and strict conditions, which the waste classification is different from MARPOL 73/78. For the purpose of the convention, waste is a substance that is disposed of according to national law or is listed specifically in the convention. Hazardous waste is waste that fits one of several definitions in the Basel

Convention or is defined as hazardous waste by the domestic laws of the waste importer, exporter, or domestic country of the transporting service. Since the Basel Convention classifications of waste are different from MARPOL 73/78 and those of individual countries, it is possible that garbage may contain substances that are classified as hazardous wastes under the Basel Convention. Malaysia has adopted and translates this convention in Merchant Shipping Ordinance (1952), Merchant Shipping (Oil Pollution Act), 1994; Solid Waste and Public Cleansing Management Act, 2007; and Environment Quality Act, 1974.

2.5.1.4 Procedure for Port State Control

Port states control (PSC) has been established to ensure an effective enforcement of the international conventions adopted by the IMO against a vessel visiting a foreign port (Rakestraw, 2012; Hare, 1997). The authority vested on a Port State Control Officer (PSCO) stipulated in Res. A.1052(27) includes; conduct inspection on the vessel compliance to maritime conventions and certify each crew familiar shipborne procedure (IMO, 2011). Contravening any maritime convention, the vessel may subject to detention. MARPOL 73/78 allows PSCO to inspect a foreign vessel shipboard pollution prevention procedures including Annex V of the convention. Ensuring an effective enforcement of the international Conventions adopted by the IMO, nine regional PSC systems has formed (namely Abuja MOU, Black Sea MOU, Caribbean MOU, Indian Ocean MOU, Mediterranean MOU, Paris MOU, Riyadh MOU, Tokyo MOU and Viña del Mar Agreement) a worldwide network to eliminate sub-standard shipping (Tokyo MOU, 2013). The calculation to determine the country performance includes the number vessel inspected, number of vessel detain over a 3 year period and allowable detention limit (set at 7%) (Tokyo MOU, 2013). Thus, excess factor (EF) is determined and ordered as black (EF>1), grey (0>EF>1) and white (EF<1) (BGW) classification has been adopted to determine the vessels' registered country performances (Degré, 2008). JLM is responsible to conduct PSC inspection under Tokyo MOU region.

2.5.2 Malaysia maritime legislation

2.5.2.1 Merchant Shipping Ordinance, 1952 (applicable throughout Malaysia since 1991 under Gazette A792/91)

This Ordinance (Federation of Malaya Ordinance, 1952) does not mention specifically on marine debris or any matter in relations to debris from ashore. However Part VA of this Ordinance elaborated control of pollution and maritime casualty from ships including foreign ships while in Malaysian waters. Relevant sections 306(b), 306(c), 306(d), 306(e), 306(f), 306(g), 306(h), 306(i), 306(j) and 306(k), prohibited from a ship any release of oil or "harmful substances" (means any substance introduce into the sea that is liable to create hazards to human health, living resources and marine life; damage amenities or to interfere legitimate uses of the sea). Incompliance by the owner of the vessel to take prevention steps or reduce the pollution, section 306(f) prescribed a fine of not more than RM50,000.00 per day throughout the default period.

2.5.2.2 Environment Quality Act, 1974

This Act (Federation of Malaya, 1974) does not mention specifically on marine debris or any matter in relations to debris from ashore. However, Section 2 of the Act has elaborated and interpreted any ship, waste owner and pollutant are liable to this regulation. Waste includes any matter whether in a solid, semi-solid or liquid form discharged or deposited in the environment (land or water) to cause pollution. Any person discharge any waste into Malaysian waters (Section 29) constitutes an offence. An offender under this Act shall be liable to a fine of not exceeding RM 500,000.00 or five year imprisonment or both (Section 29 (2)).

2.5.2.3 Solid Waste and Public Cleansing Management Act, 2007

Through the 9th Malaysia Plan, Solid Waste and Public Cleansing Management Act (Federation of Malaya, 2007) has been introduced and adopted in August 2007 and implemented in April 2008 by the National Solid Waste Management Department. The objective of the department is to create a society that is committed towards waste minimization and achieving a recycling target of 22 per cent by 2020. The Act provided executive power to the Federal Government on matters relating to solid waste and public cleansing management so that a better service can be provided. This legislation served as a catalyst for the holistic implementation of the 3R concept on waste minimization. Through the inauguration of this legislation, this can provide an impetus to move forward and effectively implementing the 3R and achieving a recycling target of 22 percent by 2020.

2.5.2.4 Environment Protection Enactment, 2002 (Sabah)

This Enactment (State of Sabah Gazette, 2002) has introduced preventive measures and pollution management from land-based activities to promote sustainable natural environment development in Sabah. There is no mention specifically on marine debris or any matter in relations to debris from ashore. However, Section 2 defines pollution as any means direct or indirect alteration of the environment or any part thereof by discharging wastes or pollutants (any substance whether liquid, solid or gaseous, or micro-organisms) thereby causing hazard to the public health and the environment. An abatement notice may be issued a person contravenes under this Enactment as describe in Section 37. Section 52 of the said Enactment provides penalty for offence not more than RM50,000.00 or a maximum of 2 year imprisonment or both.

2.5.2.5 Natural Resource and Environment Ordinance, 1993 (Sarawak)

This Ordinance (Sarawak Government Gazette, 2001) aims to encourage natural environment sustainable development in Sarawak by introducing preventive measures and pollution management from land-based activities. In addition, this Ordinance has clearly defines environmental value, pollution, and has identified each stakeholder's responsibilities including the Government agencies. Although there has no specifically mention on marine debris or any matter in relations to debris, Section 2 defines pollution as any direct or indirect alteration of the environment by discharging wastes in such amount, which is hazardous or a potentially risk to public health or the environment. Section 30B describes an offence if a surface of any land is polluted. Section 30B(3) of the said Ordinance provides penalty for offence not more than RM100,000.00 or a maximum of 5 years imprisonment or both.

2.5.2.6 The Uniform (Anti-Litter) By-laws 2010 (Sabah)

To enhance protection of the environment in Sabah, this By-laws (Local Government Ordinance, 2011) has been unified and it is applicable to all local authorities in Sabah. Under Section 4 (a), any person who places or throws any litter in any public place shall be guilty of an offence. The term "litter" is defined to have a very wide meaning and includes paper, ashes, carcasses, refuse, leaves and branches, grass, straw, boxes, barrels, bales, shavings, sawdust, garden refuse, stable refuse, trade refuse, manure, garbage, bottles, glass, can, food container, food wrapper, particles of food and other things. The term "public place" includes sea beach and sea front. Under Section 4 (d), anything dropped or spilled from a moving or stationary vehicle onto a public place, which includes highway, street or road constitutes an offence. Section 10 (1) provides for a penalty of not exceeding RM 20,000.00 or imprisonment for one year or both under this by-law.

2.5.2.7 The Local Authority (Cleanliness) By-Laws, 1999 (Sarawak)

To enhance protection of the environment in Sarawak, this By-laws (Sarawak Government Gazette, 1999) has been in place and applicable to all local authorities in Sarawak. Under Section 18 (1), any person who places or throws any waste in any public place shall be guilty of an offence. The term "waste" is defined to have a very wide meaning and includes garden refuse, trade refuse, leaves and branches, sand, gravel and stone. The term "public place" includes "sea beach". Under Section 4, anything dropped or spilled from a moving or stationary vehicle onto a public place, which includes highway, street or road constitutes an offence. Section 18 (3) provides for penalty. An offender under this by-law shall be liable to a fine of not exceeding RM 2,000.00 or imprisonment for six months or both.

2.5.2.8 The Local Government Act, 1996 (Peninsular Malaysia)

To enhance protection of the environment, the Local Government (Cleanliness) and Local Government (Refuse Collection, Removal and Disposal) By-Laws, have been established within local municipality. These by laws has define "waste" and "public place" to cover a wider area for application. “Waste” includes garden refuse, trade refuse, leaves and branches, sand, gravel and stone. While, "public place" includes any place that is common use for recreation purpose including beach area. Any person who places or throws any waste in any public place (Section 3(a)) including any waste dropped, spilled or spread from a moving or stationary vehicle onto a public place, which includes highway, street or road

(Section 3(d)) constitutes an offence. An offender under this by-law shall be liable to a fine of not exceeding RM 500.00 and RM 25.00 for recurring offence (Section 11).

2.6 Shipping in Malaysia

Ports in Malaysia have been developing avenues to provide a significant role in transport and trade between the shipping services and the inland transport system. There are 23 major ports in Malaysia which can be divided into federal ports and state ports (Khalid, 2006). The federal ports are under the authority of the Ministry of Transport, while, state ports under State Statutory Bodies. All federal ports except Kemaman port has been privatized and regulated by port authorities. Ports in Sarawak are operated by port authorities, whereas, ports in Sabah have been privatized under one private operator.

The Malacca Straits is the shortest sea route between the Indian Ocean and the Far East (Figure 7) and it is among the oldest and busiest shipping lanes in the world, serving as a crucial waterway for movement of cargoes (Khalid, 2012; Meyrick *et al.*, 2005; Chua *et al.*, 2000). The number of vessels plying within MTW especially under the Malacca Straits Traffic Separation Scheme (TSS) has grown steadily at an average rate of 3% per annum (Khalid, 2012). The average vessel of the entire global trading range vessels and types utilizes MTW daily basis has increase from 153 vessels in year 2000 to 217 vessels in year 2014 (Figure 8) (JLM, 2015). The highest numbers of vessel type operating within MTW are container (33.18%), tanker (23.05%), bulk carrier (12.86%) and general cargo (10.81%) vessels. These vessels are loaded with cargo, meeting shipping schedules, catering to avid international demand for consumers and other goods (Asariotis *et al.*, 2013; Desa *et al.*, 2012;

Chua *et al.*, 2000). The high number of vessels navigating through MTW may contribute to marine debris problem along Malaysian coastlines.

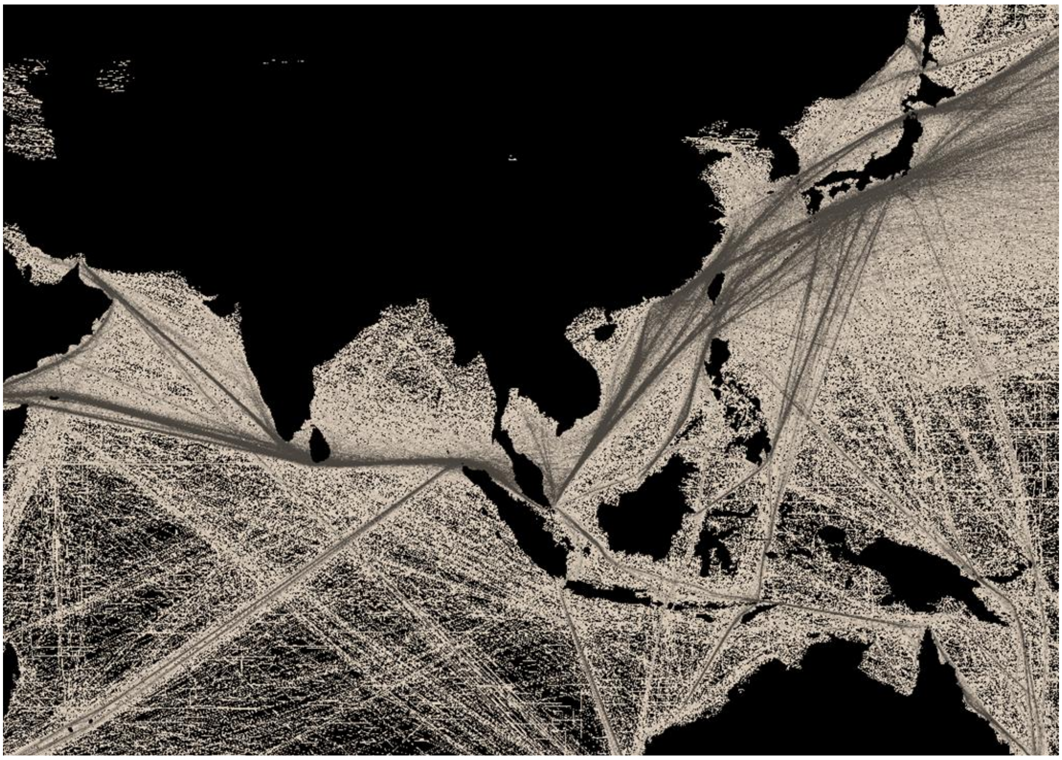


Figure 7: Commercial shipping routes density in South China Sea (Source: Halpern *et al.*, 2008)

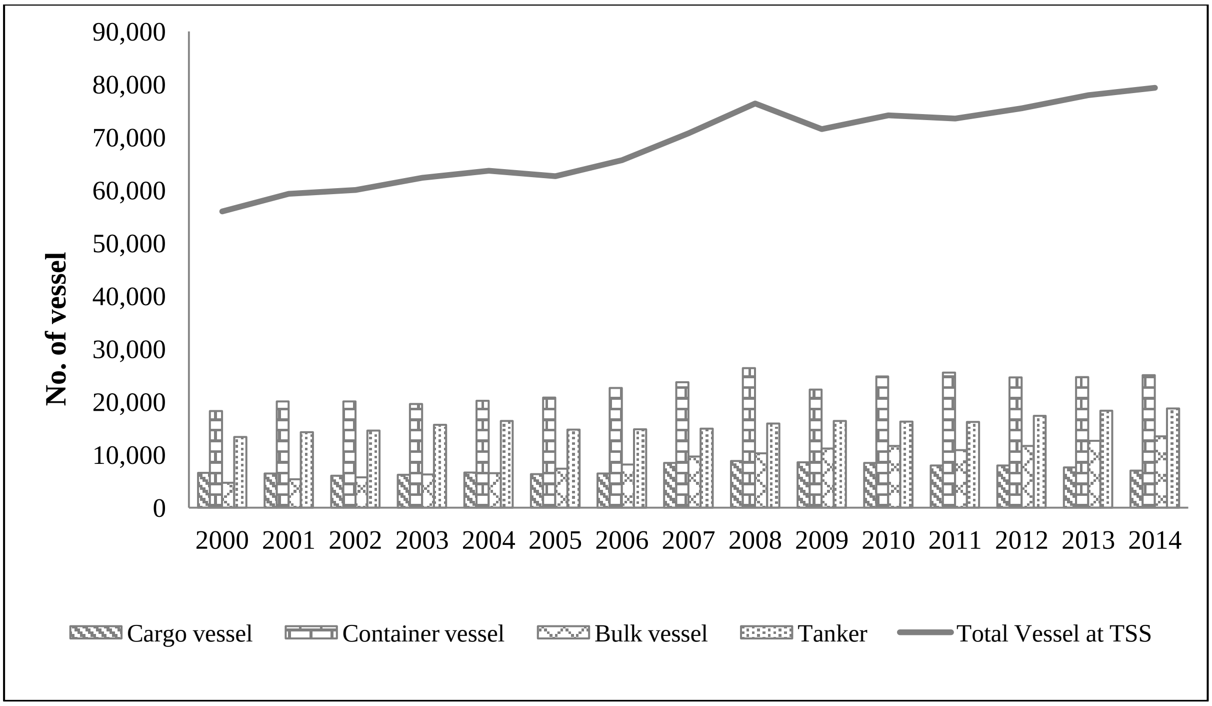


Figure 8: Straits of Malacca annual traffic volume, 2000 – 2014 (Source: JLM, 2015)

2.7 Survey protocol

2.7.1 Beach survey protocol

The use of beach survey protocols are determined by the objectives of the study and/or reasons for the research result purpose such as an operational management or cleanup program or to improve community awareness of marine litter issues (Rees & Pond, 1995; Dixon & Dixon, 1981). For the purpose of the study, the entire beach or smaller sections (transects) may be surveyed. The beach survey assessment can be divided into standing stock and accumulation rate.

2.7.1.1 Standing stock

Standing-stock or also known as standing-crop is an assessment in number of debris item changes in the diversity and distribution according to debris category. Studies have shown that coastal morphology affect marine debris abundance of debris turnover between 3-12 months using this assessment method. A study by Ryan *et al.* (2009) found debris item input such as clear plastic bottles has been stabilized, however, smaller items such as the bottle cap has increased. Therefore, this assessment gives an overview of the balance between the debris input and removal during beach clean-up. This method is suitable for the marine debris abundance study especially knowing the sources of debris input to the marine environment especially adjacent to urban areas.

2.7.1.2 Accumulation or flux rate

Accumulation rate assesses marine debris accumulation over a specific period of time. Therefore, all debris found on the study sites were recorded and removed, on a determined survey periods. In addition, the result can explain debris accumulation rates and climatic cycle relationships (Morishige *et al.*, 2007). Nevertheless, this survey method requires more effort and huge investment to conduct regular surveys over a larger area to gather accurate debris abundance trends information compared to standing stocks survey method (Sheavly, 2007). The loading rate has been reported to vary since the studies have been conducted in intervals from 3 days to 3 months (Walker *et al.*, 2006; Garrity & Levings, 1993; Vauk & Schrey, 1987). Accumulation gross rate is suitable for long term monitoring at a larger area.

2.7.2 Ship survey protocol

Shipborne garbage monitoring method on the vessel was adopted and modified from beach survey protocol. This protocol uses garbage categories as defined in MARPOL 73/78 Annex V, while, objects and sources was adopted and modified from Ribic *et al.* (1992) and Ribic *et al.* (2012). Inspection and assessment was conducted according to Res. A.1052(27) Port State Control inspection (IMO, 2011). In addition, vessel practices on shipborne waste management was extracted and observed from vessels' GMP manual, GRB and physical inspection which gives a true picture of garbage management practices on the vessel.

CHAPTER 3

BEACH DEBRIS ABUNDANCE

3.1 Introduction

Malaysia has a total area of 614,159 km^2 of marine and coastal areas along the 4,800 km coastlines. The diversity in flora and fauna has made Malaysia among the twelve mega biodiversity countries in the world (Hamid, 2012). The coastal area comprises sensitive ecosystems such as mangroves, fringed mud flats, coral reef and sandy beaches, which covers about 4.43 million hectares or 13% of the total land area of Malaysia (Ministry of Natural Resouces and Environment of Malaysia, 2014). The coastal area also has been developed to be the centre for social and economic importance. Tourism being the second largest foreign exchange after manufacturing and the seventh largest contributor to the Malaysian economy (Aruna, 2013), has shown an increasing trend where tourists increased from 15.7 million in year 2004 to 27.4 million in year 2014 (Corporate Tourism Malaysia, 2015). Despite its economic importance, this industry may contribute to a significant amount of marine debris found on Malaysian beaches.

Marine debris is categorized as pollution in Malaysia, however, less attention is given as compared to water and heavy metal pollution (Ngah *et al.*, 2012; Abdullah *et al.*, 2011; Praveena *et al.*, 2011; Law & Hii, 2006). For most coastal areas, local authorities manage solid waste found on beaches and enforcing Local Government by-Laws to ensure safety and cleanliness to the public areas. Although the regulation may impose a penalty of not more than RM 500 to littering offenders in public areas, enforcement in beaches is difficult (Agamuthu *et al.,* 2012). Furthermore, marine debris found on beaches was given less priority and only beaches in the urban areas are maintained by local authorities or appointed contractors.

Marine debris may have different impact in the marine ecosystem compared to those found on land because it may affect biodiversity, changes ecosystem function, revenue, livelihood and the cost of maintenance and cleanup (UNEP, 2005; Thiel *et al.*, 2003). Marine debris have affected at least 267 species either from ingestion or entanglement that could result in death (Baulch & Perry, 2012; Barnes *et al.*, 2009; Rios *et al.*, 2007; Laist, 1997). Not only marine debris poses a hazard to marine species, it affect many human activities and the economy associated with the ocean such as damaging and fouling ships (UNEP, 2009; Sheavly, 2005b), degrading aesthetical wilderness values and multi-use coastal habitats (Sheavly, 2005b), as well as poses a hazard to recreational divers (Jones, 1995).

The studies of marine debris in Malaysia were limited to NEM season and had applied combination of various survey methods, thus the overall picture of marine debris on Malaysian beaches is still unclear. However, those studies are in agreement that plastic materials were the highest debris type at Port Dickson (Khairunnisa *et al.*, 2012), Sarawak (Hassan & Mobilik, 2012) and Terengganu (Fauziah *et al.*, 2015; Chan *et al.*, 1996) beaches. Among the identified debris, 65% were from land-based debris, which includes food wrappers, plastic shopping bags, cardboard cartons, aluminum cans, cloths, clear and colored plastic bottles, whereas, ocean-based activities contribute between 20% and 30% of the marine debris problem. In addition, the rapid development and increasing population along the coastal area has contributed a significant impact to marine ecosystem quality (Khairunnisa *et al.*, 2012; Abdullah *et al.*, 2012; Manaf *et al.*, 2009; Hassan *et al.*, 2007; Sheavly, 2005a).

Sources of marine debris are marine, shore and urban activities (Leite *et al.*, 2014; JGESAMP, 2009; UNEP, 2006; Sheavly, 2005b; U.S. Commission on Ocean Policy, 2004).

Recent studies indicate that 60% to 80% of total marine debris stranded on the beaches was originated from land-based sources, and up to 80% of this debris is plastic (Smith, 2012; Rios *et al.*, 2007; Barnes & Milner, 2005; Sheavly, 2005a; Derraik, 2002; Gregory & Ryan, 1997). Currently, the average per capita generation rate in Malaysia between 0.5 kg/person/day (rural area) and 1.7 kg/person/day (urban area) in which domestic waste is the primary source (Manaf *et al.*, 2009; Idris *et al.*, 2004). In addition, areas which do not have rubbish collection services especially along coastal villages and squatter areas will cause residents to discharge garbage into the nearby river (Daily Express Newspaper online, 2014; Alias *et al.*, 2013). Therefore, garbage from urban areas can become marine debris if it gets into streams or rivers (JGESAMP, 2009; Sheavly, 2007) which eventually arrives in the seas or stranded on the beaches. As urbanization continues, the management of garbage waste is a major environmental concern towards marine environment health.

The study started with the hypothesis that there is no spatiotemporal variation in marine debris abundance stranded on Malaysian beaches. Therefore, this chapter discusses the (1) amount of marine debris during northeast monsoon (NEM), intermediate monsoon (IM) and southwest monsoon (SWM) seasons; (2) categorizing the debris by type of materials, and (3) determined possible sources of the debris. In addition, (4) the relationship between abundance of debris with rainfall and relative exposure were explored.

3.2 Materials and methods

3.2.1 Assessment of study site

The South China Sea has a monsoon climate (Akhir *et al.*, 2011; Saadon & Marghany, 1996). In Malaysia, monsoon seasons are characterized by the SWM from late May to

September and the NEM from November to March with two IM from April to early May and September to October. Temporal and spatial influences on debris abundance was conducted during different monsoon seasons at eight public beaches; four (4) sites in Sarawak, two (2) sites in Sabah and two (2) sites in Peninsular Malaysia as shown in Figure 9. Pandan, Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru and Kosuhoi beaches are located on the east Malaysia, whereas Saujana and Batu Rakit beaches are located in West Malaysia. The shoreline of the surveyed sites stretches between 1.0 to 6.0 km in length and between 20 to 90 m in width (Table 5).

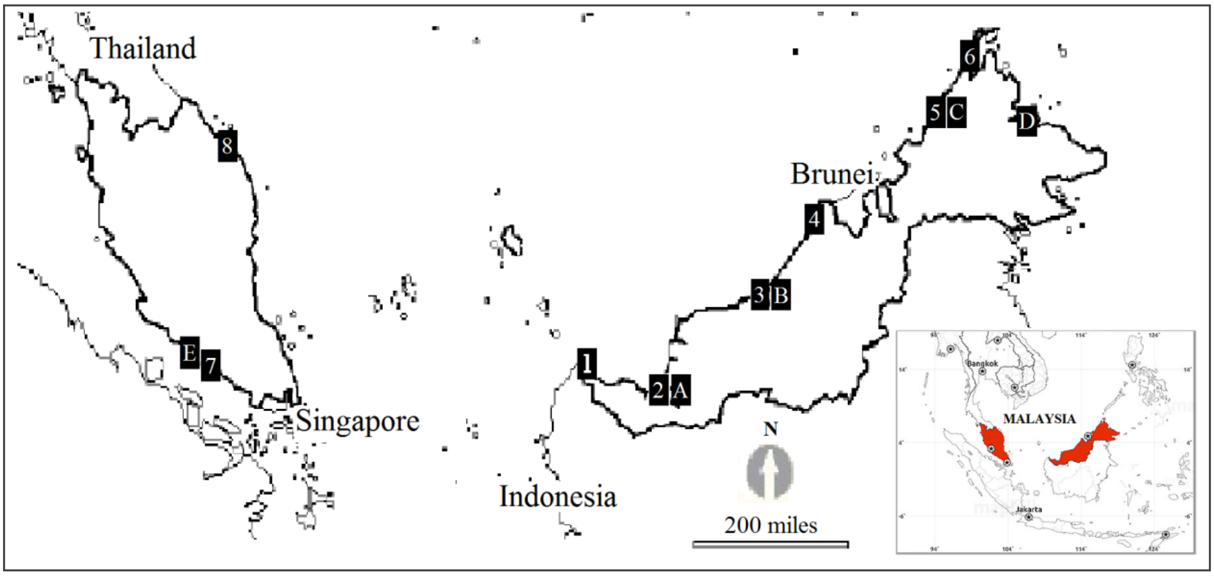


Figure 9: Map showing study sites for beach (in numeric) and ship (in alphabetic) surveys
Note: Detail information of the beach/port study sites can be referred to Table 5 (beach study sites) and Table 6 (port study sites)

The popular beaches among visitors were the Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru and Saujana beaches due to proximity to the city centre (Table 5). Pandan, Kosuhoi and Batu Rakit however adjacent to village land with one public entrance to the beach. The livelihoods of the villagers in those beaches are fishing and subsistence vegetable farming. On the other hand, Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru and Saujana beaches are adjacent to town areas, housing areas, hotels, resorts and privately owned lands. The local authorities, hotel and resort operators; and people from nearby villages take initiatives to conduct

Table 5: Beach study sites with respective survey coordinates, sampling dates and characteristics

Map Ref	Study Site	Location	Sampling date	Beach Characteristic
1	Pandan	Start point: 01° 45' 48.7" N, 109° 51' 53.2" E End point: 01° 45' 42.8" N, 109° 52' 11.2" E	NEM:24.10.12 & 11.1.14 IM:5.5.13 & 10.4.14 SWM:3.8.5.13 & 12.7.14	• 12.3 km from Lundu town • Public beach with one entry • Length 6.0 km • Width 90 m
2	Pasir Pandak	Start point: 01° 41' 30.0" N, 110° 18' 11.1" E End point: 01° 41' 38.9" N, 110° 18' 27.8" E	NEM:22.10.12 & 12.1.14 IM:12.5.13 & 20.4.14 SWM:13.7.13 & 19.7.14	• 15.1 km from Santubong village • Public beach with one entry • Length 1.2 km • Width 50 m
3	Temasyah	Start point: 03° 12' 51.5" N, 113° 02' 59.9" E End point: 03° 12' 37.3" N, 113° 02' 47.0" E	NEM:26.10.12 & 28.1.14 IM:16.5.13 & 13.4.14 SWM:3.7.13 & 30.7.14	• 5.6 km from Bintulu town • Public/Recreational beach with two entries • Length 1.0 km • Width 20 m
4	Tg. Lobang	Start point: 04° 22' 22.2" N, 113° 58' 08.5" E End point: 04° 22' 05.1" N, 113° 57' 59.8" E	NEM:28.10.12 & 26.1.14 IM:15.5.13 & 12.4.14 SWM:9.7.13 & 28.7.14	• 5.1 km from Miri city • Public beach with one entry • Length 1.0 km • Width 30 m
5	Tg. Aru	Start point: 05° 56' 4.1" N, 116° 2' 48.6" E End point: 05° 56' 29.3" N, 116° 2' 47.5" E	NEM:6.12.12 & 18.1.14 IM:6.5.13 & 24.7.14 SWM:19.7.13 & 2.7.14	• 7.4 km from Kota Kinabalu city • Public beach with one entry • Length 2.2 km • Width 40 m
6	Kosuhoi	Start point: 07° 1' 24.3" N, 116° 44' 39.1" E End point: 07° 1' 53.4" N, 116° 44' 47.4" E	NEM:21.12.12 & 19.1.1.14 IM:8.5.13 & 26.4.14 SWM:21.7.13 & 4.7.14	• 28.3 km from Kudat town • Public beach with one entry • Length 2.4 km • Width 30 m
7	Saujana	Start point: 02° 29' 51.3" N, 101° 50' 16.2" E End point: 02° 30' 9.1" N, 101° 50' 8.2" E	NEM:18.11.12 & 8.2.14 IM:19.5.13 & 17.5.14 SWM:31.7.13 & 11.8.14	• 6.3 km from Port Dickson town • 94.9 km from Kuala Lumpur city • Length 1.0 km • Width 80 m
8	Batu Rakit	Start point: 05° 27' 4.5" N, 103° 2' 22.1" E End point: 05° 27' 14.7" N, 103° 2' 15.3" E	NEM:11.11.12 & 2.2.14 IM:20.5.13 & 10.5.14 SWM:28.7.13 & 9.8.14	• 23.2 km from Kuala Terengganu city • Public beach with one entry • Length 4.8 km • Width 60 m

beach clean-up in Pandan, Kosuhoi and Batu Rakit beaches since there is no schedules of rubbish collection. Pasir Pandak, Temasyah, Tg. Lobang Tg. Aru and Saujana beaches which have public amenities are maintained by the local authorities appointed contractors for the regular schedule of rubbish collection of at least twice a week.

The study sites are exposed to swells and wind waves between 1.0-2.0 m during the NEM, 1.0-1.5 m during IM and 1.0-1.5 m during SWM seasons from the South China Sea (Chiang *et al.*, 2003a, 2003b). Saujana beach is located on the west side of Peninsular Malaysia and exposed to swells and wind waves of less than 1.0 m from the Straits of Malacca. In Malaysia, the wave directions are influenced by the monsoon winds. Predominant wave and swell direction during NEM season is from northeast, while SWM is from southwest (Akhir, 2012; Chiang *et al.*, 2003b). However, the predominant wave and swell direction for west coast of Peninsular Malaysia is from the south. For the two short IM periods, predominant wave and swell direction are from the southwest.

3.2.2 Beach survey methods

Beach surveys have been conducted at all study sites during the NEM, IM and SWM seasons according to standing stock method (Cheshire *et al.*, 2009). Identification of the starting point of the beach surveyed was marked by hammering a polyvinyl chloride (PVC) pipe into the sand above the high tide mark. On the PVC pipe it was indicated the starting point with an arrow pointing of the ending point. Then, the distance of one km along the beach was measured using a measuring tape and marked with a PVC pipe indicating the ending point. Coordinates of the points are then recorded (Table 5) using Global Positioning System (GPS).

Two trained volunteers at each study sites collected debris samples at the same site over the sampling period. Before commencing of debris collection, volunteers participated in 15 minute briefing on beach survey protocol and categories of debris conducted in the study. The items collected using large bags, carried by volunteers to be accumulated at the edge of the beach on shady area. Despite irregularity of debris deposition resulting from oceanographic condition (Ribic *et al.*, 1992, 2010) and differences in buoyancy between debris types (Santos *et al.*, 2009) all debris were collected within the area from the low tide line to the base of the beach vegetation. Where sites showed large tidal range, beach width was standardized to 20 m from the high-tide line and 1 km transect parallel to the coastline. All debris items other than fragments smaller than 0.25 cm^2 within sampling area were piled, identified and sorted according to debris types pictured on the general debris data sheet (Appendix A). The debris items were separated and classified into six main categories: plastic (23 objects); rubber (2 objects); metal (4 objects); glass (2 objects); wood (3 objects); and cloth (1 object) (Appendix A). Items for each object was characterized according to debris categories developed based on Marine Debris Survey Manual (Ribic *et al.*, 1992). Items within each category were counted and weighted to the nearest 100 gm. Upon completion of each beach survey, all debris items are removed from the beach and deposited to the central collected point of rubbish. Debris collected was then classified according to debris sources; marine source (21 objects), terrestrial source (11 objects) or common source (8 objects) following Ribic (1998) (Table 2). Results were presented in as beach debris item (item/km) and beach debris weight (kg/km). Using a method adopted from Ribic *et al.* (1992), beach debris item per km was calculated using Equation (1);

$$BDI = \frac{1}{6L}\left[\sum_{i=1}^{6}(OI_i)\right] \qquad (1)$$

where BDI is total number of objects (item/km), i is the number of samplings conducted at each study sites; L is the length (km) of the beach surveyed; and OI_i is the total number of object collected (number, *item*). Using a method adopted from Ribic *et al.* (1992), beach debris weight per km was calculated using Equation (2);

$$BDW = \frac{1}{6L}\left[\sum_{i=1}^{6}(OW_i)\right] \quad (2)$$

where BDW is total number of object weight (kg/km); and OW_i is the total objects' weight collected (kg).

3.2.3 Secondary data

Previous studies on marine debris had used secondary data to create an understanding on marine debris accumulation on beaches and the ocean (Thiel *et al.*, 2013; Walker *et al.*, 2006; Vauk & Schrey, 1987). The majority of the secondary data collected in this study are used to analyze oceanographic influence towards marine debris accumulation in the study sites according to different monsoon seasons. Although several oceanographic observed monthly data were incomplete due to equipment break-down or destroyed during bad weather condition, available data have been collaborated and analyzed to generate oceanographic understanding between different monsoon season periods. Data collected including but not limited to;

1. Wind: Wind speed and direction were obtained from MMD,
2. Current: Ocean current data was from Atlas of Pilot Charts Indian Ocean 2001 NVPUN109 4th Edition,
3. Rainfall: Monthly rainfall data (October 2012 until October 2014) from MMD,
4. Number of ship call: Number of ship call data from port authority at the study ports,
5. Number of vessel transiting Straits of Malacca from JLM.

3.2.4 Focus group interview

In depth interview was targeted on stakeholders (Table B 1 of Appendix B) in the fields of solid waste management at district level. The stakeholders were chosen based on the respective role in solid waste accumulation at the beaches. The interview was based on face to face interview to explore the marine debris accumulation issue on the public beaches, perspective on the problem and collecting supplementary information after a beach surveys has been completed. Targeted respondents were clustered among local authority and port authority. The interviews were solely open-ended questions and conducted personally by the researcher.

3.2.5 Relative Exposure Index (REI)

The wind and wave condition may determine the direction of floating debris that is presence on the beach (Garcon *et al.*, 2010; Keddy, 1984). Using a method adopted from Keddy (1984), wind exposure was calculated using Equation (3);

$$REI = \sum_{i=1}^{16} (V_i P_i F_i) \tag{3}$$

where REI is Relative Exposure Index, i is the cardinal wind direction 0º to 360º for every 22.5º interval; V_i is the average wind speed (km/h); F_i is the fetch distance (km); and P_i is the percent frequency from which the wind blew within each wind directions.

The REI is then normalized by dividing the site REI value with the average of total REI values. The calculated REI values were then ranked following Guannel *et al.*, (2011) and Gornitz *et al.*, (1994); very low exposure (rank=1), low exposure (rank=2), moderate exposure (rank=3), high exposure, (rank=4) and very high exposure (rank=5). The statistical software package R openair (Carslaw & Ropkins, 2014) was used to develop wind rose diagram using data collected by MMD at the nearest location weather observation stations from the beach study sites (Figure B 1 of Appendix B).

3.2.6 Data analysis

Upon completing each monsoon season beach survey, debris was assessed according to density, categorical and sources for each study site. Data generated from the surveys were presented statistically as BDI (±standard deviation) and BDW (±standard deviation). For statistical analysis, z-test was used to analyze the distribution of normality using skewness and kurtosis of the distribution since small size samples ($n < 300$) will give a more accurate result (Kim, 2013). Therefore, critical values for normal distribution with an alpha level 0.05 for $n < 50$ and $n < 300$ are smaller than ±1.96 and ±3.29 respectively for absolute z-scores for either skewness or kurtosis. A $\log_{10}$ transformation ($\log_{10}$+1) of the data was applied for statistical analyses that did not assume a normal distribution (Ribic *et al.*, 2010). Pearson's correlation analysis was used to identify BDI, BDW and total clear plastic bottles (CPB) relationship against urban proximity, ship call to port, rainfall and beach exposure. Where this test indicated significant relationship, a multiple linear regression (stepwise) model was used to identify predictor variables that contributed to the abundance debris items and weight. Linear regression was used to identify debris abundance relationship with rainfall and REI. BDI and BDW was calculated and compared between study sites (n=8), location (n=3), monsoon seasons (n=3), debris category (n=6) and debris source (n=3); using parametric two-way analysis of variance (ANOVA) with Tukey's Post hoc tests. Statistical Package for the Social Sciences (SPSS) version 22 package was used for statistical analysis.

3.3 Results

3.3.1 Debris abundance

In this study, total debris items collected were 46,141 items weighing 2,119.9 kg. This represents a mean BDI and BDW of 961±523 item/km and 44.2±21.2 kg/km, respectively. Figure 10 shows mean BDI and BDW of debris items according to study sites, location and monsoon seasons, while Table B 2 (refer Appendix B) shows detail debris abundance results. The mean BDI was the highest at Kosuhoi (1,263±631 item/km), while Pasir Pandak beach (657±285 item/km) was the lowest when compared among the study sites (Figure 10a.1). In terms of weight, Kosuhoi and Pasir Pandak accumulated the highest (61.3±38.3 kg/km) and lowest (32.2±12.6 kg/km) BDW, respectively (Figure 10a.2). From the study site location perspective, Sabah accumulated the highest BDI and BDW at 1,235±584 item/km and 55.5±29.3 kg/km, respectively (Figure 10b.1 and Figure 10b.2). When compared between monsoon seasons, debris accumulation for BDI (1,171±657 item/km) and BDW (47.9±28.6 kg/km) was the highest during SWM (Figure 10c.1 and Figure 10c.2).

The correlation results showed mean BDI ($p<0.05$, $z<\pm1.96$, $n=8$) was significantly correlated with BDW ($r=0.89$, $p=0.00$), while, urban proximity was significantly correlated ($p<0.05$, $z<\pm1.96$, $n=8$) against mean BDI ($r=0.75$, $p=0.03$), BDW ($r=0.72$, $p=0.04$) and CPB ($r=0.82$, $p=0.01$) (Table B 3 of Appendix B). Multiple regression result ($R^2=0.99$, $p<0.01$) shows BDI increased by 21.88 item/km for every one BDW ($\beta=0.99$, $t=22.56$, $p=0.00$) (Table B 4 of Appendix B). Multiple regression result ($R^2=0.56$, $p<0.05$) shows urban proximity ($\beta=0.75$, $t=2.78$, $p=0.03$) is a significant factor determining BDI (BDI=637.55+23.75*(Urban)) at the beaches (Table B 5 of Appendix B). While multiple regression result ($R^2=0.97$, $p<0.05$) shows urban proximity ($\beta=0.72$, $t=6.21$, $p=0.00$) and rainfall ($\beta=0.32$, $t=2.73$, $p=0.03$) are determining factor for CPB items

(CPB=6.89*(Urban)+0.23(Rainfall)) abundance at the beaches (Table B 6 of Appendix B). This indicates beach visitors from the urban area and rainfall were significant factors that determine debris items accumulation.

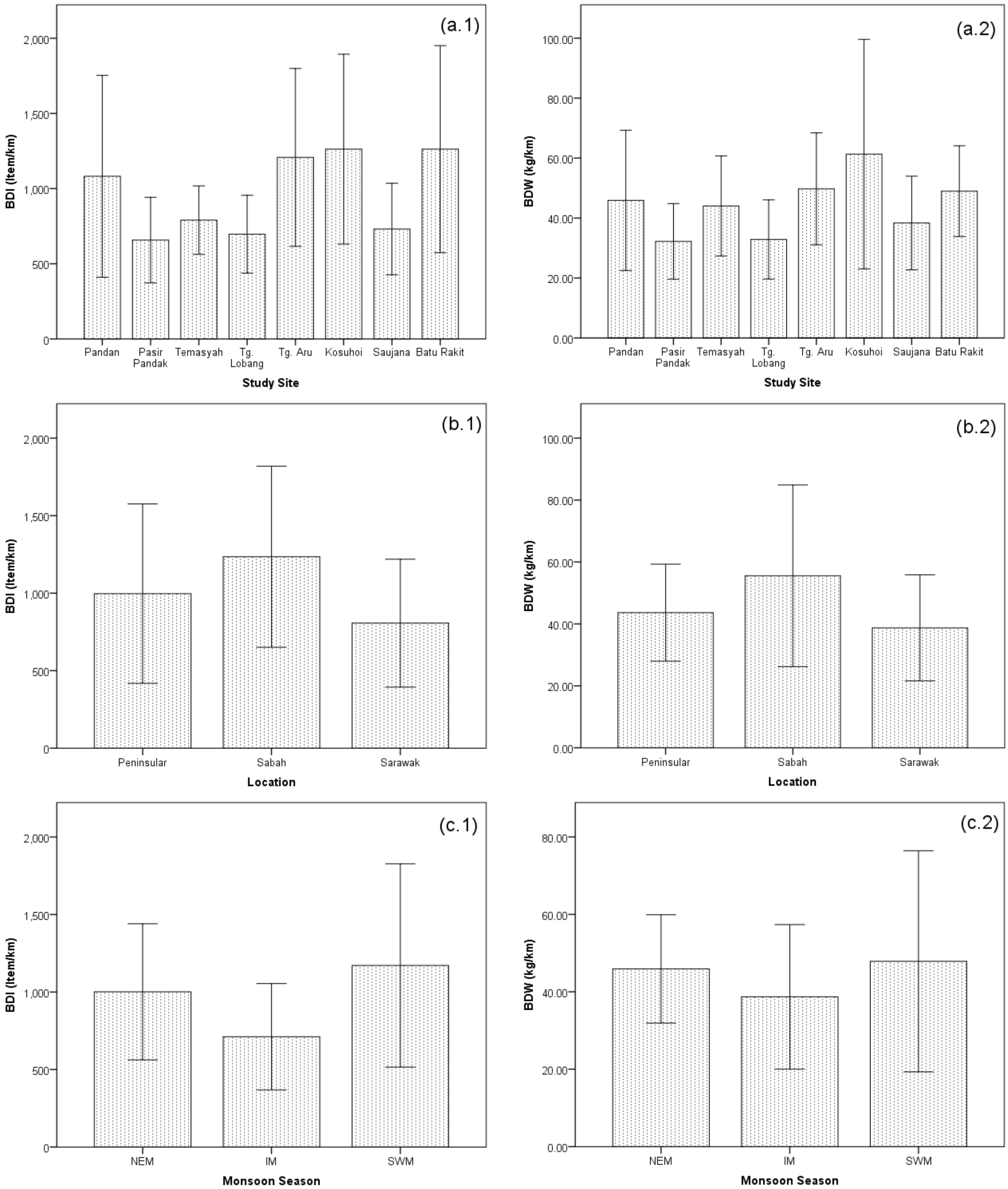


Figure 10: Means BDI and BDW (with standard deviation) of debris items in each (a) study sites, (b) location and (d) season

Figure 11 shows debris abundance (with standard deviation) for monsoon seasons according to study sites, while Table B 7 (refer Appendix B) shows detail debris abundance results. The means distribution of BDI (item/km) and BDW (kg/km) for monsoon seasons (n=3) according to study sites (n=8) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). The result from univariate ANOVA analysis to compare monsoon seasons mean BDI between study sites (Figure 11a) shows SWM season was significantly different ($p<0.05$) from IM season. However, mean BDW univariate ANOVA analysis results show no significant difference ($p>0.05$) between monsoon seasons according to study sites (Figure 11b). Univariate ANOVA analysis result to compare study sites mean BDI and BDW between monsoon seasons did not show any significant difference ($p>0.05$). Although, Tg. Aru has a regular rubbish collection, the amount of BDI is comparable with Pandan, Kosuhoi and Batu Rakit beaches with no rubbish collection.

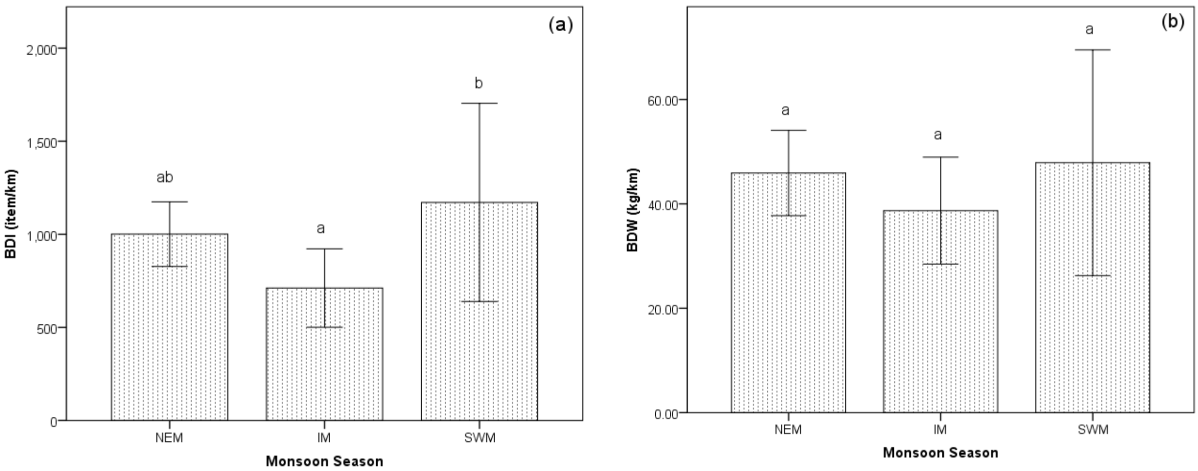


Figure 11: Means (a) BDI and (b) BDW (with standard deviation) for monsoon season (n=3) according to study sites (n=8)
Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

3.3.2 Debris category

The most debris items found in this study was plastic category at 40,825 items (851 item/km, 88%), ranging from packaging, plastic fragments, cups, plastic shopping bags, plastic food wrappers, CPB and colored plastic bottles to food wrappers; followed by wood, with 1,724 items (4%), rubber (3%), metal (2%), glass (3%) and cloth (1%) categories (Figure 12a). Plastic category was also the highest for debris weight composition at 1,223.8 kg (25.5 kg/item, 58%), followed by rubber (16%), metal (9%), glass (9%), wood (4%) and cloth (4%) (Figure 12b).

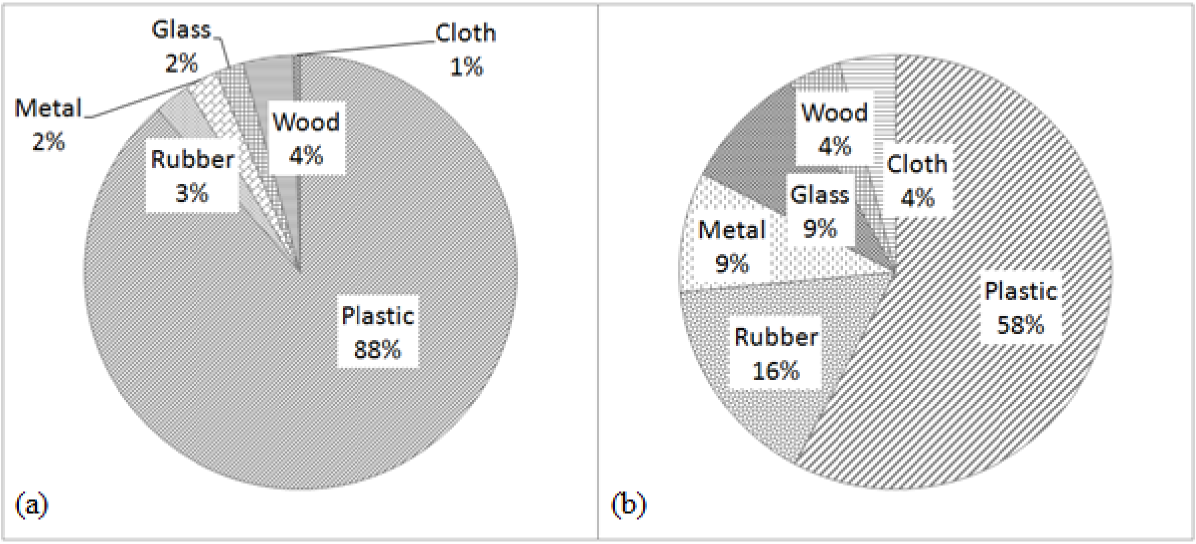


Figure 12: Composition of debris category according to (a) item and (b) weight

Figure 13 shows mean $\log_{10}$ BDI (item/km) and mean $\log_{10}$ BDW (kg/km) according to debris category, while Table B 8 (refer Appendix B) shows detail means BDI and BDW according to debris category. When analyzed between study sites, Kosuhoi had the highest mean BDI for plastic (1,101±550 item/km) category, whereas, Batu Rakit was the highest for rubber (43±26 item/km), glass (55±36 item/km) and cloth (7±15 item/km) categories (Figure 13a.1). The metal and wood categories were the highest at Pandan (1,101±550 item/km) and Tg. Aru (54±33 item/km) respectively. In terms of weight, Kosuhoi had the highest mean BDW for plastic (33.7±14.5 kg/km) and metal (11.1±18.1 kg/km) categories, whereas, Tg. Aru had the highest mean BDW for rubber (9.1±6.6 kg/km) and wood (2.4±0.9 kg/km) categories (Figure 13a.2). Batu Rakit and Saujana had the highest for glass (7.9±4.2 kg/km) and cloth (3.0±3.4 kg/km) categories respectively. From the study site location perspective, Sabah accumulated the highest means BDI and BDW for plastic, rubber, metal and wood

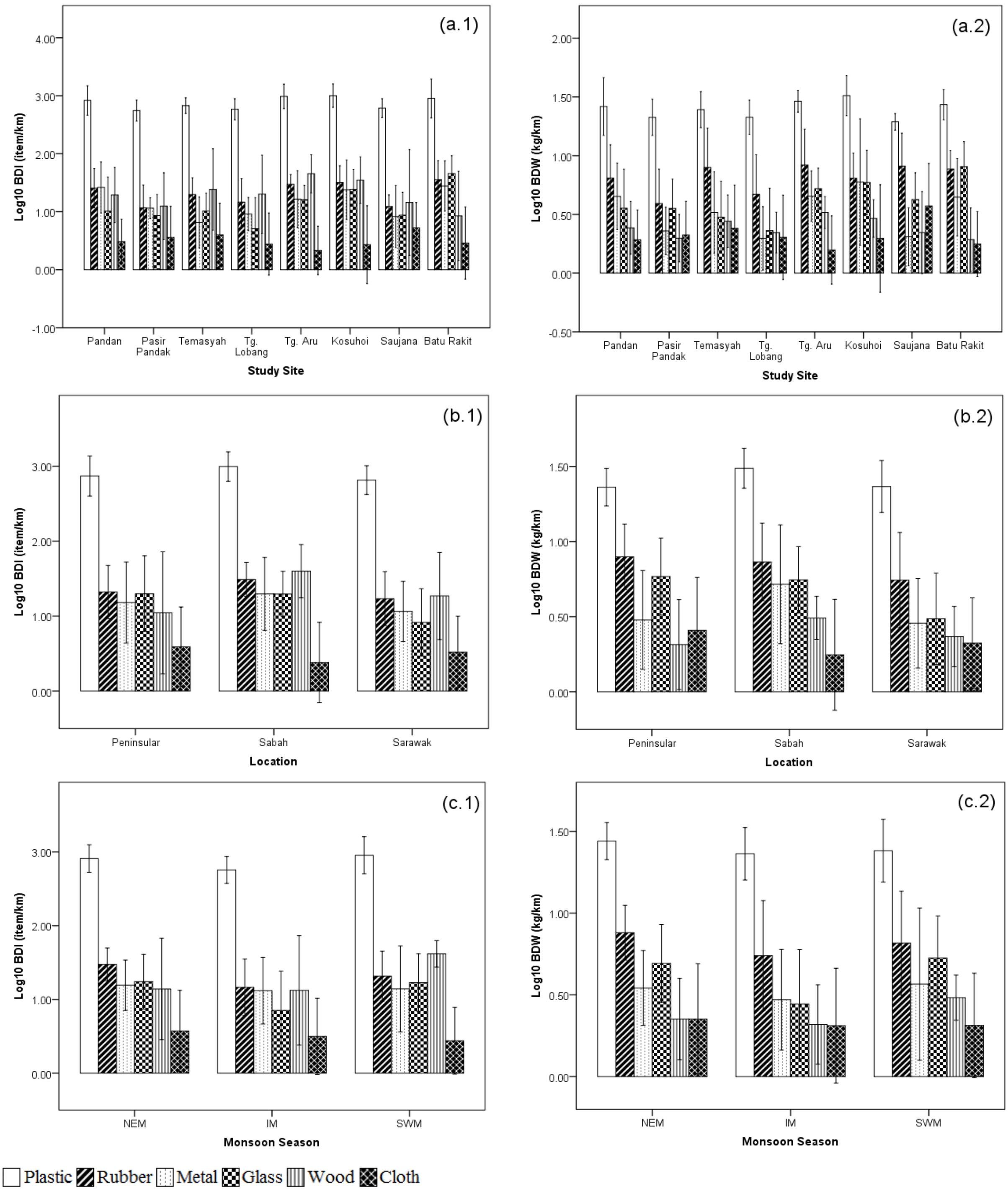


Figure 13: Means $\log_{10}$ BDI and $\log_{10}$ BDW (with standard deviation) according to debris category in each (a) study sites, (b) location and (c) season

categories, while, the glass and cloth categories were highest at Peninsular (Figure 13b.1 and Figure 13b.2). Sarawak accumulated the lowest BDI and BDW for all debris categories. When compared between seasons, mean BDI accumulation for plastic, metal and wood categories were the highest during SWM seasons, whereas, rubber, glass and cloth categories were highest during NEM (Figure 13c.1). In comparing mean BDW, NEM was the highest for plastic, rubber and cloth categories, while, metal, glass and wood categories were the highest during SWM season (Figure 13c.2).

The distribution of means $\log_{10}$ BDI and $\log_{10}$ BDW between debris category (n=6) according to study sites (n=8), location (n=3) and season (n=6) were not different from normal distribution ($p>0.05$ $z<\pm1.96$). Univariate ANOVA results to compare debris categories mean $\log_{10}$ BDI between study sites (Figure 14a.1), beach locations (Figure 14b.1) and monsoon seasons (Figure 14c.1) shows plastic category was significantly different ($p<0.05$) from rubber, metal, glass, wood and cloth categories. Cloth category was the lowest debris items accumulated at the beaches and was significantly different ($p<0.05$) from other debris categories. As for mean $\log_{10}$ BDW univariate ANOVA analysis results showed plastic category is significantly different ($p<0.05$) from other debris categories according to study sites (Figure 14a.2), beach locations (Figure 14b.2) and monsoon seasons (Figure 14c.2). The abundance of mean $\log_{10}$ BDW for wood and cloth categories showed debris weight accumulation trend were similar when compared between study sites, beach locations and monsoon seasons.

Figure 15 shows means $\log_{10}$ BDI and $\log_{10}$ BDW univariate ANOVA analysis result between study sites, beach locations and monsoon seasons against debris categories. Analyzing mean $\log_{10}$ BDI analysis result for study sites against debris categories showed Pasir Pandak and Tg. Lobang was significantly different ($p<0.05$) from Kosuhoi and Batu Rakit beaches (Figure 15a.1). Mean $\log_{10}$ BDW results show Kosuhoi was significantly different ($p<0.05$) from Pasir Pandak and Tg. Lobang beaches (Figure 15a.2). For beach locations perspective, $\log_{10}$ BDI (Figure 15b.1) and $\log_{10}$ BDW (Figure 15b.2) analysis result

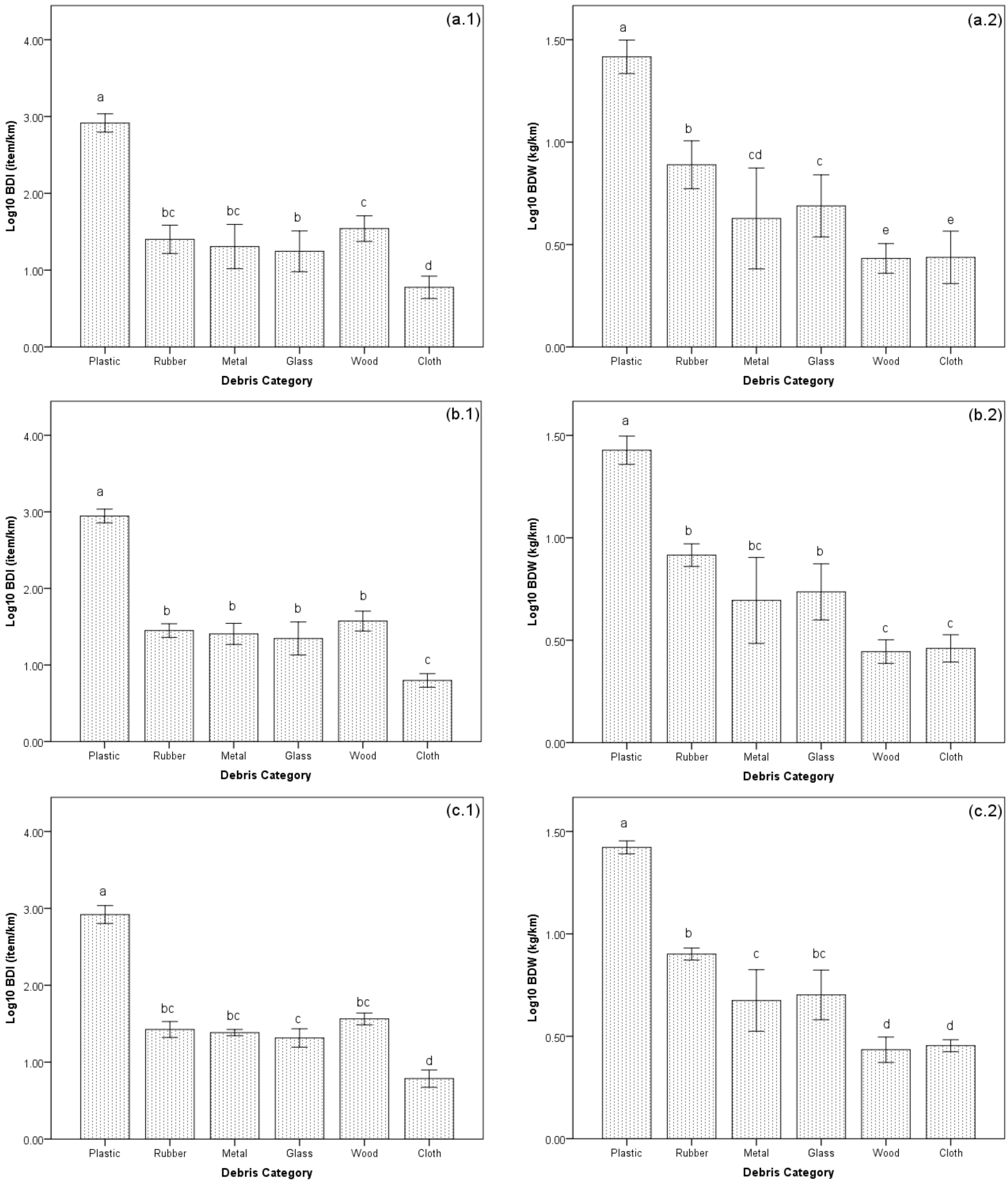


Figure 14: Means $\log_{10}$ BDI and $\log_{10}$ BDW (with standard deviation) debris category (n=6) according to (a) study sites (n=8), (b) location (n=3) and (c) season (n=6)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different (p<0.05) from the other groups.

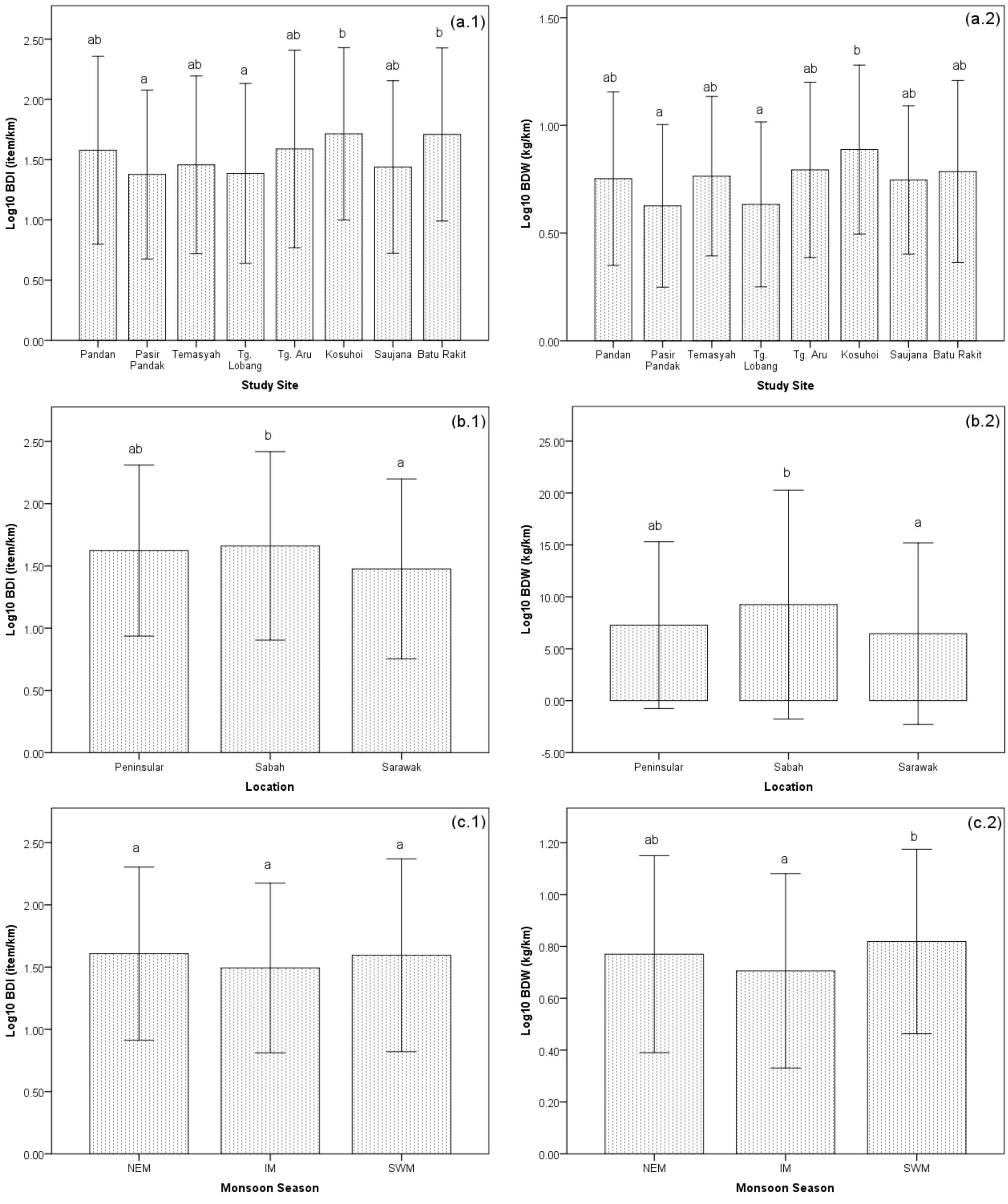


Figure 15: Debris category (n=6) means $\log_{10}$ BDI (with standard deviation) and $\log_{10}$ BDW (with standard deviation) between (a) study sites (n=8), (b) location (n=3) and (c) season (n=6)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

shows Sabah was significantly different ($p<0.05$) from Sarawak. For mean $\log_{10}$ BDI analysis result between monsoon seasons (Figure 15c.1) showed no significant different ($p>0.05$), however, mean $\log_{10}$ BDW analysis result shows IM was significantly different ($p<0.05$) from SWM season.

3.3.3 Debris source

Figure 16 shows mean BDI (item/km) according to debris sources, while Table B 9 (refer Appendix B) shows detail mean BDI results according to debris sources. Debris sources were primarily from common sources (400±249 item/km, 51%), followed by terrestrial (244±124 item/km, 31%) and marine (144±128 item/km, 18%) sources. From study site perspective, Kosuhoi accumulated the highest mean BDI from the common source at 588±300 item/km (Figure 16a). For terrestrial and marine sources were highest at Tg. Aru (373±165 item/km) and Batu Rakit (297±146 item/km) respectively. As for ports location perspective, Sabah had the highest mean BDI from the terrestrial and common sources at 528±244 item/km and 301±158 item/km respectively, while, Peninsular has the highest for marine source at 186±155 item/km (Figure 16b). Analyzing between monsoon seasons, SWM has the highest mean BDI for common, terrestrial and marine sources (Figure 16c).

The distribution of mean BDI for sources of debris (n=3) according to study sites (n=8), location (n=3) and season (n=6) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA results to compare mean BDI debris sources between study sites (Figure 17a) and location (Figure 17b) showed marine and terrestrial sources were significantly different ($p<0.05$) from common source. Analyzing results to compare debris sources mean BDI between monsoon seasons showed significantly different ($p<0.05$) between debris sources (Figure 17c). However, mean BDI univariate ANOVA analysis result

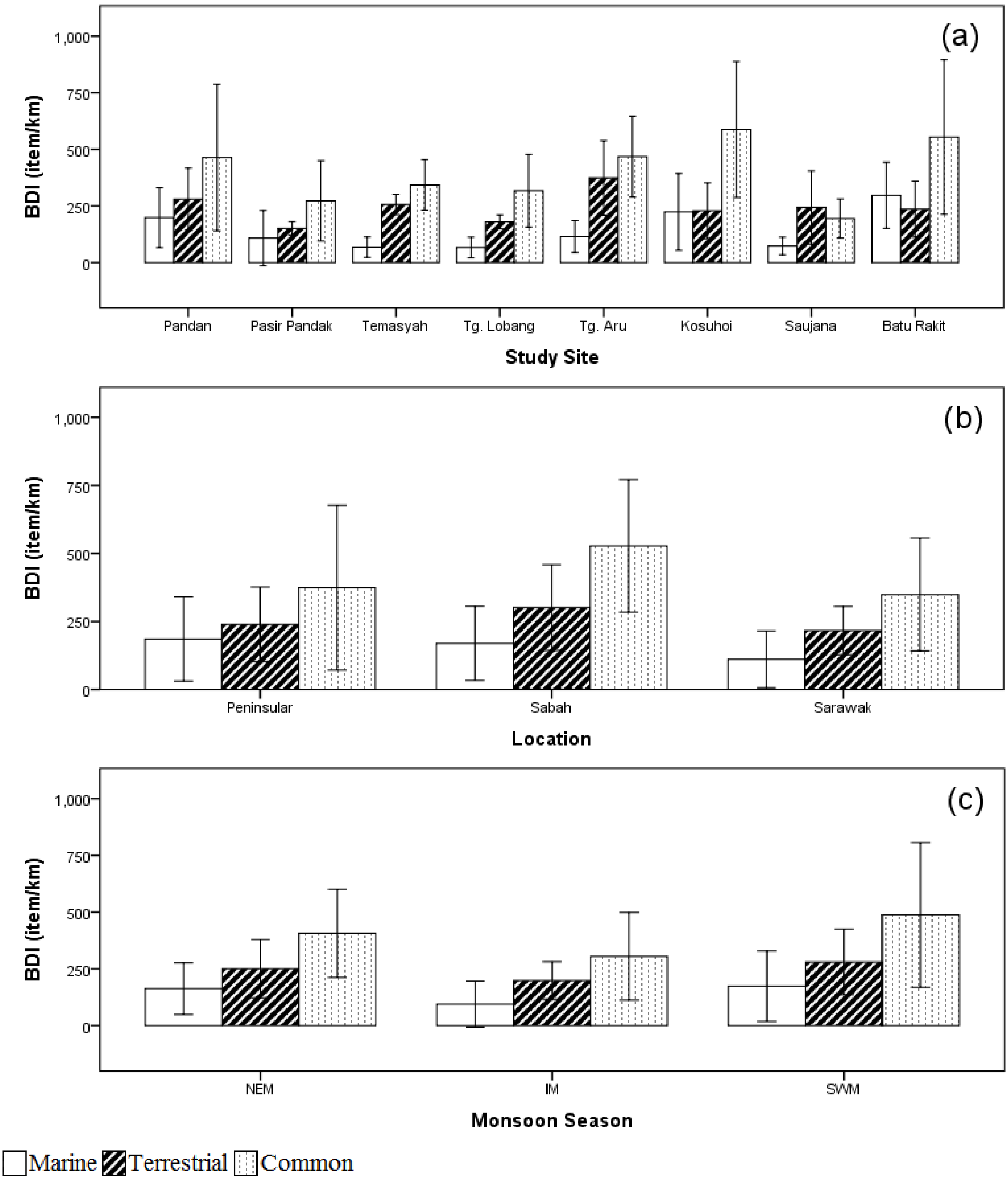


Figure 16: Mean BDI (with standard deviation) according to debris sources in each (a) study sites, (b) location and (c) season

among study sites, beach locations and monsoon seasons between debris sources were not significantly different (p>0.05). The results show objects associated with common source representing 48.32% from total item accumulates in common source includes CPB (137 item/km), foam cups (80 item/km), colored plastic bottles (74 item/km), plastic bottle caps (63 item/km) and footwear (26 item/km); resulting in the higher debris accumulated when compared to other sources on the beaches.

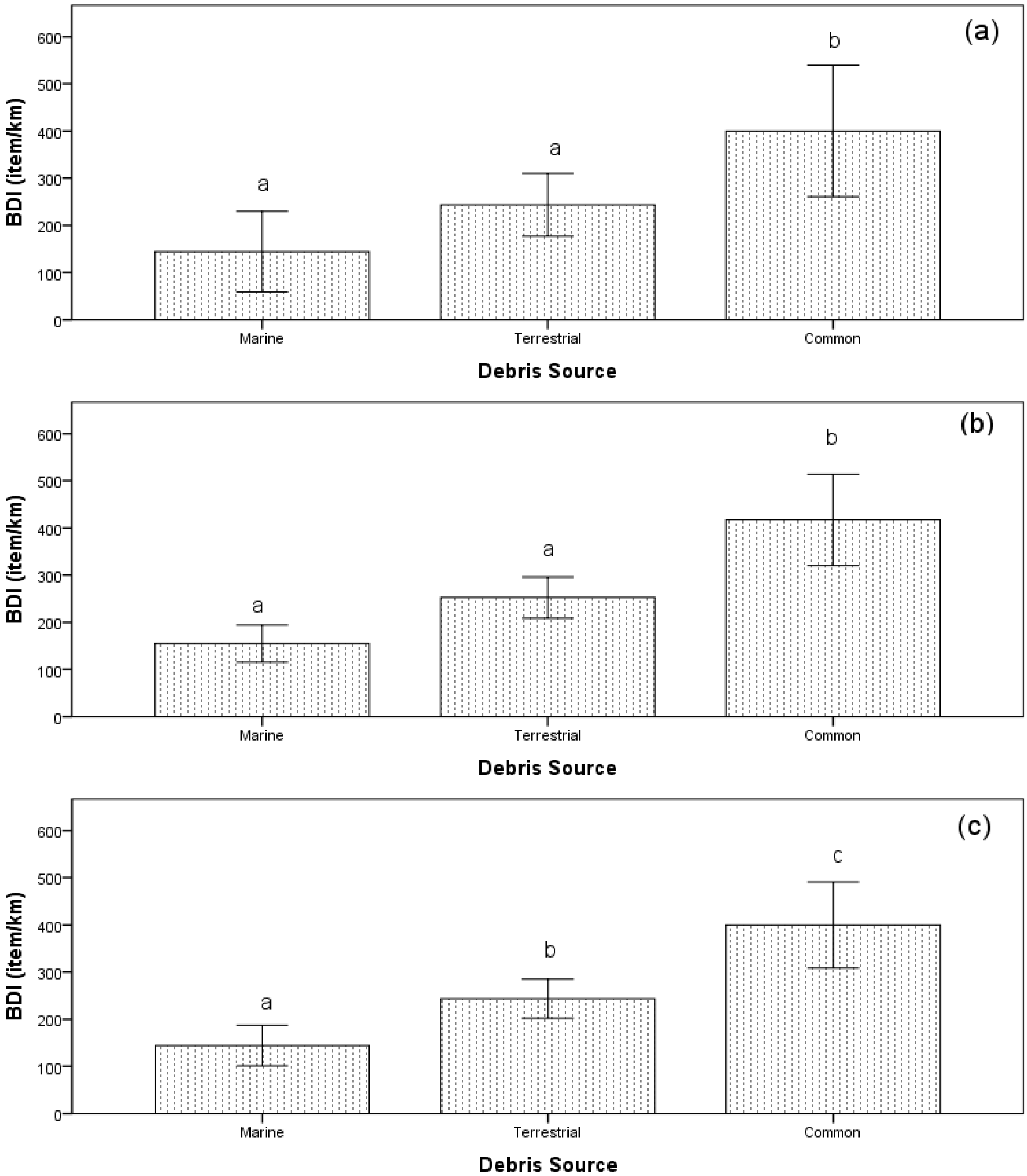


Figure 17: Mean BDI (with standard deviation) sources of debris (n=3) according to (a) study sites (n=8), (b) location (n=3) and (c) season (n=6)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

3.3.4 Correlation between debris abundance and monthly rainfall

Figure 18 shows the amount of rainfall (mm) recorded at the study sites during months of beach surveys which was collected at weather observation station conducted by MMD. Analyzing the amount of rainfall according to study sites, the distribution of rainfall was irregular and varies at each study sites between sampling month. Temasyah receive substantially higher rainfall (313±188 mm), while Batu Rakit received the lowest rainfall (111±49 mm) amount. Although, rainfall (mm) distribution between monsoon seasons (n=6) according to study sites (n=8) were not different from normal distribution ($p>0.05$, $z<\pm1.96$), there were limited evidence to conclude significant correlation ($p>0.05$) with means BDI, BDW and CPB items (Table B 10 of Appendix B). However, univariate ANOVA analysis results to compare mean rainfall between monsoon seasons according to study sites were significantly different ($p<0.05$) (Figure 18a). The result indicates Temasyah mean rainfall was significantly different from Pandak and Batu Rakit. In addition, this data indicates the rainfall distributions were most probably influenced by location, topography and morphology of the area. From monsoon seasons perspective, univariate ANOVA analyses results to compare mean rainfall between seasons according to study sites shows NEM rainfall was significantly different ($p<0.05$) from IM and SWM rainfall distributions. NEM received the highest (287±134 mm) amount of rainfall compared to IM (156±58 mm) and SWM (153±57 mm) seasons (Figure 18b).

Figure 19 illustrates the distribution of mean BDI according to monthly rainfall. The result shows inconclusive clustering distribution of debris accumulation against rainfall distributions. This explained Pearson's correlation analysis results in which mean rainfall was not significantly correlated ($p>0.05$) with means BDI ($r=0.03$, $p=0.86$), BDW ($r=0.09$, $p=0.55$) and CPB ($r=-0.14$, $p=0.33$) (Table B 10 of Appendix B).

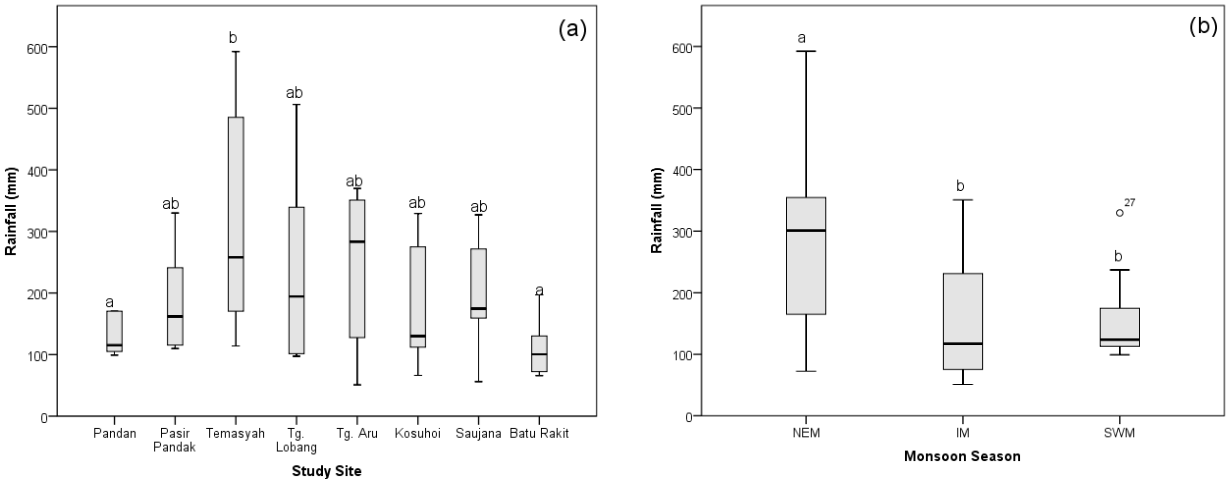


Figure 18: Rainfall (mm) (with standard deviation) in each (a) study sites (n=8), and (b) season (n=6)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

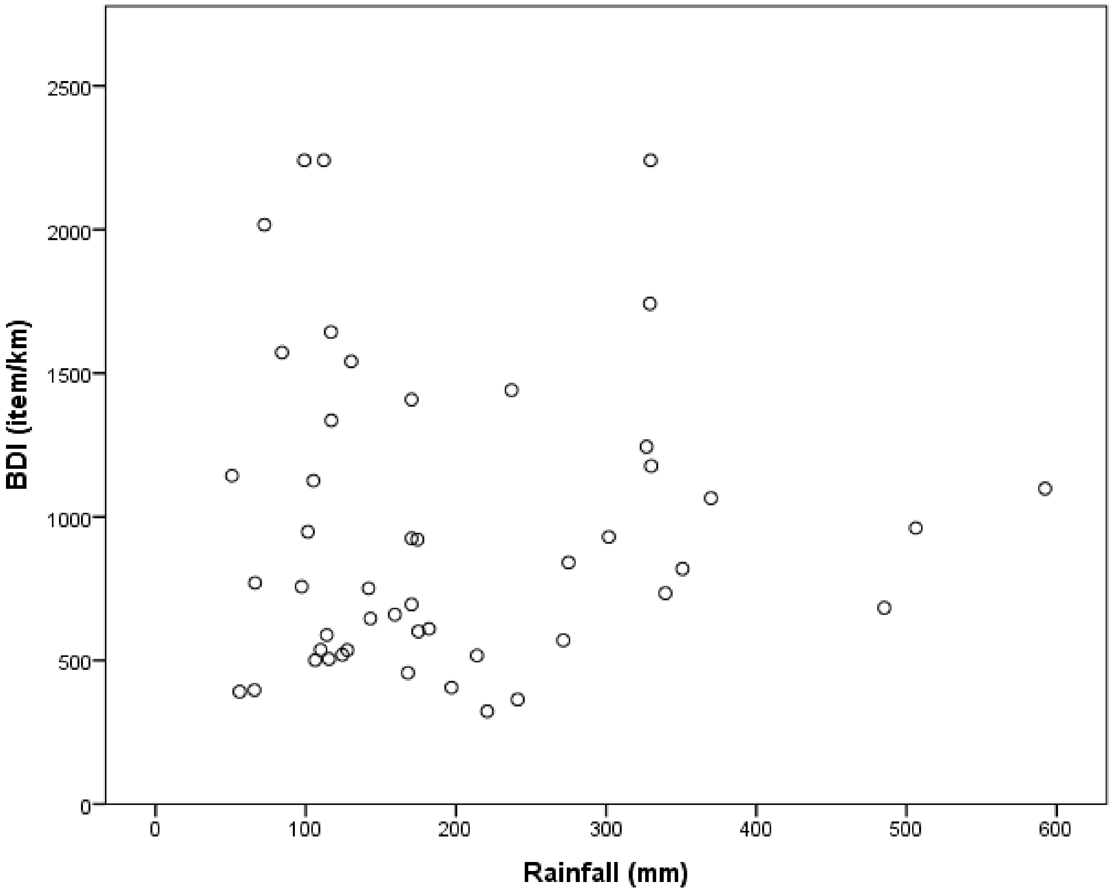


Figure 19: Scatter plot diagram between debris accumulation and rainfall distribution

3.3.5 Correlation between debris abundance and wind exposure

Wind speed and direction data obtained from the MMD at each study site showed prevailing winds were inconclusive during each monsoon seasons (Figure B 1 of Appendix B). Analyzing wind direction according to study sites (Figure 20a.1), beach locations (Figure 20b.1) and monsoon seasons (Figure 20c.1) shows the mean wind direction is from the south (Table B 11 of Appendix B). As for wind speed analysis shows mean wind speed is the highest at Kosuhoi (2.4±1.4 m/s), while Temasyah had the lowest mean wind speed at 1.8± 1.0 m/s (Figure 20a.1). When compared between beach locations, Sabah receives the highest mean wind speed at 2.3±1.2 m/s (direction 160^o), followed by Peninsular at 2.1±1.2 m/s (direction 151^o) (Figure 20b.2), while, Sarawak receives the lowest mean wind speed of 2.0±1.2 m/s (direction 172^o). Peninsular received the highest wind frequency at 35% during NEM as compared to Sabah and Sarawak wind frequency during the same season at 22% and 13% respectively (Table B 11 of Appendix B). While, the highest wind frequency during SWM is in Sabah at 33% as compared to Sarawak and Peninsular at 17% respectively. For monsoon seasons perspective, the mean wind speeds during NEM and SMW were at 2.1±1.2 m/s (direction 153^o) and 2.2±1.3 m/s (direction 171^o), whereas, IM mean wind speed was at 2.0±1.1 m/s (direction 163^o) (Figure 20c.2).

Total debris item accumulation at the study sites (Figure 21), REI did not show a significant relationship. Temasyah shows a positive trend in debris accumulation relationship with REI, while, other study sites show a positive trend during monsoon season. For example, during NEM at Pandan and Batu Rakit; IM at Tg. Lobang and Kosuhoi; and SWM at Tg. Lobang and Kosuhoi. Nevertheless, statistical analysis result shows REI value has a significant correlation ($p<0.05$, $n=48$) with means of BDI ($r=0.30$, $p=0.04$), BDW ($r=0.33$, $p=0.02$) and CPB ($r=0.56$, $p=0.00$) (Table B 10 of Appendix B). This result indicated mean

BDI accumulation was higher during NEM compared to SWM season. In addition, CPB was higher when REI value was higher during NEM.

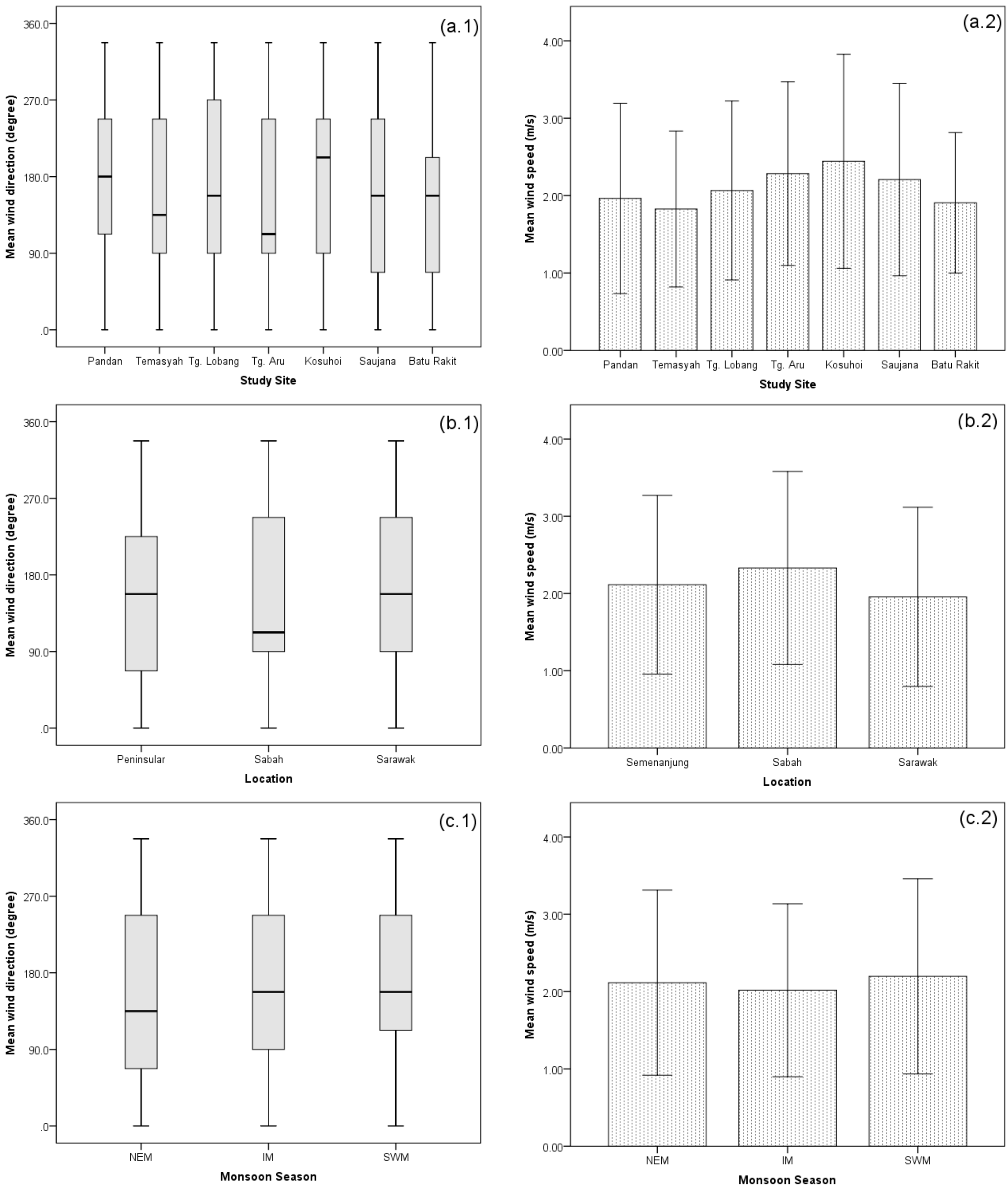


Figure 20: Means wind direction and speed (with standard deviation) at each (a) study sites, (b) location and (c) season

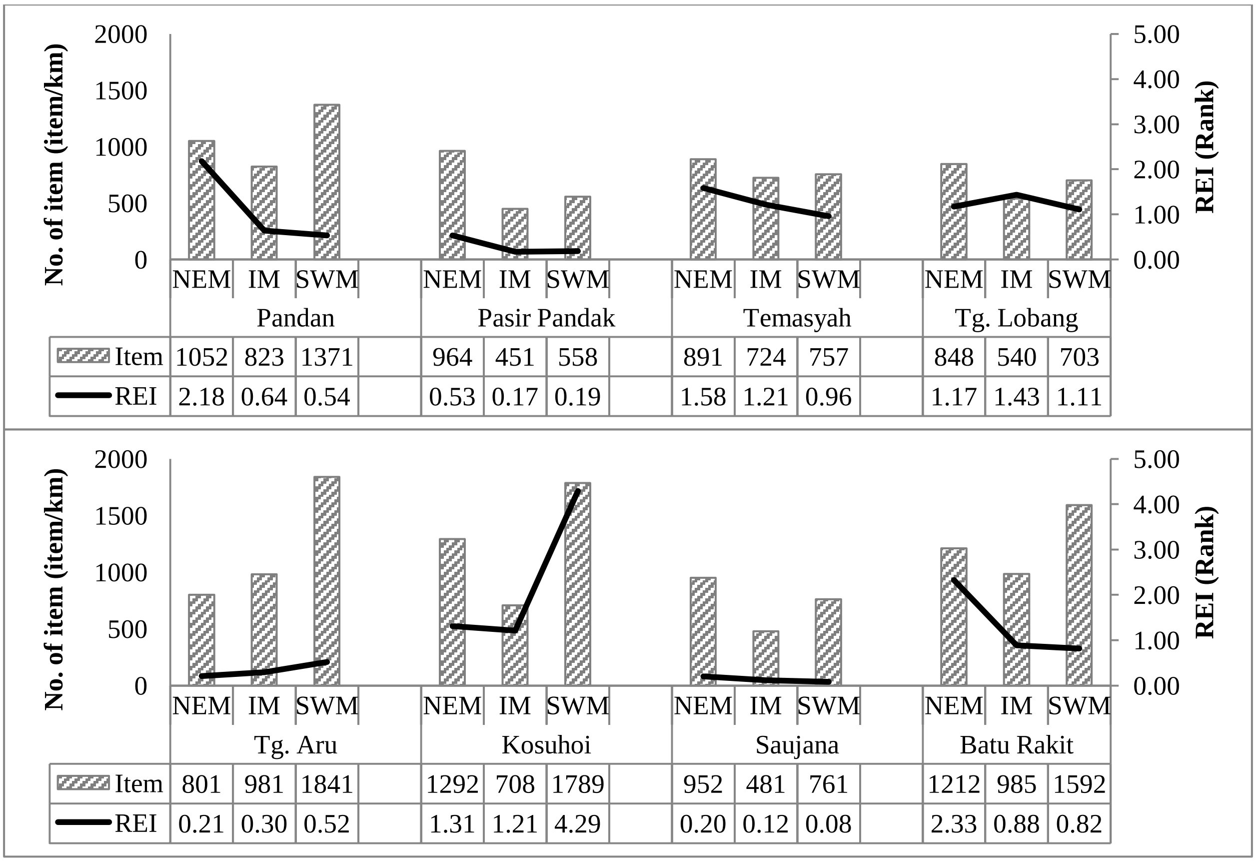


Figure 21: Relationship between relative exposure index (REI) and number of debris items on the study sites according to monsoon seasons

Linear regression analysis result shows REI is a significant factor determining BDI (BDI=797.07+164.20(REI)) (Table B 12 of Appendix B), BDW (BDW=36.77+7.40(REI)) (Table B 13: of Appendix B) and CPB (CPB=77.27+59.44(REI)) (Table B 14 of Appendix B) on the beaches. However, the degree of contribution towards debris accumulation shows REI (β=0.56, t=4.57, p=0.00) is a significant factor in CPB (R^2=0.31, $p<0.05$) abundance as compared to REI (β=0.30, t=2.12, p=0.04) with BDI (R^2=0.09, $p<0.05$) and REI (β=0.33, t=2.39, p=0.02) with BDW (R^2=0.11, $p<0.05$). Therefore, the results suggest wind exposure may influence debris abundance on the beaches.

Analyzing wind exposure further shows REI value was the highest at Kosuhoi (2.3±1.6 rank), while, the lowest REI value was at Saujana (0.1±0.1 rank) (Figure 22a). Nevertheless, the REI rank showed Kosuhoi was experiencing between low and moderate wind exposure, while, other study sites were below very low exposure. When comparing between monsoon season, NEM (1.2±0.9 rank) had the highest REI value compared to IM (0.7±0.5 rank) and SWM (1.1±1.3 rank) (Figure 22b). The distribution of mean REI between monsoon seasons (n=6) according to study sites (n=8) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA analysis results to compare mean REI between study sites shows Kosuhoi was significantly different ($p<0.05$) from Pasir Pandak, Tg. Aru and Saujana beaches (Figure 22a). However, univariate ANOVA analyses results show mean REI was not significantly different ($p<0.05$) between monsoon seasons (Figure 22b).

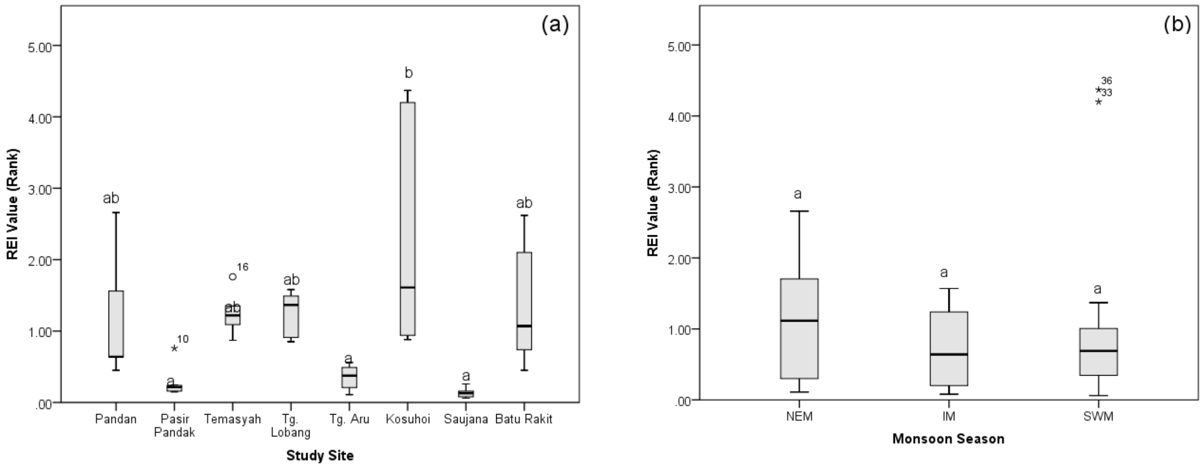


Figure 22: Relative exposure index (REI) (with standard deviation) in each (a) study sites (n=8), and (b) monsoon seasons (n=6)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

3.4 Discussion

3.4.1 Debris abundance

From this study, the means total debris item accumulated during SWM (1,171±656 item/km) seasons was higher when compared to NEM and IM seasons at 1,001±439 item/km and 711±343 item/km respectively (Table B2 of Appendix B). As for mean BDW, accumulation was also the highest during SWM season at 47.9±28.6 kg/km when compared to NEM and

IM seasons. Other studies (Leite *et al.*, 2014; Khairunnisa *et al.*, 2012; Hassan *et al.*, 2007; Sheavly, 2005b) indicated that proximity to urban, developed, industrial and recreational areas are factors influencing the type and amount of debris present in the marine environment. However, this study found that beaches within urban area except for Tg. Aru beach accumulate lower means BDI and BDW compared to beaches at non-urban areas. Pandan, Kosuhoi and Batu Rakit beaches accumulated the most BDI and BDW compared to Pasir Pandak, Temasyah, Tg. Lobang and Saujana beaches; these beaches location was not within urban area and has no schedule waste collection on the beaches (Table B2 of Appendix B). Although Pasir Pandak, Temasyah, Tg. Lobang and Saujana beaches are adjacent to urban area, ports and residential areas, the amount of debris items accumulated was between 292 item/km and 606 item/km lesser then Pandan, Kosuhoi and Batu Rakit beaches. This result may indicate regular beach cleaning by local authorities appointed contractors.

Unlike Tg. Aru which is located within urban area and has weekly waste collection on the beach, the amount of debris items found was comparable with Pandan, Kosuhoi and Batu Rakit. This study found that Tg. Aru beach is near to Pulau Gaya and coastal villages along Putatan River which is located within 2 km from the beach as well as accumulate substantially higher debris items originated from terrestrial sources. This indicates debris stranded at this beach may derive from combination of sources namely beach visitors, the surrounding activity within the beach vicinity, urban residential area, villages along the coastal area or nearby inhabitant islands (Daily Express Newspaper online, 2014; Alias *et al.*, 2013; Khairunnisa *et al.*, 2012; Waters *et al.*, 2011). Throwing garbage particularly plastic-based materials into the water is easy alternative method and will aggravate since plastics are cheap and easily available (Jayasiri *et al.*, 2013; Chan *et al.*, 1996). For this reason, an immediate and stringent solution is required in the quest for keeping local beaches clean and safe.

3.4.2 Debris category

From debris category analysis, plastic category contributed the highest objects accumulated representing 88% from the total debris item collected in this study. This finding is similar to other studies (Thiel *et al.*, 2013; Keller *et al.*, 2010; Barnes *et al.*, 2009; Derraik, 2002; Bugoni *et al.*, 2001) which found plastic items were between 60% and 90% in the marine environment. This study acknowledged objects from the plastic category including plastic shopping bags, styrofoam -based product and fishing lines, may pose hazard to marine animals and also to humans. These are the most dangerous objects because they can be ingested or entangled by marine animals (Laist, 1997). The number of sharp items, such as torn aluminum cans, broken plastic container, broken light bulbs and broken glass found at the study sites were not significant but these items could cause serious injuries to beach visitor (Mouat *et al.*, 2010). In addition, objects including ropes, plastic shopping bags and fragment of plastics found at the study sites may poses hazard to vessels such as fouling propellers, rudders and blocking water intakes (JGESAMP, 2009; Sheavly, 2005b).

Malaysian government initiatives introducing *No Plastic Bag Campaign Day* in 2011 which received positive response from the consumers (Zen *et al.*, 2013) may have resulted in lower percentage of plastic bags (3.2%) accumulation in this study compared to international average (13.4%) (International Ocean Conservancy (IOC), 2013a). However, these objects can collect moist or rain water which is a suitable condition for microhabitat breeding ground such as mosquito. Nevertheless, plastic fragment contributed 9.2% which is the third highest objects found from the plastic category should be of particular concern (Cole *et al.*, 2011).

Plastic fragments may transform to micro-plastics after going through physical and chemical processes (Zarfl *et al.*, 2011; O'Brine & Thompson, 2010; Gorycka, 2009). This eventually results in the increased amount of micro-plastic debris in the marine environment which ultimately cause harm to marine animals through ingestion when consumed.

There were 1,021 items collected relating to personal hygiene includes disposable nappies, cloths and toothbrushes, whereas, medical related debris has 131 items including partly used medicine strips, partly filled medicine bottles and syringe. These items may be deposited through the waste stream or littered by irresponsible beach visitors. The presence of these objects may indicate the existence of invisible pathogenic organisms such as streptococci, faecal coliforms, and other bacterial contamination; which could result in infectious hepatitis, diarrhea, bacillary dysentery, skin rashes, and potentially typhoid and cholera; when accidentally consumed or when a body is in contact with water polluted with these pathogens (UNEP, 2009; Minooee & Rickman, 1999; Velander & Mocogni, 1998). However, this study did not examine detail pathogenic organisms exist in the study area, thus microbial pollution on Malaysian beaches needs to be addressed in future.

3.4.3 Debris source

In this study, the common and terrestrial sources contributed 82% of the total debris items found on the beaches which includes household domestic product and recreational activities related items. This result was higher when compared to global average in 2012 (68.2%) (IOC, 2013a). Other studies (Kuo & Huang, 2014; Jayasiri *et al.*, 2013; Zhou *et al.*, 2011; Walker *et al.*, 2006) also established that marine debris items found on the beaches originated from land-based sources. Most of the debris could be attributed to the effect of human activities along the coastal areas. The high number of CPB (137 item/km), plastic food wrappers (90 item/km), plastic shopping bags (31 item/km) and disposal diapers (13 item/km) found at the study sites explain the improper disposal of garbage by the beach visitors, leading to the higher debris items accumulation at popular beaches among beach visitors such as Pasir Pandak, Tg. Aru and Saujana beaches. Despite the high volume of vessel traffic en route to Malacca Straits (Figure 8 of section 2.6), the amount of debris items for marine source accumulation was low (18%) at the study sites. Other studies (Barnes *et al.*, 2009; Walker *et al.*, 2006; Otley & Ingham, 2003) suggested such results are encouraging indicating less illegal discharge occurring at the ocean.

3.4.4 Rainfall and monsoon seasons relationship

According to Frost & Cullen (1997) the effect of climatic factors accompanied by flooding has been associated with greater amount of beach debris accumulation and distribution. In this study, the result shows mean BDI was higher during SWM season. In addition, SWM period received ocean current speed of 0.4 m/s (Akhir, 2012) and wind speed of 7.7 m/s (MMD, 2010) which is lower compared to NEM season. This finding was the opposite with result from Silva-Cavalcanti *et al.* (2009), Golik & Gertner (1992) and Vauk & Schrey (1987). Although studies has shown debris amount will increase after rain events as a result of runoff from the urban area (Gasim *et al.*, 2013; Waters *et al.*, 2011; Silva-Cavalcanti *et al.*, 2009), to consider rainfall distribution as debris accumulation indicator is not sufficient. There are other factors influencing the distribution of rainfall such as wind, location and topography (Camerlengo & Somchit, 2000; Camerlengo *et al.*, 2000). Nevertheless, the rational explanation for the abundance of debris items in this study may possibly be due to close proximity of urban areas (Khairunnisa *et al.*, 2012; Sheavly, 2005b) and higher beach visitor (Walker *et al.*, 2006) during non-rainy season.

3.4.5 REI and monsoon seasons relationship

Studies has suggested REI as a possible indicator to determine marine debris accumulation, besides providing a summary of the wind exposure on the beach (Garcon *et al.*, 2010; Walker *et al.*, 2006; Rodil & Lastra, 2004; Keddy, 1984). Similar with other studies (Jayasiri *et al.*, 2013; Walker *et al.*, 2006), this study results showed total debris item between monsoon seasons and REI was significantly correlated (r=0.30, p=0.04). Although wind may have influenced the abundance of debris items at Pandan, Temasyah, Kosuhoi and Batu Rakit beaches, the REI analysis results were inconclusive for Pasir Pandak, Tg. Lobang, Tg. Aru and Saujana beaches (Figure 21). Since marine debris items is light-weighted and can travel long distances, debris deposition at the study site might be greater at higher REI exposure value during NEM season which receives current speed of 1 m/s (Akhir, 2012) and wind speed of 10 m/s (MMD, 2010). Since the coastal villages are adjacent to the study site beaches, there is a possibility debris is transported by long-shore drift current effect along the coastal area (Taffs & Cullen, 2005; Sonu *et al.*, 1966). However, comprehensive and long-term monitoring along Malaysian coastline is necessary to identify marine debris abundance relationship against season, topography, wind and wave exposures.

3.5 Conclusions

In this study, the BDI and BDW means were 961±523 item/km and 44.2±21.2 kg/km respectively. Marine debris items accumulation was the highest at Kosuhoi beach (1,263±631 item/km), whereas, Tg. Lobang beach (697±259 item/km) accumulated the lowest debris items. In terms of beach location, Sabah beach (1,235±584 item/km) accumulates the highest debris items as compared to Peninsular (997±578 item/km) and Sarawak (807±413 item/km) beaches. Marine debris accumulation shows specific trend with monsoon season, where mean

BDI and BDW was the highest during SWM season at 1,171±657 item/km and 47.9±28.6 kg/km, respectively. Plastic category was the most abundant objects (88.55%) found at the beaches, while, other debris categories also present at the study sites. Although, many factors contributed to marine debris abundance, common sources were found to be the major source to the marine debris pollution in this study. Thus, this study result can be related to proximity with urban and island areas in general produces higher debris accumulation as compared from shipping activities. This study found, rainfall and wind speed may have influenced the abundance of objects in Sabah beaches; however, the REI analysis result was inconclusive for Pasir Pandak, Tg. Lobang, Tg. Aru and Saujana beaches; to conclude significance relationship. Therefore, long-term monitoring is important to understand marine debris abundance relationship against these dynamic climate conditions.

CHAPTER 4

SHIPBORNE GARBAGE ABUNDANCE AND CLASSIFICATION

4.1 Introduction

The tremendous growth of shipping activities in Malaysia has underline the value of maritime sector to the economic growth and importance of the sea to the lives of the population (Khalid, 2006). Ships carry more than 95% of the nation's international cargo through seaborne transport (Khalid, 2010). Anticipation of the growing intra-regional and global trade, Malaysia's container throughput is expected to grow in the years ahead (Ong Tee Keat, 2012; Khalid, 2006). Therefore, sea ports facilities which are at the forefront of the maritime sector is an important trade facilitator towards Malaysian economic growth. However, the economic growth contributed from maritime sector is parallel with environmental pollution risks.

While there are many sources of marine pollution including rivers runoff, drains, wind, improper sewage systems, rubbish left on beaches or discharge illegally at sea (Ryan *et al.*, 2009; Ribic, 1998; Coe & Rogers, 1997; Dixon & Dixon, 1981), shipborne generated waste is to be of particular concern (NRC, 1995). Shipborne garbage waste material that has been introduced into the ocean is also known as marine debris, is a problem of global significance that affects oceans, coastlines, beaches and seafloors at all depths (Al-Najjar & Al-Shiyab, 2011; Williams *et al.*, 2005; Mascarenhas *et al.*, 2004). Marine source debris from shipping industry has been estimated 35% contributed from the merchant shipping activities, while, fishing vessel accounts for 65% of the total waste in the marine environment (European Commission Directorate-General for Transport, 1998). Although the disposal of shipborne garbage is far away from coastal areas, debris will ensemble to the shores through the dynamics of the natural coastal and marine environment (Hassan & Mobilik, 2012;

Somerville *et al.*, 2003; Neumann, 1966). As a result, the presence of debris in the marine environment has shown no improvement in quantities stranded on the beach environment (Ribic *et al.*, 2010, 2012; Caldwell *et al.*, 2009; Ryan *et al.*, 2009; Hassan *et al.*, 2007; Santos *et al.*, 2005; Edyvane *et al.*, 2004) and shown an increasing trend (Barnes, 2002). In addition, pollution from the shipping activities in the world's oceans may cause a significant threat to marine life and is recognized as one of the highest environmental concerns (Valavanidis & Vlachogianni, 2012; Abdulla, 2010; Polglaze, 2003; Ball, 1999).

In Malaysia, maritime pollution is often associated with vessel oil spill incidents (Jaswar *et al.*, 2013; Law & Hii, 2006; Chua *et al.*, 2000). However, pollution from vessel could come from any annexes of the MARPOL 73/78 (IMO, 2012a), which has defined six classes of waste and indicated specific requirements for managing each waste classification. The oil (Annex I) and garbage (Annex V) are the most common waste accumulated and they make up the majority of waste tonnage on the vessels (Szepes, 2013; Palabıyık, 2003; European Commission Directorate-General for Transport, 1998). In lieu of the IMO's commitment towards global marine environment, Annex V of the MARPOL 73/78 (IMO, 2012b) has been revised, incorporating new requirements including prohibiting disposal of all types of plastic material, procedures to minimize shipborne garbage and establish specific requirements to allow shipborne garbage to discharge at sea including nature of the waste and distance from the coastlines (Table 4). Thus, this annex is an importance guideline for the maritime community (shippers, oil platforms, fishers, boaters, and cruise lines) to self regulating shipborne garbage. Although there are enabling regulation to monitor shipborne garbage discharge illegally from the vessels in Malaysia (Mustafa, 2011; Law & Hii, 2006), the probability of detecting such illegal discharge in the vastness of the Malaysian Territorial Water (MTW) is difficult. In the face of these challenges, the IMO has introduced regional

Port State Control (PSC) systems to mitigate if not eliminate sub-standard vessel (Tokyo MOU, 2013). Nine regional PSC systems have been established to enforce international Conventions adopted by the IMO including MARPOL 73/78 Annex V. Thus, black-grey-white (BGW) classification has been introduced to determine a vessels' registered country performances compliance to the International Conventions Standards. Historically, BGW classification was introduced after the *Amoco Cadiz* (1978) accident (aground) in Brittany, France.

The number of vessels transiting Malacca Straits has increased steadily since 2007, indicating MTW as an important water gateway from east to west for transporting of goods (JLM, 2015; Khalid, 2006). An average of 213 vessels operating daily; where tanker, container, bulk carrier and general cargo vessels accounts for 79.80% vessel types operating within MTW (JLM, 2015). According to Rusli (2012) estimation for number of vessels utilizing Malacca Straits in 2020, the average number of vessels operating daily will increased to 411 vessels. These ships generate waste under all of the MARPOL 73/78 annexes. Study have shown that accumulation of marine debris can be critical especially at heavy maritime traffic area (Walker *et al.*, 1997). Therefore, illegally discharge shipborne garbage could significantly impact Malaysian coastlines especially the increasing number of vessels navigating within MTW.

The study of shipborne garbage (Johnson, 2008; Butt, 2007; Polglaze, 2003; Minooee & Rickman, 1999; Horsman, 1982) are limited to passenger ship and general cargo vessels, thus the actual quantity of shipborne garbage on the vessel has only been estimated. A passenger vessel of 2,500 passengers and 800 crews can generate approximately 1 ton/day of garbage from normal operations (NRC, 1995). However, another study found a passenger ship can produce 7.8 tons of waste per day, of which 75% incinerated and 25% were taken to the port for disposal (Butt, 2007). Johnson (2008) estimated passenger vessel produces 70 times more solid waste per day than a typical general cargo vessel. A study on food waste category found that a vessel which has a 17 crew members produced 9.18 kg of food waste per day (Polglaze, 2003). Additionally, unmanaged food waste will invite infection deceases which may easily be spread and difficult to control on the vessel (Minooee & Rickman, 1999). Nevertheless, the amount of shipborne garbage waste generated by vessels varies between ship type, size of the vessel, number of passengers and crew, and consumption of material. Systematic efforts have been made to monitor shipborne garbage through debris stranded on beaches (Ribic *et al.*, 2010; Barnes *et al.*, 2009; Walker *et al.*, 2006), however, the results have been manipulated or extrapolated to estimate ship source trends.

Since study on shipborne garbage in Malaysia is limited, this study can be used as a baseline for future reference in order to compile a more complete data set. Therefore, this study aims to: (1) assess the amount of shipborne garbage waste on container, bulk carrier and general cargo vessels, (2) categorize the shipborne garbage waste by type of material, (3) determine the possible sources and (4) estimate the generation rate of garbage according to ship types.

4.2 Materials and methods

4.2.1 Assessment of study site

The spatial extent of the study was focused at federal and state ports between October 2012 to October 2014; to identify the abundance and category of shipborne garbage waste. A total of five ports has been selected for this study; two (2) in Sarawak, two (2) in Sabah and one (1) in Peninsular Malaysia as shown in Figure 9 (refer section 3.2.1) and Table 6. Bintulu and Klang ports are federal port, while Kuching, Kota Kinabalu and Sandakan ports are major state port. Port Klang is located at the west of peninsular Malaysia, whereas, Kuching, Bintulu, Kota Kinabalu and Sandakan ports are located at the east Malaysia. In compliance to MARPOL 73/78 Annex V requirement, only Kuching port provides garbage collection services. For Bintulu, Kota Kinabalu, Sandakan and Klang ports, the local ship agent makes necessary arrangement for garbage collection with private garbage contractors. Ports in Malaysia receives ship visits from many countries, various classes, types and sizes (JLM, 2015; Khalid, 2006). Thus, Malaysian ports have been growing in recent years, as evidenced by the remarkable container throughput (Khalid, 2006). The state of the art equipment and facilities in the study ports (Table 6) indicated ports in Malaysia are capable to provide all types of cargo handling, managing greater container volumes and accommodating larger vessel sizes (Khalid, 2006).

4.2.2 Shipborne garbage survey methods

A total of 115 vessels with 2,295 crew members were involved in this study between October 2012 and October 2014. Shipborne garbage survey has been inspected only on container, bulk carrier and general cargo vessel types (Plate J-5 of Appendix J) plying international route; according to PSC guideline Resolution A.1052 (27) specifically for MARPOL 73/78 Annex V inspection (IMO, 2011). During inspection, all debris other than fragments smaller than 0.25 cm^2 at the vessels' garbage station were identified, weighed, classified and sorted according to debris types on the Shipborne Garbage Survey at Ship Garbage Station data sheet (page 4 of Appendix C). The objects were separated and classified into nine categories: plastic (24 objects), food waste (1 objects), domestic waste (10 objects), cooking oil (1 objects), incinerator waste (1 objects), operational waste (4 objects), cargo residues

Table 6: Port study sites and characteristics

Map Ref	Study port	Port Operator	Garbage Reception*	Port Characteristic
A	Kuching	Kuching Port Authority	Available (Treatment and semi operational)	• State Port (Kuching Port Authority) • Berth- 7 (max 6.4 meter draft) • Maximum capacity – 12,500 DWT Facility- 34,305 m^2 covered storage; 59,021 m^2 open storage
B	Bintulu	Bintulu Port Sdn. Bhd.	Not Available (Private)	• Federal Port (Bintulu Port Authority) • Berth- 13 (max 19.5 meter draft) • Maximum capacity – 80,000 DWT • Facility- 83,650 m^2 covered storage; 71,900 m^2 open storage
C	Kota Kinabalu	Sabah Port Sdn. Bhd.	Not Available (Private)	• State Port (Sabah Port Authority) • Berth- 12 (max 10 meter draft) Maximum capacity – 16,000 DWT • Facility- 14,850 m^2 covered storage; 26,800 m^2 open storage
D	Sandakan	Sabah Port Sdn. Bhd.	Not Available (Private)	• State Port (Sabah Port Authority) • Berth- 4 main berth & 3 Oil Jetties (max 9 meter draft) • Maximum capacity – 30,000 DWT. Facility- 13,200 m^2 covered storage; 5,900 m^2 open storage
E	Klang	Westport (M) Sdn Bhd	Not Available (Private)	• Federal Port (Port Klang Authority) • Berth- 26 (max 17.5 meter draft) • Maximum capacity – 80,000 DWT. • Facility-33,723 m^2 covered storage; 139,355 m^2 open storage

**Source:* Osnin (2004)

residues (1 objects), animal carcasses (1 objects) and fishing gear (1objects) (IMO, 2012b). Each category was further sorted into objects adopted and modified from Ribic *et al.* (1992). Shipborne garbage sources were also determined and classified as: (1) maintenance source (waste associated with maintenance and operation of the vessel), (2) crew source (waste generated by crew), (3) cargo source (waste associated with cargo) and (4) common source where associated waste refers to other garbage sources. Food waste, cooking oil and incinerator waste categories were validated according to garbage weight. Results were presented as shipborne garbage item (item/vessel), shipborne garbage weight (kg/vessel) and garbage generation rate (kg/person/day). Using a method adopted from Ribic *et al.* (1992), shipborne garbage item per vessel was calculated using Equation (4);

$$SGI = \frac{n_i}{n_v} \tag{4}$$

where SGI is total number of objects (item/vessel), n_i is the total shipborne objects (number, *item*) and n_v is total number of vessels sampled. Using a method adopted from Ribic *et al.* (1992), shipborne garbage weight per vessel was calculated using Equation (5);

$$SGW = \frac{k}{n_v} \tag{5}$$

where SGW is total weight of garbage (kg/vessel) and k is the total shipborne garbage weight (kg). All garbage based on garbage category according to vessels' complete voyage duration was included in the estimation of garbage generation rate (GGR) using a method adopted from Nawadra *et al.* (2002), according to Equation (6);

$$GGR = \frac{k}{n_c d} \tag{6}$$

where GGR is garbage generation rate (kg/person/day), n_c is the total number of crew (person) and d is the duration of the vessel's travel (days) from the last port of call.

4.2.3 Data analysis

For ship survey, data was assessed according to study ports, vessel types, ports location and BGW classification. Data generated from the surveys were presented statistically as SGI (±standard deviation), SGW (±standard deviation) and GGR. For statistical analysis, z-test was used to analyze the distribution of normality using critical values smaller than ±1.96 ($n<50$) and ±3.29 ($n<300$) with an alpha level 0.05 for absolute z-scores for either skewness or kurtosis (Kim, 2013). A $\log_{10}$ transformation ($\log_{10}+1$) of the data was applied for statistical analyses that did not assume a normal distribution (Ribic *et al.*, 2010). Pearson's correlation test between SGI, SGW and GGR with number of vessels, number of crews, vessels' gross tonnage, vessels' cruise (days), vessels' voyage duration (days) and the presence of garbage processing equipment was analyzed. Multiple linear regression (stepwise) model was used to identify predictor variable contributed to the abundance of SGI and SGW when correlation test indicated significant differences. Two-way analysis of variance (ANOVA) was used to compare SGI and SGW means between shipborne garbage categories (n=7) and shipborne garbage sources (n=4) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3). All statistical comparisons were performed using SPSS version 22 package software.

4.3 Results

4.3.1 Shipborne garbage abundance

From this study, the mean SGI and SGW were 182±141 item/vessel (20,895 items) and 54.9±30.1 kg/vessel (6,316.1 kg) respectively. Sandakan port accumulated the highest mean SGI at 197±124 items/vessel, while, Kuching port accumulated the lowest mean SGI at 166±99 items/vessel (Table 7). As for garbage weight, Kota Kinabalu port accumulated the highest mean SGW at 64.0±36.6 kg/vessel, followed by Sandakan, Bintulu and Kuching at 60.3±32.3 kg/vessel, 57.2±28.7 kg/vessel and 50.6±25.6 kg/vessel, respectively (Table 7). Klang port accumulates the lowest mean SGW at 49.6±29.0 kg/vessel. Analyzing mean GGR, Kuching, Kota Kinabalu and Sandakan ports has the same mean GGR which is also the highest at 0.8 kg/person/day. Although, Klang port has the highest for number of crews and vessels' gross tonnage among the study ports, the mean GGR was the lowest at 0.5 kg/person/day. The average voyage and cruise from last visited port was 33.3 days and 4.2 days respectively.

Table 7: Summary of shipborne garbage and vessels information according to ports

Variable	Kuching	Bintulu	Kota Kinabalu	Sandakan	Klang
Number of vessel	25	20	20	14	36
Number of crew	490	387	394	288	736
Vessel gross tonnage	407,087	238,451	227,024	319,533	1,150,014
Cruise from last port (days)	3.3	4.2	4.1	3.9	5.1
Voyage duration (days)	29.4	32.5	31.2	38.9	35.6
Vessel with processing equipment	14	11	11	11	30
SGI (item/vessel)	166±99	183±118	190±118	197±124	182±193
SGW (kg/vessel)	50.6±25.6	57.2±28.7	64.0±36.6	60.3±32.3	49.6±29.0
GGR (kg/person/day)	0.8	0.7	0.8	0.8	0.5

From correlation analysis results (Table D 1 of Appendix D), mean $\log_{10}$ SGI is significantly correlated ($p<0.05$, $z<\pm3.29$, $n=115$) with number of crews ($r=-0.21$, $p=0.02$) and vessels' voyage duration ($r=0.24$, $p=0.03$), whereas, mean SGW is significantly correlated ($p<0.05$, $z<\pm3.29$, $n=115$) with vessels' voyage duration ($r=0.28$, $p=0.03$). Mean $\log_{10}$ GGR was significantly correlated ($p<0.01$, $z<\pm3.29$, $n=115$) with number of crews ($r=-0.23$, $p=0.03$) and $\log_{10}$ vessels' cruise ($r=-0.65$, $p=0.00$). Multiple linear regression results ($R^2=0.81$, $p<0.00$) shows that number of crews ($\beta=0.90$, $t=22.14$, $p=0.00$) is a significant factor in determining the abundance of $\log_{10}$ SGI ($\log_{10}$ SGI=0.02*(Crew)) (Table D 2 of Appendix D), whereas, multiple linear regression results ($R^2=0.04$, $p<0.05$) shows vessels' voyage duration ($\beta=0.21$, $t=2.27$, $p=0.03$) is a determining factor for SGW (SGW=42.24+0.38*(Voyage)) (Table D 3 of Appendix D). For $\log_{10}$ GGR, multiple linear regression results ($R^2=0.45$, $p<0.00$) show number of crews (($\beta=-0.17$, $t=-2.48$, $p=0.02$) and $\log_{10}$ vessels' cruise (($\beta=-0.64$, $t=-9.13$, $p=0.00$) were independent factor to GGR abundance ($\log_{10}$ GGR=0.84-0.02*(Crew)-0.50*($\log_{10}$ Cruise)) (Table D 4 of Appendix D).

A total of 46 container, 34 bulk carrier and 35 general cargo vessels participated voluntarily in this study (Table 8). Each ship type showed different distribution in means SGI and SGW. Bulk carrier vessels transport raw dry cargoes in large quantities, such as coal, iron ore or grain and they accumulated the highest objects and weight at 38.78% and 37.82%, respectively. Although bulk carrier vessels has the highest means for SGI and SGW, general cargo vessels' GGR was the highest at 0.9 kg/person/day compared to bulk carrier and container vessels at 0.6 kg/person/day and 0.5 kg/person/day, respectively. Analyzing ship type according to study ports, Kuching and Sandakan ports were visited with higher percentage of bulk carrier vessels at 36% and 57% respectively, while, general cargo vessels were the highest at Bintulu and Kota Kinabalu ports at 45% and 50% respectively. Klang port had the highest container vessels visited at 75%.

Table 8: Summary of vessels information according to ship type

Variable	Container	Bulk carrier	General cargo
Number of vessel	46	34	35
Total number of crew	957	686	652
Vessel gross tonnage	1,567,864	555,762	218,483
Cruise from last port (day)	3.9	5.1	3.9
Voyage duration (day)	31.6	38.8	30.3
Vessel with processing equipment	40	21	16
SGI (item/vessel)	149±114	216±182	192±122
SGW (kg/vessel)	43.1±28.8	63.8±31.6	61.8±25.8
GGR (kg/person/day)	0.5	0.6	0.9

Correlation analysis result (Table D 5 of Appendix D) showed mean SGI according to ship types was significantly correlated ($p<0.05$, $z<\pm1.96$, $n=15$) with number of vessels ($r=0.65$, $p=0.01$) and number of crews ($r=0.65$, $p=0.01$). Mean SGW also shows significant correlation ($p<0.05$, $z<\pm1.96$, $n=15$) with number of vessels ($r=0.58$, $p=0.02$) and number of crews ($r=0.56$, $p=0.03$). However, mean GGR was significantly correlation ($p<0.05$, $z<\pm1.96$, $n=15$) with vessels' cruise ($r=-0.57$, $p=0.03$) and voyage duration ($r=-0.74$, $p=0.00$). Multiple linear regression result ($R^2=0.42$, $p<0.05$) shows crew ($\beta=0.65$, $t=3.09$, $p=0.01$) is a significant factor in determining SGI (SGI=40.74+0.13*(Crew)) (Table D 6 of Appendix D), while, number of vessel ($\beta=0.58$, $t=2.58$, $p=0.02$) was a significant factor ($R^2=0.34$, $p<0.05$) in determining SGW (SGW=11.35+0.94*(Vessel)) (Table D 7 of Appendix D). Vessels' voyage duration (R^2=0.55, p<0.05; β=-0.74, t=-4.02, p=0.01) was also a determining factor for GGR (GGR=2.49-0.05(Voyage)) (Table D 8 of Appendix D).

Analyzing vessel means for SGI and SGW according to ports classification (n=2), the number of vessel visited the state port was slightly higher compared to federal port (Table 9). However, vessels' GRT at federal port was higher, indicating vessel visiting to federal port is larger compared to state port. This study found that, container vessel (53.57%) was the highest in number that visited the federal port, while bulk carrier vessels (38.98%) were the highest at state port. Thus, vessels with larger gross tonnage can travel longer days and greater distance. However, vessel at federal port has a lower mean SGW and GGR compared to state port whereby state ports' GGR (0.6 kg/person/day) is tripled compared federal ports' GGR.

Table 9: Summary of vessels information according to ports classification

Variable	Federal	State
Number of vessel	56	59
Total number of crew	1,123	1,172
Vessel gross tonnage	1,388,465	953,644
Cruise from last port (day)	10.6	5.0
Voyage duration (day)	34.5	32.2
Vessel with processing equipment	41	36
SGI (item/vessel)	182±169	181±111
SGW (kg/vessel)	52.3±28.9	57.4±31.3
GGR (kg/person/day)	0.2	0.6

From ports location perspective (n=3), means SGI and SGW were the highest at Sabah port compared to Peninsular and Sarawak ports (Table 10). Container vessels (75.00%) were the most vessels that visited Peninsular port, while, bulk carrier (44.12%) and general cargo (37.78%) was the highest vessels that visited Sabah and Sarawak ports respectively. Although, the number of crews was lesser on the vessels that visited Sabah port compared to vessel visiting Peninsular and Sarawak ports, the GGR was the highest at 0.8 kg/person/day. In addition, vessels visiting Sabah port also has the lowest garbage processing equipment installed on the vessels. Although, the means for SGI, SGW and GGR shows normal distribution ($p>0.05$, $z<\pm1.96$, $n=3$), only mean GGR according to ports location shows significant correlation ($p<0.05$) with vessels' gross tonnage ($r=-0.99$, $p=0.03$), while means SGI and SGW showed no evidence of significant correlation ($p>0.05$) (Table D 9 of Appendix D). Therefore, vessels' gross tonnage ($R^2=0.99$, $p<0.05$; $\beta=-0.99$, $t=-22.43$, $p=0.03$) is a determining factor for GGR (GGR=1.06-5.09(GRT)) (Table D 10 of Appendix D).

Table 10: Summary of vessels information according to ports location

Variable	Peninsular	Sabah	Sarawak
Number of vessel	36	34	45
Total number of crew	736	682	877
Vessel gross tonnage	1,150,014	546,557	645,538
Cruise from last port (day)	5.1	4.0	3.7
Voyage duration (day)	35.6	34.3	30.8
Vessel with processing equipment	30	22	25
SGI (item/vessel)	182±193	192±119	173±107
SGW (kg/vessel)	49.6±29.0	62.4±34.4	53.5±26.9
GGR (kg/person/day)	0.5	0.8	0.7

Analyzing vessels' BGW classification according to the port of registry (Tokyo MOU, 2013) identified 31 vessels fell in the black list, five vessels in grey list and 79 vessels in white list (Table 11). General cargo was the most vessels for black (19 vessels; 61.29%) and grey (3 vessels; 60.00%) list classification, while container vessels (41 vessels; 51.90%) was highest for the white list classification. Mean SGI was the highest for white list vessels at 195±160 item/vessel, while mean SGW was the highest for grey list vessels at 59.2±20.2 kg/vessel. Although, grey list vessels had the lowest number of crews and vessels' gross tonnage among BGW classification, GGR is tripled compared to black and white list vessels' GGR at 1.7 kg/person/day.

From correlation analysis results (Table D 11 of Appendix D) shows mean SGI is significantly correlated ($p<0.05$, $z<\pm1.96$, $n=15$) with number of vessel ($r=0.82$, $p=0.00$),

Table 11: Summary of vessels information according to BGW classification

Variable	Black	Grey	White
Number of vessel	31	5	79
Total number of crew	585	87	1,623
Vessel gross tonnage	227,381	53,664	2,061,064
Cruise from last port (day)	4.5	2	4.3
Voyage duration (day)	31.9	24.6	34.5
Vessel with processing equipment	12	4	61
SGI (item/vessel)	156±81	126±66	195±160
SGW (kg/vessel)	51.2±21.2	59.2±20.2	56.1±33.6
GGR (kg/person/day)	0.6	1.7	0.6

number of crews ($r=0.82$, $p=0.00$), vessels' gross tonnage ($r=0.65$, $p=0.01$), vessels' cruise ($r=0.59$, $p=0.02$) and vessels' voyage duration ($r=0.64$, $p=0.01$). Likewise, mean SGW is significantly correlated ($p<0.05$, $z<\pm1.96$, $n=15$) with number of vessel ($r=0.76$, $p=0.00$), number of crews ($r=0.75$, $p=0.00$), vessels' gross tonnage ($r=0.57$, $p=0.03$), vessels' cruise ($r=0.60$, $p=0.02$) and vessels' voyage duration ($r=0.65$, $p=0.01$). However, mean GGR was not significant correlated ($p>0.05$, $z<\pm1.96$, $n=15$) with the variables. Multiple linear regression result ($R^2=0.84$, $p<0.00$) shows only number of vessels ($\beta=0.92$, $t=8.51$, $p=0.00$) is a determining factor for mean SGI (SGI = 7.03(Vessel)) (Table D 12 of Appendix D). While, number of vessels ($\beta=0.21$, $t=2.27$, $p=0.03$) and vessels' gross tonnage ($\beta=0.21$, $t=2.27$, $p=0.03$) are determinant factors ($R^2=0.87$, $p<0.00$) for mean SGW (SGW = 3.54*(Vessel)-5.53*(GRT)) (Table D 13 of Appendix D).

4.3.2 Shipborne garbage category

Table 12 shows mean SGI and SGW accumulated according to shipborne garbage categories in this study. The highest objects accumulated on the vessel was plastic category contributing 63.75% from the total objects, while, cargo residues category which includes any damage cargo on the vessel, in cargo holds or tanks, accumulated the lowest objects at 4.39% in this study. In relation to the mean SGW, food waste category accumulated the highest garbage weight at 37.34% followed by cargo residue, plastic, operational waste and domestic waste at 33.15%, 9.47%, 8.74% and 6.74%, respectively. Cooking oil and incinerator ashes were the lowest garbage weight accumulated on the vessel in this study. Animal carcasses and fishing gear were not accumulated by vessels in this study.

Table 12: Percentage of SGI (item/vessel) and SGW (kg/vessel) accumulated according to garbage categories

Category	SGI	% of SGI	SGW	% of SGW
Plastic	116±100	63.75	5.2±4.3	9.47
Food waste	-	-	20.5±10.8	37.34
Domestic waste	28±38	15.38	3.7±4.5	6.74
Cooking oil	-	-	1.3±1.3	2.37
Incinerator Ashes	-	-	1.2±1.2	2.19
Operational waste	30±18	16.48	4.8±4.3	8.74
Cargo residue	8±8	4.39	18.2±18.1	33.15
Total	182±141		54.9±30.1	

Figure 23 shows garbage categories means for $\log_{10}$ SGI and $\log_{10}$ SGW accumulated according study ports, ship types, ports classification, ports location and BGW classification, while Table D 14 (refer Appendix D) shows detail garbage abundance results. Analyzing mean SGI from study ports perspective shows Sandakan port accumulates substantially higher quantity of plastic and domestic waste categories at 126±94 item/vessel and 33±29 item/vessel respectively (Figure 23a.1), while, Kota Kinabalu port accumulated the highest for operational waste and cargo residue categories at 35±20 item/vessel and 10±10 item/vessel respectively. Analyzing mean SGI between ship types, bulk carrier vessels accumulated the highest for plastic, domestic waste and operational waste categories at 135±123 item/vessel, 39±60 item/vessel and 34±16 item/vessel respectively (Figure 23b.1). General cargo vessels accumulated the highest for the cargo residue category at 10±9 item/vessel. For ports classification perspective, federal ports accumulated the highest mean SGI for plastic, domestic waste and cargo residue categories at 116±118 item/vessel, 29±49 item/vessel and 8±7 item/vessel respectively (Figure 23c.1), while, state ports accumulated the highest for operational waste at 31±19 item/vessel. Comparing mean SGI between ports

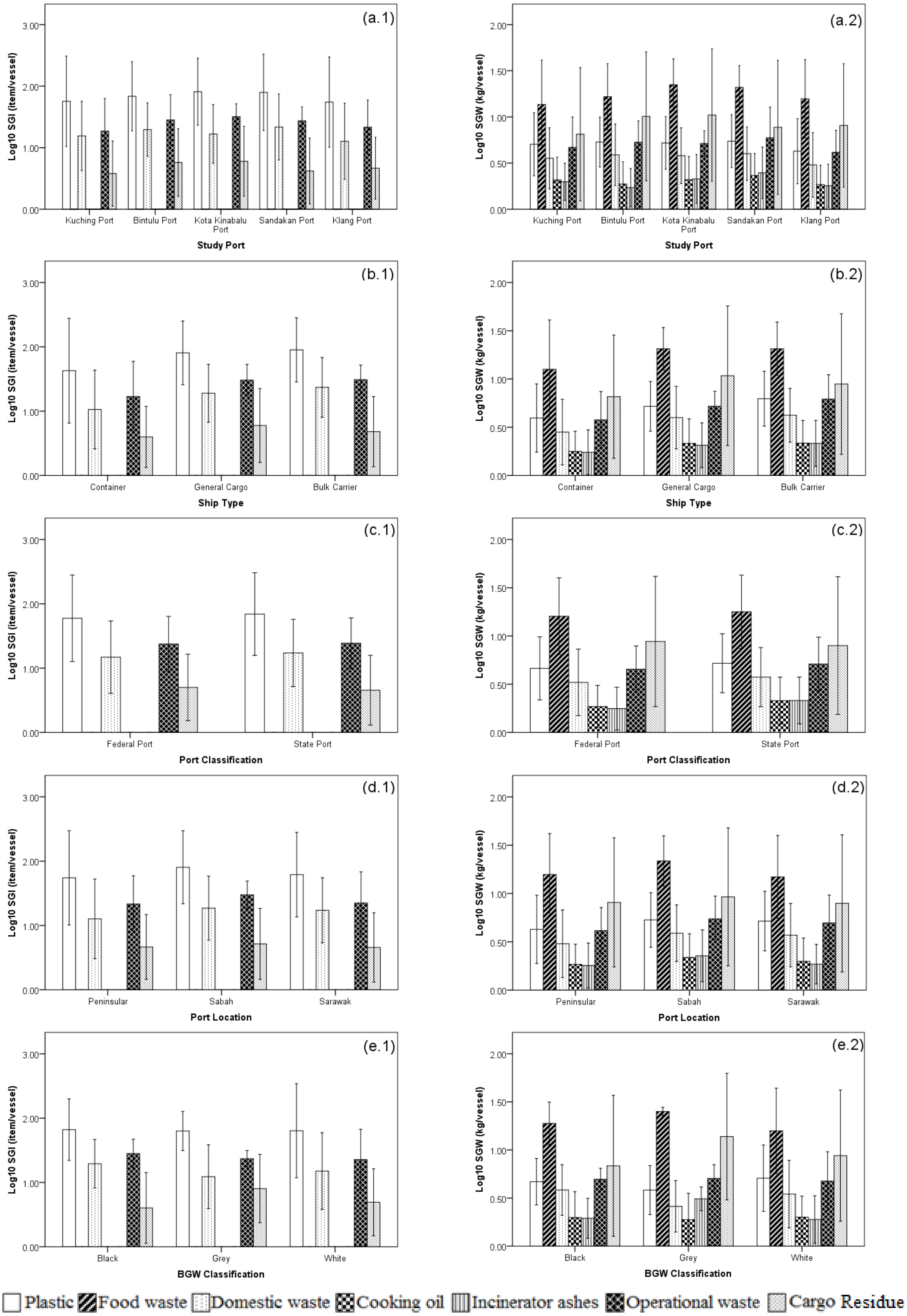


Figure 23: Means SGI and SGW (with standard deviation) according to shipborne garbage category in each (a) study ports, (b) ship types, (c) ports classification, (d) ports location and (e) BGW classification

location, Sabah port accumulated the highest for plastic (122±85 item/vessel), operational waste (33±18 item/vessel) and cargo residue (9±9 item/vessel) categories, while, Peninsular port accumulated the highest for domestic waste category (30±58 item/vessel) (Figure 23d.1). As for mean SGI according to BGW classification, white list vessels accumulated the highest for plastic, domestic waste and operational waste categories at 127±111 item/vessel, 30±44 item/vessel and 31±19 item/vessel respectively, while, grey list vessels were highest for cargo residue category at 30±58 item/vessel (Figure 23e.1).

Analyzing mean SGW from study ports perspective shows Sandakan port accumulated substantially higher quantity of plastic, cooking oil, incinerator ashes and operational waste categories at 5.5±3.6 kg/vessel, 1.6±1.3 kg/vessel, 1.9±1.5 kg/vessel and 7.2±8.4 kg/vessel respectively (Figure 23a.2). Kota Kinabalu port accumulated the highest food waste and cargo residue categories, while, Bintulu port was the highest for domestic waste category at 24.7±10.9 kg/vessel, 23.0±24.0 kg/vessel and 4.7±8.7 kg/vessel respectively. From ship type perspective, bulk carrier vessels were highest for plastic, food waste, incinerator ashes and operational waste categories at 6.7±5.7 kg/vessel, 23.0±11.2 kg/vessel, 1.5±1.3 kg/vessel and 6.6±6.8 kg/vessel respectively, whereas, general cargo vessels accumulated the highest for domestic waste, cooking oil and cargo residue categories at 4.5±6.5 kg/vessel, 1.5±1.6 kg/vessel and 22.9±18.9 kg/vessel respectively (Figure 23b.2). For ports classification perspective shows state ports accumulated the highest mean SGW for plastic (5.3±3.7 kg/vessel), food waste (21.5±11.0 kg/vessel), domestic waste (3.7±3.0 kg/vessel), cooking oil (1.5±1.5 kg/vessel), incinerator ashes (1.5±1.3 kg/vessel) and operational waste (5.4±5.6 kg/vessel) categories (Figure 23c.2). Comparing mean SGW between ports location, Sabah port accumulated the highest for food waste (23.8±10.6 kg/vessel), cooking oil (1.6±1.6 kg/vessel), incinerator ashes (1.7±1.4 kg/vessel), operational waste (5.5±5.7 kg/vessel) and cargo residue (20.9±21.9 kg/vessel) categories, while, Sarawak port had the highest for plastic (5.3±3.6 kg/vessel) and domestic waste (4.1±5.9 kg/vessel) categories (Figure 23d.2). Analyzing mean SGW according to BGW classification, white list vessels accumulated the highest for plastic, domestic waste and operational waste categories at 5.6±5.8 kg/vessel, 3.9±5.1 kg/vessel and 5.0±5.2 kg/vessel respectively (Figure 23e.2). Grey list vessels were the highest for food waste, incinerator ashes and cargo residue categories, while, black list vessels were the highest for cooking oil category at 24.2±2.4 kg/vessel, 2.2±0.8 kg/vessel, 22.0±16.0 kg/vessel and 1.4±1.7 kg/vessel respectively.

The means distribution of SGI (item/vessel) and SGW (kg/vessel) for shipborne garbage category (n=7) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA results to compare shipborne garbage category mean SGI between study ports (Figure 24a.1), ship types (Figure 24b.1), ports location (Figure 24c.1) and BGW classification (Figure 24d.1) showed plastic category was significantly different ($p<0.05$) from domestic waste, operational waste and cargo residue categories. The results show plastic category objects were accumulated higher compared to other shipborne garbage categories on the vessel (Table 12). Shipborne garbage category mean SGI univariate ANOVA analysis results among study ports, ship types, ports location and BGW classification were not significantly different ($p>0.05$).

As for mean SGW univariate ANOVA analysis results showed food waste and cargo residue categories were significantly different ($p<0.05$) from other shipborne garbage categories according to study ports (Figure 24a.2), ship types (Figure 24b.2), ports location

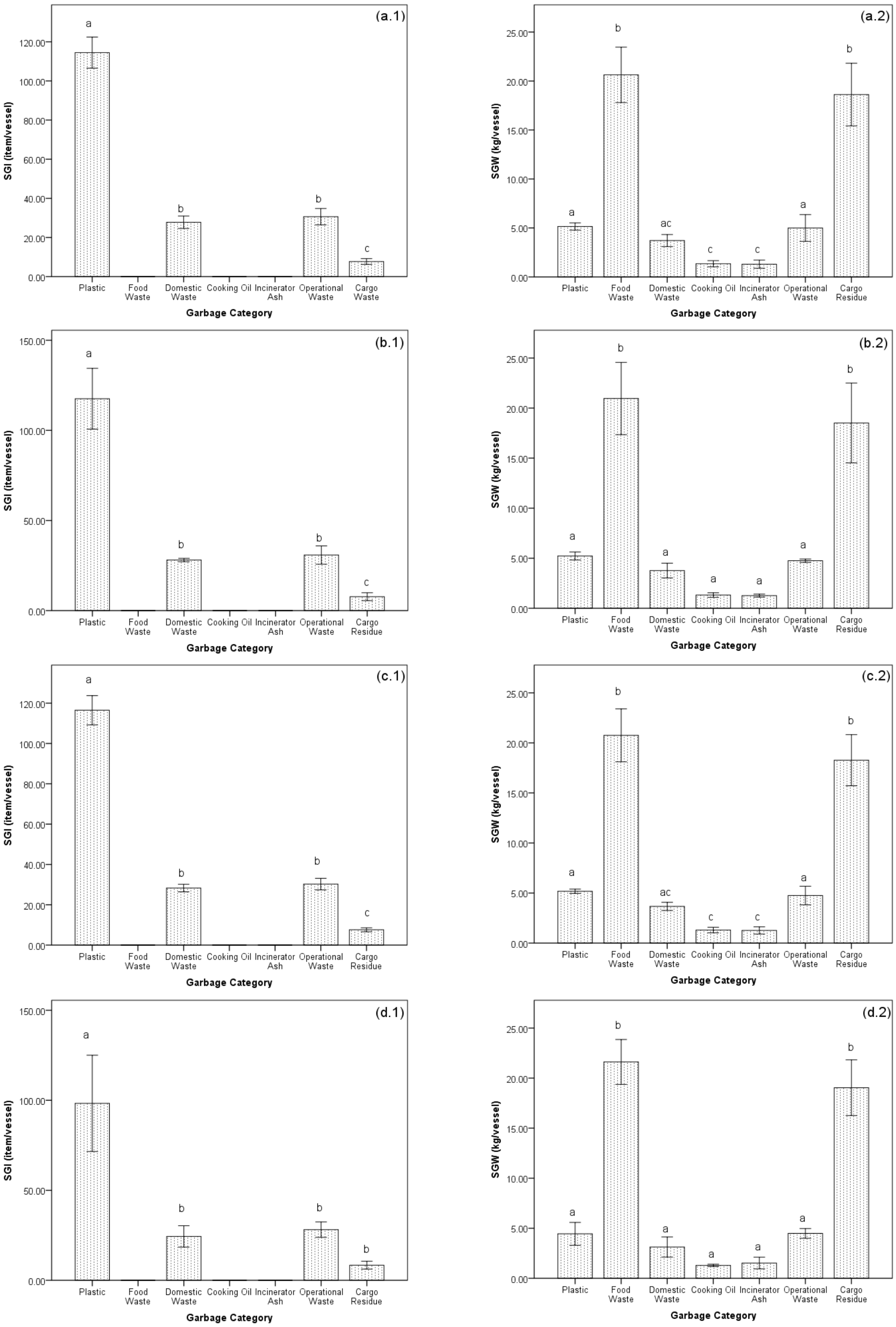


Figure 24: Mean SGI and SGW (with standard deviation) garbage category (n=7) according to (a) study ports (n=5), (b) ship types (n=3), (c) ports location (n=3) and (d) BGW classification (n=3)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different (p<0.05) from the other groups.

(Figure 24c.2) and BGW classification (Figure 24d.2). The abundance of mean SGW for food waste and cargo residue categories showed garbage weight accumulation trend were similar when compared between ship types and BGW classification. The shipborne garbage category mean SGW univariate ANOVA analysis results among study port showed Sandakan (9.1±9.0 kg/vessel) and Klang (6.5±7.0 kg/vessel) ports were significantly different ($p<0.05$). However shipborne garbage category mean SGW univariate ANOVA analysis results among ship types, ports location and BGW classification were not significantly different ($p>0.05$).

4.3.3 Shipborne garbage source

From this study, the highest mean SGI accumulated according to shipborne garbage source was common source at 116±100 item/vessel; followed by maintenance (30±18 item/vessel), crew (28±38 item/vessel) and cargo (8±8 item/vessel) sources. Figure 25 shows shipborne garbage source means SGI and SGW accumulated according to study ports, ship types, ports classification, ports location and BGW classification, while Table D 15 (refer Appendix D) shows detail shipborne garbage abundance results. From study ports perspective, mean SGI for maintenance (35±20 item/vessel) and cargo (10±10 item/vessel) sources was the highest at Kota Kinabalu port, while, Sandakan port was highest for crew and common sources at 34±28 item/vessel and 126±94 item/vessel respectively (Figure 25a.1). When comparing mean SGI according to ship type shows bulk carrier vessels accumulated the highest for maintenance, crew and common sources, while, general cargo vessels were the highest for cargo sources at 34±16 item/vessel, 39±60 item/vessel, 135±123 item/vessel and 10±19 item/vessel respectively (Figure 25b.1). As for ports classification, federal ports accumulated the highest for crew (29±49 item/vessel) and common (116±118 item/vessel) sources, while state ports accumulated the highest for maintenance (31±19 item/vessel) and cargo (8±9 item/vessel) sources (Figure 25c.1). Comparing mean SGI among ports location, vessels visiting Sabah port accumulated the highest for maintenance, cargo and common

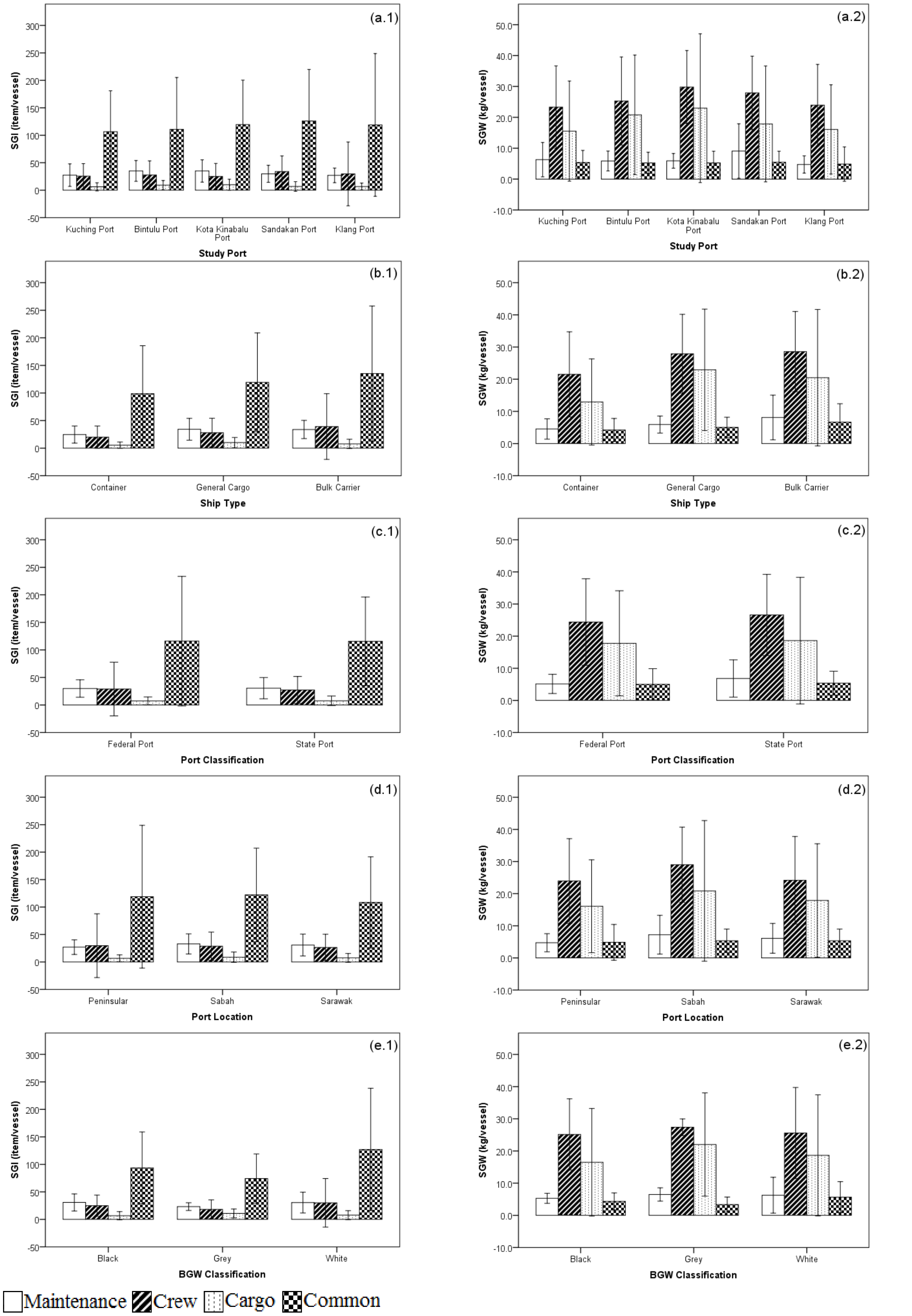


Figure 25: Means SGI and SGW (with standard deviation) garbage sources according to (a) study ports, (b) ship types, (c) ports classification, (d) ports location and (e) BGW classification

sources, while, vessels visiting Peninsular port accumulated the highest for crew source at 33±18 item/vessel, 9±9 item/vessel, 122±85 item/vessel and 30±58 item/vessel respectively (Figure 25d.1). Analyzing between BGW classifications, white list vessels accumulated thehighest for maintenance, crew and common sources, while, grey list vessels were highest for cargo source (Figure 25e.1). However, the presence of debris items associated with shipping activities shows not all vessels comply with the new revised Annex V of the MARPOL 73/78 (IMO, 2012b) which prohibits discharge of all types of plastics material and requires a port to provide facilities to receive shipborne garbage from any vessel that requires garbage disposal service. Although international conventions and regulations may be in place for the prohibition of ocean dumping of waste materials, the temptation to ignore the regulation is obvious, particularly when enforcement is relaxed (Rakestraw, 2012). Malaysia has ratified the Annex I/II, III, IV, V and VI of the convention and must follow up with necessary enforcement measures.

Analyzing garbage weight, the crew source accumulated the highest mean SGW at 25.5±13.0 kg/vessel; followed by cargo (18.2±18.1 kg/vessel), maintenance (6.0±4.7 kg/vessel) and common (5.2±4.3 kg/vessel) sources. Kota Kinabalu port accumulated the highest mean SGW for crew and cargo sources at 29.8±11.8 kg/vessel and 23.0±24.0 kg/vessel respectively, whereas, Sandakan port accumulated the highest mean SGW for maintenance and common sources at 9.1±8.8 kg/vessel and 5.4±3.6 kg/vessel respectively (Figure 25a.2). Comparing mean SGW sources according to ship types shows bulk carrier vessels accumulated the highest mean SGW for maintenance, crew and common sources at 8.1±6.9 kg/vessel, 28.6±12.5 kg/vessel and 6.7±5.7 kg/vessel respectively, while, general cargo vessels accumulated the highest for cargo at 22.9±18.9 kg/vessel (Figure 25b.2). From ports classification perspective shows vessels visiting state ports accumulated the highest for all shipborne garbage sources (Figure 25c.2). In addition, vessels visiting Sabah port also accumulate the highest for all shipborne garbage sources (Figure 25d.2). For BGW classification perspective, grey list vessels accumulated the highest for maintenance (6.5±2.1 kg/vessel), crew (27.4±2.6 kg/vessel) and cargo (22.0±16.0 kg/vessel) sources, while white list vessels was for common source (5.6±4.8 kg/vessel) (Figure 25e.2).

The mean distribution of SGI (item/vessel) and SGW (kg/vessel) for shipborne garbage source (n=4) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA results to compare shipborne garbage source mean SGI between study ports (Figure 26a.1), ship types (Figure 26b.1), ports location (Figure 26c.1) and BGW classification (Figure 26d.1) showed common source was significantly different ($p<0.05$) from maintenance, crew and cargo sources. The results show objects associated with common source includes clear plastic bottles (CPB), colored plastic bottles, food wrappers, plastic shopping bags, plastic cargo packaging and ropes; resulting in the higher objects accumulated compared to other sources on the vessel (Table 12). Accumulation of objects for cargo source was the lowest and univariate ANOVA analysis result shows mean SGI was significantly different ($p<0.05$) from other sources when compared between study ports (Figure 26a.1), ship types (Figure 26b.1), ports location (Figure 26c.1) and BGW classification (Figure 26d.1). However, the mean SGI garbage accumulation trend for shipborne garbage sources was similar whereby common and cargo sources accumulates the highest and lowest objects respectively in this study. The shipborne garbage source mean SGI univariate ANOVA analysis result among study ports, ship types, ports location and BGW classification were not significantly different ($p>0.05$).

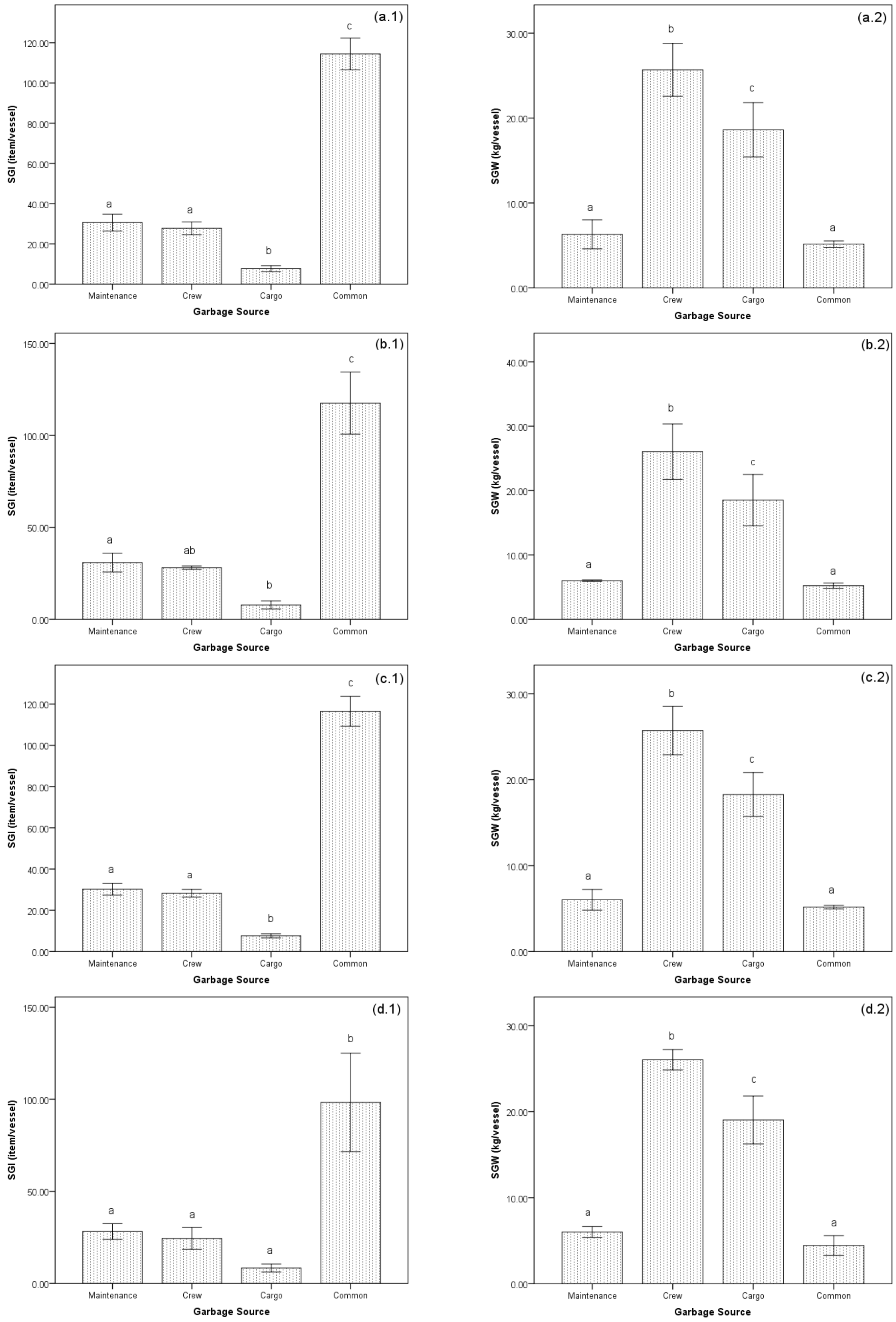


Figure 26: Means SGI and SGW (with standard deviation) garbage sources (n=4) according to (a) study ports (n=5), (b) ship types (n=3), (c) ports location (n=3) and (d) BGW classification (n=3)

Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different (p<0.05) from the other groups.

As for mean SGW univariate ANOVA analysis results showed crew sources was significantly different ($p<0.05$) from other shipborne garbage sources between study ports (Figure 26a.2), ship types (Figure 26b.2), ports location (Figure 26c.2) and BGW classification (Figure 26d.2). The results show garbage weight associated with crew source includes food and domestic wastes categories which are essentially consumed and used by crew members for health subsistence and vessel daily operations; resulting in the higher garbage accumulated compared to other sources on the vessel (Table 12). Garbage weight associated with cargo source includes used timber palette, timber for lashing cargo and damaged cargoes; accumulated substantially higher compared to maintenance and common sources. Univariate ANOVA analysis result shows mean SGW for cargo source was significantly different ($p<0.05$) from other sources as well. In addition, the mean SGW garbage accumulation trend for shipborne garbage sources was similar whereby crew and cargo sources accumulates the highest garbage weight in this study. The garbage sources mean SGW univariate ANOVA analysis result among study ports, ship types, ports location and BGW classification were not significantly different ($p>0.05$).

4.4 Discussion

4.4.1 Shipborne garbage abundance

From this study, mean SGI accumulated was 182±141 item/vessel. This study also found that vessels visiting Sandakan port accumulated the highest mean SGI at 197±124 item/vessel. Although, the number of vessels visiting ports in Sabah was the lowest (Table 10), mean SGI was the highest compared to vessels visiting Peninsular and Sarawak ports. The high number of bulk carrier (15) and general cargo (12) vessels type visiting Sabah port may contribute to the abundance of objects. In addition, the factor responsible for the abundance of objects in this study may be due to significantly higher number of white list classification (69%) vessels visiting Malaysian ports. This can be explained to the high number of crew members required by white list classification vessels to comply with international standard, thus eliminate vessels detention by PSCO at ports and minimize the time spent at port.

Mean SGW accumulated on the vessel was 54.9±30.1 kg/vessel, while, vessels visiting Kota Kinabalu port accumulated the highest mean SGW at 64.0±36.6 kg/vessel. Analyzing ship type, bulk carrier vessels which accumulated the highest mean SGW may have contributed to the abundance of SGW at Kota Kinabalu port. Although the number of container vessels visiting Malaysian port was the highest (Table 8), mean SGW was the lowest at 43.1±28.8 kg/vessel. This can be attributed to the level of awareness among crew members since there were 41 container vessels falling under white list classification. Analyzing mean SGW according to ports location, vessels visiting Sabah port contributed significantly higher mean SGW compared to vessels visiting Peninsular and Sarawak ports (Table 10). Mean SGW according to BGW classification shows accumulation of SGW approximately the same at 55 kg/vessel. This may be explained by the availability of garbage processing equipment on white list classification was higher (61 vessels) when compared to black (12 vessels) and grey (4 vessels) list classification.

Significant correlation analysis result suggested that number of vessels and number of crews and vessels' voyage duration contributed to the amount of objects and weight accumulated on the vessels. Although, this study found that container vessels was the highest ship type visiting Malaysian ports and had the highest number of crews; accumulation of objects and weight was the lowest (Table 8). In addition, there were 41 container vessels falling under white list classification which is higher compared to bulk carrier (25) and general cargo (13) vessels. This could be a factor that contributes to the low objects and weight accumulated on the vessel since white list classification vessel shows a strong commitment in compliance to international regulation (Tokyo MOU, 2013; Degré, 2008). Nevertheless, this may also be explained by the higher demand of larger vessels and more competent crew members to manage and operate sophisticated vessels. Although federal ports in Malaysia are visited by larger vessel compared to state ports (Khalid, 2006, 2010), there was no significant difference in the mean SGI abundance between ports classifications. Therefore, there is a need in ensuring vessels visiting Malaysian ports are in compliance with MARPOL 73/78 Annex V requirements particularly with the steady increase of vessels visiting Malaysian port (JLM, 2015). In addition, port authorities should pay serious attention to garbage generated by vessel and develop strategies to ensure vessels discharge shipborne garbage at Malaysian ports.

4.4.2 Shipborne garbage category

From shipborne garbage category analysis, plastic category contributed the highest objects accumulated representing 85% from the total garbage item collected on the vessel. Associating shipborne garbage accumulation relationship according to ship types, the higher mean SGI for plastic, domestic waste and operational waste can be related to higher number of bulk carrier vessels visiting the study ports, while, cargo residue category can be related to the higher number of general cargo vessels. This result indicates the lack of control measures to decrease the use of plastic materials on the vessels. The high number of objects from plastic category found on the vessel may find ways into the sea when illegally discharged, eventually adding to the existing between 60% and 90% of plastic found in the marine environment (Thiel *et al.*, 2013; Keller *et al.*, 2010; Barnes *et al.*, 2009; Derraik, 2002;

Bugoni *et al.*, 2001). As a result of the society's lifestyle dependency on plastic products indicates the level of awareness is low in understanding plastic material's consequences to the marine environment. Objects which may cause harm to marine wildlife found on the vessel includes plastic shopping bags, cargo plastic packaging, food wrappers and nylon ropes which they can be ingested or entangled by marine animals (Laist, 1997). Objects which may be of particular concern to vessels' operation are plastic shopping bags, ropes and metal drums. These objects can entangle with propellers, rudders and block water intakes (JGESAMP, 2009; Sheavly, 2005b). The number of objects for operational waste category found on the vessel was not significant. However, objects such as oil rags and gloves that are used to clean excessive oil in the engine room are mixed with engine oil, lubricating oil and grease. Although, the severity of the pollution depends on the physical properties of the oil, the potential impact can be catastrophic to marine wildlife and often destructive to the environment (Jaswar *et al.*, 2013; Ngah *et al.*, 2012; Defeo *et al.*, 2009) when discharge illegally at sea.

The information on mean SGW garbage category collected from this study shows food waste (37.34%) and cargo residue (33.15%) categories were the highest quantity by weight according to study ports, ship types and ports location. The higher mean SGW for plastic, food waste, domestic waste and incinerator ashes categories can be related to high number of bulk carrier vessels, while, general cargo and container vessels were for cargo residue and operational waste categories. The abundance of food wastes are the by-product from processing, handling, storage, preparation, cooking, and serving of foods (Kester, 2013) on the vessel. This indicates food wastage besides inviting infectious diseases (Minooee & Rickman, 1999). Similarly, other studies (Polglaze, 2003; Nawadra *et al.*, 2002; European Commission Directorate-General for Transport, 1998; Horsman, 1982) found that food wastes are produced in large quantities and difficult to process on a vessel. Therefore, there is a need to reduce food wastes by introducing healthy dietary food plan (EPA, 2010). As for cargo residue objects includes any damage cargo on the vessel, in cargo holds or tanks accumulated substantial amount in terms of weight, however, mean SGI was the lowest at 4.39% on the vessel. Although, this category is allowed to be discharged at sea, objects such as parts of wooden pallet can pose hazard to propellers, rudders and vessels' structure. There are objects found with nail still intact on a partly broken wooden pallet which if disposed to sea will eventually be stranded on the beach creating hazard to beach visitors. Although other garbage categories such as plastic, domestic waste, cooking oil, incinerator ashes and operational waste contributed insignificant amount in terms of weight, these objects are strictly prohibited to be discharged into the sea.

4.4.3 Shipborne garbage source

The mean SGI according to garbage source shows common source accumulates significantly higher objects according to study ports (114±8 item/vessel), ship types (118±17 item/vessel), ports location (116±7 item/vessel) and BGW classification (98±27 item/vessel). Objects from common sources were CPB, food wrappers, plastic packaging, plastic shopping bags, hard hats and ropes. Although these objects can be vessel provision supplies by-product; mooring gangs, shipping agents, inspection officers, port staff, cargo operation members, visiting family members and friends may introduce these objects on the vessels. Therefore, there is a need to control garbage item brought in to the vessel other than garbage generated by vessels' crew members. In Malaysia, the general public has a positive attitude towards recycling, however, effort to practice recycle is low (Omran & Gebril, 2011). Therefore, a simple yet effective measure can be introduce such as installing garbage bins and placing garbage awareness poster at strategic places on the vessel.

As for mean SGW, crew source accumulates significantly higher garbage weight according to study ports (25.7±3.1 kg/vessel), ship types (26.0±4.3 kg/vessel), ports location (25.7±2.8 kg/vessel) and BGW classification (26.0±1.2 kg/vessel). Objects identified contributing 45.89% from the total shipborne garbage weight to the abundance of crew source including food wastes (38.00%), cooking oil (2.40%), glass bottles (2.18%), cardboard cartons (1.74%) and aluminum cans (1.57%). This study found the mean SGW for cargo sources was also significantly higher when compared to maintenance and common sources. Objects identified contributing 33.14% of garbage weight from cargo source includes used wood palette, steel wrapping wire and wooden packaging box. Ship stability is a fundamental component of seaworthiness to ensure vessels' safety as well for crew on board (Khalid & Tang, 2010; Molnar & Koshure, 2009; Hutto, 2001). As additional garbage weight may affect vessels' stability, there is an increasing possibility of discharging illegally any excess garbage weight when vessels are navigating within the MTW. This action eventually may cause shipborne objects stranded along the Malaysian coastlines. For that reason, there is a need to replace product packaging that can reduce garbage weight on the vessels. In addition, monitoring and introducing strict entries of garbage at vessels' main entrance may contribute to minimizing garbage weight on the vessels.

4.5 Conclusions

In this study, the mean SGI was 182±141 item/vessel, whereas, mean SGW was 54.9±30.1 kg/vessel respectively. The accumulation of shipborne garbage is dependent on ship type and BGW classification, where, bulk carrier vessels and white classification collected the highest objects, respectively. Although, vessels visiting Sabah port had the lowest number for crew members and equip with garbage processing equipment, this port accumulated the highest items and weight. Plastic material (116±100 item/vessel) was the most abundant garbage category item found accumulating on the vessels which needs disposal at port, whereas, food waste (20.5±10.8 kg/vessel) category was the highest for garbage weight. Although, other garbage categories contributed in smaller amount of quantities, these objects are chemically hazardous and necessary to discharge at port. In addition, there is a need to encourage disposal for food waste and cargo residue categories in a sustainable manner even though MARPOL 73/78 allows the disposal at sea. The abundance of objects can be related to common source, whereas, crew source was responsible for the abundance of garbage weight. Thus, the procurement of goods and services needs to be aligned promoting green economy and eliminating wastage. Nevertheless, crew members and voyage duration which are significant factor determining shipborne garbage abundance on the vessel, requires specify and strategic solution to decrease garbage accumulation and eliminate illegal discharge practices.

CHAPTER 5

BEACH DEBRIS AND SHIPBORNE GARBAGE RELATIONSHIP

5.1 Introduction

The marine debris impact on marine environment has been the international concern and media attention around the world. Beaches across the world are polluted with marine debris, which pose an imminent threat to marine ecosystem (Oigman-Pszczol & Creed, 2007; Thompson *et al.*, 2004; Derraik, 2002). Marine debris impacts are the results of illegal discharge of any type of garbage into the marine environment. The characteristics that makes plastic-based material multipurpose packaging material, durable and lightweight, that also makes plastic litter easily spread and harmful to the marine environment.

Marine debris found on the beaches are derived either from land-based or ocean-based sources. Debris from run-off, deliberately dumped or blown by wind contribute 80%, while, 20% comes from vessels and offshore platforms (JGESAMP, 2009; UNEP, 2006; U.S. Commission on Ocean Policy, 2004). In addition, the increase usages of highly visible non-biodegradable products are illegally discharge and washed along the shoreline including large and buoyant plastic-based material (Portz *et al.*, 2011; Walker *et al.*, 2006; Fujieda & Sasaki, 2005; Edyvane *et al.*, 2004; Convey *et al.*, 2002; Frost & Cullen, 1997). Garbage from urban areas can become marine debris if it gets into rivers (JGESAMP, 2009; Sheavly, 2007) which eventually arrives in the sea or stranded on the beaches.

Although, debris derived from ocean-based or marine sources may originated from commercial shipping, fishing vessels, recreational boats, fish farming, cruise liners, military fleets, research vessels, passenger ferries, offshore oil and gas platforms; and service vessels (Sheavly, 2005b), shipborne garbage information focused on shipping activities is limited

(Jambeck *et al.*, 2015; Sarinas *et al.*, 2012; Vauk & Schrey, 1987; Horsman, 1982). The widely used of plastic-based material in the maritime activities especially in fishing equipment gears, ships' operation and ships' food packaging; has reported to have adverse effects on the marine wildlife through entanglement and ingestion (Cho, 2009; Palabıyık, 2003). Although, accumulation of marine debris can be serious particularly in areas of high maritime traffic or ocean based activities or circulating ocean currents (Sheavly, 2005b; Walker *et al.*, 1997), there is little information on the relationship between debris from ship and the presence of similar debris on the beaches (Ryan *et al.*, 2009; Vauk & Schrey, 1987). Nevertheless, vessels may contribute to debris accumulation on beaches, however, the quantity of shipborne garbage trends has been manipulated or extrapolated (Zuin *et al.*, 2009; Allsopp *et al.*, 2006; Vauk & Schrey, 1987). To determine the estimated shipborne garbage amount is subject to vast variability including sampling method, combination of multi point-source inputs, oceanographic influences, the spreading of debris lead to great temporal and spatial litter loads variability in the marine environment (Portz *et al.*, 2011; Ryan *et al.*, 2009).

Since study on beach debris and shipborne garbage relationship in Malaysia is limited, this study can be used as a baseline for future reference for a more comprehensive data set. Therefore, this study aimed to: (1) investigate the relationship between shipborne garbage waste and the beach debris abundance, (2) determine objects origin collected at beach and ship surveys and (3) access the abundance of objects origin collected during beach and ship surveys.

5.2 Materials and methods

5.2.1 Beach survey

Five public beaches (Table 13) has been selected for beach surveys during the NEM, IM and SWM seasons (Figure 9 of section 3.2.1) according to standing stock method (Cheshire *et al.*, 2009). All debris items other than fragments smaller than 0.25 cm^2 within one km sampling transects were collected. After debris item collected has been identified, weighed, classified and sorted into debris categories (Ribic *et al.*, 1992) and sources (Ribic, 1998), each debris item was examined to identify debris items country of origin. While the debris is being sorted, the country of origin is recorded using any information still present, such as barcode, the manufacturer's name, address and logo (White, 2005; Ribic *et al.*, 1992) (Appendix E). To examine debris stranded on the beach and accumulated on the vessel relationship, only objects from marine source (Table 2) was considered in the statistical analysis. Thus, marine source was further classified according to sub-marine source; marine-ship (6 objects), marine-fishing (7 objects) or marine-common (8 objects). Beach debris item per km (BDI) was calculated using Equation (1) (refer section 3.2.1).

Table 13: Location of beach and port surveys

No.	Beach, (a)	Nearest port, (b)	Distance between (a) and (b)	
			Road (km)	Sea (km)
1	Pasir Pandak	Kuching	22.9	57.6
2	Temasyah	Bintulu	18.2	2.8
3	Tg. Aru	Kota Kinabalu	13.7	8.9
4	Kosuhoi	Sandakan	422.3	235.3
5	Saujana	Klang	165.3	74.9

5.2.2 Ship survey

Five ports (Table 13) have been selected to investigate shipborne objects origin on container (34 vessels), bulk carrier (46 vessels) and general cargo (35 vessels) ship types plying international route (Figure 9 of section 3.2.1). A total of 115 vessels with 2,295 crews were involved in this study from October 2012 to October 2014. During inspection, all debris other than fragments smaller than 0.25 cm^2 at the vessels' garbage station was examined to identify garbage item's sector or country of origin. All objects which affix with any information present, such as barcode, the manufacturer's name, address and logo were recorded (page 6 of Appendix C). Shipborne garbage item per vessel (SGI) was calculated using Equation (4) (refer section 4.2.2), whereas, shipborne garbage weight per vessel (SGW) was calculated according to Equation (5) (refer section 4.2.2).

5.2.3 Data analysis

In this study, only objects bore labels indicating country of origin (logo, EAN (European Article Number) international barcodes, etc) collected at the beach and on the vessel were considered in this analysis. Items that have the same label are listed and categorized as a source origin. These items were used as variables to analyze the debris relationship between debris on the beach and vessel surveys. Data collected then calculated using Microsoft Excel 2007 to provide information on percent composition of the objects, the highest and lowest encountered items and possible sources identified for marine source from beach and ship surveys. For statistical analysis, z-test was used to analyze the distribution of normality using critical values smaller than ± 1.96 ($n<50$) with an alpha level 0.05 for absolute z-scores for either skewness or kurtosis (Kim, 2013). A $\log_{10}$ transformation ($\log_{10}+1$) of the data was applied for statistical analyses that did not assume a normal distribution (Ribic *et al.*, 2010). Pearson's correlation test between BDI and SGI with number of vessels visiting at study ports, vessels' clear plastic bottles (CPB), beach CPB, beach-urban proximity and beach-port proximity was analyzed. Multiple linear regression (stepwise) model was used to identify predictor variable contributed to the abundance of SGI and SGW when correlation test indicated significant differences. All statistical comparisons were performed using SPSS version 22 package software.

5.3 Results

5.3.1 Debris abundance

5.3.1.1 Beach objects abundance

In this study, a total of 36 objects were found present at beach surveys. The items identified were commonly found in household domestic products. Analyzing ten most abundant objects found at beach study sites contributed 80.13% from the total debris item collected includes CPB, plastic fragments, plastic food wrappers and colored plastic bottles; were found present at all study sites (Table 14). These objects contributed 14.48% (147 item/km), 10.25% (104 item/km), 10.24% (104 item/km) and 8.17% (83 item/km) respectively.

Table 14: Total items (number, *item*) accumulated during beach and ship surveys

Rank	Beach survey			Ship survey		
	Objects	Total item	Total (%)	Objects	Total item	Total (%)
1	Clear plastic bottles	4,407	14.48	Clear plastic bottles	6,148	30.36
2	Plastic fragments	3,121	10.25	Food wrapper	2,421	11.96
3	Plastic food wrapper	3,116	10.24	Rubber (Others)	2,174	10.74
4	Colored plastic bottles	2,488	8.17	Plastic fragments	2,139	10.56
5	Plastic (Others)	2,422	7.96	Aluminum cans	1,320	6.52
6	Cups	2,099	6.90	Oil rags	1,124	5.55
7	Bottle caps	1,986	6.52	Colored plastic bottles	984	4.86
8	Food wrappers	1,966	6.46	Cardboard cartons	865	4.27
9	Packaging	1,540	5.06	Tin cans	522	2.58
10	Cardboard cartons	1,246	4.09	Glass bottles	511	2.52

Table 15 shows the most objects found stranded on the study sites. Kosuhoi beach accumulated the highest mean BDI for CPB (244 item/km), plastic (other) (133 item/km) and colored plastic bottles (132 item/km), while, Temasyah beach accumulated the highest mean BDI for plastic fragments (165 item/km), food wrappers (120 item/km), bottle caps (101 item/km), cups (90 item/km) and cardboard cartons (54 item/km). Plastic food wrappers (160 item/km) and packaging (73 item/km) objects were highest at Pasir Pandak beach.

Table 15: Ten most numerous objects (item/km) found and BDI at the study sites

Objects	Beach study sites				
	Pasir Pandak	Temasyah	Tg. Aru	Kosuhoi	Saujana
Clear plastic bottles	189	118	139	244	45
Plastic fragments	66	84	165	93	113
Plastic food wrapper	160	108	128	61	64
Colored plastic bottles	130	58	85	132	8
Plastic (Others)	68	33	70	133	99
Cups	52	72	90	64	71
Bottle caps	48	57	101	77	48
Food wrappers	36	59	120	56	58
Packaging	73	25	38	83	39
Cardboard cartons	30	41	54	50	33
BDI (item/km)	657	790	1,208	1,263	731

5.3.1.2 Shipborne objects abundance

In this study, a total of 31 objects were found present during ship surveys. The items identified were commonly found in household domestic products. From the shipborne objects perspective, 62.01% objects from the plastic category were present at all vessel sampled which included CPB, food wrappers, plastic fragments, colored plastic bottles and cardboard cartons. The five most numerous objects found on the vessels which contributed 70.13% from the total shipborne items collected were CPB, plastic food wrappers, rubber-others, plastic fragments and aluminum cans (Table 14). These objects contributed 30.36% (53 item/vessel), 11.96% (21 item/vessel), 10.74% (19 item/vessel), 10.56% (19 item/vessel) and 6.52% (11 item/vessel) respectively.

Analyzing objects abundance according to study ports, Sandakan port accumulated the highest mean SGI for CPB (72 item/vessel), aluminum cans (16 item/vessel), tin cans (6 item/vessel) and glass bottles (6 item/vessel) (Table 16). Kota Kinabalu port accumulated the highest mean SGI for rubber-others (22 item/vessel) and plastic fragments (24 item/vessel), while, Bintulu port was the highest for oil rags (13 item/vessel) and cardboard cartons (10 item/vessel). Plastic food wrappers and colored plastic bottles objects were highest at Kuching and Klang ports at 26 item/vessel and 11 item/vessel, respectively.

Table 16: Ten most numerous objects (item/vessel) found and SGI at the study ports

Objects	Study port				
	Kuching	Bintulu	Kota Kinabalu	Sandakan	Klang
Clear plastic bottles	42	51	56	72	55
Plastic food wrapper	26	22	21	19	18
Rubber (Others)	16	22	22	15	19
Plastic fragments	23	12	24	18	16
Aluminum cans	13	10	11	16	10
Oil rags	9	13	12	9	7
Colored plastic bottles	6	5	9	9	11
Cardboard cartons	7	10	8	9	6
Tin cans	4	4	4	6	5
Glass bottles	3	4	4	6	5
SGI (item/vessel)	163	168	198	194	171

5.3.1.3 Analysis of marine source debris found during beach survey

Figure 27 shows total debris item for sub-marine source collected from beach survey. From 21 objects identify as marine source (Table 2 of section 2.3), 13 objects were present at all study sites amounting to 3,536 items including foam packaging (51 item/km), cigarette lighters (22 item/km), foam insulation (10 item/km), plastic oil bottles (10 item/km) and buckets (6 item/km). Analyzing each sub-marine sources, marine-common source accumulated the highest items found on the beaches at 87.02% (3,977 items or 103 item/km), while, marine-ship source presented the lowest items accumulated found on the beach at 2.38% (84 items or 3 item/km) (Figure 27). Objects associated with marine-ship source present on the beach include pallet wrappers (79 items), gloves (3 items) and steel drums (2 items). Nevertheless, objects in marine-common source are of particular concern as these objects were found abundantly at all beach study sites. Objects associated with marine-common source includes CPB, styrofoam cups and plates, colored plastic bottles, plastic bottle caps and footwear. These objects can derive from commercial vessels, domestic vessel, fishing vessel, platform, pleasure boats or passenger vessels.

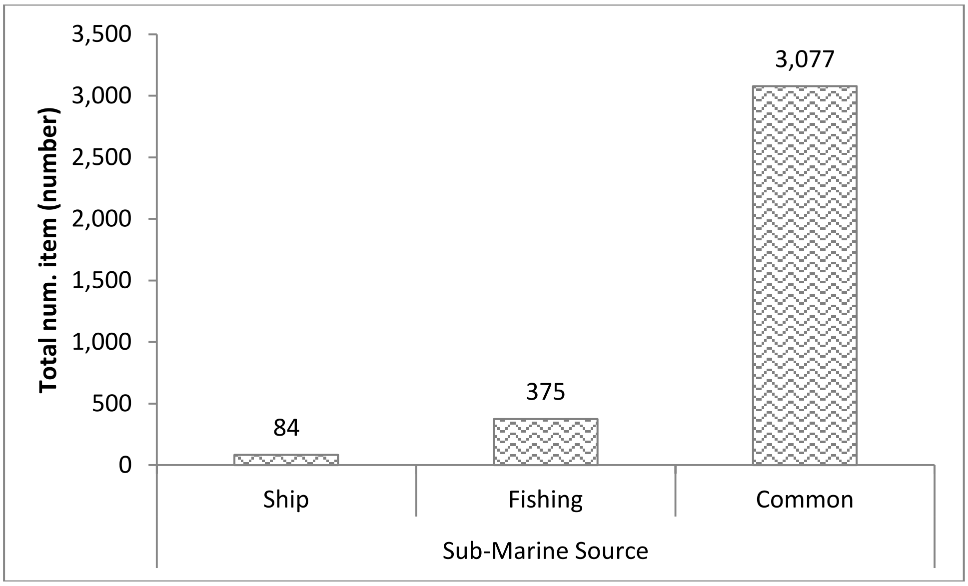


Figure 27: Total number of items for sub-marine source debris

5.3.1.4 Beach and shipborne object abundance relationship

Table 17 shows total items for marine source identified during beach survey and on the vessel. Analyzing objects found at the beach shows Kosuhoi beach accumulated the highest mean BDI (marine source) at 224 item/km, while, Temasyah beach accumulates the lowest at 69 item/km. As for mean CPB, Kosuhoi beach accumulated the highest at 244 item/km, as compared to Saujana beach at 45 item/km. Ship survey results showed Kota Kinabalu port accumulated the highest mean SGI as compared to Kuching port at 198 item/vessel and 163 item/vessel, respectively. As for CPB abundance, vessel visiting Sandakan and Kuching ports accumulated the highest and lowest CPB items at 72 item/vessel and 42 item/vessel, respectively.

Correlation analysis results show mean BDI (marine source) is significantly correlated ($p<0.05$, $z<\pm1.96$, $n=5$) with urban proximity ($r=0.89$, $p=0.05$), while mean SGI showed no evidence of significant correlation ($p>0.05$) (Table F 1 of Appendix F). Multiple linear regression results ($R^2=0.78$, $p<0.05$) shows that urban proximity ($\beta=0.89$, $t=3.30$, $p=0.05$) is a significant factors in determining BDI (BDI=73.30-0.59*(Urban proximity)) (Table F 2 of Appendix F).

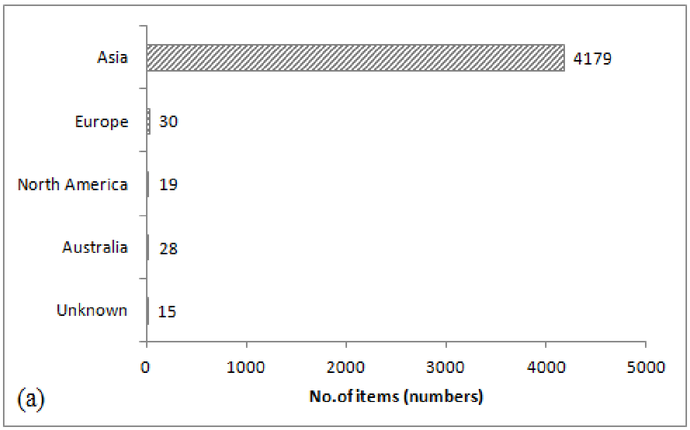
Table 17: Mean BDI (marine source) (item/km), SGI (item/vessel) and CPB items found during beach and ship surveys

Study sites / Study ports	Beach survey		Ship survey	
	Total Item (Marine source)	CPB	Total Item	CPB
Pasir Pandak / Kuching	108	189	163	42
Temasyah / Bintulu	69	118	168	51
Tg. Aru / Kota Kinabalu	115	139	198	56
Kosuhoi / Sandakan	224	244	194	72
Saujana / Klang	74	45	171	55

5.3.2 Debris origin

5.3.2.1 Beach debris labeled objects

This study has identified 9.26% (4,271 items) from the total debris items found at the beach were still affixed with labels of origin. The debris items can be identified originating from 29 countries representing six continents. The highest identified debris items was from Asia continent represents 97.86% (4,179 items) of the labeled items found at the beaches (Figure 28a). Analyzing debris labeled items country of origin showed, 81.92% of the total labeled items originated from Malaysia (or local); followed by Indonesia (6.13%), Singapore (2.58%), Vietnam (1.64%), Thailand (1.64%), and others countries (6.09%). The abundance of labeled objects according to debris categories shows plastic category represent the highest objects accumulated at 3,503 items (82.02%), followed by wood (483 items; 11.31%), metal (211 items; 4.94%) and glass (64 items; 1.50%) categories (Figure 28b). The five highest objects with affixed label indicating the country of origin representing 94.97% of the total labeled objects found were CPB (43.76%), plastic food wrappers (22.24%), colored plastic bottles (14.91%), cardboard cartons (11.31%) and aluminum cans (2.74%).



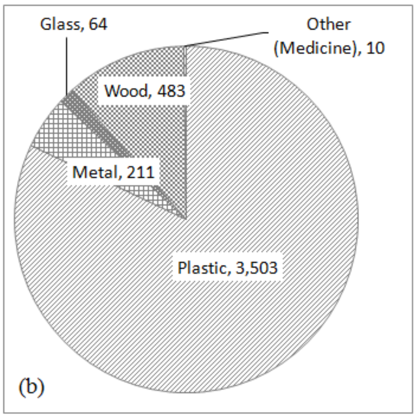


Figure 28: Total labeled items (number, *items*) found at beach surveys according to (a) continents and (b) debris category

Analyzing debris origin according to study sites, Kosuhoi beach accumulated the most items from local (1,122 item/km) and foreign (241 item/km) origins respectively, whereas, Saujana accumulated the lowest items for both local (37 item/km) and foreign (10 item/km) origins (Table 18).

Table 18: Total item for objects (item/km) origin found at beach survey

Objects	Pasir Pandak		Temasyah		Tg. Aru		Kosuhoi		Saujana	
	L	F	L	F	L	F	L	F	L	F
Clear plastic bottles	31	7	63	5	65	1	119	9	10	2
Food wrappers	18	6	20	6	40	13	29	10	15	3
Cardboard carton	9	4	22	4	23	3	7	1	5	3
Coloured plastic bottles	10	5	11	9	18	6	25	19	2	2
Aluminium cans	4	2	1	1	5	1	1	0	5	1
Aerosol cans	1	0	1	1	7	0	4	0	0	0
Glass bottles	2	0	2	0	4	2	0	0	1	0
Plastic oil bottles	0	0	1	1	0	0	2	0	0	0
Tin cans	1	0	0	0	1	0	0	0	0	0
Medicine	0	1	0	0	0	0	0	1	0	0
Product wrapper	0	0	0	0	1	0	0	0	0	0
Metal (Others)	0	0	0	0	0	0	0	0	0	0
Plastic (Other)	0	0	0	0	0	0	0	0	0	0
Plastic container	0	0	0	0	0	0	0	0	0	0
Total	75	26	120	27	164	26	187	40	37	10

L: Local origin (or Malaysia); F: Foreign origin

5.3.2.2 Shipborne garbage labeled objects

Analyzing shipborne garbage origin, 43.83% (9,158 items) were still affixed with labels indicating country of origin. Objects originated from 42 countries showed Asia continent represents 90.60% (8,297 items) of the labeled items found on the vessel surveyed (Figure 29a). The labeled items indicating country of origin can be identified from Vietnam (37.07%); followed by China (19.02%), Malaysia (14.02%), Thailand (5.11%), Singapore (4.85%) and other countries (19.93%). The abundance of labeled objects was from plastic and domestic waste categories, whereby they accumulated 6,446 items (70.39%) and 2,712 items (29.61%) respectively (Figure 29b). The five highest objects with affixed label indicating the country of origin representing 97.36% of the total shipborne items found were CPB (49.31%), aluminum cans (26.94%), plastic food wrappers (16.66%), cardboard carton (3.11%) and glass bottles (1.33%).

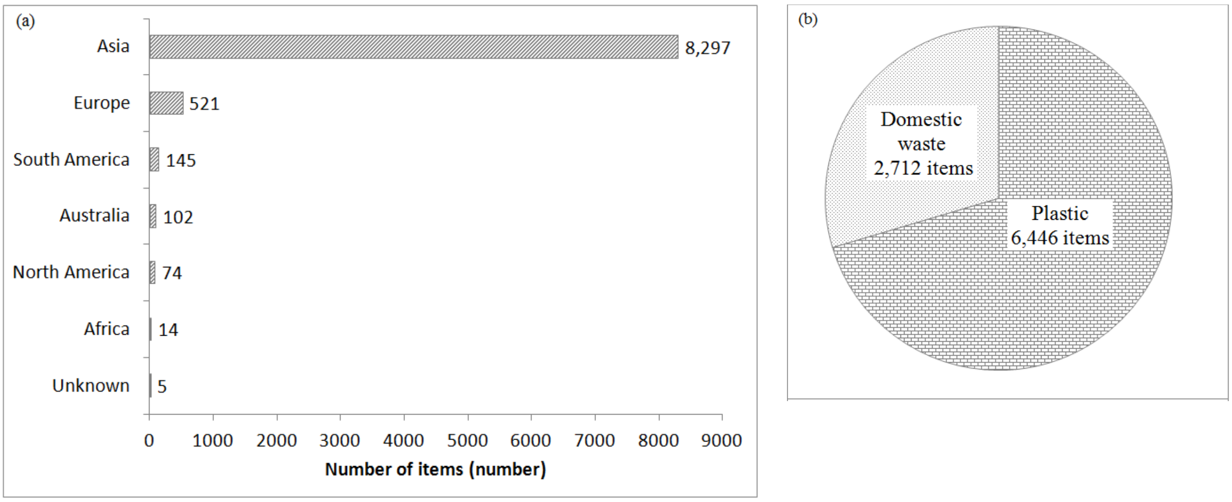


Figure 29: Total labeled items (number, *items*) found at ship surveys according to (a) continents and (b) debris category

Analyzing garbage origin according to study ports, Kuching port accumulated the highest objects for local (13 item/vessel) and foreign (130 item/vessel) origins, whereas, Bintulu and Klang ports accumulated the lowest objects for local (7 item/vessel) and foreign (42 items) origins (Table 19).

Table 19: Total objects (item/vessel) origins found at ship survey

Objects	Kuching		Bintulu		Kota Kinabalu		Sandakan		Klang	
	L	F	L	F	L	F	L	F	L	F
Clear plastic bottles	9	26	4	35	10	30	5	44	10	29
Aluminum cans	1	77	0	5	0	8	2	7	1	3
Food wrappers	2	21	2	9	2	12	1	10	1	7
Cardboard cartons	1	2	1	2	0	4	0	2	0	2
Glass bottles	0	0	0	2	0	1	0	2	0	1
Tin cans	0	0	0	0	0	1	0	2	0	1
Product wrappers	0	3	0	0	0	0	0	0	0	0
Colored plastic bottles	0	1	0	0	0	0	0	0	0	0
Aerosol cans	0	0	0	0	0	1	0	0	0	0
Plastic oil bottles	0	0	0	0	0	0	0	0	0	0
Total	13	130	7	53	12	56	9	66	12	42

L: Local origin (or Malaysia); F: Foreign origin

5.3.3 Beach and ship survey debris origin relationship

5.3.3.1 Debris origin according to objects

Table 20 shows identified objects collected at ship sampling associated with objects found during beach survey. The result shows 14 objects were identified present at beach and ship surveys amounting to 15,648 items. Local origin items showed a higher amount found on the beaches, whereas, foreign origin items were found abundant on the vessels. The highest local origin items accumulated were CPB (2,556 items or 85 item/km), food wrappers (960 items or 32 item/km) and cardboard cartons (646 items or 22 item/km). As for foreign origin items were CPB (3,591 items or 31 item/vessel), aluminum cans (2,383 items or 21 item/vessel) and food wrappers (1,336 items or 12 item/vessel).

5.3.3.2 Debris origin according to objects EAN international barcodes

Table 21 shows items identified from EAN international barcode found at beach and ship survey. The result shows five objects has been identified having the same EAN international barcode affix on the product was present at beach and ship surveys amounting to 2,447 items (Table F 3 of Appendix F). Although, there were presence of local origin objects found on

Table 20: Number of objects (number, *items*) origin found at beach and ship surveys

Objects	Beach survey		Ship survey	
	Local	Foreign	Local	Foreign
Clear plastic bottles	1,727	142	925	3,591
Food wrappers	729	221	189	1,336
Aluminum cans	397	240	2	40
Cardboard cartons	393	90	45	240
Colored plastic bottles	86	31	84	2,383
Glass bottles	68	11	0	11
Product wrapper	48	16	11	111
Tin Cans	20	5	0	2
Aerosol cans	13	2	21	91
Plastic oil bottles	12	5	0	76
Medicine	2	8	0	0
Metal (Others)	2	2	0	0
Plastic (Other)	0	1	0	0
Total	3,497	774	1,277	7,881

the vessel with the same EAN labeled found on the beach, it is difficult to distinguish whether these objects found on the beach were originated from the vessels. However, objects of foreign origin are of particular concern. A total of 83 foreign origin items with the same EAN labeled affix found on the beach were present on the vessels including CPB (81 items) and aluminum cans (2 items) (Table 21).

Table 21: Total objects (number, *items*) according to EAN international barcodes found at beach and ship surveys

Objects	Beach survey		Ship survey	
	Local	Foreign	Local	Foreign
Clear plastic bottles	342	81	644	832
Aluminum cans	42	2	222	18
Food wrappers	94	0	80	0
Colored plastic bottles	46	0	2	0
Cardboard cartons	27	0	15	0
Total	551	83	963	850

From correlation analysis results (Table F 4 of Appendix F), mean log_{10} beach (foreign item) is significantly correlated ($p<0.01$, $z<\pm1.96$, $n=5$) with log_{10} ship (foreign item) ($r=0.98$, $p=0.00$), whereas, mean log_{10} beach (local item) showed insufficient evidence to conclude significant correlation ($p>0.05$) against mean ship (local item). Multiple linear regression results (R^2=0.97, p<0.01) shows $\log_{10}$ ship (foreign item) (β=-0.94, t=-4.87, p=0.02) has a strong relationship against $\log_{10}$ beach (foreign item) abundance at the beaches ($\log_{10}$ beach (foreign item)=0.610*($\log_{10}$ ship (foreign item)) (Table F 5 of Appendix F).

5.4 Discussion

5.4.1 Marine source debris abundance

This study demonstrates that the amount of marine debris from shipping activity found on the beach indicates crew members may have discharged shipborne garbage illegally. The factor responsible to the presence of shipborne garbage could be attributed to the attitude and behavior of an individual (Slavin *et al.*, 2012; Silva, 2002; Hungerford & Volk, 1990). In the advent of the revise MARPOL 73/78, illegal shipborne garbage discharge practice requires stern preventive measures. Other studies (Butt, 2007; Ball, 1999) suggested that vessels operation's on a tight schedule and probability not to be detected are among the reasons illegal discharge is still being practiced. This study has identified CPB as the most abundant objects found on the beach originating from neighboring countries. Statistical analysis results show CPB (R^2=0.99) may be used as an indicator to determine shipborne garbage abundance on the vessels. Figures calculated for shipborne objects abundance on container, bulk carrier and general cargo vessels during this study period had given an approximately 16.52 item/vessel for every 100 CPB of foreign origin objects found on the beach. Therefore, there is a need to conduct a detail PSC inspection on the vessels registered with neighboring countries. In addition, the PSC inspection outcome should be communicated to the vessels' country registrar office in hope that preventive measures can be introduced on these neighboring countries registered vessels.

5.4.2 Estimation of SGI and SGW in year 2020

The amount of debris items stranded on beach found in this study may have been abandoned and discharged from urban area or rubbish discarded by beach visitors. However, the presences of foreign origin objects found on the beach are of particular concern. This study found, 14% of shipborne garbage items were from local origin suggesting these vessels' obtains food supply at Malaysian ports. Analyzing labeled objects shows foreign origin items dominate the abundance of objects found on the vessel including aluminum cans CPB (3,591 items or 31 item/vessel), CPB (2,383 items or 21 item/vessel) and food wrappers (1,336 items or 12 item/vessel). In addition, 63.86% garbage items that were accumulated on the vessel could also be found on the beaches including CPB, food wrappers, rubber and plastic fragments. However, these objects can be associated with household domestic products and may have contributed from urban areas. Thus, it is difficult to make a conclusion that objects originating from local origin present at the beaches did come from shipping activities. Nevertheless, there is a possibility that these objects are illegally discharged at sea given the amount of CPB found at the beach which are adequate to make the assumption. These plastic-based items were reported to pose serious threat to turtle (Campani *et al.*, 2013), seabirds (Verlis *et al.*, 2014; Lavers *et al.*, 2013) and marine biodiversity (Williams *et al.*, 2011; Coombes & Jones, 2010; Todd *et al.*, 2010; Defeo *et al.*, 2009) when illegally discharged at sea. In addition, they could act as a means of transportation for invasion of marine organisms (Kuo & Huang, 2014; Barnes, 2002). Therefore, a long-term study on shipborne garbage produced on the vessel should be initiated to determine plastic-based garbage trend generated on the vessels, in order to develop and introduce a suitable and precision mitigation measures.

Malaysia aspires to become a fully developed nation by the year 2020. Thus, this implies more vessels will be visiting Malaysian ports and using Malacca straits as transit or innocent passage. Considering the number of vessel using Malacca straits in year 2014 (JLM, 2015), an estimated total number of 95,000 vessels is expected to use Malacca straits in year 2020. This will translate to an amount of 5,217 MT of shipborne garbage with a staggering 12.4 million of garbage items on the vessels. This study found garbage contractors engaged to collect shipborne garbage and charged between USD 200 and USD 500 for shipborne garbage collection services since the study ports were not equipped with reception facilities for receiving shipborne garbage. The high cost incurred for the handling and disposal of waste by garbage contractors can deter vessels from sending shipborne garbage to ports (Carpenter & Macgill, 2005; Ball, 1999). Thus, this will aggravate illegal discharge practices from vessels navigating within MTW, eventually, magnifying the amount of garbage items in the marine environment. Therefore, there is a need to develop preventive strategies to ensure illegal discharge practices from vessel navigating within MTW are totally eliminated.

5.4.3 Oceanographic influences

Studies on floating marine debris trajectories (Martinez *et al.*, 2009; Pichel *et al.*, 2007; Kubota *et al.*, 2005; Thiel *et al.*, 2003) shows wind distribution and current effect determines the amount of debris accumulations. The analyzed wind data collected by MMD shows the wind pattern movement in the study area was in accordance with the monsoon wind circulation in unprotected beach areas at Kosuhoi and Saujana beaches. The wind pattern movement at Pasir Pandak, Temasyah and Tg. Aru beaches were erratic could be due to the influence of hilly topography. This study found the amount of debris items was more abundant during SWM season when compared to NEM and IM seasons. Kubota *et al.* (2005) explains that it is probable that steady wind affects debris movement at sea. Therefore, debris accumulation at the study sites may have been influenced by Ekman drift during monsoon winds.

Analyzing Ekman currents, the debris movement is deflected left angle of 45^{o} between the surface wind vectors and the Ekman current vectors. According to Wyrtki (1961), the current movement patterns concentration during NEM and SWM seasons (Figure 6 of section 2.2.2.2) are stronger and towards the Peninsular Malaysia coastal area, whereas, the current movement patterns in Sabah and Sarawak is weaker. Thus, this current movement forms a small circulation pattern. The circulation movement move anti-clockwise during NEM, whereas, clockwise during SWM. Thus, garbage accumulation may focus within the circulation pattern, which may be located between the Peninsula and Sabah/Sarawak water body. Therefore, the fate of shipborne floating garbage may remain in the marine environment if the garbage is illegally discharge beyond 100 nmi. This may explain the insignificant amount of marine-ship sources objects found stranded at the beach study sites.

Despite public concern on marine debris pollution at coastal area from marine source, little attention has been given to address debris from marine-ship source. The growing number of vessel en route through Malacca Straits (JLM, 2015; Rusli, 2012; Khalid, 2006) indicates the amount of shipborne garbage accumulated on the vessel increases and the possibilities to illegally discharge shipborne garbage within MTW will deteriorate the marine environment. The situation may be worsen as studies on accumulation of marine debris concentrated in specific regions (Martinez *et al.*, 2009; Pichel *et al.*, 2007; Kubota *et al.*, 2005; Thiel *et al.*, 2003), identified debris are being transported by wind and current distribution are located far from accumulation region.

Although this study is unable to quantify the amount of shipborne garbage discharge illegally, garbage disposal within 12 nmi is of particular concern as garbage discharge may be trapped by near shore current systems and transported through long-shore drift current to coastal areas (Sonu *et al.*, 1966). In addition, debris from land-based source including runoff and rubbish thrown into rivers (Ryan *et al.*, 2009; Ribic, 1998; Coe & Rogers, 1997; Dixon & Dixon, 1981) may also be transported by long-shore drift currents to coastal beach areas (Sonu *et al.*, 1966). Therefore, the continued use of plastic-based products should be replaced with biodegradable material, while, cultivating environmental awareness to renew public attitude to appreciate the marine environment.

5.4.4 Shipborne garbage management

5.4.4.1 Vessel assessment on shipborne garbage production

This study found plastic-based material such as CPB and food wrappers are discharge illegally at sea. These may contribute to the destruction of marine wildlife (Baulch & Perry, 2012; Bellwood *et al.*, 2004; Barnes, 2002). Thus, the amount of shipborne garbage may increase on the vessel if garbage production continued in an unsustainable manner. As a result of rising living standard, wastes generated are becoming a crisis especially in a confine area such as on the vessel. Therefore, it is essential that every crew member take responsible to waste produced on the vessel by practicing reduction, recycling and reuse. The final fate of every product must be anticipated at the beginning of the supply and to identify cost incurred for disposal. Thus, practical solutions and innovative approach to minimize if not totally eliminate waste generation require priority action at every level including suppliers, ships chandler, port authorities, and crew members to government agencies. In addition, cultivating environmental awareness has to be a continuous effort to ensure changes in behavior and attitude to appreciate the marine environment. Eventually, accumulation of garbage on board could be controlled and illegal discharge practices into sea be eliminated.

5.4.4.2 Garbage processing equipment

Although garbage processing equipment can improve shipborne garbage management (IMO, 2012c), the requirement to installation a shipborne garbage on the vessel is not compulsory. Studies (Delfosse *et al.*, 2010; Zuin *et al.*, 2009; Johnson, 2008) have shown garbage processing equipment can facilitate vessels by reducing shipborne garbage volume to a manageable size to store on the vessels before sending to port for disposal. Depending on the type of ship, area of operation, vessels voyage duration and number of crews; installing garbage processing equipment can be costly. Nevertheless, innovative and portable garbage processing equipment which is available in the market can be considered such as the Smart Ash Portable Waste Incinerator, Plasma Arc Waste Destruction System and manual trash compactor which can process all types of waste generated on the vessel and reduce waste volume to between 3% and 25%. Therefore, ship owners have a wider range of option to improve and initiate commitment by investing on affordable garbage processing equipment which ultimately contributes to environmental conservation.

5.4.4.3 Controlling shipborne garbage entry

The amount of shipborne garbage accumulated in this study indicates the need for monitoring of waste entry into the vessel. The practice of accepting provision goods from a ship chandler without considering the waste generated from the provision packaging may result in continuous illegal discharge into the sea. Therefore, it is necessary to review GMP to consider generated waste from provision goods received. In promoting such effort, port authorities may introduce “no plastic day” campaign to create awareness on the effect of shipborne objects when illegally discharge into sea. Subsequently, these minor changes could contribute a greater impact towards the marine environment.

5.5 Conclusions

Findings in this study have identified 14 labeled objects were present at the beach and ship surveys, amounting to 15,648 items which originated from 75 countries. Substantially higher amount of objects found were CPB, food wrappers and cardboard cartons. This is expected as these objects are daily consumer goods which can be easily thrown directly on the streets, rivers, beaches or into the sea. Although, this is a common practice especially in urban area, however from shipping activities perspective is totally prohibited according to MARPOL 73/78. Nevertheless, objects stranded on the beaches which can be attributed to shipping activities is utmost concern. Although, the amount of objects from shipping activity (1.3%; 2 items/km) found on the beaches was low; it indicates there are vessels disposing garbage illegally at sea. The strong correlation (r=0.98, p=0.00) between foreign origin items stranded on the beach and found on the vessel, indicates CPB can be used as an indicator to estimate shipborne garbage. The increasing use of plastic-based materials as packaging will aggravate the environmental pollution problem. Therefore, it is necessary to encourage garbage disposal in a responsible and sustainable approach on the vessel. The general public, coastal villagers, beach visitors, vessel crews, garbage collection contractors, local government authorities, port authorities and other stakeholders have the ability to reduce debris problem, by improving waste reduction, practicing effective waste management and introduce recycling initiatives.

CHAPTER 6

SHIPBORNE GARBAGE COMPLIANCE AND PRACTICES AMONG MERCHANT VESSELS

6.1 Introduction

The IMO has raised concern towards the protection of the world's oceans from marine pollution. Various contaminations have been identified that can diminish the oceans' health including illegal or accidental discharge of solid waste (Gomez *et al.*, 2004). These contaminant poses hazards to human health, wildlife, organism invasion and depleting the marine ecosystem aesthetically (Barnes, 2002; Horsman, 1982). Although there are studies of marine pollution sources (Jambeck *et al.*, 2015; Ryan *et al.*, 2009; Derraik, 2002), shipborne generated waste has not been studied in depth. The presence of garbage from ships in the ocean can be harmful to the environment (Valavanidis & Vlachogianni, 2012; Polglaze, 2003; Ball, 1999). A study by European Commission, Directorate-General for Transport (1998) assumed that merchant shipping and fishery vessels accounts for 15-35% and 65% of the total waste respectively, which, adding to the increasing amount of debris found along the coastline around the world (Barnes & Milner, 2005). Due to limited information on waste disposal methods and the potential effects of illegal discharge activities into the environment, most people are ignorant of the significance of their roles in minimizing garbage accumulation (Slavin *et al.*, 2012; Waters *et al.*, 2011).

MARPOL 73/78 (IMO, 2012a) governs all types of pollution generated by ship. Annex V which regulates the disposal of garbage at sea has been revised. With new regulatory requirements regarding the disposal of garbage from ships, it entered into force on 1 January 2013 (IMO, 2012b). The new amendments include the prohibition on the disposal of all types of plastic material, introduction of procedures to minimize shipborne garbage and establishment of specific requirements for shipborne garbage to be discharged at sea. Besides plastic and other synthetic waste materials on a ship, food waste is another major component of the shipborne garbage (Polglaze, 2003) which could be one of the most difficult to deal with since it is not allowed to be discharged to the sea within 12 nmi from the nearest land (IMO, 2012a). Thus, it is crucial for vessels operating within restricted area requires an effective management of food waste disposal (IMO, 2012c; Polglaze, 2003; Horsman, 1982). Malaysia has ratified Annex I/II, III, VI, V and VI, enabling instrument are the Merchant Shipping Ordinance, 1952 and Environment Quality Act, 1974 (JLM, 2014; Mustafa, 2011; Law & Hii, 2006).

Ensuring an effective enforcement of the international Conventions adopted by the IMO, nine regional Port State Control (PSC) systems has been formed namely Abuja MOU, Black Sea MOU, Caribbean MOU, Indian Ocean MOU, Mediterranean MOU, Paris MOU, Riyadh MOU, Tokyo MOU and Viña del Mar Agreement, a worldwide network to eliminate sub-standard shipping (Tokyo MOU, 2013). Black-grey-white (BGW) classification has been adopted to determine the vessels' registered country performances. JLM is the responsible agency to conduct PSC inspection under Tokyo MOU region.

Ports in Malaysia can be classified as Federal and State ports (Khalid, 2006). The federal ports are under the authority of the Ministry of Transport, while, state ports under State Statutory Bodies. All Federal ports except Kemaman port has been privatized and regulated by port authorities. Ports in Sarawak are operated by port authorities, while ports in Sabah have been privatized under one private operator. The Malacca Straits is the shortest sea route between the Indian Ocean and the Far East and it is among the oldest and busiest shipping lanes in the world, serving as a crucial waterway for movement of cargoes (Khalid, 2012; Meyrick *et al.*, 2005; Chua *et al.*, 2000). The number of vessels plying within Malaysia

Territorial Water (MTW) especially under the Malacca Straits Traffic Separation Scheme (TSS) has grown steadily at an average rate of 3% per annum (Khalid, 2012). The entire range of global trading vessels and types utilizes MTW with an average of 213 vessels operating daily in 2013 (JLM, 2015). The highest numbers of vessel type operating within MTW were container (33%) and tanker (23%) vessels. These vessels are loaded with cargo, meeting shipping schedules, catering to avid international demand for consumer and other goods (Asariotis *et al.*, 2013; Desa *et al.*, 2012; Chua *et al.*, 2000). This high number of vessels navigating through MTW may contribute to the effect of marine debris problem along the coastlines.

Therefore, to determine the compliance of vessels calling to Malaysian port to the implementation of MARPOL 73/78 Annex V practice (IMO, 2012c), this study aimed to: estimate the total shipborne garbage on selected ports, assess the abundance of shipborne garbage by category, determine the possible shipborne garbage sources, identify the effectiveness of garbage processing equipment on container, bulk carrier and general cargo vessels and determine vessel compliance to MARPOL 73/78 Annex V.

6.2 Materials and methods

6.2.1 Assessment on shipborne garbage abundance

A total of 115 vessels with 2,295 crews were involved in this study from October 2012 to October 2014. The survey instrument was administered using face to face interview at Kuching, Bintulu, Kota Kinabalu, Sandakan and Klang ports as shown in Figure 9 (refer section 3.2.1). The answers for each respondent were collected to establish the vessel's compliance to MARPOL 73/78 regulation.

GRB was reviewed to determine the amount of shipborne garbage weight by category, discharge at port according to vessels' complete voyage duration. After each shipborne garbage category weights were recorded, the garbage was then classified according to shipborne garbage sources (divided according to MARPOL 73/78 garbage categories); maintenance source (waste associated with maintenance and operation of the vessel), crew source (waste generated by crew), cargo source (waste associated with cargo) and common source where associated waste refers to other garbage sources. Shipborne garbage weight per vessel was calculated using Equation (5) (refer section 4.2.2), whereas, garbage generation rate (GGR) was calculated according to Equation (6) (refer section 4.2.2). The total SGW was used to estimate garbage weight (EGW) for vessels calling to Malaysian port using a method adopted from Nawadra *et al*. (2002) as shown in Equation (7);

$$EGW = \frac{N * SGW}{1000} \tag{7}$$

where EGW is estimated garbage on the vessel (MT), *N* is the number of vessel type plying under TSS.

6.2.2 Assessment on shipborne garbage practices

A survey instrument was used to assess shipborne garbage practices on container, bulk carrier and general cargo vessels type trading international voyage. A researcher-made questionnaire-checklist was adopted and modify from Bayliss & Cowles (1989) and Sarinas *et al.* (2012); and the assessment has been conducted according to PSC guideline Resolution A.1052(27) specifically for MARPOL 73/78 Annex V inspection. The instrument (Appendix C) contain consists of questions on vessel complies with the ship GMP and different management practices adopted for handling shipborne garbage as mandated by MARPOL 73/78.

6.2.2.1 Recruitment of participants

The instrument (Appendix C) was administered to the person in-charge of GMP on a randomly selected vessel type using face to face interviews. The respondents were master mariners (83) and chief officers (32) who participated voluntarily. In addition, the respondents were asked as to where they discharged their shipborne garbage and to identify waste generated from the vessels. Official records, statutory documents for maintaining shipborne garbage, MARPOL 73/78 Annex V compulsory training and disposal certificates were reviewed and inspected to determine proper garbage disposal procedure and record keeping of each garbage category.

6.2.2.2 Survey questions

The aim of the survey was to assess the ships' management of garbage according to Annex V of the MARPOL 73/78. Ship garbage management practices and actions towards the marine environment were also determined. This surveys maintained respondent's confidentiality, took approximately 50 minutes to complete, and was divided into five sections:

1. SHIP INFORMATION: This section collected information related to ship particular.
2. SHIP OPERATION: Respondents were asked ships' operation, port of call, number of voyage and type of cargo transported. Ships' official document was sighted to verify information regarding number of days in last port, duration of steaming from last port and cargo transported.
3. PROCESSING EQUIPMENT: Primarily to gather information availability of incinerator, compactor and food grinding equipments install on the ship. Respondent provide opinion on benefit of installed equipment. In cases non-availability of processing equipment, respondents provide method of processing shipborne garbage.

4. ESTIMATE OF SHIPBORNE GARBAGE: Garbage Record Book was inspected and reviewed to determined proper garbage disposal procedure, record keeping for quantities of each garbage categories and calculate estimated amount of each garbage categories according to ships' complete voyage duration.
5. SUPPLY OF PROVISION: Respondents were asked to evaluate provision supply received from ship's chandler. In addition, respondent were to estimate garbage reduction if the supply were non-compliance stipulated in MARPOL 73/78.

A further description of the survey instrument is provided in Appendix C.

6.2.3 Data analysis

For statistical analysis, z-test was used to analyze the distribution of normality. Assessing normality using skewness and kurtosis of the distribution will give a more accurate result for small size samples ($n < 300$) (Kim, 2013). Therefore, critical values for normal distribution with an alpha level 0.05 for $n < 50$ and $n < 300$ are smaller than ±1.96 and ±3.29 respectively for absolute z-scores for either skewness or kurtosis. A $\log_{10}$ transformation ($\log_{10}$+1) of the data was applied for statistical analyses that did not assume a normal distribution (Ribic *et al.*, 2010). Pearson's correlation test between SGW (kg/vessel) and GGR (kg/person/day) with number of vessels, number of crews, vessels' gross tonnage, vessels' cruise (days), vessels' voyage duration (days) and garbage processing equipment were analyzed. Where this test indicated significant differences, a multiple linear regression (stepwise) model was used to identify which predictor variable contributed to the abundance of SGW and GGR. Two-way analysis of variance (ANOVA) was used to compare mean SGW between shipborne garbage categories (n=7) and shipborne garbage sources (n=4) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3). All statistical comparisons were performed using SPSS version 22 package software.

6.3 Results

6.3.1 Shipborne garbage abundance

From this study, the means SGW and GGR were 130.8±108.0 kg/vessel (15,037 kg) and 1.62±0.13 kg/person/day. Kota Kinabalu port accumulated the highest mean SGW at 159.2±126.3 kg/vessel (Table 22). Klang, Sandakan, Kuching and Bintulu ports accumulated 134.2±142.2 kg/vessel, 125.0±81.1 kg/vessel, 113.2±66.6 kg/vessel and 112.2±72.9 kg/vessel, respectively. Analyzing GGR, Kota Kinabalu port was the highest at 2.0 kg/person/day, followed by Kuching, Sandakan and Bintulu ports. Klang port had the lowest GGR at 1.3 kg/person/day considering vessels' gross tonnage was the highest among the study ports. The average cruise from last port of call and voyage duration was 4.2 days and 33.3 days respectively. From correlation analysis results (Table G 1 of Appendix G), $\log_{10}$ SGW is significantly correlated ($p<0.05$, $z<\pm3.29$, $n=115$) with the number of crews ($r=0.22$, $p=0.02$), $\log_{10}$ vessels' gross tonnage ($r=0.36$, $p=0.00$), $\log_{10}$ vessels' cruise ($r=0.28$, $p=0.00$) and vessels' voyage duration ($r=0.36$, $p=0.00$). Whereas $\log_{10}$ GGR was significantly correlated with ($p<0.05$, $z<\pm3.29$, $n=115$) with $\log_{10}$ vessels' cruise ($r=-0.67$, $p=0.00$). Multiple linear regression results ($R^2=0.91$, $p<0.00$) show that $\log_{10}$ vessels' gross tonnage ($\beta=0.65$, $t=7.49$, $p=0.00$), $\log_{10}$ vessels' cruise ($\beta=0.17$, $t=2.20$, $p=0.00$) and vessels' voyage duration ($\beta=0.15$, $t=2.08$, $p=0.00$) are significant factors in determining the abundance of $\log_{10}$ SGW ($\log_{10}$ SGW=0.09*($\log_{10}$ GRT)+0.14*($\log_{10}$ Cruise)+0.02*(Voyage) (Table G 2 of Appendix G), whereas, multiple linear regression results ($R^2=0.49$, $p<0.00$) shows $\log_{10}$ vessels' cruise ($\beta=-0.74$, $t=-10.34$, $p=0.00$) and vessels' voyage duration ($\beta=0.20$, $t=2.79$, p=0.01) are the determining factors for $\log_{10}$ GGR ($\log_{10}$ GGR = 0.81-0.67*($\log_{10}$ Cruise)+0.03*(Voyage) (Table G 3of Appendix G).

Table 22: Summary of shipborne garbage and vessels information according to ports

Variable	Number of vessel	Number of crew	Cruise duration (days)	Voyage duration (days)	SGW (kg/vessel)	GGR (kg/person /day)
Study ports						
Kuching	25	490	3.3	29.4	113.2±66.6	1.8
Bintulu	20	387	4.2	32.5	112.2±72.9	1.4
Kota Kinabalu	20	394	4.1	31.2	159.2±126.3	2.0
Sandakan	14	288	3.9	38.9	125.0±81.1	1.6
Klang	36	736	5.1	35.6	134.2±142.2	1.3
Ship types						
Container	46	957	3.9	31.6	131.1±127.6	1.6
Bulk carrier	34	686	5.1	38.8	156.4±114.4	1.5
General cargo	35	652	3.9	30.3	105.1±59.6	1.4
Ports classification						
Federal	56	1,123	10.6	34.5	129.9±121.4	0.6
State	59	1,172	5.0	32.2	131.6±94.6	1.3
Ports location						
Peninsular	36	736	5.1	35.6	134.2±142.2	1.2
Sabah	34	682	4.0	34.3	145.1±109.8	1.8
Sarawak	45	877	3.7	30.8	117.2±68.8	1.6
BGW classification						
Black	31	585	4.5	31.9	90.1±47.7	1.1
Grey	5	87	2.0	24.6	126.2±82.4	3.6
White	79	1,623	4.3	34.5	147.0±122.1	1.7

Analyzing mean SGW according to ship type (n=3) showed different distribution in amount of garbage weight (Table 22). Although, bulk carrier vessels has the highest mean SGW, container vessels' GGR was the highest at 1.6 kg/person/day compared to bulk carrier and general cargo vessels at 1.5 kg/person/day and 1.4 kg/person/day respectively. Analyzing correlation analysis results (Table G 4 of Appendix G) shows mean SGW is significantly correlated ($p<0.05$, $z<\pm1.96$, n=15) with vessels' voyage duration (r=0.53, p=0.04) between ship type (n=3) according to study ports (n=5), whereas, GGR was significantly correlated ($p<0.05$) with vessels' cruise (r=-0.57, p=0.03) and vessels' voyage duration (r=-0.66, p=0.01). Multiple linear regression analysis result shows vessels' voyage duration is a significant factor determining SGW (SGW=3.607*(Voyage)) (Table G 5 of Appendix G) and GGR (GGR=4.04-0.07(Voyage)) (Table G 6 of Appendix G) on the vessels. However, the degree of contribution towards the debris accumulation shows vessels' voyage duration (β=0.96, t=12.69, p=0.00) is a significant factor in SGW abundance (R^2=0.92, $p<0.05$) as compared to vessels' voyage duration (β=-0.66, t=-3.20, p=0.00) with GGR (R^2=0.44, $p<0.05$). Therefore, the results suggest vessels' voyage duration significantly correlate to garbage abundance on the vessels.

Analyzing mean SGW according to ports classification (n=2), the number of vessels calling to state ports was slightly higher compared to federal port (Table 22). However, vessel calling to federal ports has lower SGW and GGR compared to state ports. State ports' GGR is 1.3 kg/person/day, double compared to GGR at federal ports. From ports location (n=3) perspective, mean SGW was the highest at Sabah port compared to Peninsular and Sarawak ports (Table 22). Vessels visited Sabah port also has the lowest garbage processing equipment installed on the vessel. Although, the number of crew was lesser compared to vessels visited Peninsular and Sarawak ports, the GGR was the highest at 1.8 kg/person/day. Pearson's correlation result (Table G 7 of Appendix G) shows mean SGW is significantly correlated ($p<0.05$, $z<\pm1.96$, n=3) with number of crews (r=-1.00, p=0.00). GGR was not significant correlated with the variables. Multiple linear regression analysis results show (R^2=1.00, $p<0.05$) that number of crew (β=-1.00, t=-128.20, p=0.01) is a significant factors in determining SGW (SGW=234.58-0.134*(Crew)) (Table G 8 of Appendix G). This indicates number of crews influences the mean SGW abundance on the vessel.

BGW classification (n=3) of vessel according to the port of registry (Tokyo MOU, 2013) identified 31 vessels fell in the black list, five vessels in grey list and 79 vessels in white list (Table 22). Means SGW and GGR were the highest for white and grey list vessels at 147.0±122.1 kg/vessel and 3.6 kg/person/day, respectively. Analyzing correlation results (Table G 9 of Appendix G) shows mean SGW is significantly correlated ($p<0.05$, $z<\pm1.96$, n=15) with number of vessel (r=0.53, p=0.04), number of crews (r=0.53, p=0.04), vessels' cruise (r=0.63, p=0.01) and vessels' voyage duration (r=0.69, p=0.01) according to study ports (n=5) and BGW classification (n=3). However, mean GGR was not significant correlated ($p>0.05$, $z<\pm1.96$, n=15) with the variables. Multiple linear regression results ($R^2=0.87$, $p<0.05$) shows that vessels' voyage duration ($\beta=0.93$, t=9.47, p=0.00) is a significant factors in determining SGW (SGW=3.68*(voyage)) on the vessels (Table G 10 of Appendix G).

6.3.2 Shipborne garbage category

Table 23 shows mean SGW accumulated according to garbage categories in this study. Food waste category accumulated the highest garbage weight on the vessels at 32.63%; followed by cargo residue (26.20%) and plastic (16.35%) categories, while, cooking oil was the lowest SGW accumulated at 0.92%. Animal carcasses and fishing gear were not accumulated by vessels in this study.

Table 23: Mean SGW and percentage of shipborne garbage accumulated according to garbage categories

Category	Mean SGW (kg/vessel)	% of total SGW
Plastic	21.4±31.5	16.35
Food waste	42.7±45.0	32.62
Domestic waste	15.5±30.1	11.84
Cooking oil	1.2±2.4	0.92
Incinerator Ashes	4.1±6.7	3.13
Operational waste	11.7±10.6	8.94
Cargo residue	34.3±41.6	26.20

Figure 30 shows garbage categories mean SGW accumulated according study ports, ship types, ports classification, ports location and BGW classification, whereas Table G 11 (refer Appendix G) shows detail garbage abundance result. The results show Klang port accumulates substantially higher quantity of plastic, food waste and domestic waste categories at 27.7±49.9 kg/vessel, 48.8±67.4 kg/vessel and 17.9±49.1 kg/vessel, respectively (Figure 30a). Whereas, Kuching, Bintulu, Sandakan and Kota Kinabalu ports accumulated the highest for operational waste, incinerator ashes, cooking oil and cargo residue categories at 13.8±13.6 kg/vessel, 6.6±12.3 kg/vessel, 1.9±2.6 kg/vessel and 70.0±80.8 kg/vessel, respectively. Analyzing mean SGW from ship's type perspective, container vessels accumulated the highest for plastic, domestic waste and operational waste categories at 27.4±44.4 kg/vessel, 17.8±43.9 kg/vessel and 13.3±10.8 kg/vessel, respectively (Figure 30b). Bulk carrier vessels were the highest for food waste, cooking oil and cargo residue categories at 50.9±37.5 kg/vessel, 1.8±2.0 kg/vessel and 46.5±60.1 kg/vessel respectively, whereas, general cargo vessel accumulated the highest for incinerator ashes at 5.7±9.9 kg/vessel. For ports classification perspective, federal port accumulated the highest SGW for plastic, food waste, domestic waste and incinerator ashes categories at 24.7±41.9 kg/vessel, 45.4±56.5 kg/vessel, 15.9±40.5 kg/vessel and 4.2±8.1 kg/vessel respectively (Figure 30c). State port accumulated the highest for cooking oil, operational waste and cargo residue at 1.3±1.8 kg/vessel, 11.9±12.2 kg/vessel and 40.9±53.6 kg/vessel respectively. Comparing mean SGW between ports location, Peninsular port accumulated the highest for plastic (27.7±49.9 kg/vessel), food waste (48.8±67.4 kg/vessel), domestic waste (17.9±49.1 kg/vessel) and cooking oil (1.4±3.5 kg/vessel) (Figure 30d). Sarawak port accumulated the highest for incinerator ashes (5.0±8.9 kg/vessel) and operational waste (12.4±11.8 kg/vessel) categories, while, Sabah port were the highest for cargo residue (52.8±67.0 kg/vessel) category. Analyzing mean SGW according to BGW classification, white list vessels accumulated the

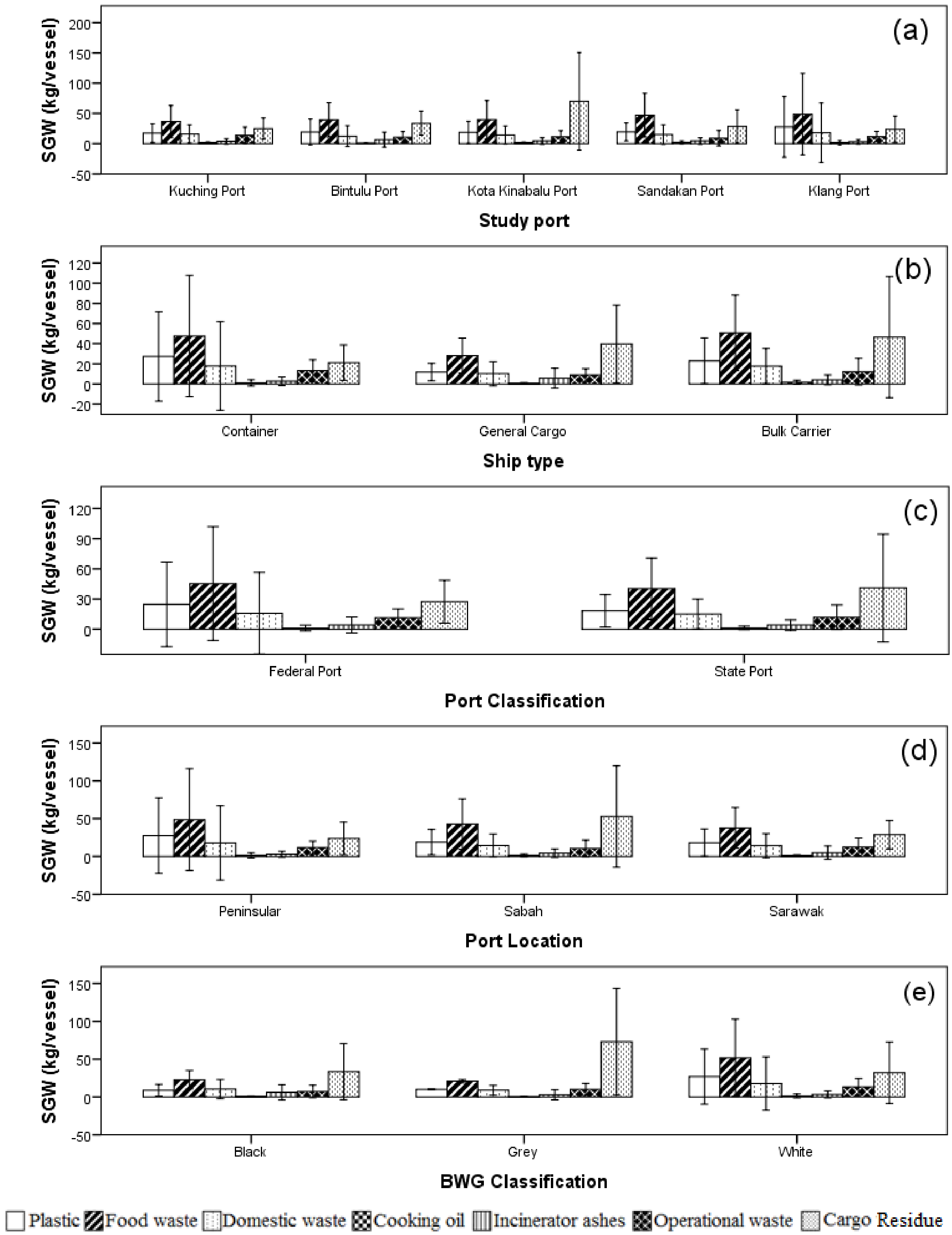


Figure 30: SGW (with standard deviation) garbage category according to (a) study ports, (b) ship types (c) ports classification, (d) ports location and (e) BGW classification

highest for plastic, food waste, domestic waste, cooking oil and operational waste categories at 27.0±36.4 kg/vessel, 51.8±51.3 kg/vessel, 17.8±35.2 kg/vessel, 1.4±2.8 kg/vessel and 13.5±11.1 kg/vessel respectively, while, black and grey list vessels were the highest for incinerator ashes and cargo residue categories at 6.1±10.1 kg/vessel and 73.0±70.5 kg/vessel respectively (Figure 30e).

The distribution of mean SGW (kg/vessel) for garbage category (n=7) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA analysis results to compare garbage categories mean SGW between study ports showed plastic category was significantly different ($p<0.05$) from food waste and cooking oil categories (Figure 31a). However, food waste category was significantly different ($p<0.05$) from all garbage categories except for cargo residue category. Univariate ANOVA analysis results to compare between ship type shows mean SGW for plastic category was not significantly different ($p>0.05$) from other garbage categories, however, food waste category was significantly different ($p<0.05$) from domestic waste, cooking oil, incinerator ashes and operational waste categories (Figure 31b). From ports location perspective, univariate ANOVA results showed mean SGW for plastic category was significantly different ($p<0.05$) from food waste, cooking oil and operational waste categories, while, food waste category was significantly different ($p<0.05$) from other garbage categories except for cargo residue category (Figure 31c). Univariate ANOVA results for BGW classification showed mean SGW for plastic and food waste categories were not significantly different ($p>0.05$) from other garbage categories (Figure 31d). The garbage categories mean SGW univariate ANOVA analysis results among study ports, ship types, ports location and BGW classification were not significantly different ($p>0.05$).

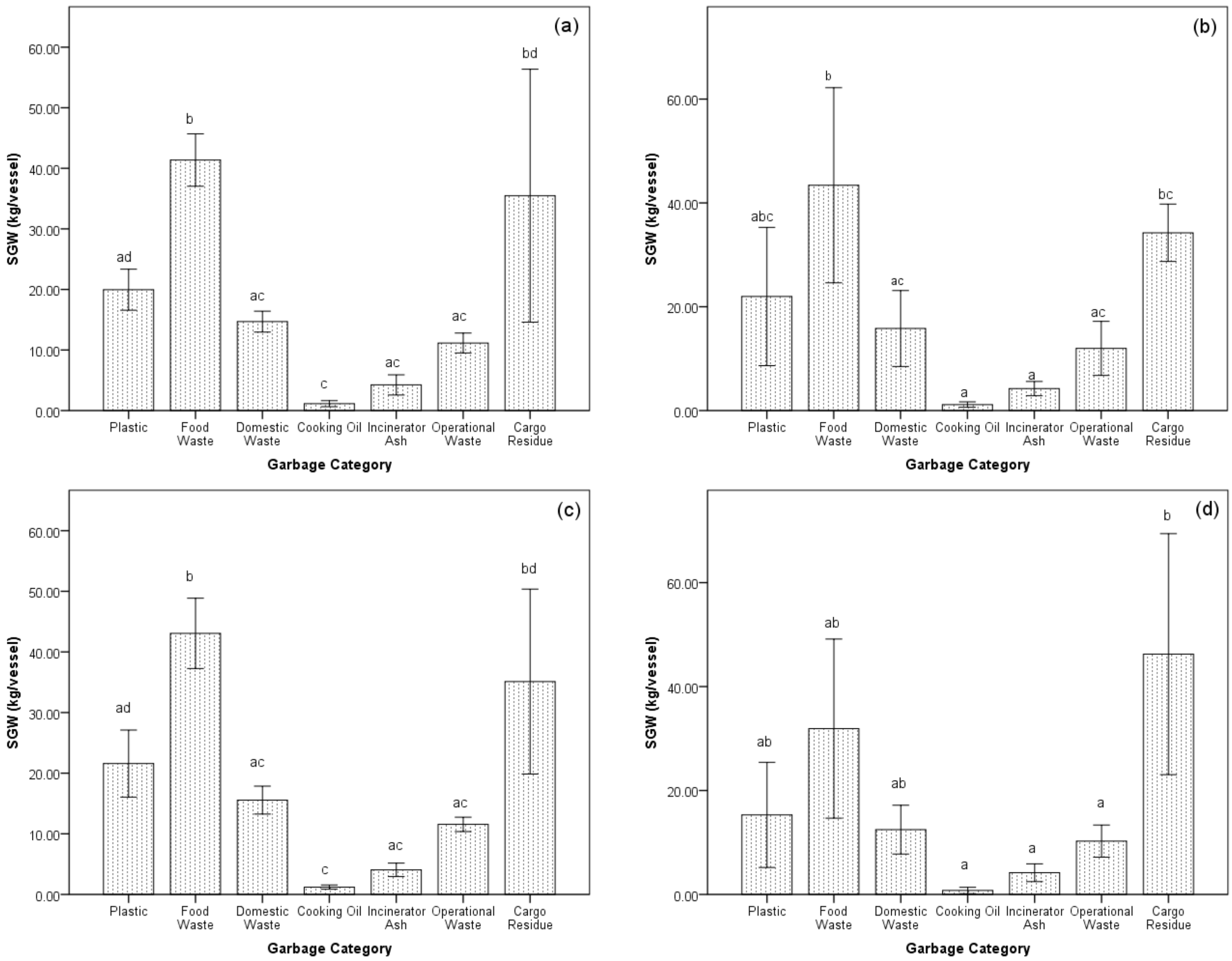


Figure 31: SGW (with standard deviation) garbage category (n=7) according to (a) study ports (n=5), (b) ship types (n=3), (c) ports location (n=3) and (d) BGW classification (n=3)
Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different ($p<0.05$) from the other groups.

6.3.3 Shipborne garbage source

As for sources of shipborne garbage, crew source has the highest mean SGW at 47.8±48.5 kg/vessel compared to maintenance, cargo and common sources at 40.1±37.2 kg/vessel, 32.9±23.7 kg/vessel and 30.4±16.9 kg/vessel, respectively. Figure 32 shows garbage source mean SGW accumulated according study ports, ship types, ports classification, ports location and BGW classification, whereas, Table G 12 (refer Appendix G) shows detail garbage abundance results. Klang port accumulated the highest mean SGW for crew and common sources at 69.0±90.5 kg/vessel and 28.0±49.9 kg/vessel respectively.

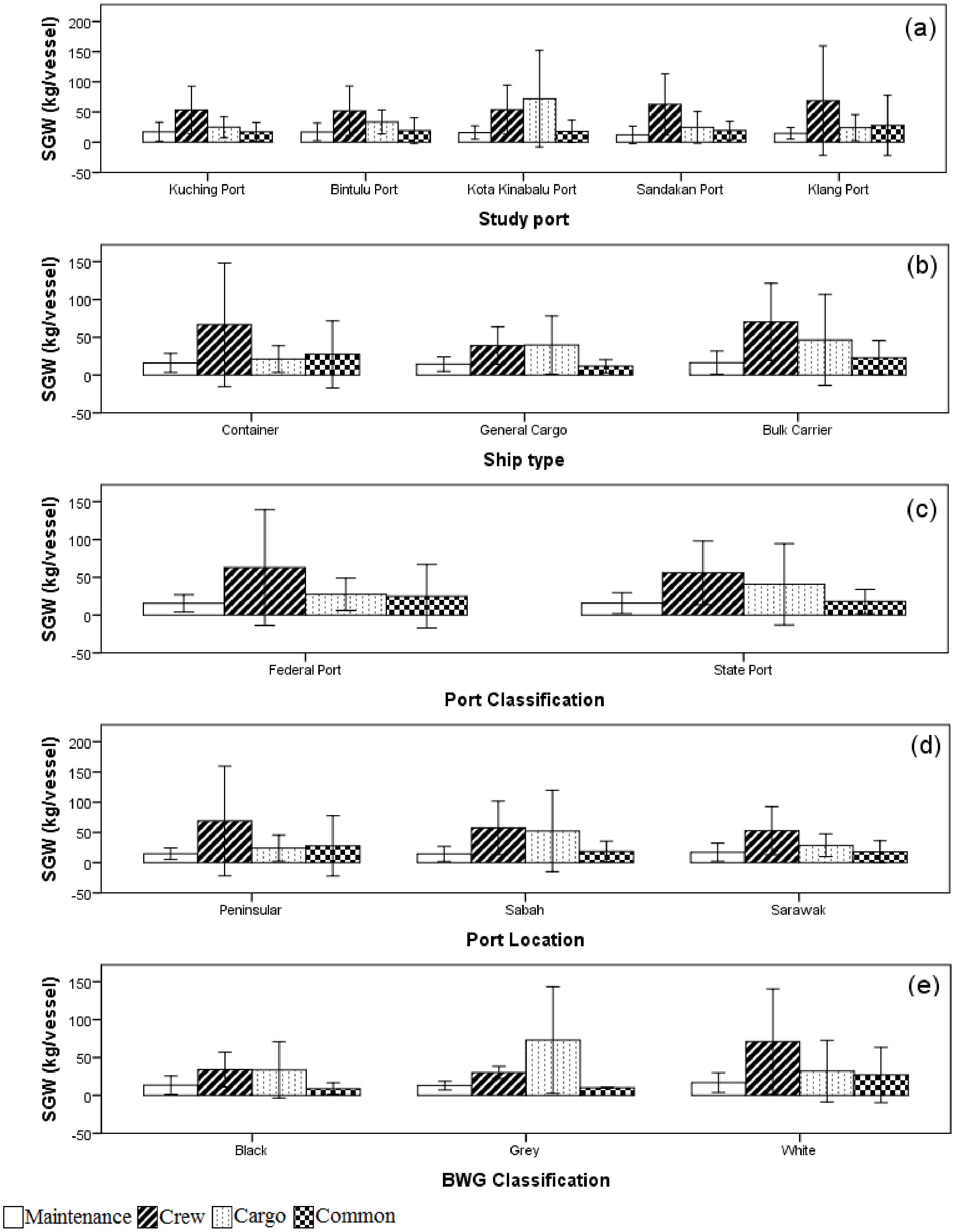


Figure 32: SGW (with standard deviation) garbage source according to (a) study ports, (b) ship types (c) ports classification, (d) ports location and (e) BGW classification

Kuching port accumulated the highest for maintenance sources at 17.5±15.6 kg/vessel, while, Kota Kinabalu port accumulated the highest for cargo source at 72.0±79.9 kg/vessel (Figure 32a). Analyzing garbage source according to ship types, bulk carrier vessels accumulated the highest mean SGW for maintenance, crew and cargo sources at 16.5±15.5 kg/vessel, 70.4±50.9 kg/vessel and 46.5±60.1 kg/vessel respectively, while, container vessels accumulated the highest for common source (Figure 32b). As for ports location, federal ports accumulated the highest mean SGW for crew and common sources, while, state ports were the highest for maintenance and cargo sources (Figure 32c). Comparing mean SGW between ports location, Peninsular port accumulated the highest for crew (69.0±90.5 kg/vessel) and common (28.0±49.9 kg/vessel) sources, while, Sabah and Sarawak ports accumulated the highest for cargo and maintenance sources at 52.5±67.2 kg/vessel and 17.4±15.0 kg/vessel respectively (Figure 32d). For BGW classification perspective, white list vessels accumulated the highest for maintenance, crew and common sources at 16.9±13.1 kg/vessel, 71.0±69.5 kg/vessel and 27.0±36.4 kg/vessel respectively. The grey list vessels accumulated the highest for cargo source at 73.0±70.5 kg/vessel (Figure 32e).

The distribution of mean SGW (kg/vessel) for garbage sources (n=4) according to study ports (n=5), ship types (n=3), ports location (n=3) and BGW classification (n=3) were not different from normal distribution ($p>0.05$, $z<\pm1.96$). Univariate ANOVA analysis results to compare garbage source mean SGW between study ports showed crew source was significantly different ($p<0.05$) from other garbage sources (Figure 33a). Univariate ANOVA results to compare between ship types (Figure 33b) and ports location (Figure 33c) shows mean SGW for crew source was significantly different ($p<0.05$) from maintenance and common sources. Univariate ANOVA results for BGW classification showed mean SGW for crew source was not significantly different ($p>0.05$) from other garbage categories (Figure

33d). The garbage categories mean SGW univariate ANOVA analysis result among study ports, ship types, ports location and BGW classification were not significantly different (p>0.05).

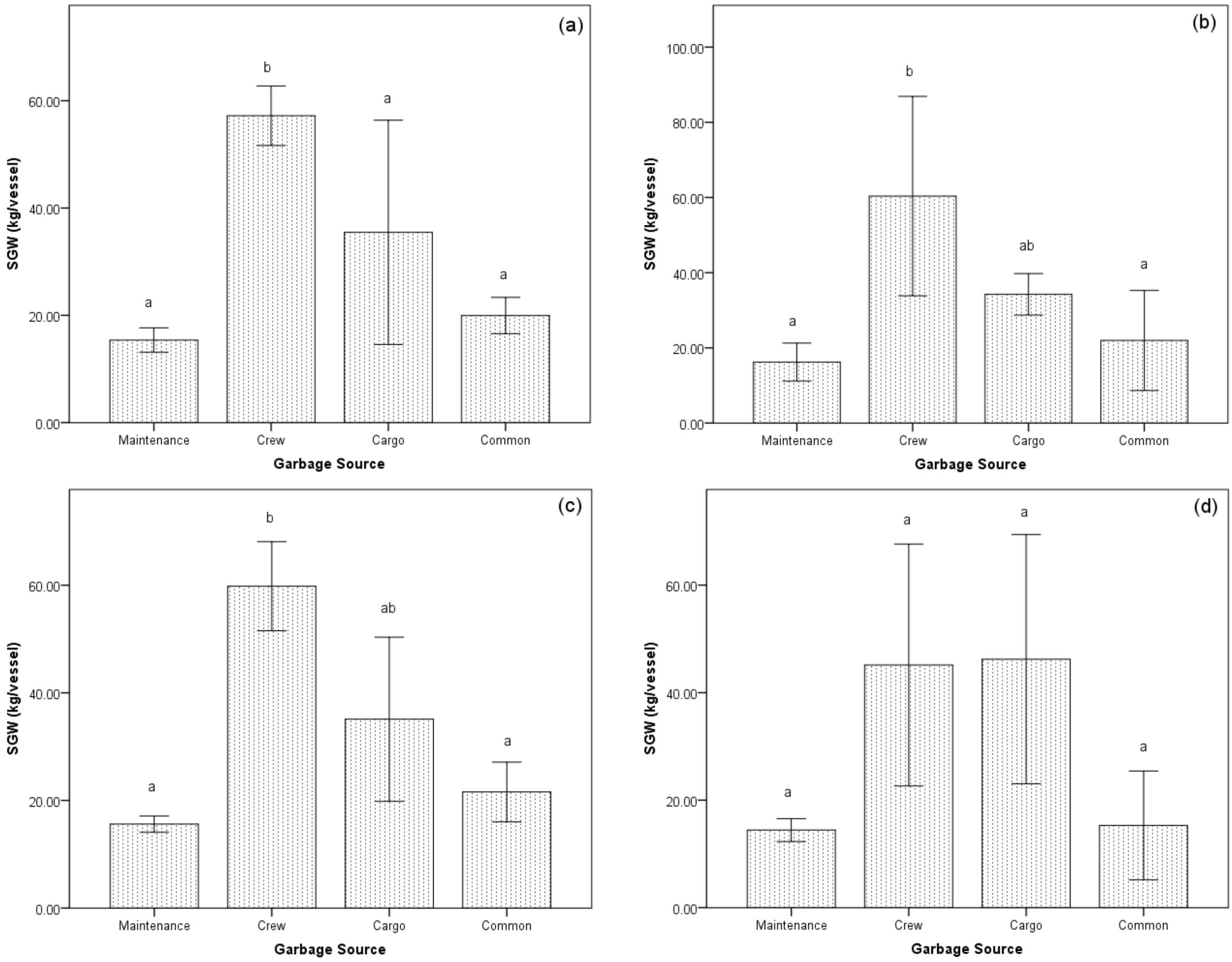


Figure 33: Mean SGW (with standard deviation) garbage sources (n=4) according to (a) study ports (n=5), (b) ship types (n=3), (c) ports location (n=3) and (d) BGW classification (n=3)
Note: The groups with the same letter indicates homogeneous, while, those with different letter were significantly different (p<0.05) from the other groups.

6.3.4 Vessel processing equipment

This study found that 77 (66.70%) vessels were equipped with garbage processing equipment, while, 63 (54.78%) vessels discharged shipborne garbage at Malaysian ports. From the total vessel sampled, 72 (62.61%) vessels were equipped with incinerator, 40 (34.78%) vessels were equipped with comminutor and five (4.35%) vessels equipped with garbage compactor (Figure 34a). Availability of garbage processing equipment on the vessels according to study ports shows Klang port (37.61%) has the most vessels equipped with garbage processing equipment (Figure 34b). From ship's type perspective, bulk carrier (50.43%) was the highest vessels equipped with garbage processing equipment (Figure 34c).

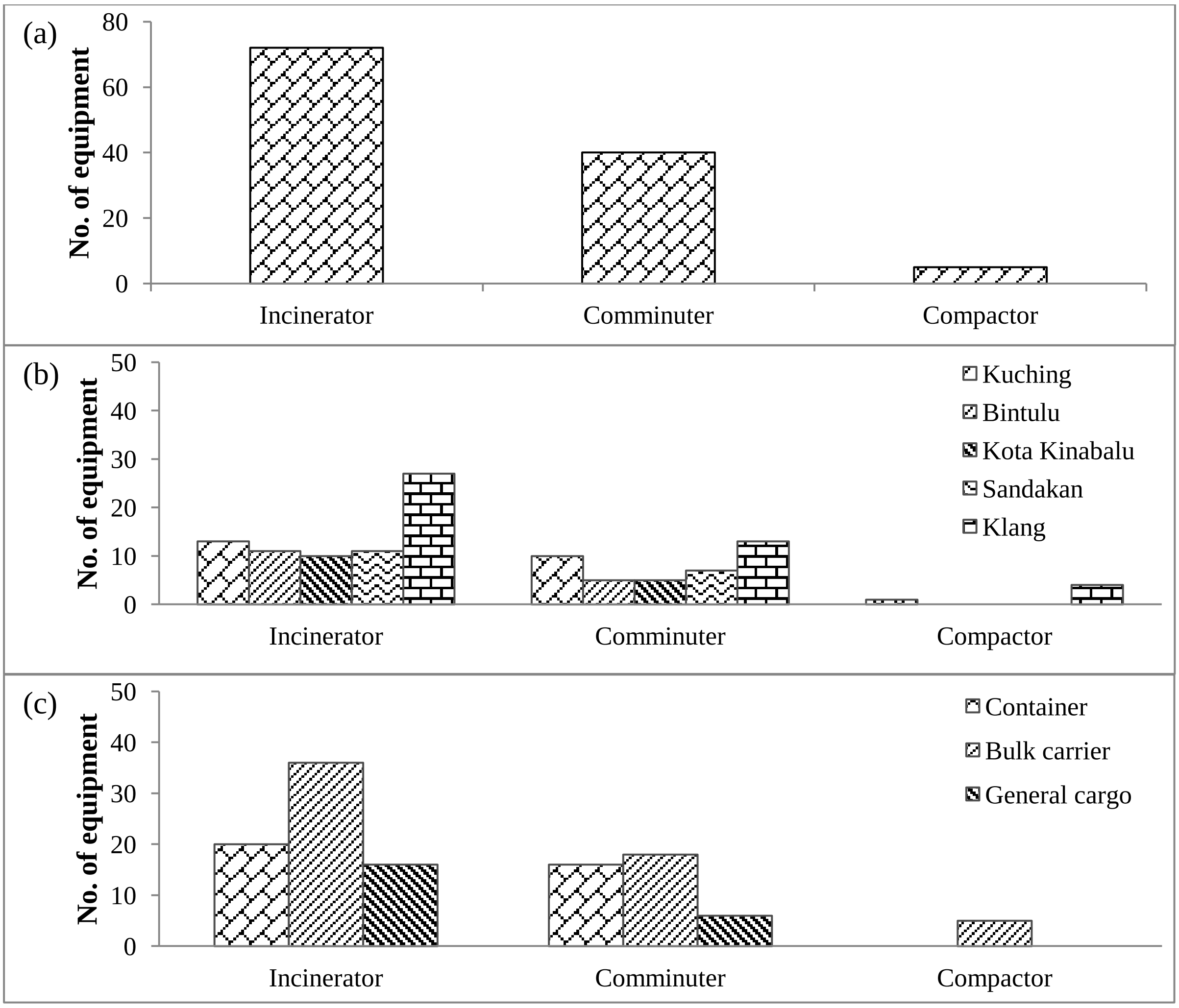


Figure 34: Number of processing equipment on the (a) vessel, (b) according to study ports and (c) according to ship type

From correlation analysis, number of vessels' processing equipment is significantly correlated ($p<0.05$, $z<\pm3.29$, $n=115$) with $\log_{10}$ SGW ($r=0.31$, $p=0.00$), number of crews ($r=0.39$, $p=0.00$), $\log_{10}$ vessels' gross tonnage ($r=0.62$, $p=0.00$) and vessels' voyage duration ($r=0.32$, $p=0.00$) (Table G 1 of Appendix G). However, multiple linear regression results

(R^2=0.38, $p<0.05$) show that $\log_{10}$ vessels' gross tonnage (β=0.62, t=8.33, p=0.00) is the only significant factor in determining installation of vessels' processing equipment (Proc. equipment=1.08*($\log_{10}$ GRT)-3.36) (Table G 13 of Appendix G). When analyzed according to ship types, correlation analysis result (Table G 4 of Appendix G) shows that number of vessels (r=0.95, p=0.00), number of crews (r=0.96, p=0.00) and vessels' gross tonnage (r=0.98, p=0.00) are significantly correlated ($p<0.05$, $z<\pm3.29$, n=15) with number of vessels' processing equipment. Multiple linear regression results (R^2=0.99, $p<0.05$) shows number of crews (β=0.52, t=8.60, p=0.00) and vessels' gross tonnage (β=0.50, t=8.14, p=0.00) were determining factors for installing garbage processing equipments on the vessel (Proc. equipment =0.20*(Crew)+1.28*(GRT)) (Table G 14 of Appendix G). Ports location perspective, correlation analysis results (Table G 7 of Appendix G) shows GGR (r=-0.99, p=0.03) is significantly correlated ($p<0.05$, n=3) with number of vessels' processing equipment. Multiple linear regression results (R^2=0.99, $p<0.05$) shows GGR (β=-0.99, t=-21.36, p=0.03) is a determining factors for installing garbage processing equipments on the vessel (Proc. equipment=45.93-13.21*(GGR)) (Table G 15 of Appendix G). From BGW classification perspective, correlation result (Table G 9 of Appendix G) also showed number of vessel (r=0.96, p=0.00), number of crews (r=0.97, p=0.00) and vessels' gross tonnage (r=0.98, p=0.00) were significantly correlated ($p<0.05$, n=15) with number of vessels' processing equipment. Multiple linear regression results (R^2=0.99, $p<0.00$) also showed number of crews (β=0.53, t=7.50, p=0.00) and vessels' gross tonnage (β=0.48, t=6.81, p=0.00) were determining factors for garbage processing equipment's installation on the vessel (Garbage proc. equipment=0.20*(Crew)+1.28*(GRT)) (Table G 16 of Appendix G).

6.3.5 Estimating shipborne garbage weight

Analyzing the number of vessel using Malacca straits in year 2014 (JLM, 2015), this study estimated a total of 6,131.1 MT of shipborne garbage weight was carried by container, bulk carrier and general cargo vessels that used Malacca straits (Table 24). This analysis results show the estimated amount of shipborne garbage weight may increase 16% by the year 2020 at 7,320.8 MT. Although this study found container vessels mean SGW was lower when compared to bulk carrier vessels, this analysis results show container vessel may contribute the highest garbage weight in the year 2020 at 3,931.4 MT.

Table 24: Mean SGW (kg/vessel) and estimated garbage weight (EGW) according to ship types

Ship type	This study SGW	EGW (MT)		
		2014	2015	2020
Container	131.1±127.6	3,292.5	3,391.2	3,931.4
Bulk carrier	156.4±114.4	2,104.0	2,167.1	2,512.2
General cargo	105.1±59.6	734.6	756.7	877.2
Total		6,131.1	6,315.1	7,320.8

Estimating shipborne garbage weight according to garbage category, food waste category is the highest garbage weight carried by container, bulk carrier and general cargo vessels amounting to 1,943.4 MT in the year 2014 and expected to increase to 2,320.6 MT in the year 2020 (Table 25). In addition, cargo residue is estimated at 1,561.1 MT which is substantially higher when compared to other garbage categories. The lowest garbage category estimated on the vessels was cooking oil category amounting to 54.6 MT.

Table 25: Mean SGW (kg/vessel) and EGW (MT) according to garbage categories

Garbage Category	This study SGW	EGW		
		2014	2015	2020
Plastic	21.4±31.5	974.0	1,003.2	1,163.0
Food waste	42.7±45.0	1,943.4	2,001.8	2,320.6
Domestic waste	15.5±30.1	705.5	726.6	842.4
Cooking oil	1.2±2.4	54.6	56.3	65.2
Incinerator ashes	4.1±6.7	186.6	192.2	222.8
Operational waste	11.7±10.6	532.5	548.5	635.8
Cargo residue	34.3±41.6	1,561.1	1,608.0	1,864.1

6.3.6 Vessels' provision supply

A vessel generates a range of shipborne garbage depending on vessel types and routine activities. This study identified 59 vessels having a contract with a ship chandler for a specified contract period in order to get a guaranteed competitive price for the service rendered. From the information gathered, 36% (41) respondents were keen to get provision supply from Malaysian ports due to varieties, fresh supplies, more choices and competitive price, while, 51% (49) respondents get provision supply from other ports (Figure 35a). However, 44% (50) respondents were not satisfied with the level of MARPOL 73/78 Annex V requirement awareness among ship's chandler (Figure 35b). This study found that, vessels which operates with minimum operational budget are categorized in the black list (Tokyo MOU, 2013). These vessels will opt for even cheaper supply of food and raw materials. Such trade could result in the provision supply with unfriendly environment packaging and non-compliance according to MARPOL 73/78 Annex V. In contrast, 25% (29) respondents concurred ship's chandler adherence to MARPOL 73/78 requirement due to vessel receiving provision supply pre-arranged by the owner or a vessel implementing strict GMP towards garbage intake or company implementing strict policy for compliance to international conventions.

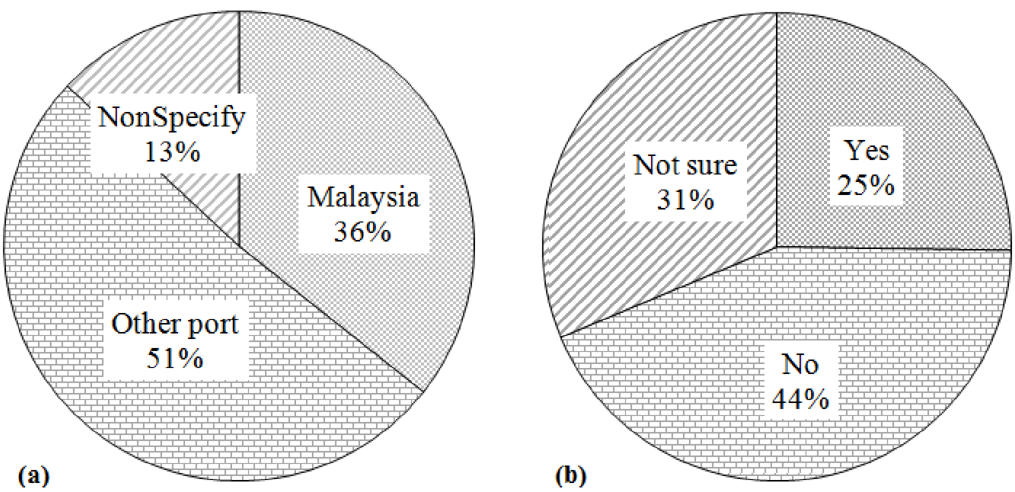


Figure 35: Composition of (a) vessels' acquire provision supplies according to port and (b) ship's chandler perceive MARPOL 73/78 Annex V according to respondents' observation

Figure 36 shows the estimated amount of shipborne garbage reduction when a ship chandler is aware and more responsible towards the MARPOL 73/78 Annex V requirements. The results show 95 respondents (83%) agreed that the amount of shipborne garbage could reduce between 10-30 kg on the vessel. A reduction between 30-50 kg of shipborne garbage on the vessel can be achieved as suggested by 17 respondents (14%), whereas, three respondents (3%) anticipated a reduction of more than 50 kg of shipborne garbage on the vessel.

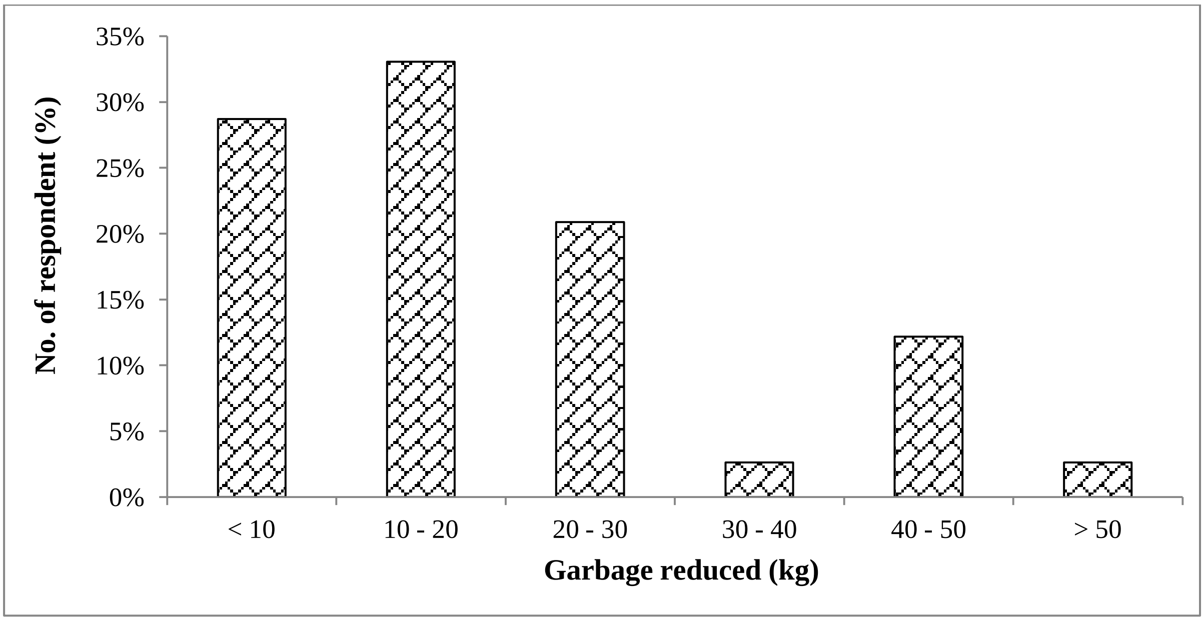


Figure 36: Estimated shipborne garbage reduction when ship chandler adheres to MARPOL 73/78 Annex V requirement

6.3.7 Respondents’ suggestions to reduce SGW

In this study, suggestions to reduce shipborne garbage waste on the vessel were collected through an open ended question (Appendix C). The information gathered was grouped into awareness programs, garbage management, product improvements and garbage entry (Figure 37). Awareness program was the highest suggested by 72 respondents (63%). The proposal to use eco-friendly product presents a perspective on the responsibility of the respondent. This study result shows, 20 respondents (17%) suggested conventional packaging should be replaced with innovative packaging. Although, MARPOL 73/78 annex V has developed guidelines to reduce garbage on the vessel, 14 respondents (12%) suggested the regulation can be improved. However, the lowest but not the least important is garbage entry to the vessel; nine respondents (8%) believe garbage entry point should be regulated.

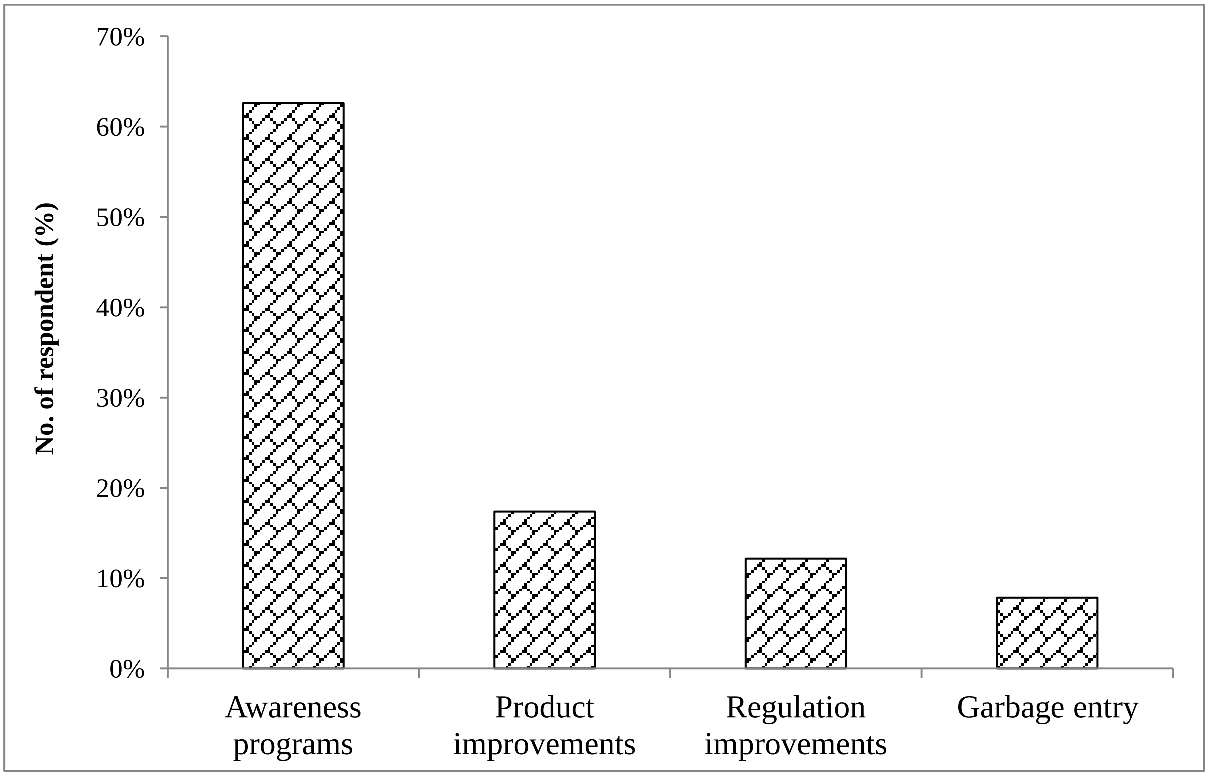


Figure 37: Respondent suggestion to reduce shipborne garbage

6.4 Discussion

6.4.1 Shipborne garbage abundance

From this study, the mean SGW accumulated was 130.8±108.0 kg/vessel. This study found that vessel visiting Kota Kinabalu port accumulated the highest mean SGW at 159.2±126.3 kg/vessel. Although container vessels recorded the highest vessel type visiting at Malaysian ports, bulk carrier vessels accumulated the highest mean SGW at 156.4±114.4 kg/vessel which may be attributed to the abundance of mean SGW at Kota Kinabalu port. Analyzing mean SGW according to ports location shows vessels visiting Sabah port contributed significantly higher mean SGW compared to vessels visiting Peninsular and

Sarawak ports. Significant correlation analysis results suggest number of crews, vessels' gross tonnage and voyage duration contribute to the amount of garbage weight accumulated on the vessel, thus, the substantially higher number of white list classification vessels (69%) visiting Malaysian ports could contribute to the garbage weight abundance. This can explain the requirement of larger and more competent crew member to manage and operates sophisticated vessels. Although, federal ports are major regional distribution and trans-shipment hub, whereas, state port handles intra-regional cargo (Khalid, 2010, 2006); there were no significant difference in mean SGW abundance between ports classifications. Therefore, this study result suggests, vessel generates shipborne garbage depending on vessel types, routine activities and the type of trade at the study ports. Realizing Malaysia as a leading maritime global *halal* hub (Khalid, 2009), the importance of protecting the environment should be paralleled with economic progress targeted in Malaysia.

The information on mean SGW garbage category collected from this study shows food waste was the highest (32.62%) category accumulated according to study ports, ship types and ports location. Similar studies (Polglaze, 2003; Nawadra *et al.*, 2002; European Commission Directorate-General for Transport, 1998; Horsman, 1982) also recorded food waste was the most dominant and difficult waste to handle on a vessel. The mean SGW for plastic category in this study where accumulation was 16.35% is lower compared to Zuin *et al.* (2009) at 20%. Cargo residues category which includes any damage cargo on the vessel, in cargo holds or tanks accumulated 26.20% in this study. The higher mean SGW for plastic, food waste, domestic waste and incinerator ashes categories can be related to the high number of bulk carrier vessels, while, general cargo and container vessels were for cargo residue and operational waste categories (Table 22). In addition, this study found vessels categorized in the black list classification, preferred for cheaper food supplies and raw materials with unfriendly environment packaging and non-compliance according to MARPOL 73/78 Annex V. Identifying the garbage on the basis of ownership alone is difficult since plastics material are durable, buoyant and can travel long distance (Sheavly, 2005a; Derraik, 2002). Other studies (Sesini, 2011; Johnson, 2008; UNEP, 2005) found discarded plastic items floating on the ocean transported to locations far from the site of discharge, therefore, debris may land on Malaysian coastline if vessels illegally discharge shipborne garbage within MTW.

The study of garbage sources has given better understanding on shipborne garbage's root cause on the vessels. This study which analyzed mean SGW according to garbage sources shows garbage from crew source accumulated significantly higher mean SGW according to study ports, ship types and ports location (Figure 33). Garbage weight identified contributing to the abundance of crew source was food waste. Although the revised MARPOL 73/78 (IMO, 2012b) which requires all types of plastics, cooking oil and incinerated ashes discharged into the sea be totally prohibited, the possibilities for discharging shipborne garbage illegally within the MTW could be significant especially vessels that navigate through Malacca strait (JLM, 2015) to Japan or China is within MTW. Those vessels most likely contribute to the debris wash ashore at the coastlines.

6.4.2 Vessel garbage management

To ensure every vessel complies to MARPOL 73/78 annex V (IMO, 2012b), Reg.10 describes the requirement to provide written procedure to manage shipborne garbage. In this study, six vessels were incompliance to this requirement, while, 15 vessels were not keeping GRB particulars updated. These vessels operate within ASEAN countries (near coastal trade) and falls under black list classification. From the researcher observation, these vessels are unlikely practicing garbage segregation especially vessels' voyage at open sea. In the event of such vessels en route through MTW, illegal shipborne garbage discharge most likely increased and eventually causes significant impact towards marine wildlife and Malaysia marine environment. Therefore, port authority and shipping agent should play an important role by allowing and engaging only vessel which complies with international regulation, thus, minimizing substandard vessels visiting Malaysian ports. In the event of such vessel visiting Malaysian port, enforcement should not be relaxed especially to vessels with poor shipborne garbage management (Rakestraw, 2012).

This study found private garbage collection contractors were engaged to collect and dispose vessels' garbage since the study ports were not equipped with reception facilities for processing shipborne garbage. Although these contractors are capable of collecting all types of shipborne garbage, the most common garbage type discharge from vessels were plastic, domestic waste, medical waste, operational and cargo residue categories. Since garbage collected by contractors are charged according to garbage volume, food waste and mixed food waste are discharged at sea; thus, indicating the possibilities of other garbage categories being discharge illegally at sea. Nevertheless, shipborne garbage is the responsibility of all parties that are dealing directly or indirectly with vessels' operation. In this competitive industry, ship's chandler should be proactive and be supportive of the shipping industry by being more responsible and aware of the international convention requirements. Biodegradable plastic or other forms of innovative packaging can be introduced to reduce the use of plastic packaging materials (O'Brine & Thompson, 2010; Song *et al.*, 2009; Zheng *et al.*, 2005).

This study found the GGR for container, bulk carrier and general cargo vessels were 1.6 kg/person/day, 1.5 kg/person/day and 1.4 kg/person/day, which is approximately the same as estimated by IMO at 1.5 kg/person/day (Palabıyık, 2003; Nawadra *et al.,* 2002). Although, this study statistical analysis results show GGR was not significantly correlated with number of crews, IMO suggested shipborne garbage from crew source is to be of particular concern (Nawadra *et al.*, 2002). Crew members generate garbage consists of food wastes, glass, plastics, paper, cans, cardboard and rubber materials. If each crew fails to secure garbage appropriately from windblown, makes no effort to segregate garbage at vessels garbage station, fails to process food waste shipborne garbage before discharge to the sea or litters overboard; there is a high possibility for plastic-based garbage materials being introduced into the marine environment. In addition to information gathered from respondents, monitoring illegal discharge at sea is difficult due to crew members' attitude of performing illegal discharge without guilt, therefore, with the introduction of environmentally friendly packaging products, to some extent, can reduce the impact of pollution on the marine environment. From an environmental perspective, it is appropriate to focus on reducing the shipborne garbage particularly plastic-based material from going into the vessel.

In this study, 63% respondent concurs awareness programs on the vessel is an essential effort that needs to be conducted on regular basis. On the vessel, awareness program is a compulsory program stipulated in the International Safety Management Code (ISM Code) to be conducted on a weekly basis to all crew members. Among the awareness program undertaken on the vessel are the procedures for waste management, operation of garbage processing equipment, waste reduction practices and crew personal hygiene. However, to ensure the management of waste at sea is implemented effectively, awareness programs should also be focused on all businesses that deal indirectly with shipping activities. Port authority should lead in ensuring the implementation of MARPOL 73/78 Annex V effectively within port area, such as providing $1m^3$ mobile garbage bins for each vessel to discharge shipborne waste at which the cost can be incorporated in the port charges or require every vessel to discharge all shipborne waste before sailing. Although this method will not eliminate illegal discharge at sea, this can ensure shipborne garbage to be managed in a more responsible manner and may indirectly prevent ships illegally discharging at sea. Nevertheless, awareness of marine environment pollution should start from the source that supplies the products since traders are unaware plastic material elements will enter the vessel. Therefore, awareness programs can be targeted at vessels' crew member, ports' operation staff, ships chandler, traders and other groups dealing indirectly with shipping activities. Consequently, this will create awareness to all parties dealing direct or indirectly with shipping activities as the responsibilities of marine environment do not lie on vessel alone.

6.4.3 Vessel processing equipment

This study found there were three major debris disposal methods practiced by crew members; discharge to port, discharge to sea and processing garbage at sea. The requirement of garbage processing equipment elaborated in Section 2.5 of Res.MEPC 219(63) describes alternative methods to improve the shipborne garbage management (IMO, 2012c). Although, the requirement of garbage processing equipment is not compulsory, ship owners are obligated to ensure sufficient processing equipment are installed on the vessels depending on the type of ship, area of operation and number of crew. The use of compactors (processing operational waste), incinerators (processing cargo residues, operational and domestic wastes), and comminutors (processing food waste) are among recommended equipments to process shipborne garbage on the vessel. Vessels may be installed with one or more processing equipment depending on the ship owners' commitment towards environmental protection.

In this study, 63% vessels were equipped with incinerator, while, 35% vessels were equipped with comminutor and only 4% vessels equipped with garbage compactor from the total vessels sampled (Figure 34a). Among the reasons in low vessel equipped with garbage processing equipments was due to vessels' cruise from last port and voyage duration. Although, studies have shown that processing equipment can reduce shipborne garbage volume and weight by 90% and 70% respectively (Delfosse *et al.*, 2010; Zuin *et al.*, 2009; Johnson, 2008; Butt, 2007; Prelec *et al.*, 2006; European Commission Directorate-General for Transport, 1998), this study found that discharging shipborne garbage at port is cheaper for vessels operating on shorter cruise or voyage compared to having processing equipment installed on the vessels. Nevertheless, vessels equipped with garbage processing equipment indicate the commitment shown by these vessels to establish support and determination towards minimizing if not totally eradicating illegal discharge of garbage to sea.

In a complementing effort, 12 vessels did engage in some form of waste recycling for objects including plastic bottles, used batteries, aluminum cans and cardboard carton which were sold to local recycler company in Thailand, Vietnam and India. Although, recycling company in Malaysia gives attractive prices for plastic bottles (RM 0.20/kg), copper (RM8.30/kg), aluminum cans (RM 3.80/kg), metal (RM 0.10/kg) and cardboard carton (RM 0.25/kg), these information were not communicated to the vessels' crew. Therefore, port authorities and recycling companies in Malaysia should cooperate by providing such initiatives to vessels visiting Malaysian ports. As a result, recyclable objects would not be deliberately discarded at sea instead discharged at port for sale. However, for non-recyclable objects such as plastic fragments, plastic shopping bags and plastic packaging might be illegally discharged to sea. Thus, it indicates a need to improve GMP in giving detail information for shipborne garbage segregation at ship kitchen, crew dining hall, crew accommodation, ships office and ships' stores.

6.4.4 Estimating shipborne garbage weight

As a result to the number of vessels and range of vessel types that utilizes MTW steadily increasing at 3% per annum (JLM, 2015; Khalid, 2012), the average number of vessel operating daily in MTW will be 260 vessels by the year 2020. Analyzing results show that the number of container, bulk carrier and general cargo vessels operating in MTW on daily basis will increase from 125 vessels in year 2014 to 149 vessels in year 2020. Therefore, there are possibilities that the amount of shipborne garbage on these vessels will increase since MARPOL 73/78 restricts on the disposal of shipborne garbage at sea particularly vessel operating within MTW. According to year 2014 statistics on number of vessel using Malacca Straits (JLM, 2015), this study calculated a total of 6,315 MT of EGW will be carried by container, bulk carrier and general cargo vessels that use Malacca straits as transit passage in the year 2015. By the year 2020 this amount will increase to 7,321 MT, a 16% increase.

According to garbage category perspective shows plastic category most likely accumulates 1,003 MT of the total shipborne garbage in year 2015 which is equivalent to 527 unit of 40' ISO container size. Therefore, unprocessed plastics will represent higher amount of the total volume waste. Due to plastics material durability and buoyancy (Sheavly, 2005a; Derraik, 2002), this material can travel long distance and may land on Malaysian coastline if vessels illegally discharge shipborne garbage within MTW. Food wastes accumulation was estimated at 2,001 MT on the vessels in the year 2015. This study found food waste category are mixed with plastic material, thus, indicating not all vessels maintaining garbage practices according to vessels GMP. Therefore, there is a high possibility that plastic materials may enter the marine environment through the disposal of mixed food waste beyond 12 nmi from the nearest land. This study found that cargo residue materials are made of wood material for compartmental pallet, wooden cargo box or lashing cargoes represents 1,606 MT from the total EGW. Although, these materials are allowed to be discharged into the marine environment beyond 12 nmi from the nearest land, these materials are buoyant and may pose hazards to vessels' propeller or water intake pump.

6.4.5 Harmonizing shipborne garbage prevention

The IMO has introduced recommendation to reduce shipborne garbage on the vessel (IMO, 2002, 2012c, 2012d). However the recommendation explained in the guidelines for waste management reduction was non-mandatory in developing management plan or legislation for the implementation of MARPOL 73/78 Annex V. Therefore, the level of understanding and interpretation of MARPOL 73/78 Annex V requirements for waste reduction management varies between vessel type and class. Although compulsory requirement for MARPOL 73/78 Annex V compliance is achieved, commitment level which is portrayed in the development of MARPOL 73/78 Annex V differs between vessels trading areas. In addition, MARPOL 73/78 Annex V has not specified compliance for a ship chandler or supplier to comply with services rendered by the vessel.

From the ship-side perspective, crew members are unable to control the types of products or waste entering the vessel due to the needs on the vessel which is similar to household domestic need. Thus, various procedures were translated into vessels' GMP to ensure generated waste is minimized to eradicate illegal discharge into the marine environment. Although, it is vessels' prerogative to make necessary arrangement and request with ships chandler, there are situation where supplies were incompliance with vessels' GMP requirements. In most situations, the supplies were accepted to ensure vessel operates according to shipping schedules. Nevertheless, having a more stringent regulation may improve garbage management on the vessel. However, this actually creates a situation of difficulty in implementing GMP procedures on the vessel. The impact from supply chain companies particularly ships chandler need to be included in the overall GMP as they are the reason the sources of garbage enters the vessel. Thus, every individual should take serious attention towards marine environment conservation as imposing strict guidelines on the vessel alone will not eliminate illegal discharge practices. Port authorities should take lead in monitoring and overseeing shipborne garbage management by ensuring ship chandler supplies to the vessels adhere Annex V of the MARPOL 73/78 requirements. In supporting these efforts, the IMO should view shipborne garbage waste management holistically and gives the equal responsibilities to the port-side and ship's chandler to comply the MARPOL 73/78 Annex V.

The factors regarding illegal discharging practices among crew member views towards environmental aspiration are caused by irresponsible attitudes (Coe & Rogers, 1997; NRC, 1995). The practice by white list classification vessels discharging shipborne garbage at Malaysian port shows the determination of the vessel classification to ensure each crew members has a greater awareness for conservation and protection of the marine environment. Therefore, marine environment awareness among crew members can be strengthened through environmental education. In addition, giving environment knowledge and associated issue can change behavior and perception (Hungerford & Volk, 1990) among crew members. For that reason, port authority or shipping association should promote environmental education and outreach programs for the vessels' crew member. The programs should focus on raising awareness of the marine environment, their potential contribution to the problem of shipborne waste and harmful effects on the ecosystem. This program is expected to create a sense of environmental responsibility among crew members and promote behavior change in a more sustainable manner (Butt, 2007). In addition, the role of a vessels' master (or captain) in initiating crew behavior change on shipborne garbage disposal is paramount. Therefore, environmental education program for vessels' captain and owner should be encouraged, to introduce practical and effective technique to improve and instill crews' behavior towards garbage disposal.

Major shipping route may contribute significant amount of shipborne garbage in the marine environment (Zuin *et al.*, 2009; Vauk & Schrey, 1987). Although Annex V of the MARPOL 73/78 (IMO, 2012b) prohibits discharge of all types of plastics material, this study found not all vessels (35%) complies to the requirement. Despite the high volume of vessel traffic en route through Malacca Straits (Figure 8), the amount of debris items for marine source accumulation may be huge within MTW. Although regulations and conventions may be in place for the prohibition of ocean dumping of waste materials, the temptation to ignore the regulation is obvious, particularly when enforcement is relaxed. Malaysia has ratified the Annex I/II, III, VI, V and VI of the MARPOL 73/78 and must follow up with necessary enforcement measures.

6.5 Conclusions

The mean SGW for vessels visiting Malaysian ports is 130.8±108.0 kg/vessel according to vessels' voyage duration. Bulk carrier vessels (40%) accumulated the highest total shipborne garbage weight and are responsible for the abundance of plastic, food wastes, domestic wastes and incinerator ashes categories. This study calculated a total of 6,131 MT of EGW equivalents to 3,220 unit of 40’ ISO container size carried by container, bulk carrier and general cargo vessels in the year 2014. This indicates unprocessed plastics will represent higher amount in terms of total volume. In addition, food wastes and cargo residue categories contributed 59% to the total amount of shipborne garbage accumulated on the vessels; however, they were given less attention on the vessel before discharge to the sea. Statistical result shows vessels’ gross tonnage and number of crew members are factors contributing to shipborne garbage abundance, which explained more competent crews are needed to operate larger vessels. In addition, this study found one out of three vessels was equipped with shipborne garbage processing equipment, which extends the probability for garbage illegally discharged within MTW. The poor garbage management practices on black and grey list classification vessels will farther encourage garbage disposal illegally. Although, MARPOL 73/78 allows the disposal for food waste and cargo residue categories beyond 12 nmi from the nearest land, there is a need to promote garbage disposal in a responsible and sustainable approach. Since only a small amount of shipborne garbage can be processed on the vessel, it is the obligation of each crew members to ensure unprocessed garbage are not illegally discharged to the marine environment.

CHAPTER 7

GENERAL DISCUSSION

7.1 Introduction

Previous studies (Ribic *et al.*, 2010; Ryan *et al.*, 2009; Sheavly, 2005a; Derraik, 2002) have the same opinion that marine pollution is a serious problem that needs to be addressed immediately. There are many different types of pollution in the marine environment and many of them are widespread phenomenon that causes serious threat to marine organisms. Pollutants can be in variety of forms collectively, from raw sewage, oil spills, pollution from rivers, non-point pollution from agriculture and industrial effluents to dumping of garbage which has immense impact on the marine environment. Although, the oceans' vastness can assimilate pollutants (Palatinus, 2009), there is a limit to allow pollutant into the ocean. As a result of these uncontrolled practices, ocean has been an option for easy disposal of waste especially garbage.

The abundance of marine debris results found in this study shows garbage pollution in Malaysian beaches requires an immediate attention. The debris abundance in the ocean can be related to plankton and debris item ratio of 5:1, while, plankton and debris density ratio is at 1:6 (Ebbesmeyer, 2003). The amount of debris items in the marine environment estimated to be 5.25 trillion weighing at 268,940 tons (Eriksen *et al.*, 2014) is just one part of the puzzle. Jambeck *et al.*, (2015) has estimated plastic pollution floating on Malaysia Ocean's surface at 255,000 MT. While, this study found that mean debris weight accumulation at the beach was 44.2±21.2 kg/km which can be translated to 212 MT along Malaysian coastlines. Unfortunately Malaysia contributes 3.5% of the global plastic pollution and categorized among the top 10 garbage producer in the world after Indonesia, the Philippines and Vietnam (Parker, 2015; Reuters, 2015). Therefore, the need to continue implementing 3R strategy in

Malaysia is paramount. However, funding and support from government agency requires public participation to ensure successful process implementation.

In this study, marine debris accumulation shows a trend with monsoon season. Plastic category is the most abundant objects found at in this study especially during SWM season. The abundance of plastic category found at the beaches required immediate preventive action to be implemented. Although, many factors contributed to the marine debris abundance, human-generated debris was found to be the major source to the marine debris problem in this study. Therefore, a comprehensive and long-term monitoring along Malaysian coastline is paramount to identify marine debris point source continual input and then introduce strategic solution to reduce marine debris accumulation on the beaches. In addition, understanding marine debris abundance relationship against seasonal, current and wind exposure will enable to specify preventive program to improve solid waste management on the beaches.

Although, the general public is aware of the importance of beach cleanliness, the response in beach clean-up participation is poor. Nevertheless, non-governmental organizations (NGO) have continued conducting awareness programs through beach clean-up. A beach clean-up sponsored by Suzuki conducted at Pandan (Lundu) and Belawai (Sibu) beaches, collected 2,000 kg and 370 kg of garbage respectively (Global Suzuki, 2014; Borneo Post Online, 2013). An International Coastal Cleanup (ICC) conducted in Malaysia reported a total of 320 kg (2 km) and 80 kg (0.4 km) collected during beach and underwater cleanup in 2012 respectively (IOC, 2013b). An underwater cleanup effort at 14 dive spot surrounding Tunku Abdul Rahman Park, Sabah organized by Astro Kasih managed to collect 3,171 kg of garbage (Lee, 2013). A total of 543 kg of underwater debris was extracted from Sabah’s east coast Billean and Tegaipil islands (Vanar, 2013). In another related activity, underwater clean-up off Sematan coast collected 150 kg of garbage at the famous wreck site WWII Katori Maru wreck (Tan, 2014). From beach and underwater cleanup organized by NGO in Malaysia, garbage pollution is a serious threat along Malaysian coastlines. This information gathered only represents 0.1% of beach and 0.01% of maritime area covered in Malaysia. With larger area unexplored, garbage accumulated within MTW definitely requires attention in order to curb illegal discharge into the ocean.

7.2 Marine source – Shipping activities

Previous studies (Allsopp *et al.*, 2006; U.S. Commission on Ocean Policy, 2004) has indicated that 80% of the debris found on the beach can be related to terrestrial and common sources, while, 20% was related to marine source. Despite the high volume of vessel traffic en route through Malacca Straits (Figure 8), this study found that 18% (6,912 items or 144±128 item/km) of the total debris items can be related to marine source. Although, this amount is lower compared to Zuin *et al.* (2009), Allsopp *et al.*(2006) and Vauk & Schrey (1987) at 20%, 46% and 99.2% respectively; it indicates that vessels en route within MTW was discharging shipborne garbage illegally. Analyzing further, marine source debris items that can be related directly with shipping activities was only 1.30% (2 item/km), whereas, fishing vessel contributed 15.9% (23 item/km) from the total marine source debris items. Other studies (Barnes *et al.*, 2009; Walker *et al.*, 2006; Otley & Ingham, 2003) suggested such results are encouraging indicating less illegal discharge occurring at the ocean. However, the presence of debris items associated with shipping activities shows not all vessels comply with the new revised Annex V of the MARPOL 73/78 (IMO, 2012b) which prohibits discharge of all types of plastics material and requires a port to provide facilities to receive shipborne garbage from any vessel that requires garbage disposal services. Nevertheless, regulations and conventions may be in place for the prohibition of ocean dumping of waste materials, the temptation to ignore the regulation is obvious, particularly when enforcement is relaxed. Malaysia has ratified the MARPOL 73/78 and must follow up with necessary enforcement measures.

The most common objects found on the beaches that were also found on the vessels in this study were CPB, colored plastic bottles and food wrappers, which can be an immense threat to marine wildlife (Baulch & Perry, 2012; Bellwood *et al.*, 2004; Barnes, 2002). Although, there was no evidence to conclude household domestic products being illegally discharged from the vessels, the presence of CPB items from vessel found on the beaches indicated most likely household domestic products items found on the beaches may also originate from vessels. Since the number of vessels using MTW as international passage is increasing by the years (JLM, 2015), it is likely that illegal dumping will be detrimental to the MTW marine environment. In another perspective, there is a possibility of other pollutants from other annexes in the MARPOL 73/78 such as oil (Annex I), noxious liquid (Annex 2), harmful substance (Annex III) and sewage (IV) being discharge illegally. This matter should be treated as immense concern in view of the serious pollution that may cause severe impact to marine wildlife and the communities in Malaysia. Thus, it is critical to identify marine debris sources from shipping activities to enable and develop a specific strategy to prevent continuous dumping in the marine environment.

7.3 Estimating SGI and SGW

In this study, result shows mean SGI for plastic (166±100 item/vessel) category was the most abundant objects on the vessels, whereas, food waste (20.5±10.8 kg/vessel) category was the highest for mean SGW. As for garbage source, this study found mean SGI was the highest from common sources (166±100 item/vessel), while, crew source (25.5±13.0 kg/vessel) accumulated the highest for mean SGW. Analyzing vessels using Malacca straits statistics (JLM, 2015), vessel will increase from 79,344 vessels in 2014 to 94,741vessels in the year 2020 at a steadily average rate of 3% per annum (Khalid, 2012). From this study results, shipborne garbage accumulation on container, bulk carrier and general cargo vessels can be estimated to increase from 6,131 MT in the year 2014 to 7,321 MT in the year 2020. This estimated shipborne garbage weight in the year 2020 is equivalent to 3,850 unit of 40' ISO container size. Thus, the total number of objects that may be stranded along Malaysian coastlines from shipping activities can be estimated to be 59,983 items (12 item/km) when illegal shipborne garbage discharge practices continues.

Estimation of shipborne garbage abundance has given better understanding on objects stranded on beach environment. There were 82 items found on the beach which is very likely to be associated with bulk carrier vessels from black list classification. This vessel type also accumulated the highest mean SGI and SGW, whereby, the possibility for illegally discharge practices within the MTW could be significant. This also implies black list classification vessels are ignorant and irresponsible towards IMO vision to eliminate adverse environmental impacts from shipping activities. Therefore, necessary action plan has to be developed to mitigate illegal discharge practices especially from the black list classification vessels. Revoking entries for these vessels to Malaysian ports will not solve illegal discharge practices; instead environmental education awareness should be an option. In addition, black list classification vessels should be categorized as sub-standard vessels in terms of the non-compliance to the MARPOL 73/78 Annex V requirements when plying within MTW. Therefore, a detailed PSC inspection should be carried out on this vessel type and classification. Although, reception facilities in Malaysian ports are still at the infancy stage, necessary arrangement should be in place for these vessels to send shipborne garbage to ports.

Statistically, vessels' gross tonnage and number of crews are significant factors in determining the mean SGI and SGW on the vessel. Therefore, there is a need to emphasis the importance of protecting the marine environment among crew members. In addition to the regular awareness program organized on the vessel, GMP should be simplified yet concise. Nevertheless, environmental conservation is a long process for appreciating the effort that has been initiated, this will makes even difficult for some crew members to understanding which has been practicing discharge illegally at sea. Thus, environmental education should be incorporate with the present awareness program on the vessel, to instill appreciation to environmental conservation. However, monitory incentives can be a significant drive in motivating crew members to participate and have a positive attitude towards immediate changes.

7.4 Shipborne garbage implication

The practice of discharging shipborne garbage illegally at sea is a major issue that needs serious attention. Regardless of pollution in any form, it can cause severe impact to the marine environment including marine debris. However, marine debris has more severity on marine biodiversity compared to human health. Marine plants and animals have very specialized habitats defined by specific physical (substrate, light, nutrient flow, temperature) and biological (interactions between animals - food, symbiosis or other) factors. With the number of debris item (46,141 items or 961±523 item/km) found in at the beaches, the floating debris implication in the ocean may contribute to the disturbance of marine ecosystem especially the coral reef ecosystem (Cózar *et al.*, 2014; Sadri & Thompson, 2014; Bellwood *et al.*, 2004). This study found that a total number of 1,459 items were of foreign origin which may have originated from neighboring countries or shipping activities stranded on the beaches. Since debris is light weighted and can travel long distance, biological invasion of species (e,g. *Vibrio cholerae*) can be transported that may be damaging to biodiversity through natural resources competition with native species which leads to fundamental changes in natural communities (Barnes, 2002).

Plastic material is harmful in physical and chemical form (Heskett *et al.*, 2012; Thompson *et al.*, 2009). With the amount of plastic materials (116±100 item/vessel) found on the vessels, dispersal can accelerate and enhance the prospects for invasions by alien species (Gregory, 2009). Plastic contains polychlorinated biphenyls (PCB) an additive to increase the plastic material strength (Webb *et al.*, 2012), thus, floating plastic debris emits these PCBs which are eventually absorbed by marine life which leads to reproductive disorder and altered hormone level (Galgani *et al.*, 2014; Gomez *et al.*, 2004; Derraik, 2002). Phthalate plasticizers and brominated flame are harmful to marine life (Barnes *et al.,* 2009) and these chemical could be transferred through the food chain and to human through consumption (bioaccumulation and biomagnifications).

The obvious effect of shipborne garbage on the beach is the aesthetic degradation. However, the effect is more significant when garbage is still floating on the ocean. This study found the total number of plastic shopping bags at beach and ship surveys were 1,473 items and 1,124 items respectively. These debris items have been reported to wrap around propellers or clog cooling water intakes, eventually causing vessel engine failure and vulnerable to collision (NRC, 1995). Nevertheless, plastic is far more harmful in physical form as marine animals often become entangled and vulnerable to plastic ingesting (Galgani *et al.*, 2014; Rodríguez *et al.*, 2013; Gregory, 2009). In a recent incident, a short finned pilot whale was found dead in Sabah waters attributed to ingestion of 44 pieces of plastic material including 21 small plastic bags, 11 plastic sheets and one plastic detergent; weighing 4.25 kg (Lajiun, 2015). In a beach clean-up activity in Sabah had also found a dead Hawksbill adult turtle entangled in the net (Vanar, 2013). These are among the proof showing the severity of garbage waste within Malaysia marine environment towards the ocean wildlife.

Shipborne garbage is the responsibility of all parties that are dealing directly or indirectly with a ships' operation. Although MARPOL 73/78 has restrictions on the disposal of plastic material into the marine environment, ensuring illegal discharge practices will be a difficulty especially with the increasing number of vessel operating within MTW as transit or innocent passage (JLM, 2015). Unlike solid waste from land, information and database on shipborne garbage generated and landed in Malaysian port are unavailable. Thus, it is difficult to draw a firm conclusion for Malaysian port to establish port waste reception facilities with fragmented data. Therefore, each port in Malaysia is required to develop a comprehensive and long-term monitoring waste discharge at port. A simple standardized form which need not be complicated can be introduced to identify the shipborne garbage amount according to ship types, BGW classification and garbage categories. By compiling accurate reporting of annual totals for each MARPOL 73/78 Annex would be a major step forward.

Therefore, this study finding provides a foundation for authorities to take serious measure on garbage from shipping activities. Although, the mean GGR found in this study was 0.7 kg/person/day which is lower when compared to an estimated GGR by IMO at 1.5 kg/person/day (Palabıyık, 2003; Nawadra *et al.*, 2002), the increasing number of vessels en route through MTW (JLM, 2015) will cause severe implication of shipborne garbage in Malaysia's marine environment. In addition, shipborne objects found on the beach indicate garbage that is illegally discharged in MTW may aggravate. Thus, the concern lies with plastic-based material discharge which may cause serious threat towards marine wildlife through entanglement or ingestion. For that reason, action oriented program needs to be intensified besides introducing preventive and mitigation plan to improve crew members commitment towards environmental conservation.

7.5 Management strategy for improvement

7.5.1 Global initiatives and legislation

From this study, the uncontrolled input of waste on the vessel indicated a need to regulate waste entry into the vessel. Although, MARPOL 73/78 guidelines has outline effort from vessel to minimizing acceptance of product or material that can generate waste on the vessel, controlling waste entry is difficult without guideline or procedure to accept the inclusion of waste. Current practices made on the vessel to render supply services (i.e. food provision, stocks provision, spares parts) includes forward requisition to vessels' shipping agency, agreement on the price and delivery period; and receiving supplies from ships chandler. Time is a deterrence factor in shipping operation activities to ensure cargoes are delivered timely at designated destination port. With strict working schedules, it is difficult to control and minimizing waste at entry process. Therefore, the garbage control from entry point should be given the same responsibility equally to ships chandler and port authority to ensure effective implementation of MARPOL 73/78 Annex V requirements.

This study has identified the present solid waste management in Malaysia has improved in ensuring effective collection and disposal practices. However, marine debris has not been clearly defined and it has been given less attention compared to solid waste garbage in urban area. There are at least 14 ministries and 26 departments/authorities that have responsibilities related to maritime sector with approximately 74 laws including major laws such as Merchant Shipping Ordinance 1952, Environmental Quality Act 1974, Fisheries Act 1963, Exclusive Economic Zones Act 1984, Continental Shelf Act 1966 and Malaysian Maritime Enforcement Agency Act 2004 (Mustafa, 2011; Maidin, 2005; Kamaruddin, 1998). However, overlapping of jurisdiction between several agencies leads to ineffective strategy to curb marine environment cleanliness issues (Maidin, 2005). As intermediate measure, government agencies and stakeholders should establish Marine Debris Coordinating Program to discuss responsibilities and clarifies overlapping jurisdiction between government agencies followed by developing a national contingency plan for preventing and mitigating marine debris in Malaysia. Thus, there is an urgency in developing marine debris legislation to ensure commitment on prevention, reduction and removal strategy to address marine debris adverse impacts on the national economy, the marine environment, and navigation safety.

7.5.2 Technology invention

In this study, the abundance of objects in the plastic category has shown an alarming result. The plastic category accumulation was 88% which is higher compared to global average in 2012 (IOC, 2013a) at 61%. The abundance of these objects in the marine environment indicated plastic product is part of life for the worlds' community. Many of the commercial plastics today originated from petroleum-based polymers that are non-degradable (Moore, 2008). McCarthy (2003) emphasized that non-degradable plastics packaging is blamed for shortening the life expectancy of commercial landfills, increasing the operational cost, contaminating the environment, and posing a threat to animal and marine life. Thus, this lifestyle perception of the love of plastic has to be changed.

Innovation in plastic technologies can reduce the usage of plastics and uncertainties about how to decrease their disposal into the marine environment. One possible way to mitigate these problems is using biodegradable and enhanced-photodegradable plastic (Song *et al.*, 2009; Gregory & Andrady, 2003; Derraik, 2002). Bio-plastic invention may increase sustainable industry product and decrease environmental effects particularly to the marine environment (Marjadi & Dharaiya, 2010; Thompson *et al.*, 2009; Zheng *et al.*, 2005). Researchers from Universiti Sains Malaysia (USM) had produced biodegradable and environmental-friendly plastics product called the “fruitplast” which is made from tropical fruits waste, suitable to replace regularly non-biodegradable plastics used in packaging utilization (USM, 2010). Charting a new milestone in Malaysia's efforts to provide an alternative to non-biodegradable petroleum-based plastic, an automated Polyhydroxylalkanoate (PHA) Bioplastic plant was designed and built through the partnership between SIRIM Bhd., USM, Universiti Putra Malaysia (UPM), and the Massachusetts Institute of Technology (MIT) (Ministry of Science Technology and Innovation, 2011). The bioreactor facilities and integrated manufacturing process of the plant is able to produce various options of PHA materials from crude palm kernel oil and palm oil mill effluent. With the efforts that have been made by the local R&D institutes in Malaysia, the government should endorse and encourage the use of bio-plastic products made in Malaysia in an effort to promote conservation and sustainable endeavor in Malaysia.

7.5.3 Education and attitude changes

Educating about the precious value of marine environment and how to defend the nature from devastation may be the salvation of this ecosystem for future generations. Government agencies, NGO, academic institutions, national marine parks and many other entities are working hard to provide scientifically based environmental information to educate the general public in realizing and be conscious about the importance to protect marine environment (Desa *et al.*, 2012; Portz *et al.*, 2011; Williams *et al.*, 2011; Weber *et al.*, 2000). However, to ensure effective environmental education, developing strategies has to be identified and priorities for the successful implementation. Marine users had been targeted through posters, brochures, magazines articles, publications, signage, mass media, social media and annual beach clean-ups programs at beaches to increase awareness among the general public about the hazard of plastic debris (Barnes *et al.*, 2009; Jones, 1995). Thus, environmental awareness can be achieved through variety communications platform and supporting in community actions (Slavin *et al.*, 2012; Sesini, 2011). Through the development of environmental education, aspiration to promote environment conservation may instill pride and appreciation at all levels of societies (Chen & Liu, 2013; Portz *et al.*, 2011; Roca *et al.*, 2009; Santos *et al.*, 2009; Cho, 2005). Thus, positive communication can be accomplished among environmentally educated society, aware and conscious towards environment responsibility.

In addition to developing environmental education programs, the change of attitude is also necessary to minimize generation of solid waste specifically plastics, and to reduce the amount of waste illegally discharged into the oceans and coastal area. The 1992 United Nations Conference on Environment and Development (UNCED) Earth Summit was organized to address an urgent problem of environmental protection and socio-economic development. It resulted in Agenda 21 (A21), a plan for achieving sustainable development in the 21st century. Local Agenda 21 (LA21) can be a solution to marine debris distress. LA21 has been initiated in Malaysia since 2000 and four local authorities have been selected to implement LA21 Pilot Project Malaysia including Miri City Council (MCC). The key objective for the success of LA21 in Miri is the direct involvement of communities implementing LA21 initiatives (Personal communication with Puan Dayang Siti Nurbaya Bt Awg Kipli). Although with limited budget allocated to MMC LA21 office, the commitment and dedication shown by the communities has successfully conducted 82 projects in year 2012 and 78 projects in year 2013 including awareness programs, seminars, outreach programs and garbage composting programs (MCC, 2014). From this successful LA21 implementation, other local authorities has set path implementing LA21 towards sustainable development (Ismail, 2014; Sesini, 2011; Addison, 2002).

7.5.4 Beach clean-up and awareness program

Malaysia beach clean-up awareness has developed over the years within the capacity of ICC campaign conducted by International Ocean Conservancy (IOC). IOC has been conducting voluntary beach clean-up around the world since 1986; however, Malaysian general public participation has been poor, likely due to insufficient publicity or lack of knowledge on the importance of such activities. Nevertheless, NGOs in Malaysia has helped to promote the awareness among beach visitors and local communities in marine conservation. The collaboration and commitment among the communities can be seen through the clean-up activities and monitoring programs results. According to ICC annual report from 2008 until 2013, the top three debris items collected were plastic bags (63%), styrofoam pieces (16%) and food wrappers (6%). However, beverage bottles (CPBs) and plastic cups contributed 10% of the total garbage collected in ICC Malaysia which falls under shoreline and recreational activities or terrestrial source. This indicates irresponsible beach-goers do not dispose their garbage in a civilized manner (Abdullah *et al.*, 2012). Nevertheless, the information obtained can develop marine debris database for scientific study on the types of debris collected, the sources and impact of debris to environment (Sesini, 2011; UNEP, 2009; Sheavly, 2005b) to develop strategies to reduce marine debris and enhance marine conservation.

Awareness programs in Malaysia have shown a positive respond and involvement from the general public over the years. Although the implementation of 3R and “no plastic day” programs has shown a positive participation from the general public (Zen *et al.*, 2013), this study mean BDI (961 item/km) was higher when compared to global average in the year 2013 (656 item/km) (IOC, 2014). This may likely indicates approaches towards promulgating awareness program through media alone for the general public were insufficient. Therefore, there is a need to introduce customized environmental education programs for the general public as has been develop for primary and secondary schools awareness program in Malaysia (Department of Environment, 2013; Shell (M) Sdn. Bhd., 2012). Nevertheless, the present initiatives awareness programs initiated should be continued, at the same time to include community involvement (Hidalgo-Ruz & Thiel, 2013; Roca *et al.*, 2009), where, a grass roots community based program can often make quite a difference as shown by MCC LA21 programs.

For that reason, it is important to target the appropriate group such as beach users, students, coastal villagers and crew members; to instill awareness and educate the general public on pathway of marine debris in the marine environment. However, the campaign needs to be molded with public participation and to instill consciousness on marine debris issues in

Malaysia. The Ministry of Natural Resource and Environment through local government authorities should take the lead in effort to include direct participation of the general public, coastal villagers, crew members and shipping communities as part of Malaysia's commitment towards combating illegal garbage disposal at sea. In addition, "no plastic day" initiatives should be introduced at Malaysian ports to instill awareness on the use of biodegradable material to replace non-biodegradable materials. Ultimately these actions will drive Malaysian society towards an ecologically sustainable life style and sustainable disposal practices.

7.5.5 Shipborne garbage on the vessel

Waste can be treated in a variety of ways on the vessels; methods of treatment, notwithstanding the requirements of MARPOL 73/78, being dependent on the age of the vessel, type of ship, area of operation, facilities on board, size of crew, and the owner's environmental commitment. Ships may be equipped with incinerators, compactors, comminutors or other devices for shipboard garbage processing (IMO, 2012d). This study result suggested that installation of garbage processing equipment has a significant relationship with vessels' gross tonnage, number of crew and voyage duration. However, vessels mean cruise duration of less than 3.7 days are not equip with any garbage processing equipment and incline to discharge at port. Although installing this equipment can be costly, this equipment are able to reduce shipborne garbage volume and weight tremendously (Delfosse *et al.*, 2010; Zuin *et al.*, 2009; Johnson, 2008; Butt, 2007; Prelec *et al.*, 2006). Thus, eliminate illegal discharge at sea practices. Therefore, findings in section 5.3.4 suggest vessel with gross tonnage of 10,890 GRT or more should require installing garbage processing equipment. Upon installation of garbage processing equipment, all crew members should be assigned periodically to operate the equipment on a schedule commensurate with ship needs. Eventually, the use of processing equipment makes it possible to discharge certain garbage at sea which otherwise would not be permitted (e.g. food waste and cargo residue categories), reducing shipboard space for garbage storage, making it easier to off-load garbage in ports, and enhancing assimilation of garbage discharged into the marine environment (IMO, 2012d).

A recent advance in shipboard waste management that could be of great benefit in the future is Plasma Arc Waste Destruction Systems (PAWDS) which uses plasma energy to destroy combustible waste (Kaldas *et al.*, 2007). This system trial on a cruise ship showed the ability to treat paper, cardboard, plastics, textiles, wood and food (Picard *et al.*, 2006; Kaldas *et al.*, 2003). Similar to any other new technology, the cost of retro-installation on vessel may be expensive, but this could be a feasible option for waste management on all new building of vessels. Although, there is a relatively high use of incinerator equipment in waste processing to reduce the garbage volume and weight in this study, plastic material (category A) is still required for discharge on shore (IMO, 2012b; Cantin *et al.*, 1990). With the advent of garbage processing equipment, illegal disposal of shipborne garbage can be reduced and infectious diseases controlled (UNEP, 2009; Polglaze, 2003).

7.5.6 Ensuring adequate facilities for disposal of garbage from ships

Following a discussion and review by the Marine Environment Protection Committee (MEPC), various amendments to MARPOL 73/78 Annex V took effect on 1 January 2013 (IMO, 2012b). Prior to the revisions, bulk carrier vessels were free to clean their cargo hold residues with wash water and discharge this waste to the sea, regardless of the cargo that they had loaded. As a result of the amendments to MARPOL 73/78 Annex V, cargo residues are included within the definition of “garbage”, defined in Regulation 1.9. The revised Annex V now prohibits the discharge of all garbage into the sea, with limited exceptions.

Under Regulation 8 of Annex V, a government undertakes to ensure that adequate port reception facilities for garbage from ships are provided. The adequate provision is not only an obligation under MARPOL 73/78, but essential factor in the prevention of pollution from vessel. In view of the fact that Malaysia has ratified MARPOL 73/78, she is required to ensure adequate port waste reception facilities for receiving waste from vessels. However, only 27 ports (Appendix H) in Malaysia are equipped with waste reception facilities capable of accepting noxious liquid substance waste, sewage waste, oily waste and garbage waste (Osnin, 2004), while, other ports in Malaysia still do not provide reception facilities for this purpose which is likely to lead to pollution disposal at seas. Nevertheless, IMO has acknowledged the inadequate or non-availability of reception facilities in Malaysia and other ports in the world face the same problem (IMO, 2014a; BIMCA & INTERTANKO, 2013). Therefore, development and installation of adequate reception facilities is imminent especially at major ports to see the realization of Malaysia as the leading maritime global *halal* hub (Khalid, 2009).

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Beach has become synonymous with a place for physical and emotion relaxation, whereas, shipping is associated with technology advancement that can promote the country economic development. Pollution occurrence in the marine environment can come in many forms including oil, sewage, garbage, sedimentation, chemical waste and thermal; which can affect human health, safety and ecosystem disturbance. Pollution even in small quantities can have an effect on ocean wildlife, local economy and society. Marine debris in particular, has great adverse impacts on ocean disrupting effects.

As the summary of the overall findings shown in Appendix K, this study has collected numerous information on marine debris as shown in generated from shipping activities (marine sources) at the beaches and vessels. From beach survey result perspective, marine debris accumulation shows a positive relationship with monsoon season. The majority of objects found at the beach can be associated with daily domestic household products which consist of plastic-based material. Plastic category is the most abundant objects of debris found on Malaysian beaches during the monsoon seasons; however, significant amount was higher during SWM period. Although, many factors contributed to the marine debris abundances, human-generated debris was found to be the major source to the marine debris problem in this study. The dominant objects affixed with country of origin labels at the beaches were from Malaysia. For that reason, it is important to target the appropriate group (such as beach users and coastal villagers) to instill awareness and educate the general public on pathway of marine debris in the marine environment. The campaign should be geared to environmental education and collaborated with public participation and instill consciousness on marine debris issues in Malaysia. Nevertheless, a comprehensive and long-term monitoring along Malaysian coastline is necessary to identify marine debris point source and then introduce strategic solution to reduce marine debris accumulation on the beaches besides understanding marine debris abundance relationship against seasonal, current and wind exposure.

From vessel survey result perspective, all vessel types accumulate the range of shipborne garbage categories. However, the majority of objects accumulated were from plastic category whereby bulk carrier vessels accumulated the highest objects. In terms of garbage weight, food waste category was of particular concern also from bulk carrier vessels especially visiting Sabah port. Therefore, shipborne garbage accumulation on the vessel should be viewed in the perspective of input-process-output (IPO) pattern. Input components involve provision of food supplies, cargo, goods, spare parts and packaging for securing cargoes. Process components includes waste by-product generated from materials used on the vessel to ensure smooth shipping operation. In an ideal situation, every crew member is responsible for ships' garbage in a manner stipulated in the GMP, while, output component are shipborne garbage discharge to port. The MARPOL 73/78 Annex V states detail procedures for garbage process and output components; however input component was not explained. This leaves a gap in the international efforts to address shipping source garbage pollution which needs to identify and catalog garbage from entry to ensure each by-product material is accountable by vessels.

Vessels trading internationally operate around the world and manned by competent crew members who comes for various nations and nationalities. However, the upbringing of each crew members towards environmental conscience may differ from individual, nationality or nations, which can be a factor in the production of various types of waste on the vessels. Thus, environmental awareness programs on the vessel should include scientific based environmental information to ensure crew members realize and be conscious about the importance to protect marine environment. Nevertheless, vessel also generates other types of objects which can be associated with terrestrial source including mineral bottles, shampoo bottles and plastic shopping bags which would degrade marine environment quality if discharged into the sea. However, attention needs to be given on food waste mixed with other garbage category especially plastic category. This can increase plastic accumulation in the ocean when illegally discharged at sea. Therefore, there is a need to identify and control plastic-based material entering the vessel to ensure plastic pollution at sea is minimized from shipping source.

This study found that crew members engaging in initiated practices can create an environmentally responsible behavior. Therefore, based on this study finding, management strategies to encourage vessel to bring shipborne garbage to port, include developing garbage recycling centre at the port, port to providing a 1 m^3 mobile garbage bins for each vessel, encouraging environmental education for crew members and the requirement for ships' garbage station to be emptied before sailing. Hopefully, these proposed management measures can encourage policy-makers to acknowledge the potential problems arising from shipborne garbage especially vessels operating within MTW and implement necessary action plans to ensure Malaysia's marine environment is protected from illegal discharge.

8.2 Recommendations for improving this study

The following recommendations are offered as possible ways to improve this study.

1. Given the valuable information gathered in this study, the sampling size for number of vessel and length of beach should be expanded to ensure a detail result is acquired to support the development of mitigation and preventive strategies against marine debris pollutions.
2. Given the multi process of procurement for services and goods on the vessel, a detail Input-Process-Output study would document detail product material trends and thereby identifies the potential material of becoming shipborne garbage.
3. Research related to other marine source debris including on platforms, fishing vessels, recreational boats and trading vessels plying domestic; may provides another perspective towards garbage contribution to the debris accumulation into marine environment. Exploring their contribution to debris accumulation stranded on the beach would be of value to the field of marine debris pollution.
4. While the secondary data such as rainfall, wind and current speed, may be helpful in this study, it may be advantageous to conduct research which considers primary data in the context of marine debris study. Although it is costly, it may be more efficient to enable data collection to be molded with the study objectives and presenting more accurate result interpretation.
5. Given that this study provides a basis for concluding that awareness is an important program contributes to environmental education, defining the attributes that focus on attitude change and instill responsibility would prove to be of valuable information to understand behavioral changes. Such an effort would enable to customized and develop effective environmental education for target group such as school children, coastal villagers, vessels' crew members and the general public.
6. Government effort in promoting the 3Rs through media can be an effective way of extending the reach at all levels of society; however, media awareness program should be

simple and exciting to allow the younger generation to foster passion for the environmental conservation.

7. Local Agenda 21 (LA21) has been initiated in Malaysia since 2000; however media coverage and local authorities' success stories were kept within local news. The successful implementation of LA21 in Malaysia should be priority highlighted in a specific mass media program to instill appreciation and enhance awareness towards sustainability environmental development.
8. Beach Cleanliness Index should be introduced to provide a quantitative measurement for beach cleanliness which can establish determining factors affecting marine debris abundance. This will also create a sense of ownership among beach visitors and communities residing around the beaches.
9. Garbage collection is not social obligation but rather sustainable environmental development. Therefore, garbage collection services must be provided along the coastal villages and inhabited islands by respective local government authorities.

8.3 Delimitation of the research

Duration of monsoon periods in Malaysia is not the same. The NEM and SWM periods are approximately five months, whereas, IM period is approximately two months. Debris sampled during IM periods could be biased from debris accumulation at the end of NEM and SWM periods. Thus, sampling was conducted approximately in the middle of each season. In addition, a discussion has been conducted with the local authorities appointed contractor for beach cleaning at Pasir Pandak, Temasyah, Tg. Lobang, Tg. Aru and Saujana beaches pertaining to this study objective and has agreed to assist in this study. Dates of each survey has been conveyed to the contractor one month prior to beach surveys to ensure accumulation of marine debris at the beach will represent each season.

Data on wind speed and surface current have been conducted by MMD and categorized as secondary data. Wind speed information at the ocean was collected from reporting Voluntary Observation Ship (VOS). The observation can be bias due to differential evaluation from each person on the vessel. Surface current data sampling was not comprehensive or incomplete due to malfunction in data collection. Furthermore, surface current data sampling station for Sabah and Sarawak was unavailable since current meter equipment broke down in Mac 2011. Therefore wind speed and wind direction data from MMD weather observation station was used in this study analysis.

Shipborne garbage item count was only conducted at vessel garbage station as stipulated in the vessel Garbage Management Plan (GMP) document. Garbage accumulation at crews' accommodation, crew dining hall, vessels' kitchen and vessels' office was not included. Therefore, shipborne garbage information collected in this study was restricted to vessels' garbage station and total shipborne garbage accumulation on the vessel maybe was underestimated.

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APPENDICES

Appendix A: General Debris Data Sheet

WWF

RUBBISH ON OUR SHORES AND AT SEA

Marine Debris Survey – EXCLUDING NETS

DETAILS:

Date: ______________________ Survey No: ______________________

Community: ______________________

Contact Name: ______________________ Phone: ______________________

No. of people in survey: ______________________ Survey Day No: ______________________

Location: ______________________

GPS Reading: Start Lat ____________ Finish Lat ____________

Long ____________ Long ____________

Length of beach surveyed: ______________________

Comments / Notes: ______________________

HOW TO DO THE SURVEY AND PAPERWORK

Step 1. Select a beach for a survey, longer than 1km and less than 5km.

Step. 2 Fill out the details above, number of people doing the survey, the date and survey location name and starting point (latitude and longitude).

Step 3. Walk the survey site in a line collecting all manmade rubbish, no smaller than a bottle cap, between the waters edge and base of the first sand dune.

Step. 4 Place smaller items in bags and larger items such as nets on vehicle or trailer.

Step 5. Once the area has been completed, record where you stopped (Latitude and Longitude) above.

Step 6. Find a shady place, empty collection bags and sort the rubbish into groups according to the categories used on this for (see 'Rubbish Group'). Remember to record the nets separately.

RUBBISH ON OUR SHORES AND AT SEA

	No. of Items	Bag Weights	TOTALS
Rubbish Group: PLASTICS			
Plastic Bottles Clear 	50	10kg	Any bottles with bite marks? No: 3
	45	8kg	
			Total Number: 95
			Total Weight: 18kg

Step 7. Count the number of items in each debris group until you have filled a bag. Write the number in the number column.

Step 8. Weigh each bag and record in the weight column.

Step 9. Write the total number and total weight in the total column.

Step 10. Continue counting, weighing and recording each debris group until everything collected from the beach has been counted, weighed and recorded. Take the rubbish to the dump.

Step 11. Send or fax a couple of the survey sheet to WWF-Australia in Darwin.

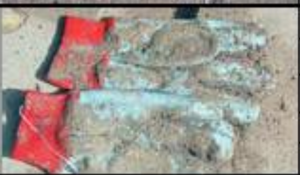
RUBBISH ON OUR SHORES AND AT SEA

		No. of Items	Bag Weights	TOTALS
Rubbish Group: PLASTICS				
Plastic Bottles Clear				Any bottles with bite marks? No: Total Number: Total Weight:
Plastic Bottles Coloured				Any bottles with bite marks? No: Total Number: Total Weight:
Plastic Oil Bottles				Any bottles with bite marks? No: Total Number: Total Weight:
Bottle Caps				Any bottles with bite marks? No: Total Number: Total Weight:
Buckets Baskets/Crates				Total Number: Total Weight:
Hard Hats				Total Number: Total Weight:
Cigarette Lighters				Total Number: Total Weight:
6 Pack Rings				Total Number: Total Weight:
Food Wrappers				Total Number: Total Weight:
Plastic Bags				Total Number: Total Weight:

RUBBISH ON OUR SHORES AND AT SEA

		No. of Items	Bag Weights	TOTALS
Rubbish Group: PLASTICS (continued)				
Palette Wrappers				Total Number: Total Weight:
Strapping				Total Number: Total Weight:
Ropes				Total Number: Total Weight:
Buoys & Floats				Total Number: Total Weight:
Fishing Line				Total Number: Total Weight:
Lures				Total Number: Total Weight:
Cups Plates/Trays				Total Number: Total Weight:
Packaging				Total Number: Total Weight:
Insulation (Inc Esky Material)				Total Number: Total Weight:
Syringe				Total Number: Total Weight:

RUBBISH ON OUR SHORES AND AT SEA

		No. of Items	Bag Weights	TOTALS
Rubbish Group: PLASTICS (continued)				
Disposable Nappies				Total Number: Total Weight:
Toothbrushes Hairbrushes				Total Number: Total Weight:
Fragments of Plastic				Total Number: Total Weight:
Other				Total Number: Total Weight:
Rubbish Group: RUBBER				
Thongs & Footwear				Total Number: Total Weight:
Gloves				Total Number: Total Weight:
Other				Total Number: Total Weight:
Rubbish Group: METAL				
Aluminium Cans				Total Number: Total Weight:
Tin Cans				Total Number: Total Weight:

RUBBISH ON OUR SHORES AND AT SEA

		No. of Items	Bag Weights	TOTALS
Rubbish Group: METAL (continued)				
Aerosol Cans				Total Number: Total Weight:
Metal Drums				Total Number: Total Weight:
Other				Total Number: Total Weight:
Rubbish Group: GLASS				
Bottles & jars				Total Number: Total Weight:
Light Bulbs				Total Number: Total Weight:
Other				Total Number: Total Weight:
Rubbish Group: TIMBER				
Cardboard Cartons				Total Number: Total Weight:
Paper & Cardboard				Total Number: Total Weight:
Timber (Wood)				Total Number: Total Weight:
Other				Total Number: Total Weight:

RUBBISH ON OUR SHORES AND AT SEA

		No. of Items	Bag Weights	TOTALS
Rubbish Group: CLOTH / FABRIC				
Cloth & Fabric				Total Number:
				Total Weight:
Other				Total Number:
				Total Weight:
ALL OTHER				

Appendix B: Beach Survey Statistical Analysis

Table B 1: List of stakeholder participated in the survey

1. Ship captain
2. Ship crew maintaining vessel garbage station
3. Ship galley crew
4. Kuching Port Authority
5. Bintulu Port Authority
6. Sabah Port Authority
7. Port Klang Authority
8. Kuching North City Counsel
9. Bintulu Development Authority
10. Miri City Council
11. Kota Kinabalu City Hall
12. Port Dickson Municipal Counsel
13. Terengganu City Municipal Counsel
14. Kudat District Counsel
15. Lundu District Council
16. Sematan District Council

Table B 2: Mean BDI (item/km) and BDW (kg/km) debris items according to study sites, locations and monsoon seasons

	BDI (± standard deviation)	BDW (± standard deviation)
Study sites		
Pandan	1,082±672	45.9±23.4
Pasir Pandak	657±285	32.2±12.6
Temasyah	790±278	44.0±16.7
Tg. Lobang	697±259	32.9±13.2
Tg. Aru	1,208±591	49.8±18.7
Kosuhoi	1,263±631	61.3±38.3
Saujana	731±304	38.4±15.6
Batu Rakit	1,263±688	49.0±15.1
Location		
Peninsular	997±578	43.7±15.7
Sabah	1,235±584	55.5±29.3
Sarawak	807±413	38.7±17.1
Season		
NEM	1,001±439	45.9±14.0
IM	711±343	38.7±18.7
SWM	1,171±656	47.9±28.6

Table B 3: Pearson correlation matrix of BDI, BDW and CPB items at the significance level of 0.05 (n=8)

	BDI	BDW	C.P.B	Log_{10} City proximity
BDW	0.893**			
C.P.B	0.427	0.475		
Log_{10} City proximity	0.421	0.519	0.024	
Urban proximity	0.751*	0.724*	0.818*	0.501

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table B 4: Regression analysis result determining BDI (item/km) abundance

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.993[a]	.986	.984	123.719

a. Predictors: kg/km
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7789099.511	1	7789099.511	508.875	.000[c]
	Residual	107145.489	7	15306.498		
	Total	7896245.000[d]	8			

a. Dependent Variable: item/km
b. Linear Regression through the Origin
c. Predictors: kg/km
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	kg/km	21.877	.970	.993	22.558	.000

a. Dependent Variable: item/km
b. Linear Regression through the Origin

Table B 5: Regression analysis result determining factor for BDI (item/km)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.751[a]	.563	.491	191.191

a. Predictors: (Constant), town (km)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	282984.934	1	282984.934	7.742	.032[b]
	Residual	219324.941	6	36554.157		
	Total	502309.875	7			

a. Dependent Variable: item/km
b. Predictors: (Constant), town (km)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	637.545	134.593		4.737	.003
	town (km)	23.746	8.534	.751	2.782	.032

a. Dependent Variable: item/km

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	lg.City.Distance	.060[b]	.177	.866	.079	.749
	rainfall	-.002[b]	-.005	.996	-.002	.628
	REI Rank Value	.098[b]	.280	.791	.124	.695

a. Dependent Variable: item/km
b. Predictors in the Model: (Constant), town (km)

Table B 6: Regression analysis result determining factor for CPB (item/km)

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.957[a]	.916	.904	46.509
2	.981[c]	.963	.950	33.524
3	.994[d]	.987	.980	21.522

a. Predictors: town (km)
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: town (km), rainfall
d. Predictors: town (km), rainfall, lg.City.Distance

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	165643.515	1	165643.515	76.578	.000[c]
	Residual	15141.485	7	2163.069		
	Total	180785.000[d]	8			
2	Regression	174042.012	2	87021.006	77.432	.000[e]
	Residual	6742.988	6	1123.831		
	Total	180785.000[d]	8			
3	Regression	178469.122	3	59489.707	128.439	.000[f]
	Residual	2315.878	5	463.176		
	Total	180785.000[d]	8			

a. Dependent Variable: Clear bottles (item/km)
b. Linear Regression through the Origin
c. Predictors: town (km)
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: town (km), rainfall
f. Predictors: town (km), rainfall, lg.City.Distance

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	town (km)	9.124	1.043	.957	8.751	.000
2	town (km)	6.891	1.110	.723	6.207	.001
	rainfall	.230	.084	.318	2.734	.034
3	town (km)	9.494	1.103	.996	8.606	.000
	rainfall	.350	.067	.485	5.262	.003
	lg.City.Distance	-43.197	13.972	-.440	-3.092	.027

a. Dependent Variable: Clear bottles (item/km)
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	lg.City.Distance	-.002[c]	-.006	.995	-.002	.192
	rainfall	.318[c]	2.734	.034	.745	.458
	REI Rank Value	.179[c]	.774	.468	.301	.237
2	lg.City.Distance	-.440[d]	-3.092	.027	-.810	.126
	REI Rank Value	.009[d]	.048	.964	.021	.202
3	REI Rank Value	-.012[e]	-.093	.931	-.046	.201

a. Dependent Variable: Clear bottles (item/km)
b. Linear Regression through the Origin
c. Predictors in the Model: town (km)
d. Predictors in the Model: town (km), rainfall
e. Predictors in the Model: town (km), rainfall, lg.City.Distance

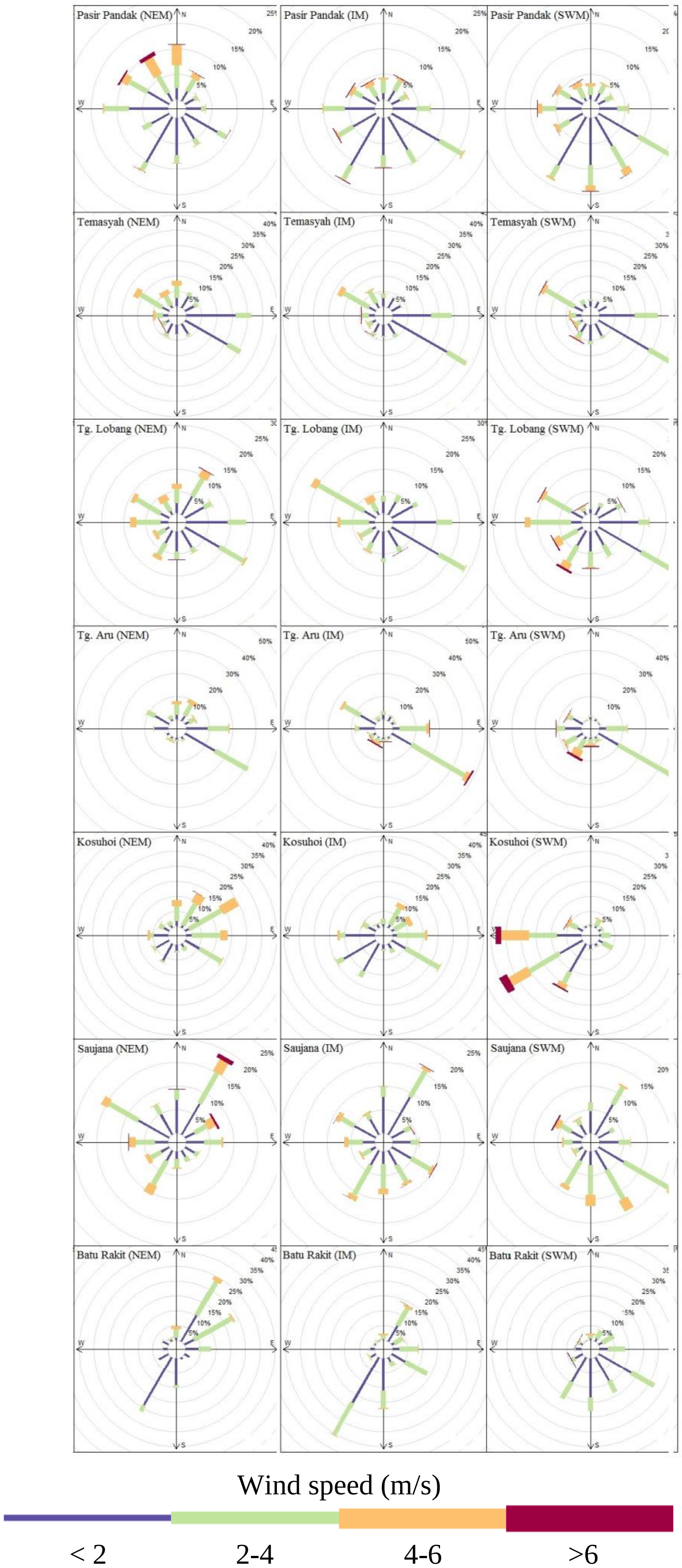


Figure B 1: Distribution of wind speed and direction according to study sites and monsoon seasons sampling. This figure was constructed with the R package openair

Table B 7: Means BDI (item/km) and BDW (kg/km) for monsoon seasons according to study sites

Site	BDI			BDW			Total	
	NEM	IM	SWM	NEM	IM	SWM	BDI	BDW
Pandan	1052	823	1371	47.5	41.7	48.6	1082±275	45.9±3.7
Pasir Pandak	964	451	558	46.4	25.7	24.6	657±271	32.2±12.3
Temasyah	891	724	757	41.3	49.7	41.1	790±88	44.1±4.9
Tg. Lobang	848	540	703	44.1	25.5	29	670±154	32.9±9.9
Tg. Aru	801	981	1841	37.5	40.8	71.1	1208±556	49.8±18.5
Kosuhoi	1292	708	1789	64.6	32.9	86.5	1263±541	61.3±26.9
Saujana	952	481	761	44.2	40	30.9	731±237	38.5±6.8
Batu Rakit	1212	985	1592	41.9	53.5	51.5	1263±307	49.1±6.2
Total	1,001±174	711±211	1,711±532	45.9±8.2	38.7±10.2	47.9±21.6	961±383	44.2±14.5

Table B 8: Means BDI (item/km) and BDW (kg/km) of debris abundance according to debris category

		Plastic	Rubber	Metal	Glass	Wood	Cloth
BDI	*Study sites*						
	Pandan	960±588	31±22	40±43	17±20	30±31	3±3
	Pasir Pandak	596±274	15±13	11±5	10±9	18±13	6±10
	Temasyah	701±218	23±16	8±6	12±8	41±31	6±8
	Tg. Lobang	623±227	19±14	10±6	89±9	33±24	4±6
	Tg. Aru	1075±535	31±13	29±37	18±11	54±33	2±4
	Kosuhoi	1101±550	36±19	38±41	31±29	50±54	6±10
	Saujana	649±256	12±5	12±11	11±9	41±44	7±7
	Batu Rakit	1100±617	43±26	38±30	55±36	20±23	7±15
	Location						
	Peninsular	874±508	28±24	25±26	33±34	30±35	7±11
	Sabah	1088±517	33±16	33±37	24±22	52±43	4±8
	Sarawak	720±337	22±17	17±25	12±12	31±26	5±7
	Season						
	NEM	883±373	33±16	22±27	24±26	33±45	7±10
	IM	619±271	20±19	22±31	14±26	31±34	5±8
	SWM	1050±592	26±20	26±30	22±17	44±17	4±6
BDW	*Study sites*						
	Pandan	28.4±13.1	6.7±4.9	4.4±3.8	3.5±3.2	1.7±1.3	1.2±1.3
	Pasir Pandak	21.3±7.9	3.7±3.0	1.5±1.2	3.1±1.9	1.2±1.0	1.5±1.5
	Temasyah	25.0±9.5	8.9±6.7	3.2±2.9	2.6±3.3	2.1±1.1	2.3±3.0
	Tg. Lobang	21.2±6.9	5.2±5.7	1.4±1.6	2.1±2.6	1.3±0.7	1.7±2.3
	Tg. Aru	28.5±6.7	9.1±6.6	4.1±3.0	4.6±2.1	2.4±0.9	1.1±1.8
	Kosuhoi	33.7±14.5	6.2±4.1	11.1±18.1	6.1±4.3	2.1±1.1	2.3±3.5
	Saujana	18.6±3.3	9.1±8.1	1.3±1.3	5.7±1.9	2.1±2.7	3.1±3.4
	Batu Rakit	27.2±8.3	7.1±3.0	1.4±3.2	7.9±4.2	1.3±1.3	1.1±1.3
	Location						
	Peninsular	22.9±7.5	8.1±6.0	2.9±2.9	5.8±3.8	1.6±2.1	2.4±2.8
	Sabah	31.1±11.0	7.7±5.5	7.6±12.9	5.3±3.6	2.2±0.9	1.6±2.7
	Sarawak	23.9±9.5	6.1±5.3	2.6±2.7	2.8±2.4	1.6±1.0	1.7±2.0
	Season						
	NEM	27.5±7.7	7.1±3.3	3.1±2.2	4.6±3.3	1.6±1.7	2.3±2.7
	IM	23.6±9.5	6.4±6.6	2.8±3.0	2.7±3.0	1.4±1.2	1.9±2.6
	SWM	25.4±12.1	7.4±6.2	6.1±11.6	5.2±3.4	2.2±0.9	1.7±2.0

Table B 9: Mean BDI (item/km) according to debris source

	Marine	Terrestrial	Common
Study sites			
Pandan	199±132	280±137	464±323
Pasir Pandak	108±122	151±29	273±177
Temasyah	69±45	257±45	343±111
Tg. Lobang	67±46	180±30	317±160
Tg. Aru	115±70	373±165	468±178
Kosuhoi	234±170	229±123	588±300
Saujana	74±39	243±162	195±86
Batu Rakit	297±146	237±124	554±342
Location			
Peninsular	186±155	240±137	374±303
Sabah	169±136	301±158	528±244
Sarawak	111±105	217±89	349±207
Season			
NEM	163±114	251±128	406±194
IM	95±102	199±83	306±193
SWM	174±155	281±145	488±319

Table B 10: Pearson correlation matrix of BDI, BDW and CPB items at the significance level of 0.05 (n=48)

	BDI	BDW	CPB	Rainfall
BDW	0.826**			
CPB	0.765**	0.665**		
Rainfall	0.026	0.089	-0.144	
REI	0.299*	0.332*	0.559**	-0.036

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table B 11: Means surface wind speed (m/s) and wind direction (degree, °) (with standard deviation) according to monsoon seasons at weather observation station.

Station ID	Study site	NEM		IM		SWM	
		wind speed	wind direction	wind speed	wind direction	wind speed	wind direction
Pertanian Sematan (95201)	Pandan	2.0±1.4	187±107	1.8±1.1	176±86	2.0±1.2	178±80
Bintulu (96441)	Temasyah	1.9±1.0	152±102	1.8±0.9	162±96	1.9±1.0	164±87
Miri (96449)	Tg. Lobang	2.1±1.2	153±100	2.0±1.1	173±98	2.1±1.2	180±83
Kota Kinabalu (96471)	Tg. Aru	2.1±1.0	134±95	2.4±1.3	163±93	2.4±1.2	168±77
Kudat (96477)	Kosuhoi	2.5±1.2	125±92	2.0±1.0	167±90	2.8±1.7	226±67
Atherton Estate (45220)	Saujana	2.3±1.3	164±117	2.1±1.1	153±105	2.3±1.2	150±89
Kuala Terengganu (48618)	Batu Rakit	1.9±1.0	121±88	2.0±0.9	148±71	1.8±0.8	154±62

Table B 12: Regression analysis result determining REI factor for BDI (item/km) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.299[a]	.089	.070	504.121

a. Predictors: (Constant), REI Value

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1146619.332	1	1146619.332	4.512	.039[b]
	Residual	11690324.147	46	254137.481		
	Total	12836943.479	47			

a. Dependent Variable: Total Item/km
b. Predictors: (Constant), REI Value

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	797.074	106.161		7.508	.000
	REI Value	164.197	77.302	.299	2.124	.039

a. Dependent Variable: Total Item/km

Table B 13: Regression analysis result determining REI factor for BDW (kg/km) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.332[a]	.110	.091	20.22978

a. Predictors: (Constant), REI Value

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2327.418	1	2327.418	5.687	.021[b]
	Residual	18825.232	46	409.244		
	Total	21152.650	47			

a. Dependent Variable: Total kg/km
b. Predictors: (Constant), REI Value

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	36.767	4.260		8.631	.000
	REI Value	7.398	3.102	.332	2.385	.021

a. Dependent Variable: Total kg/km

Table B 14: Regression analysis result determining REI factor for CPB (item/km) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.559[a]	.312	.297	84.879

a. Predictors: (Constant), REI Value

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	150243.181	1	150243.181	20.854	.000[b]
	Residual	331408.298	46	7204.528		
	Total	481651.479	47			

a. Dependent Variable: Clear bottles (item/km)
b. Predictors: (Constant), REI Value

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	77.293	17.874		4.324	.000
	REI Value	59.437	13.015	.559	4.567	.000

a. Dependent Variable: Clear bottles (item/km)

Appendix C: Instrument for Assessment Shipborne Garbage on the Vessel

QUESTIONNAIRE FORM (SHIP SURVEY)
STUDY FOR THE MANAGEMENT OF MARINE DEBRIS FROM SHIPS IN COMPLIANCE TO MARPOL 73/78 ANNEX V

Marine Department Malaysia is conducting a study to determine the distribution and abundance of marine debris in relation to MARPOL 73/78 Annex V in Malaysia. The study is attempting to determine the amount and type of refuse generated by the industry. We would appreciate your assistance in answering the following questions. All responses will be kept **confidential**.

…………………………………
A. Responded particular

1. Name (optional):
2. Address:
3. Phone Number:
4. Date of interview:
5. Last Port of Call:
6. Next Port of Call:

…………………………………
B. Ship Particular

1. Name of ship :- ....
2. Flag of ship :- ....
3. Type of ship :- ....
4. Call sign :- ....
5. IMO number :- ....
6. Gross Tonnage :- ....
7. Year keel laid :- ....
8. Classification society :- ....
9. Particulars of owner/operator :- ....
10. Number of crew :- ....
11. Validity of IOPP Cert :- ....

…………………………………
C. Ship Operation;

1. Length of typical voyage:
Number of days at last port : ______
Steaming hours from last port : ______
Number of days in port of call : ______

2. Frequency of visit to this port;

	Once a month
	Once in 3 month
	Once in 6 month
	Once in 12 month
	Others (please specify)

…………………………………….

3. Type of Cargo:- ....

4. Number of voyages each year:- .... Total voyage duration:- ………………… (days)

5. Port of call in the year 2012;

Port Name	Number of visit per year

**Refer to Voyage memo*

……………………………………

D. MARPOL 73/78 Annex V;

1. Estimate total amount of refuse/waste (kg) generated by your vessel per voyage:_____
2. Estimate refuse/waste per voyage;

Category of refuse	**m^3 or kg**
Plastic	
Food waste	
Domestic Wastes	
Cooking oil	
Incinerator waste	
Operational waste	
Cargo residues	
Animal carcass(es)	
Fishing gear	

**Refer to Garbage Record Book year 2012*

3. How do your vessel manage the refuse/waste;

Throw overboard	
Deliver to port	
Process	

Which port:………………………………

4. Vessel waste storage

Does your vessel have a storage area?	Yes		No	
Is the space a problem?	Yes		No	

5. Compaction

Does your vessel has a trash compactor	Yes		No	
If "yes"; -Model:_______________ -Do you feel that it assists in disposing of refuse; Is practical___ Is cost effective___ Is beneficial___ If "no"; 6. -do you feel that use of an compaction on your vessel would assist in disposing of refuse Be practical___ Be cost effective___ Be beneficial___				
Do you intend to install one?	Yes		No	
If "no", why not? Too expensive Don't generate enough refuse Other:______________________				

7. Incinerator

Does your vessel has a incinerator	Yes		No	
If "yes"; -Model:________________ -Do you feel that it assists in disposing of refuse; Is practical___ Is cost effective___ Is beneficial___ If "no"; -do you feel that use of an incinerator on your vessel would assist in disposing of refuse Be practical___ Be cost effective___ Be beneficial___				
Do you intend to install one?	Yes		No	
If "no", why not? Too expensive Don't generate enough refuse Other:_______________________				

8. Comminutor

Does your vessel has a comminutor	Yes		No	
If "yes"; -Model:________________ -Do you feel that it assists in disposing of refuse; Is practical___ Is cost effective___ Is beneficial___ If "no"; -do you feel that use of an comminutor on your vessel would assist in disposing of refuse Be practical___ Be cost effective___ Be beneficial___				
Do you intend to install one?	Yes		No	
If "no", why not? Too expensive Don't generate enough refuse Other:_______________________				

9. Where do you get food and supply provision;

Port :……………………… Contract: yes / no

10. Do you feel that the people you buy your supplies from are in understand with the need to reduce the amount of generated refuse on your vessel?

Yes	
No	
Not sure	

11. If the people you buy your supplies from were in tune with the need to reduce the amount of generated refuse, how much of a volume reduction do you think could be accomplished on your vessel?

12. Do you have any suggestions about possible ways to handle refuse more efficient?

____

____

____

Shipborne Garbage Survey at Ship Garbage Station
Marine Debris Survey

Date :
Location :
Comment/Note :

Rubbish Group: PLASTIC

Object	***No. of Item***	***Total Weight***
Clear Plastic Bottles		
Colored Plastic Bottles		
Plastic Oil Bottles		
Bottle caps		
Buckets		
Hard Hats		
Cigarette Lighters		
6 pack rings		
Food wrappers		
Plastic bags		
Palette wrappers		
Strapping		
Ropes		
Buoys & Floats		
Fishing Lines		
Lures		
Cups		
Packaging		
Insulations		
Syringe		
Disposable Nappies		
Toothbrushes		
Fragments of Plastic		
Cardboard Cartons		
Others		

Rubbish Group: FOOD WASTE

Object	***No. of Item***	***Total Weight***
Food waste		
Others		

Rubbish Group: DOMESTIC WASTE

Object	***No. of Item***	***Total Weight***
Thongs & Footwear		
Aluminum cans		
Tin Cans		
Aerosol Cans		
Bottles & Jars		
Light bulbs		
Paper & Cardboard		
Others		
Cloth & Fabric		
Gloves		
Others		

Rubbish Group: COOKING OIL

Object	***No. of Item***	***Total Weight***
Cooking oil		
Others		

Rubbish Group: INCINERATOR ASHES

Object	***No. of Item***	***Total Weight***
Incinerator ashes		
Others		

Rubbish Group: OPERATIONAL WASTE

Object	***No. of Item***	***Total Weight***
Gloves		
Belting		
Oil rags		
Metal Drums		
Others		

Rubbish Group: CARGO RESIDUE

Object	***No. of Item***	***Total Weight***
Timber (wood)		
Others		

Rubbish Group: ANIMASL CARCASSES

Object	***No. of Item***	***Total Weight***
Animal carcasses		
Others		

Rubbish Group: FISHING GEAR

Object	***No. of Item***	***Total Weight***
Fishing gear		
Others		

Shipborne Garbage Survey – ORIGINS

Item Description	Manufacturer / Product Name	Barcode/Origin	Total No

Appendix D: Ship Survey Statistical Analysis

Table D 1: Pearson correlation matrix of $\log_{10}$ SGI, SGW and $\log_{10}$ GGR at the significance level of 0.05 (n=115)

	Log_{10} SGI	SGW	Log_{10} GGR	Crew	Log_{10} GRT	Log_{10} Cruise	Voyage
SGW	0.643^{**}						
Log_{10} GGR	0.313^{**}	0.557^{**}					
Crew	0.210^{*}	0.066	-0.203^{*}				
Log_{10} GRT	0.117	-0.023	-0.108	0.644^{**}			
Log_{10} Cruise	0.070	0.065	-0.648^{**}	0.045	0.062		
Voyage	0.204^{*}	0.208^{*}	-0.107	0.204^{*}	0.415^{**}	0.340^{**}	
Proc. Equipment	0.113	0.018	-0.039	0.394^{**}	0.617^{**}	0.004	0.324^{**}

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table D 2: Regression analysis result determining SGI (item/vessel) abundance

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.901[a]	.811	.810	.17767

a. Predictors: Number of crew
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.478	1	15.478	490.343	.000[c]
	Residual	3.599	114	.032		
	Total	19.077[d]	115			

a. Dependent Variable: log.Sitem.vessel
b. Linear Regression through the Origin
c. Predictors: Number of crew
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Number of crew	.018	.001	.901	22.144	.000

a. Dependent Variable: log.Sitem.vessel
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Voyage	.176[c]	1.900	.060	.176	.189

a. Dependent Variable: log.Sitem.vessel
b. Linear Regression through the Origin
c. Predictors in the Model: Number of crew

Table D 3: Regression analysis result determining SGW (kg/vessel) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.208[a]	.043	.035	29.6059

a. Predictors: (Constant), Voyage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4494.798	1	4494.798	5.128	.025[b]
	Residual	99045.424	113	876.508		
	Total	103540.221	114			

a. Dependent Variable: Total Weight VDS
b. Predictors: (Constant), Voyage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	42.241	6.244		6.765	.000
	Voyage	.380	.168	.208	2.265	.025

a. Dependent Variable: Total Weight VDS

Table D 4: Regression analysis result determining factors for GGR (kg/person/day) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.648[a]	.420	.415	.15280
2	.671[b]	.450	.440	.14943

a. Predictors: (Constant), lg.Cruise
b. Predictors: (Constant), lg.Cruise, Number of crew

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.908	1	1.908	81.717	.000[b]
	Residual	2.638	113	.023		
	Total	4.546	114			
2	Regression	2.045	2	1.023	45.800	.000[c]
	Residual	2.501	112	.022		
	Total	4.546	114			

a. Dependent Variable: lg.SGGR
b. Predictors: (Constant), lg.Cruise
c. Predictors: (Constant), lg.Cruise, Number of crew

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.613	.038		16.082	.000
	lg.Cruise	-.505	.056	-.648	-9.040	.000
2	(Constant)	.842	.100		8.458	.000
	lg.Cruise	-.499	.055	-.640	-9.124	.000
	Number of crew	-.012	.005	-.174	-2.481	.015

a. Dependent Variable: lg.SGGR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Number of crew	-.174[b]	-2.481	.015	-.228	.998

a. Dependent Variable: lg.SGGR
b. Predictors in the Model: (Constant), lg.Cruise

Table D 5: Pearson correlation matrix of SGI, SGW and GGR according to ship type at the significance level of 0.05 (n=15)

	SGI	SGW	GGR	Num. of Vessel	Crew	GRT	Cruise	Voyage
SGW	0.932**							
GGR	-0.632*	-0.414						
Num. of Vessel	0.649**	0.582*	-0.406					
Crew	0.651**	0.563*	-0.427	0.996**				
GRT	0.462	0.338	-0.361	0.901**	0.927**			
Cruise	0.154	-0.003	-0.568*	-0.004	0.017	0.068		
Voyage	0.418	0.253	-0.744**	0.107	0.125	0.154	0.757**	
Proc. Equipment	0.540*	0.453	-0.359	0.949**	0.963**	0.984**	0.014	0.154

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table D 6: Regression analysis result determining SGI (item/vessel) abundance according to ship type

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.651[a]	.423	.379	19.79101

a. Predictors: (Constant), Crew

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3737.443	1	3737.443	9.542	.009[b]
	Residual	5091.891	13	391.684		
	Total	8829.333	14			

a. Dependent Variable: S SGI
b. Predictors: (Constant), Crew

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	40.744	8.144		5.003	.000
	Crew	.128	.041	.651	3.089	.009

a. Dependent Variable: S SGI

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	num.vessel	.156[b]	.062	.952	.018	.008
	Equip	-1.185[b]	-1.613	.133	-.422	.073

a. Dependent Variable: S SGI
b. Predictors in the Model: (Constant), Crew

Table D 7: Regression analysis result determining SGW (kg/vessel) abundance according to ship type

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.582[a]	.338	.288	8.16099

a. Predictors: (Constant), num.vessel

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	442.922	1	442.922	6.650	.023[b]
	Residual	865.823	13	66.602		
	Total	1308.745	14			

a. Dependent Variable: S SGW
b. Predictors: (Constant), num.vessel

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.353	3.509		3.236	.007
	num.vessel	.944	.366	.582	2.579	.023

a. Dependent Variable: S SGW

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Crew	-2.126[b]	-.809	.434	-.228	.008

a. Dependent Variable: S SGW
b. Predictors in the Model: (Constant), num.vessel

Table D 8: Regression analysis result determining factors for GGR (kg/person/day) abundance according to ship type

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.744[a]	.554	.520	.43356

a. Predictors: (Constant), Voyage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.034	1	3.034	16.141	.001[b]
	Residual	2.444	13	.188		
	Total	5.478	14			

a. Dependent Variable: S GGR
b. Predictors: (Constant), Voyage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.492	.400		6.228	.000
	Voyage	-.047	.012	-.744	-4.018	.001

a. Dependent Variable: S GGR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Cruise	-.010[b]	-.034	.973	-.010	.427

a. Dependent Variable: S GGR
b. Predictors in the Model: (Constant), Voyage

Table D 9: Pearson correlation matrix of SGI, SGW and GGR according to ports location at the significance level of 0.05 (n=3)

	SGI	SGW	GGR	Num. of Vessel	Crew	GRT	Cruise	Voyage
SGW	0.657							
GGR	0.079	0.803						
Num. of Vessel	-0.949	-0.385	0.241					
Crew	-0.976	-0.476	0.143	0.995				
GRT	-0.123	-0.829	-0.999*	-0.197	-0.098			
Cruise	0.233	-0.579	-0.951	-0.529	-0.441	0.936		
Voyage	0.726	-0.041	-0.628	-0.906	-0.860	0.593	0.838	
Proc. Equipment	-0.343	-0.933	-0.963	0.028	0.128	0.974	0.834	0.397

*. Correlation is significant at the 0.05 level (2-tailed).

Table D 10: Regression analysis result determining factors for GGR (kg/person/day) abundance according to ports location

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.996	.01038
2	1.000[b]	1.000	.	.

a. Predictors: (Constant), GRT
b. Predictors: (Constant), GRT, Voyage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.054	1	.054	503.231	.028[b]
	Residual	.000	1	.000		
	Total	.054	2			
2	Regression	.054	2	.027	.	.[c]
	Residual	.000	0	.		
	Total	.054	2			

a. Dependent Variable: S GGR
b. Predictors: (Constant), GRT
c. Predictors: (Constant), GRT, Voyage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.062	.019		56.841	.011
	GRT	-5.087E-7	.000	-.999	-22.433	.028
2	(Constant)	1.173	.000		.	.
	GRT	-4.920E-7	.000	-.966	.	.
	Voyage	-.004	.000	-.055	.	.

a. Dependent Variable: S GGR

Table D 11: Pearson correlation matrix of SGI, SGW and GGR according to BGW classification at the significance level of 0.05 (n=3)

	SGI	SGW	GGR	Num. of Vessel	Crew	GRT	Cruise	Voyage
SGW	0.985**							
GGR	-0.233	-0.220						
Num. of Vessel	0.821**	0.759**	-0.246					
Crew	0.819**	0.752**	-0.249	0.998**				
GRT	0.652**	0.567*	-0.187	0.923**	0.937**			
Cruise	0.588*	0.601*	-0.285	0.649**	0.632*	0.454		
Voyage	0.638*	0.645**	-0.020	0.557*	0.546*	0.380	0.789**	
Proc. Equipment	0.772**	0.696**	-0.175	0.964**	0.973**	0.980**	0.502	0.461

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table D 12: Regression analysis result determining factors for SGI (item/vessel) abundance according to BGW classification

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.915[a]	.838	.826	34.11342
2	.941[c]	.885	.868	29.78985

a. Predictors: num.vessel
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: num.vessel, GRT

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	84232.841	1	84232.841	72.382	.000[c]
	Residual	16292.159	14	1163.726		
	Total	100525.000[d]	15			
2	Regression	88988.344	2	44494.172	50.138	.000[e]
	Residual	11536.656	13	887.435		
	Total	100525.000[d]	15			

a. Dependent Variable: S SGI
b. Linear Regression through the Origin
c. Predictors: num.vessel
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: num.vessel, GRT

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	num.vessel	7.033	.827	.915	8.508	.000
2	num.vessel	10.829	1.792	1.409	6.044	.000
	GRT	.000	.000	-.540	-2.315	.038

a. Dependent Variable: S SGI
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Crew	-1.290[c]	-.560	.585	-.153	.002
	GRT	-.540[c]	-2.315	.038	-.540	.162
	Cruise	.210[c]	1.032	.321	.275	.279
	Voyage	.305[c]	1.761	.102	.439	.336
2	Crew	6.042[d]	2.141	.054	.526	.001
	Cruise	-.134[d]	-.536	.602	-.153	.149
	Voyage	.100[d]	.450	.661	.129	.189

a. Dependent Variable: S SGI
b. Linear Regression through the Origin
c. Predictors in the Model: num.vessel
d. Predictors in the Model: num.vessel, GRT

Table D 13: Regression analysis result determining factors for SGW (kg/vessel) abundance according to BGW classification

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.889[a]	.790	.775	11.69665
2	.933[c]	.870	.850	9.56546

a. Predictors: num.vessel
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: num.vessel, GRT

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7204.826	1	7204.826	52.662	.000[c]
	Residual	1915.362	14	136.812		
	Total	9120.188[d]	15			
2	Regression	7930.713	2	3965.356	43.338	.000[e]
	Residual	1189.475	13	91.498		
	Total	9120.188[d]	15			

a. Dependent Variable: S SGW
b. Linear Regression through the Origin
c. Predictors: num.vessel
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: num.vessel, GRT

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	num.vessel	2.057	.283	.889	7.257	.000
2	num.vessel	3.540	.575	1.530	6.153	.000
	GRT	-5.530E-5	.000	-.700	-2.817	.015

a. Dependent Variable: S SGW
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Crew	-3.199[c]	-1.278	.223	-.334	.002
	GRT	-.700[c]	-2.817	.015	-.616	.162
	Cruise	.340[c]	1.538	.148	.392	.279
	Voyage	.409[c]	2.179	.048	.517	.336
2	Crew	3.811[d]	1.134	.279	.311	.001
	Cruise	-.046[d]	-.170	.868	-.049	.149
	Voyage	.154[d]	.655	.525	.186	.189

a. Dependent Variable: S SGW
b. Linear Regression through the Origin
c. Predictors in the Model: num.vessel
d. Predictors in the Model: num.vessel, GRT

Table D 14: Mean SGI (item/vessel) and SGW (kg/vessel) according to shipborne garbage categories

	Variable	Plastic	Food waste	Domestic waste	Cooking oil	Incinerator ashes	Operational waste	Cargo residue
SGI	*Study ports*							
	Kuching	106±75	0	25±23	0	0	27±21	6±7
	Bintulu port	111±94	0	28±26	0	0	35±19	9±9
	Kota Kinabalu port	119±81	0	25±24	0	0	35±20	10±10
	Sandakan port	126±94	0	33±29	0	0	30±15	7±9
	Klang port	119±130	0	30±58	0	0	27±13	7±6
	Ship types							
	Container	98±87	0	20±20	0	0	25±16	5±6
	Bulk carrier	135±123	0	39±60	0	0	34±16	8±8
	General cargo	119±90	0	28±26	0	0	34±20	10±9
	Ports classification							
	Federal	116±118	0	29±49	0	0	30±16	8±7
	State	116±80	0	27±25	0	0	31±19	8±9
	Ports location							
	Peninsular	119±130	0	30±58	0	0	27±14	7±6
	Sabah	122±85	0	29±26	0	0	33±18	9±9
	Sarawak	108±83	0	26±24	0	0	31±20	7±8
	BGW classification							
	Black	94±65	0	25±19	0	0	31±16	7±7
	Grey	127±111	0	30±44	0	0	31±19	8±8
	White	74±45	0	18±17	0	0	23±7	11±8

	Variable	Plastic	Food waste	Domestic waste	Cooking oil	Incinerator ashes	Operational waste	Cargo residue
SGW	*Study ports*							
	Kuching	5.4±3.9	18.3±11.0	3.6±3.3	1.4±1.3	1.2±1.1	5.1±5.5	15.5±16.2
	Bintulu port	5.3±3.4	19.4±10.4	4.7±8.2	1.2±1.1	0.9±0.9	5.0±2.8	20.8±19.4
	Kota Kinabalu port	5.3±3.8	27.4±10.9	3.7±2.9	1.5±1.9	1.5±1.3	4.4±1.9	23.0±24.0
	Sandakan port	5.5±3.6	22.5±10.4	3.8±2.6	1.6±1.9	1.9±1.5	7.2±8.4	17.9±18.8
	Klang port	4.9±5.6	19.7±10.8	3.2±3.8	1.1±0.9	1.1±1.0	3.7±2.2	16.1±14.4
	Ship types							
	Container	4.2±3.6	17.8±11.0	2.8±2.9	1.0±0.9	1.0±1.1	3.5±2.4	12.9±13.4
	Bulk carrier	6.7±5.7	23.0±11.2	4.1±3.5	1.5±1.2	1.5±1.3	6.6±6.8	20.5±21.2
	General cargo	5.0±3.1	21.9±9.6	4.5±6.5	1.5±1.6	1.3±1.1	4.6±2.2	22.9±18.9
	Ports classification							
	Federal	5.0±4.9	19.6±10.6	3.7±5.7	1.1±1.0	1.0±1.0	4.1±2.5	17.8±16.4
	State	5.3±3.7	21.5±11.0	3.7±3.0	1.5±1.5	1.5±1.3	5.4±5.6	18.6±19.7
	Ports location							
	Peninsular	4.9±5.6	19.7±10.8	3.2±3.7	1.1±0.9	1.1±1.0	3.7±2.2	16.0±14.4
	Sabah	5.3±3.6	23.8±10.6	3.7±2.7	1.6±1.6	1.7±1.4	5.5±5.7	20.9±21.9
	Sarawak	5.3±3.6	18.8±10.6	4.1±5.9	1.3±1.2	1.1±1.0	5.0±4.5	17.9±17.7
	BGW classification							
	Black	4.3±2.7	20.2±9.9	3.5±2.7	1.4±1.7	1.2±0.9	4.1±1.3	16.5±16.7
	Grey	5.6±5.8	20.5±11.5	3.9±5.1	1.3±1.0	1.2±1.2	5.0±5.2	18.6±18.8
	White	3.3±2.3	24.2±2.4	2.0±1.6	1.2±1.3	2.2±0.8	4.3±1.7	22.0±16.0

Table D 15: Means SGI (item/vessel) and SGW (kg/vessel) according to garbage sources

	Variable	Maintenance	Crew	Cargo	Common
SGI	*Study ports*				
	Kuching	21±21	25±23	6±7	106±75
	Bintulu	35±19	28±26	9±9	111±94
	Kota Kinbalu	35±20	25±24	10±10	119±81
	Sandakan	30±15	34±28	7±9	126±94
	Klang	27±13	30±58	7±6	119±130
	Ship types				
	Container	25±116	20±20	5±6	99±87
	Bulk carrier	34±16	39±60	8±8	135±123
	General cargo	34±20	28±26	10±9	119±90
	Ports classification				
	Federal	30±16	29±49	8±7	116±118
	State	31±19	27±25	8±9	116±81
	Ports location				
	Peninsular	27±13	30±58	7±6	119±130
	Sabah	33±18	29±26	9±9	122±85
	Sarawak	31±20	26±24	7±8	108±83
	BGW classification				
	Black	31±16	25±19	7±7	94±65
	Grey	31±19	30±44	8±8	127±111
	White	23±7	18±17	10±8	74±45
SGW	*Study ports*				
	Kuching	6.3±5.6	23.3±13.3	15.5±16.2	5.4±3.9
	Bintulu	5.9±3.2	25.3±14.3	20.8±19.4	5.3±3.4
	Kota Kinbalu	5.9±2.4	29.8±11.8	23.0±24.0	5.3±3.8
	Sandakan	9.1±8.8	27.9±11.9	17.9±18.8	5.4±3.6
	Klang	4.7±2.8	23.9±13.2	16.1±14.4	4.9±5.6
	Ship types				
	Container	4.5±3.2	21.5±13.2	12.9±13.4	4.2±3.6
	Bulk carrier	8.1±6.9	28.6±12.5	20.5±21.2	6.7±5.7
	General cargo	5.9±2.7	27.9±12.3	22.9±18.9	5.0±3.1
	Ports classification				
	Federal	5.1±3.0	24.4±13.5	17.8±16.4	5.0±4.9
	State	6.8±5.8	26.6±12.6	18.6±19.7	4.4±3.8
	Ports location				
	Peninsular	4.7±2.8	24±13.2	16.3±14.4	4.9±5.6
	Sabah	7.2±6.1	29±11.7	20.9±21.9	5.3±.6
	Sarawak	6.1±4.6	24.2±13.6	17.9±17.7	5.3±3.6
	BGW classification				
	Black	5.3±1.6	25.1±11.1	16.5±16.7	4.3±2.7
	Grey	6.3±5.6	25.6±14.2	18.6±18.8	5.6±4.8
	White	6.5±2.1	27.4±2.3	22.0±16.0	3.4±2.3

Appendix E: Marine Debris Origin Detail

WWF

RUBBISH ON OUR SHORES AND AT SEA

Marine Debris Survey - ORIGINS

DETAILS:

Survey site: ______________________ Date: ______________________

Recorder's Name: ______________________ Survey Day No: ______________________

Item Description	Manufacturer/Product Name	Barcode/Origin	Total No.
Plastic water bottle	Good Water	7410088002850	3

EAN International Barcodes

000 - 139	U.S.A. & Canada
300 - 379	France
380	Bulgaria
383	Slovenia
385	Croatia
387	Bosnia-Herzegovina
400-440	Germany
450-459 & 490-499	Japan
460-469	Russia
470	Kyrgyzstan
471	Taiwan
474	Estonia
475	Latvia
476	Azerbaijan
477	Lithuania
478	Uzbekistan
479	Sri Lanka
480	Philippines
481	Belarus
482	Ukraine
484	Moldova
485	Armenia
486	Georgia
487	Kazakhstan
489	Hong Kong
500-509	United Kingdom
520	Greece
528	Lebanon
529	Cyprus
531	Macedonia
535	Malta
539	Ireland
540-549	Belgium &.Luxembourg
560	Portugal
569	Iceland
570-579	Denmark
590	Poland
594	Romania
599	Hungary
600-601	South Africa
608	Bahrain
609	Mauritius
611	Morocco
613	Algeria
616	Kenya
619	Tunisia
621	Syria
622	Egypt
624	Libya
625	Jordan
626	Iran
627	Kuwait
628	Saudi Arabia
629	Emirates
640-649	Finland
690-695	China
700-709	Norway
729	Israel
730-739	Sweden
740	Guatemala
741	El Salvador
742	Honduras
743	Nicaragua
744	Costa Rica
745	Panama
746	Dominican Republic
750	Mexico
759	Venezuela
760-769	Switzerland
770	Colombia
773	Uruguay
775	Peru
777	Bolivia
779	Argentina
780	Chile
784	Paraguay
786	Ecuador
789-790	Brazil
800-839	Italy
840-849	Spain
850	Cuba
858	Slovakia
859	Czech Republic
860	Yugoslavia
867	North Korea
869	Turkey
870-879	Netherlands
880	South Korea
884	Cambodia
885	EAN Thailand
888	Singapore
890	India
893	Vietnam
899	Indonesia
900-919	Austria
930-939	Australia
940-949	New Zealand
955	Malaysia
958	Macau

Appendix F: Beach Debris and Shipborne Garbage Relationship Statistical Analysis

Table F 1: Pearson correlation matrix of SGI, SGW, BDI and BDW at the significance level of 0.05 (n=5)

	SGI	BDI (Marine Source)	SGI CPB	BDI CPB	Nom. of Vessel	Nom. of crew	Gross Tonnage	Total Ship Call	Distance Beach to Town (km)
BDI (Marine Source)	0.646								
SGI CPB	0.740	0.779							
BDI CPB	0.372	0.843	0.384						
Nom. of Vessel	-0.523	-0.641	-0.430	-0.815					
Nom. of crew	-0.520	-0.628	-0.432	-0.800	1.000**				
Gross Tonnage	-0.669	-0.252	-0.646	-0.067	0.557	0.574			
Total Ship Call	-0.387	-0.443	0.044	-0.765	0.762	0.749	0.067		
Distance Beach to Town (km)	-0.908*	-0.629	-0.598	-0.565	0.806	0.805	0.721	0.656	
Distance Beach to Port (km)	0.371	0.885*	0.775	0.620	-0.299	-0.287	-0.060	-0.023	-0.244

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table F 2: Regression analysis result determining BDI (item/km) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.885[a]	.784	.712	33.58215

a. Predictors: (Constant), Sea Beach to Port (km)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12271.796	1	12271.796	10.882	.046[b]
	Residual	3383.282	3	1127.761		
	Total	15655.078	4			

a. Dependent Variable: BMarine item/km
b. Predictors: (Constant), Sea Beach to Port (km)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	73.290	20.203		3.628	.036
	Sea Beach to Port (km)	.587	.178	.885	3.299	.046

a. Dependent Variable: BMarine item/km

Table F 3: List of objects found at beach and ship survey according to EAN International Barcode

Object	Items' Manufacturer / Product Name	Barcode/Origin
Aluminum cans	Heineken	87120158
Aluminum cans	Tiger Beer	9556027010047
Aluminum cans	tiger beer	086428230007
Aluminum cans	singha beer (thailand)	8850999113005
Aluminum cans	coke cola	9555589200385
Aluminum cans	Sprite	9555589200668
Aluminum cans	tiger beer	9556027010047
Aluminum cans	anglia	9556027040013
Cardboard cartons	gudang garam cigratte	8998989110129
Cardboard cartons	drinho soya	9556007000303
Food wrappers	Cloud 9	9556196004663
Food wrappers	mi sedaap asli	8998866200301
Food wrappers	maggi kari	9556001128836
Food wrappers	bika prawn	9556378300101
Food wrappers	gula	9556434100010
Clear plastic bottles	vinh hao lemona	8934840012348
Clear plastic bottles	V3	8887512003079
Clear plastic bottles	c2 green tea lemon	8934564600128
Clear plastic bottles	Cestbon	6901285991240
Clear plastic bottles	(china) mineral	6920459905401
Clear plastic bottles	nongfu spring mineral	6921168509256
Clear plastic bottles	then hue mineral	6938298900051
Clear plastic bottles	c2green tea	8934564600173
Clear plastic bottles	khong do herbal tea	8936006170305
Clear plastic bottles	dr. thank herbal tea	8936006171746
Clear plastic bottles	(vietnam) drink	8936020460048
Clear plastic bottles	5star mineral (500ml)	9555006600705
Clear plastic bottles	K2 mineral	9555168200225
Clear plastic bottles	sasa mineral (500ml)	9555168209303
Clear plastic bottles	cap keluarga mineral	9555272900349
Clear plastic bottles	splash mineral	9555530900104
Clear plastic bottles	coca cola	9555589200415
Clear plastic bottles	coke cola	9555589200637
Clear plastic bottles	cactus mineral	9556135011509
Clear plastic bottles	desani mineral	9556135185002
Clear plastic bottles	summer mmineral	9556135421506
Clear plastic bottles	spritzer mineral	9556145115051
Clear plastic bottles	borneo mineral	9556244881434
Clear plastic bottles	ice mountain mineral	9556270312858
Clear plastic bottles	plus 1 mineral	9556391111418
Clear plastic bottles	borneo mineral (1.5l)	9556544880437
Clear plastic bottles	ocean mineral	9557041338810
Clear plastic bottles	aquacooler	Vietnam
Colored plastic bottles	100 plus (1.5l)	9556570312131
Colored plastic bottles	kicap cair cap ayam	9557764013025

Table F 4: Pearson correlation matrix of $\log_{10}$ Beach local items, $\log_{10}$ Beach foreign items, $\log_{10}$ Ship local items and $\log_{10}$ Ship Foreign items at the significance level of 0.05 (n=5)

	Log_{10} Beach local item	Log_{10} Beach foreign item	Ship local item
Log_{10} Beach foreign item	0.850		
Ship local item	0.866	0.992**	
Log_{10} Ship foreign item	0.779	0.982**	0.986**

**. Correlation is significant at the 0.01 level (2-tailed).

Table F 5: Regression analysis result determining factors for foreign origin objects abundance found on the beach

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.986[a]	.972	.965	.16526

a. Predictors: lg.ShipF

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.781	1	3.781	138.448	.000[c]
	Residual	.109	4	.027		
	Total	3.890[d]	5			

a. Dependent Variable: lg.BeachF

b. Linear Regression through the Origin

c. Predictors: lg.ShipF

d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	lg.ShipF	.610	.052	.986	11.766	.000

a. Dependent Variable: lg.BeachF

b. Linear Regression through the Origin

Appendix G: Shipborne Garbage Assessment Statistical Analysis

Table G 1: Pearson correlation matrix of SGW and $\log_{10}$ GGR at the significance level of 0.05 (n=115)

	SGW	Log_{10} GGR	Crew	Log_{10} GRT	Log_{10} Cruise	Voyage
Log_{10} GGR	0.421**					
Crew	0.221*	-0.063				
Log_{10} GRT	0.364**	0.139	0.644**			
Log_{10} Cruise	0.283**	-0.674**	0.045	0.062		
Voyage	0.362**	-0.052	0.204*	0.415**	0.340**	
Proc. Equipment	0.314**	0.180	0.394**	0.617**	0.004	0.324**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table G 2: Regression analysis result determining SGW (kg/vessel) abundance

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.948[a]	.899	.898	.17929
2	.952[c]	.906	.904	.17381
3	.954[d]	.909	.907	.17132

a. Predictors: lg.GrossTonnage
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: lg.GrossTonnage, lg.Cruise
d. Predictors: lg.GrossTonnage, lg.Cruise, Voyage

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32.575	1	32.575	1013.318	.000[c]
	Residual	3.665	114	.032		
	Total	36.239[d]	115			
2	Regression	32.826	2	16.413	543.320	.000[e]
	Residual	3.414	113	.030		
	Total	36.239[d]	115			
3	Regression	32.952	3	10.984	374.243	.000[f]
	Residual	3.287	112	.029		
	Total	36.239[d]	115			

a. Dependent Variable: log.Qkg.vessel
b. Linear Regression through the Origin
c. Predictors: lg.GrossTonnage
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: lg.GrossTonnage, lg.Cruise
f. Predictors: lg.GrossTonnage, lg.Cruise, Voyage

Coefficients[a,b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	lg.GrossTonnage	.130	.004	.948	31.833	.000
2	lg.GrossTonnage	.102	.010	.747	9.881	.000
	lg.Cruise	.179	.062	.218	2.883	.005
3	lg.GrossTonnage	.090	.012	.653	7.488	.000
	lg.Cruise	.141	.064	.171	2.200	.030
	Voyage	.002	.001	.150	2.075	.040

a. Dependent Variable: log.Qkg.vessel
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Number of crew	-.077[c]	-.292	.771	-.027	.013
	lg.Cruise	.218[c]	2.883	.005	.262	.146
	Voyage	.197[c]	2.786	.006	.253	.168
	NumOfProcEquip	.072[c]	1.398	.165	.130	.327
2	Number of crew	-.107[d]	-.422	.674	-.040	.013
	Voyage	.150[d]	2.075	.040	.192	.154
	NumOfProcEquip	.096[d]	1.904	.060	.177	.320
3	Number of crew	-.037[e]	-.144	.885	-.014	.013
	NumOfProcEquip	.076[e]	1.469	.145	.138	.303

a. Dependent Variable: log.Qkg.vessel
b. Linear Regression through the Origin
c. Predictors in the Model: lg.GrossTonnage
d. Predictors in the Model: lg.GrossTonnage, lg.Cruise
e. Predictors in the Model: lg.GrossTonnage, lg.Cruise, Voyage

Table G 3: Regression analysis result determining factors for GGR (kg/person/day) abundance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.674[a]	.454	.450	.17263
2	.700[b]	.490	.481	.16767

a. Predictors: (Constant), lg.Cruise
b. Predictors: (Constant), lg.Cruise, Voyage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.804	1	2.804	94.086	.000[b]
	Residual	3.368	113	.030		
	Total	6.171	114			
2	Regression	3.023	2	1.511	53.765	.000[c]
	Residual	3.149	112	.028		
	Total	6.171	114			

a. Dependent Variable: lg.QGGR
b. Predictors: (Constant), lg.Cruise
c. Predictors: (Constant), lg.Cruise, Voyage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.858	.043		19.924	.000
	lg.Cruise	-.612	.063	-.674	-9.700	.000
2	(Constant)	.803	.046		17.373	.000
	lg.Cruise	-.674	.065	-.742	-10.341	.000
	Voyage	.003	.001	.200	2.791	.006

a. Dependent Variable: lg.QGGR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Number of crew	-.033[b]	-.470	.639	-.044	.998
	lg.GrossTonnage	.182[b]	2.680	.008	.245	.996
	Voyage	.200[b]	2.791	.006	.255	.884
	NumOfProcEquip	.183[b]	2.700	.008	.247	1.000
2	Number of crew	-.074[c]	-1.069	.287	-.101	.958
	lg.GrossTonnage	.124[c]	1.683	.095	.158	.821
	NumOfProcEquip	.134[c]	1.881	.063	.176	.882

a. Dependent Variable: lg.QGGR
b. Predictors in the Model: (Constant), lg.Cruise
c. Predictors in the Model: (Constant), lg.Cruise, Voyage

Table G 4: Pearson correlation matrix of SGW and GGR according to ship type at the significance level of 0.05 (n=15)

	SGW	GGR	Num. Vessel	Crew	GRT	Cruise	Voyage
GGR	-0.079						
Num. Vessel	0.318	-0.163					
Crew	0.337	-0.181	0.996**				
GRT	0.273	-0.136	0.901**	0.927**			
Cruise	0.418	-0.573*	-0.004	0.017	0.068		
Voyage	0.531*	-0.664**	0.107	0.125	0.154	0.757**	
Proc. Equipment	0.308	-0.124	0.949**	0.963**	0.984**	0.014	0.154

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table G 5: Regression analysis result determining SGW (kg/vessel) abundance according to ship type

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.959[a]	.920	.914	37.33962

a. Predictors: Voyage
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	224597.155	1	224597.155	161.088	.000[c]
	Residual	19519.465	14	1394.248		
	Total	244116.620[d]	15			

a. Dependent Variable: Q SGW
b. Linear Regression through the Origin
c. Predictors: Voyage
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Voyage	3.607	.284	.959	12.692	.000

a. Dependent Variable: Q SGW
b. Linear Regression through the Origin

Table G 6: Regression analysis result determining factors for GGR (kg/person/day) abundance according to ship type

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.664[a]	.441	.398	.78184

a. Predictors: (Constant), Voyage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.271	1	6.271	10.260	.007[b]
	Residual	7.946	13	.611		
	Total	14.218	14			

a. Dependent Variable: Q GGR
b. Predictors: (Constant), Voyage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.043	.722		5.602	.000
	Voyage	-.068	.021	-.664	-3.203	.007

a. Dependent Variable: Q GGR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Cruise	-.165[b]	-.506	.622	-.145	.427

a. Dependent Variable: Q GGR
b. Predictors in the Model: (Constant), Voyage

Table G 7: Pearson correlation matrix of SGW and GGR according to ports location at the significance level of 0.05 (n=3)

	SGW	GGR	Num. Vessel	Crew	GRT	Cruise	Voyage
GGR	0.089						
Num. Vessel	-0.994	0.019					
Crew	-1.000**	-0.081	0.995				
GRT	0.091	-0.984	-0.197	-0.098			
Cruise	0.434	-0.859	-0.529	-0.441	0.936		
Voyage	0.856	-0.439	-0.906	-0.860	0.593	0.838	
Proc. Equipment	-0.136	-0.999*	0.028	0.128	0.974	0.834	0.397

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table G 8: Regression analysis result determining SGW (kg/vessel) abundance according to ports location

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	.14875
2	1.000[b]	1.000	.	.

a. Predictors: (Constant), Crew
b. Predictors: (Constant), Crew, num.vessel

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	363.636	1	363.636	16434.892	.005[b]
	Residual	.022	1	.022		
	Total	363.658	2			
2	Regression	363.658	2	181.829	.	.[c]
	Residual	.000	0	.		
	Total	363.658	2			

a. Dependent Variable: Q SGW
b. Predictors: (Constant), Crew
c. Predictors: (Constant), Crew, num.vessel

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	234.576	.804		291.842	.002
	Crew	-.134	.001	-1.000	-128.199	.005
2	(Constant)	235.648	.000		.	.
	Crew	-.144	.000	-1.078	.	.
	num.vessel	.180	.000	.078	.	.

a. Dependent Variable: Q SGW

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	num.vessel	.078[b]	.	.	1.000	.010
	GRT	-.008[b]	.	.	-1.000	.990
	Cruise	-.009[b]	.	.	-1.000	.805
	Voyage	-.015[b]	.	.	-1.000	.261
	Equip	-.008[b]	.	.	-1.000	.984
2	GRT	.[c]	.	.	.	.000
	Cruise	.[c]	.	.	.	.000
	Voyage	.[c]	.	.	.	.000
	Equip	.[c]	.	.	.	.000

a. Dependent Variable: Q SGW
b. Predictors in the Model: (Constant), Crew
c. Predictors in the Model: (Constant), Crew, num.vessel

Table G 9: Pearson correlation matrix of SGW and GGR according to BGW classification at the significance level of 0.05 (n=15)

	SGW	GGR	Num. Vessel	Crew	GRT	Cruise	Voyage
GGR	0.374						
Num. Vessel	0.531*	-0.366					
Crew	0.526*	-0.361	0.998**				
GRT	0.386	-0.273	0.923**	0.937**			
Cruise	0.631*	-0.129	0.649**	0.632*	0.454		
Voyage	0.687**	-0.007	0.557*	0.546*	0.380	0.789**	
Proc. Equipment	0.468	-0.303	0.964**	0.973**	0.980**	0.502	0.461

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table G 10: Regression analysis result determining SGW (kg/vessel) abundance according to BGW classification

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.930[a]	.865	.855	44.32725

a. Predictors: Voyage

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	176253.758	1	176253.758	89.701	.000[c]
	Residual	27508.677	14	1964.905		
	Total	203762.435[d]	15			

a. Dependent Variable: Q kg/vessel
b. Linear Regression through the Origin
c. Predictors: Voyage
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Voyage	3.683	.389	.930	9.471	.000

a. Dependent Variable: Q kg/vessel
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	num.vessel	.147[c]	.858	.407	.231	.336
	Crew	.141[c]	.859	.406	.232	.362
	Cruise	.221[c]	.700	.496	.191	.101

a. Dependent Variable: Q kg/vessel
b. Linear Regression through the Origin
c. Predictors in the Model: Voyage

Table G 11: Total SGW (kg/vessel) according to shipborne garbage categories

	Plastic	Food waste	Domestic waste	Cooking oil	Incinerator ashes	Operational waste	Cargo residue
Study ports							
Kuching	17.3±15.4	36.7±26.3	15.8±15.1	1.1±1.5	3.7±4.6	13.8±13.6	24.8±17.5
Bintulu port	19.3±21.2	39.3±28.3	12.3±17.1	0.4±0.5	6.6±12.3	10.7±9.2	33.8±19.8
Kota Kinabalu port	18.6±18.4	39.5±31.8	14.2±14.8	1.0±1.3	4.4±5.7	11.5±9.9	70.0±80.8
Sandakan port	19.4±14.9	47.1±36.3	14.9±16.0	1.9±2.6	4.4±5.6	9.1±12.8	28.2±27.6
Klang port	27.7±49.9	48.8±67.4	17.9±49.1	1.4±3.5	2.8±3.9	11.8±8.5	23.8±21.7
Ship types							
Container	27.4±44.4	47.6±60.2	17.8±43.9	1.2±3.1	2.9±4.4	13.3±10.8	21.2±17.6
Bulk carrier	23.0±22.6	50.9±37.5	17.8±17.6	1.8±2.0	4.1±4.9	12.3±13.2	446.5±60.1
General cargo	11.9±8.6	28.2±17.4	10.2±12.0	0.6±0.9	5.7±9.9	8.8±6.4	39.7±38.5
Ports classification							
Federal	24.7±41.9	45.4±56.5	15.9±40.5	1.1±2.9	4.2±8.1	11.4±8.7	27.3±21.4
State	18.2±16.1	40.1±30.5	15.1±15.0	1.3±1.8	4.1±5.2	11.9±12.2	40.9±53.6
Ports location							
Peninsular	27.7±49.9	48.8±67.4	17.9±49.1	1.4±3.5	2.8±3.9	11.8±8.5	23.8±21.7
Sabah	18.9±16.8	42.7±33.4	14.5±15.1	1.4±2.0	4.4±5.6	10.5±11.1	52.8±67.0
Sarawak	18.2±18.0	37.8±26.9	14.2±16.0	0.8±1.2	5.0±8.9	12.4±11.8	28.8±18.9
BGW classification							
Black	8.9±7.7	23.1±12.2	10.6±12.8	0.7±0.7	6.1±10.1	7.3±8.3	33.6±37.2
Grey	27.0±36.4	51.8±51.3	17.8±35.2	1.4±2.8	3.4±4.7	13.5±11.1	32.2±40.5
White	10.0±0.0	21.0±2.2	9.0±42.5	0.2±0.4	3.0±6.7	10.0±7.9	73.0±70.5

Table G 12: Total SGW (kg/vessel) according to sources

	Maintenance	Crew	Cargo	Common
Study ports				
Kuching	17.5±15.6	56.6±339.4	24.8±17.5	17.3±15.4
Bintulu port	17.2±14.5	52.0±41.4	33.8±19.8	19.3±21.2
Kota Kinabalu port	16.2±11.1	54.1±40.6	72.0±79.9	18.1±18.5
Sandakan port	12.3±14.4	62.7±50.6	24.6±26.3	19.4±14.9
Klang port	14.9±9.3	69.0±90.5	24.0±21.7	28.0±49.9
Ship types				
Container	16.2±12.4	66.6±81.6	21.2±17.65	27.4±44.4
Bulk carrier	16.5±15.5	70.4±50.9	46.5±60.1	23.0±22.6
General cargo	14.6±9.7	39.0±34.8	39.7±38.5	11.9±8.6
Ports classification				
Federal	15.7±11.4	62.9±76.6	27.5±21.4	24.9±41.9
State	15.8±13.9	55.9±42.1	40.8±53.7	18.1±16.2
Ports location				
Peninsular	14.9±9.3	69.0±90.5	24.0±21.7	28.0±49.9
Sabah	14.6±12.5	57.6±44.4	52.5±67.2	18.6±16.9
Sarawak	17.4±15.0	52.9±39.9	28.8±18.9	18.2±18.0
BGW classification				
Black	13.4±12.2	34.2±23.0	33.6±37.2	8.9±7.7
Grey	16.9±13.1	71.0±96.5	32.2±40.5	27.0±36.4
White	13.0±5.7	30.2±8.1	73.0±70.5	10.0±0.0

Table G 13: Regression analysis result to determine factors to install garbage processing equipment on the vessel

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.617[a]	.381	.375	.645

a. Predictors: (Constant), lg.GrossTonnage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28.907	1	28.907	69.413	.000[b]
	Residual	47.058	113	.416		
	Total	75.965	114			

a. Dependent Variable: NumOfProcEquip
b. Predictors: (Constant), lg.GrossTonnage

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.355	.528		-6.351	.000
	lg.GrossTonnage	1.075	.129	.617	8.331	.000

a. Dependent Variable: NumOfProcEquip

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	log.Qkg.vessel	.103[b]	1.295	.198	.121	.867
	Number of crew	-.006[b]	-.064	.949	-.006	.585
	Voyage	.083[b]	1.018	.311	.096	.828

a. Dependent Variable: NumOfProcEquip
b. Predictors in the Model: (Constant), lg.GrossTonnage

Table G 14: Regression analysis result to determine factors to install garbage processing equipment on the vessel according to ship types

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.975[a]	.951	.948	1.69239
2	.996[c]	.992	.991	.71132
3	.997[d]	.995	.993	.60003
4	.997[e]	.994	.993	.63690

a. Predictors: Crew
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: Crew, GRT
d. Predictors: Crew, GRT, num.vessel
e. Predictors: GRT, num.vessel

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	780.902	1	780.902	272.645	.000[c]
	Residual	40.098	14	2.864		
	Total	821.000[d]	15			
2	Regression	814.422	2	407.211	804.806	.000[e]
	Residual	6.578	13	.506		
	Total	821.000[d]	15			
3	Regression	816.680	3	272.227	756.101	.000[f]
	Residual	4.320	12	.360		
	Total	821.000[d]	15			
4	Regression	815.727	2	407.863	1005.490	.000[g]
	Residual	5.273	13	.406		
	Total	821.000[d]	15			

a. Dependent Variable: Equip
b. Linear Regression through the Origin
c. Predictors: Crew
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: Crew, GRT
f. Predictors: Crew, GRT, num.vessel
g. Predictors: GRT, num.vessel

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Crew	.037	.002	.975	16.512	.000
2	Crew	.020	.002	.523	8.599	.000
	GRT	1.284E-5	.000	.495	8.139	.000
3	Crew	-.037	.023	-.980	-1.627	.130
	GRT	1.716E-5	.000	.662	7.876	.000
	num.vessel	1.045	.417	1.354	2.504	.028
4	GRT	1.420E-5	.000	.547	11.199	.000
	num.vessel	.369	.038	.478	9.770	.000

a. Dependent Variable: Equip
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	num.vessel	-2.019[c]	-2.561	.024	-.579	.004
	GRT	.495[c]	8.139	.000	.914	.166
2	num.vessel	1.354[d]	2.504	.028	.586	.001
4	Crew	-.980[e]	-1.627	.130	-.425	.001

a. Dependent Variable: Equip
b. Linear Regression through the Origin
c. Predictors in the Model: Crew
d. Predictors in the Model: Crew, GRT
e. Predictors in the Model: GRT, num.vessel

Table G 15: Regression analysis result to determine factors to install garbage processing equipment on the vessel according to ports location

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.996	.26726

a. Predictors: (Constant), Q GGR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32.595	1	32.595	456.333	.030[b]
	Residual	.071	1	.071		
	Total	32.667	2			

a. Dependent Variable: Equip
b. Predictors: (Constant), Q GGR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	45.929	.961		47.794	.013
	Q GGR	-13.214	.619	-.999	-21.362	.030

a. Dependent Variable: Equip

Table G 16: Regression analysis result to determine factors to install garbage processing equipment on the vessel according to BGW classification

Model Summary

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.979[a]	.959	.956	1.72617
2	.996[c]	.991	.990	.83811

a. Predictors: Crew
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: Crew, GRT

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	985.285	1	985.285	330.671	.000[c]
	Residual	41.715	14	2.980		
	Total	1027.000[d]	15			
2	Regression	1017.868	2	508.934	724.539	.000[e]
	Residual	9.132	13	.702		
	Total	1027.000[d]	15			

a. Dependent Variable: Equip
b. Linear Regression through the Origin
c. Predictors: Crew
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
e. Predictors: Crew, GRT

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Crew	.037	.002	.979	18.184	.000
2	Crew	.020	.003	.531	7.495	.000
	GRT	1.279E-5	.000	.483	6.811	.000

a. Dependent Variable: Equip
b. Linear Regression through the Origin

Excluded Variables[a,b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	num.vessel	-2.926[c]	-3.485	.004	-.695	.002
	GRT	.483[c]	6.811	.000	.884	.136
2	num.vessel	-.378[d]	-.450	.660	-.129	.001

a. Dependent Variable: Equip
b. Linear Regression through the Origin
c. Predictors in the Model: Crew
d. Predictors in the Model: Crew, GRT

Appendix H: List of Ports Having Waste Reception Facilities

No.	Port	Oily waste	NLS	Sewage	Garbage
1	Bintulu Port	NA	NA	NA	NA
2	ESSO Malaysia Bhd Port Dickson	NA	NA	NA	**YES**
3	Felda Transport Services, Lahad Datu	NA	NA	NA	NA
4	Johor Port Berhad, Pasir Gudang	**YES**	NA	NA	NA
5	Kedah Cement Jetty, Langkawi	NA	NA	NA	**YES**
6	Kemaman Port	NA	NA	NA	**YES**
7	Kota Kinabalu Port	NA	NA	NA	NA
8	Kuantan Port	NA	NA	NA	NA
9	Kuching Port	**YES**	**YES**	**YES**	**YES**
10	Kudat, Sabah	NA	NA	NA	NA
11	Kunak, Sabah	NA	**YES**	NA	NA
12	Lahad Datu, Sabah	**YES**	NA	NA	NA
13	Langkawi Port Sdn. Bhd.	NA	NA	NA	NA
14	Lumut Maritime Terminal	NA	NA	NA	**YES**
15	Miri Port	NA	NA	NA	**YES**
16	North Port	NA	NA	NA	**YES**
17	Penang Port	**YES**	NA	NA	**YES**
18	Sungai Udang Melaka	**YES**	NA	NA	**YES**
19	Kerteh, Terengganu	**YES**	NA	NA	NA
20	Port Klang	**YES**	NA	NA	**YES**
21	Port of Tg. Pelepas	**YES**	NA	**YES**	**YES**
22	Rajang Port	NA	NA	NA	**YES**
23	Sandakan Port	NA	NA	NA	NA
24	Shell Refining, Port Dickson	NA	NA	NA	NA
25	Sibu, Sarawak	NA	NA	NA	**YES**
26	Tg. Bruas, Melaka	NA	NA	NA	**YES**
27	Tawau, Sabah	NA	NA	NA	NA
28	Teluk Sepangar Terminal	NA	NA	NA	NA
29	West Port	NA	NA	NA	**YES**
30	Labuan Port	NA	NA	NA	NA

*Source:*Osnin, 2004

Appendix I: Debris Objects Illustration during Beach Surveys

Plate I-1: Objects found on the beach according to (a) plastic, (b) rubber, (c) metal, (d) glass, (e) wood and (f) cloth categories.

Plate I-2: Marine debris stranded at (a) Pandan, (b) Kosuhoi and (c) Batu Rakit beaches.

Plate I-3: Example of foreign origin clear plastic bottles found on the beach study sites.

Plate I-4: Hazardous objects found on the beach during this study including (a) metal drum, (b) lubricating oil bottles, (c) used medicine, (d) construction materials, (e) broken glass bottles and (f) wood with nail.

Appendix J: Debris Objects Illustration during Ship Surveys

Plate J-1: Objects found on the vessel according to (a) plastic, (b) food waste, (c) domestic waste, (d) cooking oil, (e) incinerator ashes, (f) operational waste and (g) cargo residue categories.

Plate J-2: GMP best practice for (a) vessels’ garbage station, (b) securing garbage prior to disposal at port and (c) manual compaction by crew member.

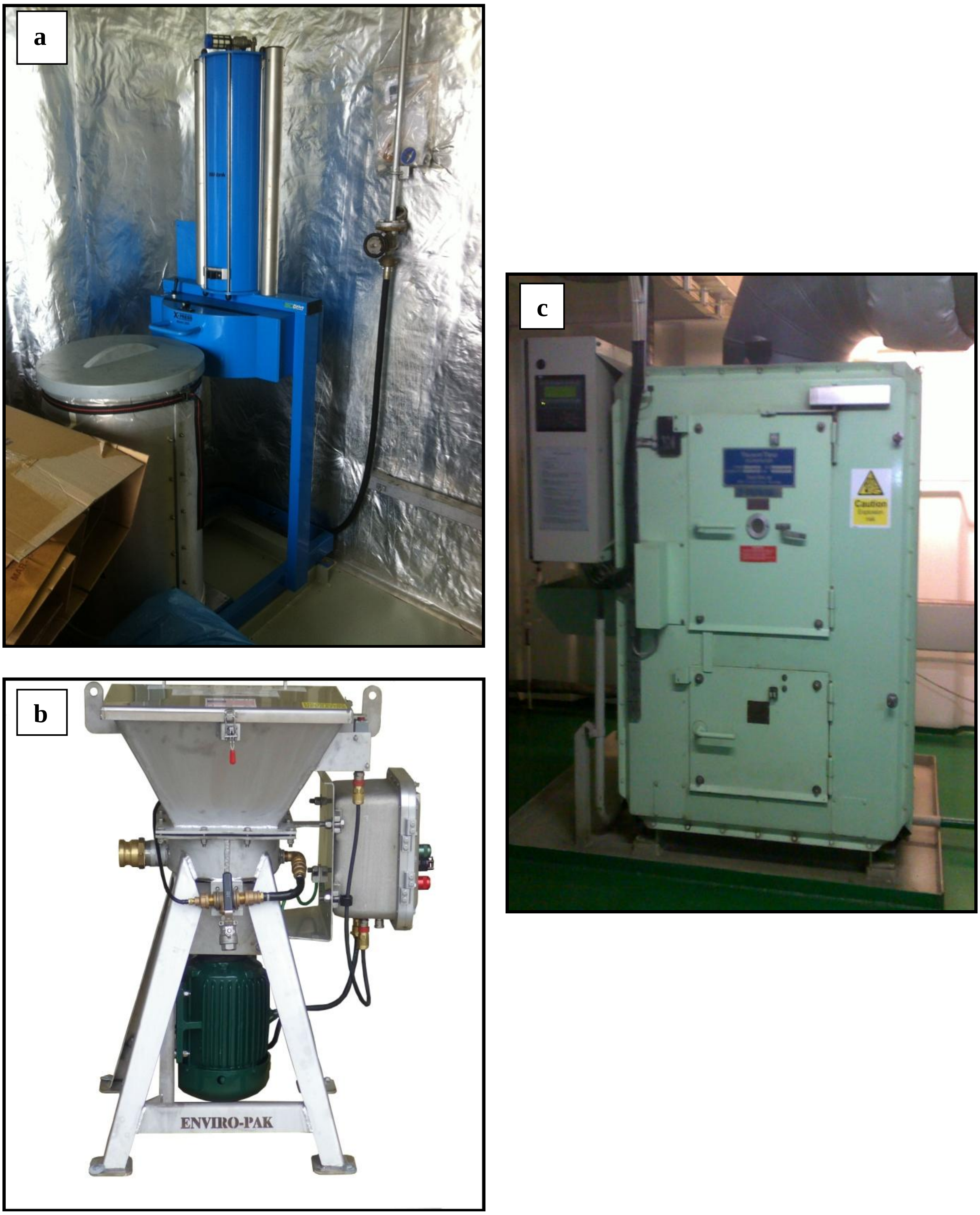


Plate J-3: Garbage processing equipment available on the vessel including (a) compactor, (b) comminutor and (c) incinerator.

Plate J-4: Shipborne garbage practices incompliance to MARPOL Annex V requirements including (a) garbage not segregated according to garbage category, (b) food waste mix with plastic at vessels' kitchen, (c) garbage storage not maintain, (d) garbage was not manage according to GMP, (e) unavailable prove of disposal and (f) GMP was not implemented on the vessel.

Plate J-5: Example of vessel type surveyed in this study.

Appendix K: Summary of Overall Findings

Objective (O)		Specific Objectives (SO)		How/Method				Result
No.	**Description**	**No.**	**Description**	**Description**	**Q**	**1^o**	**2^o**	
1	Assess spatio temporal marine debris abundance across the eight study sites during NEM, SWM and IM periods.	1	Amount of marine debris during northeast monsoon (NEM), intermediate monsoon (IM) and southwest monsoon (SWM) seasons	- Sampling at 1 km stretch of beach at selected site according to Ribic *et. al.(*1992) - Debris identify and quantify by item/km and kg/km		√		- Beach visitor and rainfall significant factor determining debris abundance - BDI highest during SWM
		2	Categorizing the debris by type of materials	- Debris sorted and weighted according to debris category following Ribic *et. al.(*1992)		√		- Plastic category significant different from other debris category
		3	Determined possible sources of the debris	- Debris object identified according to potential sources (Marine, Terrestrial and Common sources) following Ribic (1998)		√		- Common source significant different from other sources
		4	Debris abundance relationship between rainfall and relative exposure	- Wind data to obtain from Malaysia Meteorology Department to develop wind-rose. - Current data to obtain from Malaysia Meteorology Department to identify current direction. - To compare wind and current result with Atlas of Pilot Charts Indian Ocean 2001 NVPUN109 4th Edition.			√	- Rainfall – inconclusive - REI may influence debris abundance
2	Determine the abundance and classification of shipborne garbage on container, bulk carrier and general cargo vessels at five study ports in Malaysia.	1	Assess the amount of shipborne garbage waste on container, bulk carrier and general cargo vessels	- Sampling at vessels' garbage station according to modified Ribic *et. al.(*1992) - Debris identify and quantify by item/vessel and kg/vessel		√		- Voyage, Nom. of crew & GRT significant factor determining shipborne garbage abundance
		2	Categorize the shipborne garbage waste by type of material	- Rubbish at garbage station sorted, categories and weighted according to MARPOL Annex V categories.		√		- Item: Plastic category significant different from other debris category - Weight: Food waste & Cargo Residue significant different from other debris category
		3	Determine the possible shipborne garbage sources	- Garbage identified according to potential sources (Maintenance, Crew, Cargo and Common sources) as modify from Ribic	√	√		- Item: Common source significant different from other sources

				(1998)				- Weight: Crew source significant different from other sources
		4	Estimate the generation rate of garbage (GGR) according to ship types	- Inserting value (i.e garbage weight, no. of crew, voyage duration) to calculate GGR from last port of call.		√		- Voyage, Cruise, Nom. of crew & GRT significant factor determining GGR
3	Analyze debris accumulation relationships between debris found at beach and ship surveys.	1	Investigate the relationship between shipborne garbage waste and the beach debris abundance	- Analyzing the abundance of debris items found at the beach from Marine Source - Analyzing the abundance of shipborne garbage items from foreign origin		√		- Beach: ship account 2% of total item - Port proximity may influence BDI (Marine) abundance
		2	Determine objects origin collected at beach and ship surveys	- Analyze object that may originate from vessel found at the beach by comparing the same EAN number on the items - Analyze the potential country source of objects		√		- Beach: 24% foreign object (81% is Plastic) - Vessel: 86% foreign (70% is Plastic)
		3	Access the abundance of objects origin collected during beach and ship surveys.	- Analyze object that may originate from vessel found at the beach by comparing the same EAN number on the items - Only object of foreign origin was included in the statistical analysis		√		- 83 item (CPB 81 item) - Statistical analysis suggest foreign item found at the beach may originated from the vessel ($r=0.99$, $R^2=0.97$, $p=0.00$)
4	Assess shipborne garbage practices on the vessel in relation to MARPOL 73/78 Annex V.	1	Estimate the total shipborne garbage on selected ports	- Vessel inspection according to Protocol Port State Control Resolution A.1052 (27) - Review vessels' GRB correspond to garbage disposal receipt		√		- Voyage, Cruise, Nom. of crew & GRT significant factor determining SGW abundance - Year 2020: SGW may accumulate to 7,320 ton
		2	Assess the abundance of shipborne garbage by category	- Review GRB correspond to garbage disposal receipt. - Shipborne garbage categories compiled according to MARPOL Annex V categories.		√		- Weight: Food waste & Cargo Residue significant different from other debris category
		3	Determine the possible shipborne garbage sources	- Garbage quantity recorded in GRB compiled according to potential sources (Maintenance, Crew, Cargo and Common sources) as modify from Ribic (1998)		√		- Weight: Crew source significant different from other garbage sources
		4	Identify the effectiveness of garbage processing	- Review GRB, Oil Record Book part 1 & garbage processing equipment log book	√	√		- GRT & Nom. of crew significant factor determining

			equipment on container, bulk carrier and general cargo vessels	- Physical inspection of garbage processing equipment				installation garbage processing equipment
		5	Determine vessel compliance to MARPOL 73/78 Annex V.	- Interview (Focus Group) with ship Captain on management of garbage on vessel - Interview (Focus Group) with crew on garbage management practices on vessel - Review GMP, training record, drill record and other statutory document related to garbage management - Physical inspection at ship bridge, deck, cabin crew, galley, provision room & engine room on	√	√		- 36%- Provision from Malaysian ports - 25%- Ship chandler observe MARPOL requirements - 83% respondents agree 30kg garbage can be reduce

Q- Quationnaire; **1º**- Primary data; **2º**- Secondary data

PUBLICATIONS

The following scientific/conference manuscripts are published/presented from this study;

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (2014). Type and abundance of marine debris at selected public beaches in Sarawak, East Malaysia, during the northeast monsoon. *Journal of Sustainability Science and Management*, *9*(2): 43-51.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (in press). Assessment of shipborne garbage on merchant vessel calling to Malaysian ports. *IKMAL Journal Maritime Malaysia*.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (2015). Seasonal trends in abundance and composition of marine debris at selected public beaches in Peninsular Malaysia. *In*: A. Ahmad, N. H. A. Karim, N. I. Hassan, S. I. Zubairi, S. A. Bakar, Z. Ibarahim, H. K. Agustar, H. B. Samsudin, I. R. Hazmi, M. M. Hanafiah, M. S. M. Noorani, M. S. M. Nadzir, N. Ibrahim & N. B. Ibrahim (Eds.). *Proceedings of the Universiti Kebangsaan Malaysia, Faculty of Science and Technology 2015 Postgraduate Colloquium*, (pp. 020020). Bangi, Malaysia: AIP Publishing. doi:10.1063/1.4931205.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R (in press). Type and quantity of marine debris at selected public beaches in Sabah, Malaysia during different monsoon seasons. *Borneo Science Journal*.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. *Abundance of shipborne garbage on merchant vessels calling at selected ports in Malaysia.* Manuscript submitted to Asian Journal of Shipping and Logistics on 20 August 2015.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. *Type and quantity of shipborne garbage at selected tropical beaches.* Manuscript submitted to The Scientific World Journal on 29 April 2016.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. *Marine debris at selected tropical beaches during different monsoon seasons.* Manuscript submitted to Journal of Environmental and Public Health on 29 April 2016.

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Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (2015). Seasonal trends in abundance and composition of marine debris in selected public beaches in Sabah. *Presented at International Conference on Marine Science & Aquaculture 2015,* 17-19 March 2015, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (2013). Marine debris on selected public beaches in Malaysia during different monsoon seasons. *Presented at the 7th International Symposium on Kuroshio Science*, 21-23 November 2013, Tanjungpura University, Pontianak, Indonesia.

Mobilik, J. M., Husain, M. L., Ling, T. Y., & Hassan, R. (2013). Spatial variability of marine debris in selected beaches in Malaysia. *Poster presentation at 6th International Marine Debris Conference*, 21–24 October 2013, Hawaii State Capital, USA.