Pantai Project

CIE4061-09
Multidisciplinary Project

R.P. de Klerk, J.R. Memelink, E.J.F. van Utenhove, T.M. van Welsenes, J.F.S. van Wijland

Delft University of Technology

TU Delft Delft University of Technology

Challenge the future

PANTAI PROJECT

CIE4061-09
MULTIDISCIPLINARY PROJECT

by

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Project duration:	September – December, 2018	
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PREFACE

This report consists of a research on the dynamics behind plastic pollution in the Southwest area of Bali. Last year, the team came across a Dutch news article about a *"garbage emergency"* in Bali declared by the government. This article was so disturbing that we wanted to do something about it, which is how Pantai Project was established. Pantai, which means *"beach"* in the Indonesian language Bahasa, made it seem as a natural name.

Various companies and individuals have contributed to the evolution of the research, all with the same vision to battle plastic pollution. Without their support, the research would have progressed less fluently. Therefore, we want to take this opportunity to thank the following companies: Arcadis, The Ocean Cleanup, Allseas, and Jongste Beheer for their accompaniment and support. In particular, we are very grateful for the equipment and guidance from The Ocean Cleanup for the river research.

Also we would like to warmly thank some local organizations for their amazing support in providing us key data, measuring equipment and guidance in Bali. BWS Bali Penida, Udayana University, Eco-Bali, Bali Hotel Association, and DLHK Badung. Without their help we wouldn't have been able to identify the local waste management system and processes like ocean currents. Also the meteorological data that was provided, gave us a clear view of what is happening in Bali during the plastic season.

Finally, we would like to thank our two supervisors; Stefan Aarninkhof and Mark Voorendt for their support throughout our project. The project was fully built from scratch and without the guidance in the early stages we wouldn't have been able to deliver this result.

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Delft, December 2018

PARTNERS

THE OCEAN CLEANUP

ARCADIS

Allseas

TU Delft | Global Initiative

Jongste Beheer b.v.

LOCAL PARTNERS

UNIVERSITAS UDAYANA

ecoBali

BALI HOTELS ASSOCIATION

SUMMARY

For the past years large quantities of plastic waste have been accumulating on the beaches in Southwest Bali. This has economical, environmental and health implications in this area. This event mainly occurs between December to March.

The objective of this report is to map the plastic waste problem in Southwest Bali and look for efficient solutions to mitigate plastic washing ashore at its beaches. To reach this objective the main drivers for the plastic waste accumulation are investigated. Furthermore, research on the distribution and composition is provided. The local waste management system and its shortcomings are assessed. Personal waste treatment is analyzed using a survey.

Background information on the problem was gathered with the use of a literature study and area analysis. A conceptual model is introduced to reach the research objective. This conceptual model is a schematization, in order to better understand the research area and the behavior of the plastic in the case area. In order to quantify the model further research is required. This consist of four research disciplines. Namely, ocean, boundaries and bottom; river measurements; beach measurements and waste management & social studies.

Via literature studies and interviews, research on the ocean, boundaries and bottom is performed. Three rivers where measured over the course of 2 months. Research was done to determine river parameters. Plastics were caught by a manta trawl and visual waste counting was performed to understand the plastic flux in rivers. Research on the beaches was done on the composition and quantity of various plastic sources namely oceanic, terrestrial and river inputs. Via interviews with local stakeholders the waste management system the the case area is mapped. With the use of a survey, personal awareness and motivation among plastic pollution is analyzed.

The plastic accumulation is largely dependent on the climate and local waste treatment. As waste management facilities are lacking and local awareness and motivation is limited, large quantities of plastic enter local rivers. Together with increased rain conditions large quantities of plastic end up in the ocean. Wind then transports plastic waste towards the beaches. This debris is mainly 'pushed' towards the beaches in Southwest Bali due to the coastal shape. During the research single use plastics are found to be the most common plastic type.

Four solutions are proposed to reduce the plastic accumulation in the beaches of Southwest Bali. Intercepting plastics in rivers prevents further dispersion into the ocean and thus limits plastics accumulating on the beaches. Improved waste management could tackle the source of plastics pollution and reduce the amount of plastics entering our nature. Increased education on plastic pollution can result in improved personal waste management, especially in remote areas. As a lot of stakeholders are involved in the problem an improved communication network is desired in order to achieve a combined goal and work more efficiently.

Contents

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Our Story

Last December, officials in Bali have again declared a "garbage emergency" after the country's most popular beaches were inundated with shocking amounts of plastic waste. During the peak of rainy season 100 tonnes of plastic wash ashore on a daily basis. Over 600 workers are called to work daily to remove the plastic in order to maintain the beaches enjoyable for tourists. However, the same amount washes ashore the next day, leaving loads of tourists and locals affected. Because the economy of Bali is largely depending on the tourist industry, the effects of plastic pollution have become more and more problematic for locals.

When we first heard about the plastic problem in Indonesia, we were astonished by the amount of plastics that wash ashore during rainy season and felt the necessity to do something about it. These concerns eventually motivated us to start our own project, Pantai Project, in order to contribute to a cleaner and more sustainable living environment. Over the past year we saw an increase of concern about plastic waste and how it is being handled in different parts of the world. We hope that the counter-offence to this problem continues to develop and that our team can contribute to spreading awareness and motivate other students and institutes. We hope that this framework can be a benchmark for further studies and give a better insight on the plastic waste problem in Bali and possibly other locations. We strongly support follow-up studies that can elaborate more on the plastic waste crisis globally.

Team Introduction

Pantai project is a non-profit student initiative which has been established in August 2018. In cooperation with TU Delft, TU Delft Global Initiative, The Ocean Cleanup, Allseas, Arcadis and Jongste Beheer, and together with many local institutes, we aim to create a cleaner living environment in Bali and contribute to a reduction of plastic pollution worldwide. By assessing the problem from both a scientific and social perspective we hope to increase global recognition and that more action will be taken to reduce plastic pollution. The team has visited Bali between the 10th of September and the 10th of November 2018.

The team of Pantai Project consists of five TU Delft master students. The project is a team effort, however, each member of the team is responsible for a certain task in which a certain discipline of the project is treated. Each of the members are introduced below, including their project task and current master track.

Project members

Name: Joris Memelink
Education: MSc. Civil Engineering
Task: Joris will perform river research by measuring amounts of plastic and other waste in the rivers. Besides measurements, he will investigate the governance structure in Bali regarding waste management.

Name: Sebastiaan van Wijland
Education: MSc. Civil Engineering
Task: Sebastiaan will perform river research by measuring amounts of plastic and other waste in the rivers. He will then focus on analyzing the conceptual model after inserting the results from the river data.

Name: Erik van Utenhove
Education: MSc. Civil Engineering
Task: Erik will perform beach surveys by measuring amounts of plastic and other waste on stretches of coastline. He will then focus on defining the model boundaries and how marine plastics are distributed in the area.

Name: Thomas van Welsenes
Education: MSc. Civil Engineering
Task: Thomas will perform beach surveys by measuring amounts of plastic and other waste on stretches of coastline. He will then focus on the conceptual model by analyzing results from the beach data.

Name: Reinoud de Klerk
Education: MSc. Civil Engineering
Task: Reinoud will focus on the governance structure regarding waste in Bali. Also he will investigate the social perspective among local inhabitants regarding plastic by setting out a large scale survey.

SUPERVISOR

Name: Prof. dr. ir. S.G.J. Aarninkhof
Profession: Head of Section Coastal Engineering Professor of Coastal Engineering.
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Name: Dr. ir. M.Z. Voorendt
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RESEARCH SETUP

2.1. CONTEXT

Over the last 70 years plastics have integrated in society and have become an indispensable part of modern life [1]. Thanks to their great characteristics such as low cost, ease of manufacture, versatility and high durability they are being used for innumerable products. A great amount of traditional, mainly natural products, have been replaced by plastic versions over the years. Also, plastics have enabled the development of innovative products and solutions in many other sectors that could not have existed today without these materials. However, these materials have a serious downside. Plastics are quite resistant to wearing, enabling them to survive in the environment for decades or even centuries [2]. Up until recently, product designers and consumers did not consider what will happen after the initial product lifetime [1]. The exponential increase in consumption and production of plastic, has become a global problem as much of the plastic does not get disposed properly. Figure 2.1 shows the global distribution of plastic waste and how much of the waste is littered or inadequately disposed. This 'mismanaged waste' could eventually end up in our oceans via, for example, inland waterways. Despite widespread recognition for the problem, global plastic pollution is still growing and the increase in popularity of plastic products in economically developing countries will contribute to even further escalation of serious environmental problems that we are already facing today [3].

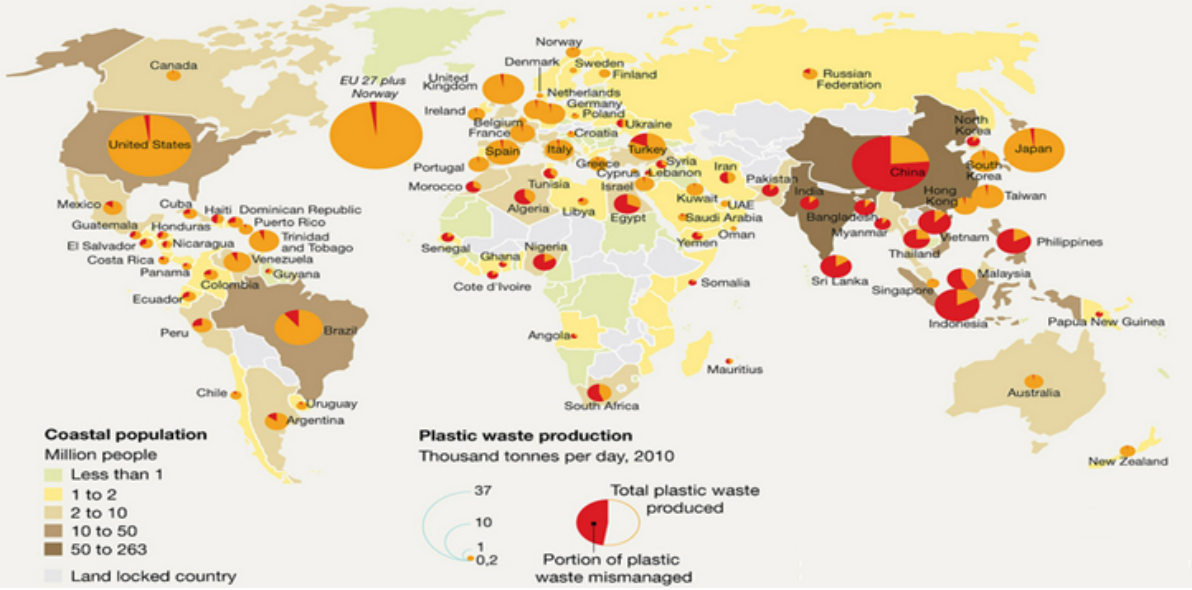


Figure 2.1: Map of the global distribution of plastic waste produced by coastal countries and the percentage of plastic waste that is mismanaged [4, 5]

2.2. PROBLEM DESCRIPTION

In Bali, the plastic pollution problem is experienced first hand. The persistence of plastics have soared in recent years and has become a major concern for visitors, residents and marine life. During the rainy season, typically from November to March, it gets even worse. During this season, huge volumes of plastic debris are found washing ashore on Bali's beaches. The largest amount of plastic are accumulating at the Southwest beaches of Bali during the rainy season as displayed in Figure 2.2. This part of Bali is the most touristic area and the huge amounts of plastic are scaring off tourists. This has impact on the local economy as tourism is an important driver for Bali's economy. Furthermore, local fishermen who used to fish in the area mentioned that during this season, their fishing nets often trap more plastics and other litters than fish [6]. It is clear that Bali is in great need of an efficient strategy to tackle this problem.
In order to assess efficient mitigating measures, plastic pollution requires defining, understanding and quantification both geographically and temporally [7]. Currently, the origin of plastic debris that wash ashore at Bali's beaches is still unclear. Opinions vary on the source of all plastic waste. Some locals blame densely populated islands in the area such as Java and Sumatra, whereas others mention that tourists in Bali are the main source. It is a great challenge to map this complex problem.

Figure 2.2: Plastic waste accumulation on beaches of Bali (Photo source: www.ad.nl)

2.3. RESEARCH OBJECTIVE

The objective of our research is to map the plastic waste problem in Southwest Bali and look for efficient solutions to mitigate plastic washing ashore at its beaches.

2.4. RESEARCH QUESTIONS

In order to obtain the research objective, several research questions were composed.

- What are the main drivers for the plastic waste accumulation in the Southwest of Bali?
- What is the distribution and composition of plastic waste on Bali?
- How does the waste management system in Bali currently look like and is the system lacking?
- Are locals aware of plastic pollution in Bali and are they motivated to improve on the matter?
- Which efficient solutions can be provided to mitigate plastic pollution?

2.5. RESEARCH STRATEGY

In order to gain more primary knowledge on plastics, their history timeline, characteristics and life-cycle will be reviewed. Also waste management, both globally and in developing countries, and the impact of plastic waste will be reviewed by means of a literature study. This primary knowledge is needed, because the research team has relatively little expertise in the field of plastics and waste management. The results of this literature review are presented in Chapter 3.

Secondly, because the area of interest of the research objective is Bali, an area analysis will be conducted. This includes an analysis of the topography, economic drivers, climate conditions, the culture and characteristics of the population and the legislation structure. In the end, a conceptual model will be introduced, schematizing all the plastic waste streams in the area of interest. This area analysis is given in Chapter 4.

Subsequently, a methodology will be elaborated which is required to guesstimate quantities of the in- and outputs of (plastic) waste in the conceptual model. The methodology consist of the following four parts:

- the ocean, boundaries and bottom
- the river measurements
- the beach measurements
- social study & waste management

The methodology of the research will be outlined in Chapter 5.

In Chapter 6, 7, 8 and 9 every part of the methodology will be treated separately, in which the results of our research will be presented. Finally, the results of the different elements will be translated back into the conceptual model. This is displayed in Chapter 10. Here also additional relations between the various elements will be further outlined. In Chapter 11 a conclusion and recommendation will be given with solutions from the results to mitigate the plastic waste accumulation in the ocean and beaches of Bali.

3

LITERATURE REVIEW

To gain more insight in plastic waste a literature study is conducted. This will provide relevant knowledge for further research. General aspects of plastics are treated in Section 3.1, and their environmental, health and economical impact are outlined in Section 3.2. At last, literature on waste generation and waste management is being reviewed as this information is of essence to identify shortcomings in waste treatment in Bali.

3.1. PLASTIC IN GENERAL

3.1.1. WHAT IS PLASTIC

For a long time natural polymers have been used by humans such as natural rubber, silk and wool. Synthetic polymers, or in other words plastics, are created from petroleum oil. The word plastic is derived from the Greek word 'platikos' meaning 'able to be molded'. According to the Oxford Dictionaries, plastics are defined as:

> *"a synthetic material made from a wide range of organic polymers such as polyethylene, PVC, nylon, etc., that can be molded into shape while soft and then set into a rigid or slightly elastic form"*

So plastics are not just one material, but is an umbrella term that encompasses a family of hundreds of different materials designed to meet the different needs of end products. Plastics can be divided into two categories: thermoplastics and thermosets. The majority of plastics fall in the group of thermoplastics, which can be reheated and reformed repeatedly without appreciable change of properties. Since no chemical bonding occurs while being heated and/or cooled thermoplastics are highly recyclable [8]. The other category, thermosets, can not be reheated and reformed as it hardens permanently after one application of heat. However, thermosets have high heat resistance and are applied in various high heat applications [8].

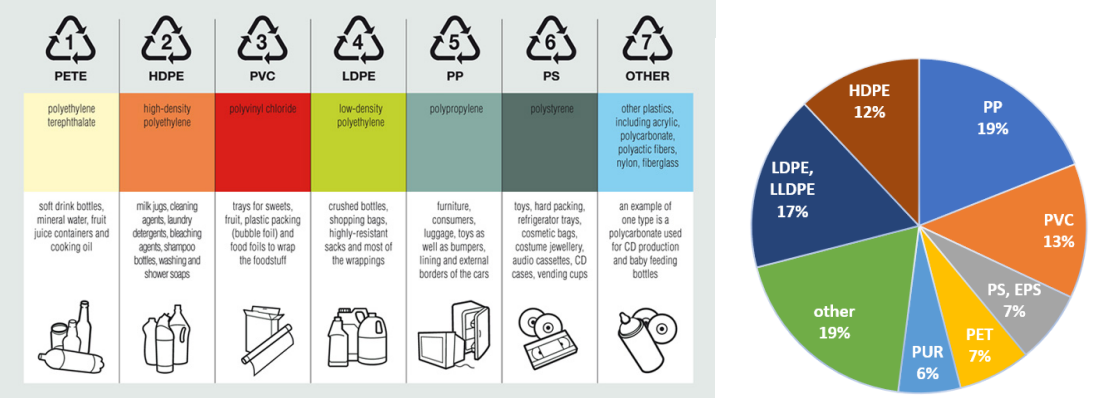
In order to improve and fit plastics to certain applications, additives can be added. Examples are: inorganic fillers, plasticizers, thermal stabilizers, fire retardants, colorants and UV stabilizers. These additives can reinforce the material, improve on the flexibility, make them more heat resistant, change the color of the material and prevent sunlight degradation respectively [9].

Plastics can be categorized into 7 main different types when following the SPI Resin Identification Coding System [10]. This classification system is based on the recycling properties of certain plastic products. In Figure 3.1 (a) an overview of the 7 types of plastics along with their SPI code and product examples is shown and Figure 3.1 (b) shows the global demand of various resin types in 2006. The most popular plastics are PP, LDPE and PVC, which form 49% of the total plastic demand.

3.1.2. WHY WE USE PLASTIC

Nowadays plastic is a dominant product in daily society. Its versatility, cheap production costs and simple production resulted in the vast growth and eventually mass production of plastic worldwide. Plastic has proven to be applicable in a wide variety of products, because of their unique properties. It can be used in a wide range of temperatures, are strong and though, chemical- and light-resistant and very workable materials [9].

Plastic packaging can be applied perfectly in the food industry, providing improvement on global health and safety in this industry [9]. Fresh products can be protected and preserved using temperature and atmosphere



(a) SPI Codes [10]

(b) World plastic demand by resin types [9]

Figure 3.1: Categorization of plastics in 7 groups and world plastic demand

control inside the package. The packaged food can also be monitored with the use of indicator labels, for example providing consumers information on the storage life of the food item. Water bottles are an excellent vessel to transport and store clean drinking water, greatly improving the water quality in developing countries.

Plastic materials also show great improvements on energy savings. Plastics have provided great substitutes for various materials such as metals in aircraft designs. Therefore, aircrafts have become lighter resulting in a significant reduction of fuel costs. As an example the Boeing 787, which consists of 100 percent composite material on the outer skin and 50 percent in the interior, had a reduction of 20% in fuel costs [9]. Furthermore the production process of plastic materials, such as a polystyrene cup, is found to be significantly lower in energy expenditure compared to its ceramic or disposable paper counterparts. A reusable ceramic cup would require several hundred uses before matching the energy expenditure of a single-use polystyrene cup [11].

Plastics provide excellent strength with minimum weight required [9]. This means that used plastics take less space and material than their glass or carton complement. Results are a reduction in transportation cost per unit, energy saving (units take less space in refrigerator), less material demand and reduction in waste volume.

3.1.3. HISTORY OF PLASTIC

As stated in Section 3.1.2 plastic products are currently highly popular. Together with its low production costs the worldwide plastic production has increased drastically over the course of a century. In Figure 3.2 the development of plastic production over the course off a century is shown. One can conclude that plastics are everywhere, despite that it is merely a product that started mass production a couple of decades ago.

THE PLASTIC TIMELINE

Humans have been using natural polymers since approximately 1600 BC [9], where ancient Meso-americans first processed natural rubber into figurines and balls. In the following years humans kept experimenting with natural polymers until the nineteenth century. After the first discovery of synthetic polymers in 1839 in the form of polystyrene, by the German apothecary Eduard Simon, the modern thermoplastic age began [9]. It was Alexander Parkes who unveiled the first man-made plastic at the Great International Exhibition in London in 1862, where he claimed that this new material could do anything that rubber was capable of, yet at a lower price. Moreover, his 'new material' could be molded into thousands of different shapes [9]. The first commercial production of plastics and widespread application started in the 1920s, as polyvinyl chloride (PVC) was used in a large variety of products. Soon in the following decades, many new types of plastics where discovered. The diversity and the possibilities of plastic became apparent. After World War II, the postwar economic boom took plastic usage to a new level as the production started to grow exponentially.

Already in 1960 the first effects of plastic on the environment and wildlife where felt when plastic debris was found in the guts of seabirds [12][13]. Over a decade later, plastic had reached a worldwide production of over

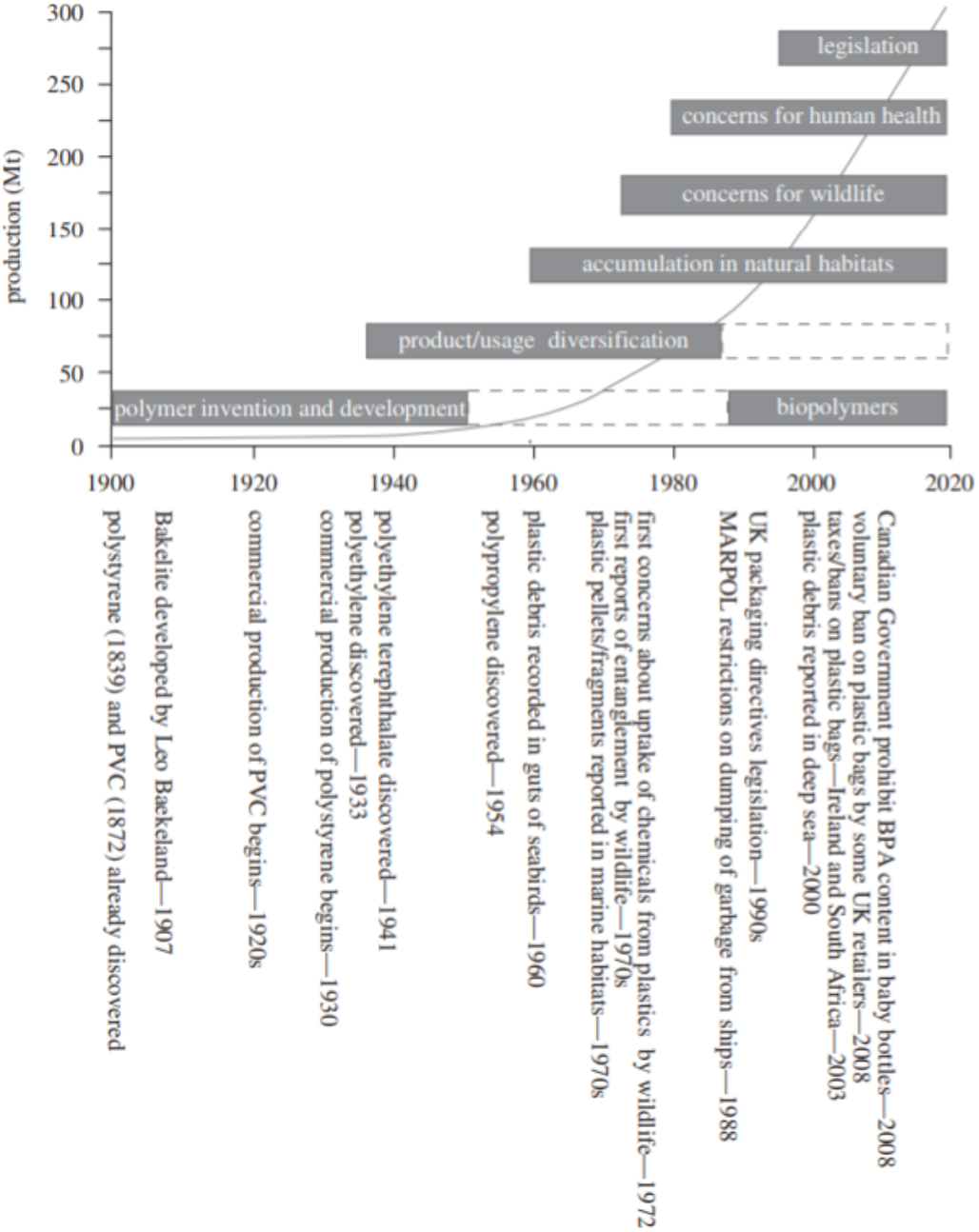


Figure 3.2: Plastic timeline [12]

50 million MT. This was accompanied with an increased impact on wildlife; the first reports started to show up regarding plastic entanglement of various wildlife and of plastic fragments in marine habitats. As a result the first public concerns were recorded as well. The following decade plastic production kept on increasing exponentially, eventually in the late 1980s and early 1990s legislation was applied for the first time on plastic. In the following years the concern for wildlife and human health increased, more legislation was applied, and reports of plastic in deep sea waters appeared. In the past decade society became more and more aware on the effects of plastic and more organizations and projects started to work on solutions, however plastic production still grows and currently contains a production of over 300 million MT per year [1].

PLASTICS NOWADAYS

Plastic production may have fruitfully started in Europe and North America but other countries have started to contribute as well. In Figure 3.3 the global distribution of plastic production is shown. The rapid rise of China's economy is accompanied with a large increase in plastic production, as China currently is responsible for 29% of the global plastic production. The rest of Asia experiences economic growth as well and is producing large amounts of plastic 3.1.2. Together with large populations in Southern Asian countries the contribution to global plastic production currently holds around 50%. The traditional economic powers, such as North America and Europe, are still big factors in plastic production and respectively take up 18% and 19% of the global production. Developing countries such as Africa and Latin America currently play a minor role in global plastic production.

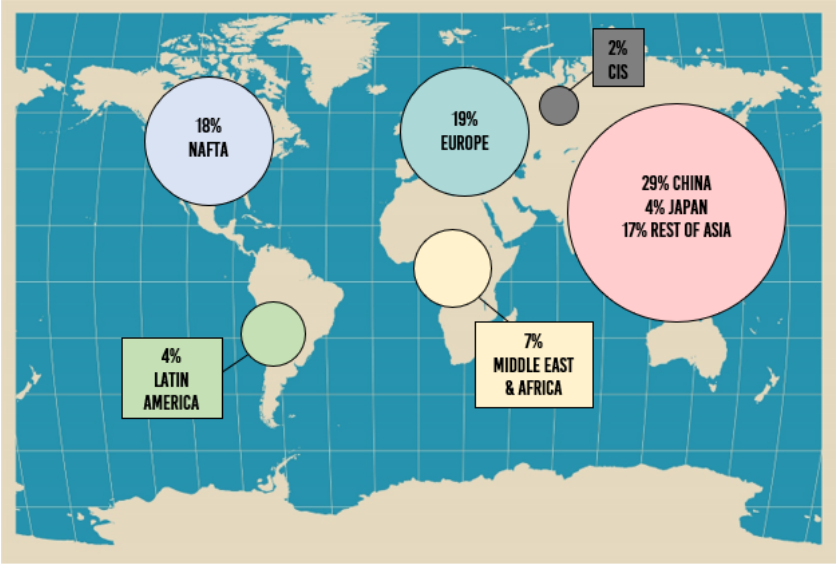


Figure 3.3: Distribution of global plastic materials production [14]

3.1.4. PLASTIC LIFE CYCLE

In order to understand the life cycle of plastic products it is important to stress that not all plastic products are the same and therefore there is no general service lifetime. Single-use plastics have a service life of less than a year, whereas some other products have a service life of 50 years or more [14]. During the life cycle of a plastic product certain stages can be distinguished, which starts with the production from crude oils. In Figure 3.4 a depiction is given of the life cycle stages of plastics. The life cycle is ended in three ways. The product is recycled, gets destroyed by incineration or is disposed in a landfill or in the environment.
Different life cycle stages of plastics all have their own implications for the environment. Each of these implications require certain mitigating measures. Table 3.1 is constructed to give an insight in these stages. Similar to the food chain, this table can be seen as a plastic chain where the plastic moves from step 1 down to step 7. Measures will be most effective higher up the chain, but then require rigorous actions. Down the chain measures are less effective since the plastic pollution is more dispersed, the conditions get more complex and plastics have had more time to affect the environment.

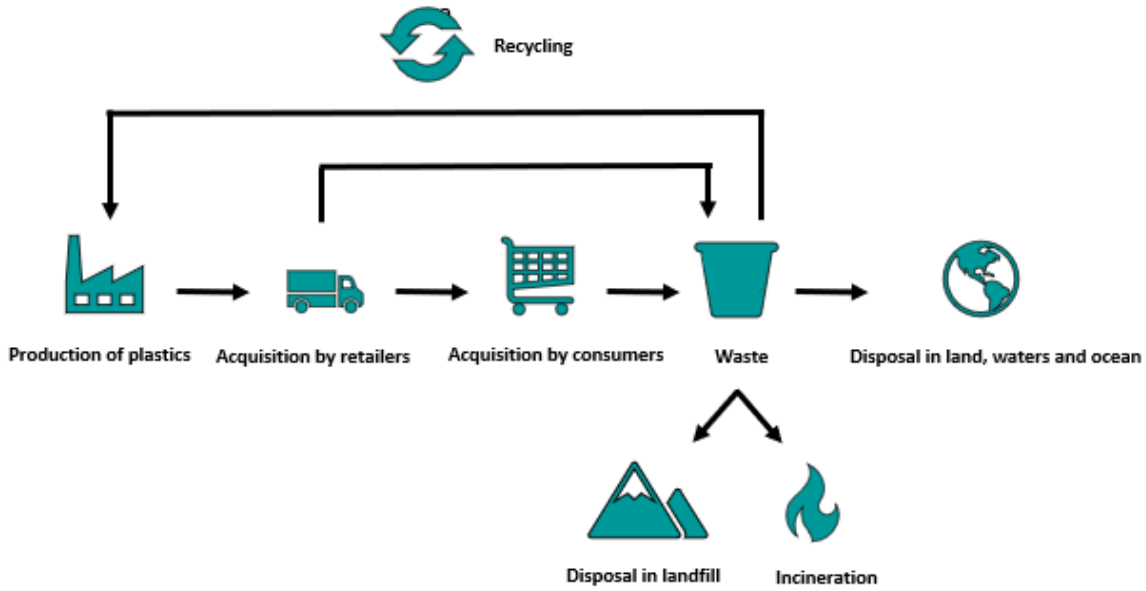


Figure 3.4: Life cycle of a plastic product

	Description	Implications	Mitigating measures
Step 1	Production of plastics via crude oil	Creation of plastic material that can affect the environment and public health further down the chain	Legal hamper of plastic production, find alternatives to plastic products
Step 2	Bulk acquisition by large retailers	Large acquisitions of plastic by big companies motivates the production and usage of plastic	Legal hamper, tax raise on plastic materials
Step 3	Acquisition by consumers	Plastics become public domain. Thus plastic waste becomes more dispersed and responsibility more individual. Contaminating plastics start to affect human health	Tax raise on plastic materials, education on plastic pollution and handling
Step 4	Disposal of plastic	If no correct education and facilities are available plastic gets discarded into the (marine) environment	Application of disposal and recycle facilities, active cleaning services and education on the effects of littering
Step 5	Plastic in rivers and beaches	Plastics have entered, and are affecting, the marine environment and are dispersed even more while losing an owners responsibility, getting subjected to natural forces	Active cleaning in rivers and beaches
Step 6	Degradation of plastics in the ocean	More dispersion and micronization of plastic waste effecting more wildlife and difficult to remove	Detailed and active cleaning in plastic soups and ocean
Step 7	Microplastics enter the food chain	Microplastics can travel up the food chain and affect human health and other wildlife even more	Improved food inspection and restriction on certain food to reduce health risks, almost impossible to remove plastic out of system

Table 3.1: The various implications during a plastic life cycle

To effectively reduce the pollution of plastic waste one should desire to find efficient measures that are both within their executive powers and can be applied as high as possible in the plastic chain. However since plastic has been commercially produced for almost 100 years [12] plastic materials have had enough time to affect the environment lower down the chain. Around 4900 million MT of plastic roams the (marine) environment [1]. This amount is currently contained in steps 4, 5, 6 and 7 of the plastic chain. Mitigating measures lower down the chain are therefore still required in order to prevent further pollution.

Certain types of plastic behave differently within the plastic chain. Some resin types are only used briefly and therefore are disposed quicker. As a result these are more often found lower in the plastic chain. Consequently these plastics are the type that will cause damage earlier and more frequently. In figure 3.5 the lifetime distributions of plastics from various industrial sectors are shown.

From figure 3.5 it is clear that packaging and consumer products are disposed far quicker than the other sectors, within 0 to 3 years. Therefore one would expect a higher frequency of these plastics to be found lower down the chain and having a larger impact on (marine) environments. The building and construction sector, industrial machinery sector and transportation sector require far less attention due to product lifetimes of 10 to 65 years.

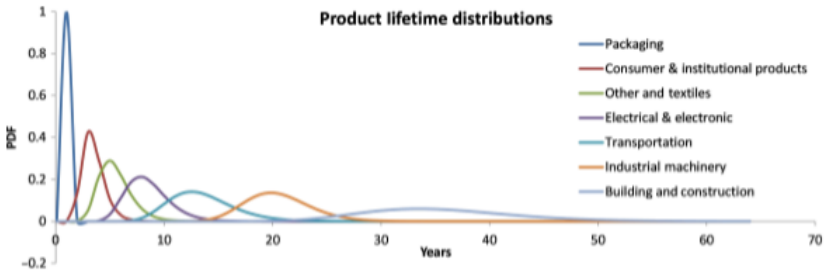


Figure 3.5: Lifetime distribution of plastics from various industrial sections [1]

3.2. IMPACT OF PLASTIC WASTE

Our current lifestyle regarding production, usage and end-of-life management of plastics impose a serious threat on the environment and wildlife. In addition, discarded plastic contaminates a wide range of ecosystems, freshwater and marine habitats [2]. As the majority of common used plastic products is not biodegradable, plastics are accumulating in our environment. After almost 100 years of commercial plastic production, large amount of plastics have been developed and due to their properties – durability and resistance to degradation – plastics that were disposed in nature are still around today. As discussed in Section 3.3, substantial quantities of plastic are being disposed in landfills or other systems, but also considerable amounts are dumped in the open, burned, buried or tossed into rivers and oceans.

3.2.1. MARINE ENVIRONMENT IMPACT

The marine environment is the greatest victim regarding plastic pollution, as it is the end station of every river on the planet. The release of plastics into the marine environment can occur through a variety of sources, which can be derived into two main sources: debris dumped directly at sea and land-based dumping. Land-based sources, dominated by river runoff, are the largest contributor to marine pollution with approximately 80% of the total marine waste [4][15]. Figure 3.6 presents a schematic diagram with the main sources and movements for plastics in the marine environment.
There is a strong correlation between population growth, rapid economic development and the amount of mismanaged plastic waste produced [4, 17]. Figure 2.1 shows the amount of plastic waste produced and mismanaged per country. By linking data on solid waste, population density and economic status, Jambeck *et al.* estimated the amount of land-based plastic waste entering the ocean. Their calculations show that the annual input of plastic to the ocean from waste generated by coastal populations recently reached up to 12.6 million MT, equivalent to 4.6% of the total plastic waste generated in those countries[4]. The top 10 of largest marine polluters is presented in Table 3.2. The majority is located in Southeast Asia.

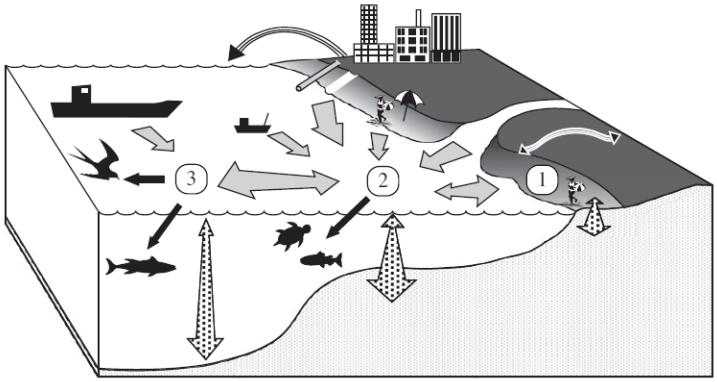


Figure 3.6: Schematic diagram showing the main sources and trajectories for plastics in the marine environment, with sinks occurring (1) on beaches, (2) in coastal waters and their sediments and (3) in the open ocean. Curved arrows depict wind-blown litter, grey arrows water-borne litter, dotted arrows vertical movement through the water column (including burial in sediments) and black arrows ingestion by organisms. (source: Ryan *et al.* [16])

Rank	Country	Econ. classif.[1]	Coastal pop. [mln]	waste gen. rate [kg/ppd]	% plastic waste	% mis-managed waste	Mismanaged plastic waste [MMT/year]	% of total mismanaged plastic waste	Plastic marine debris [MMT/year]
1	China	UMI	262.9	1.10	11	76	8.82	27.7	1.32–3.53
2	Indonesia	LMI	187.2	0.52	11	83	3.22	10.1	0.48–1.29
3	Philippines	LMI	83.4	0.5	15	83	1.88	5.9	0.28–0.75
4	Vietnam	LMI	55.9	0.79	13	88	1.83	5.8	0.28–0.73
5	Sri Lanka	LMI	14.6	5.1	7	84	1.59	5.0	0.24–0.64
6	Thailand	UMI	26.0	1.2	12	75	1.03	3.2	0.15–0.41
7	Egypt	LMI	21.8	1.37	13	69	0.97	3.0	0.15–0.39
8	Malaysia	UMI	22.9	1.52	13	57	0.94	2.9	0.14–0.37
9	Nigeria	LMI	27.5	0.79	13	83	0.85	2.7	0.13–0.34
10	Bangladesh	LI	70.9	0.43	8	89	0.79	2.5	0.12–0.31

[1]Economic classification: HIC, high income; UMI, upper middle income; LMI, lower middle income; LI, low income

Table 3.2: Waste estimates for 2010 ranked by mass of mismanaged plastic waste (units of millions of metric tons per year) [4]

IMPACT ON MARINE LIFE

The impact of plastic debris on marine wildlife is mainly caused by entanglement and ingestion. Many birds, turtles, fish but also marine mammals have already died because of marine plastic debris. [18]. Figure 3.7 shows a few images of events that happen daily and is only getting worse. These organisms interpret small plastic fragments and microplastics as food, which then results in starvation because the animals have a stomach filled with plastic. A study on fulmars in the North Sea suggested that 95% of the dead animals that wash ashore have plastic in their guts [19]. Another example is Figure 3.7(a), which shows the content that has been found in the stomach of a single sea turtle [20].

3.2.2. HEALTH IMPACT

Microplastics have just been discovered recently and have created an new area of concern. These particles are created due to deterioration of larger plastics into smaller fragments by for instance UV light and wave action [21]. Microplastics also occur in daily applications such as shampoo and toothpaste, and can directly enter the marine environment via the sewer system. Some plastic resins contain chemical additives that are considerably toxic. Especially microplastics and small plastic fragments present a likely source for the release of chemical toxics because of their large surface area to volume ratio. As these plastics can enter fish via ingestion, they can enter our own food chain. Moreover, plastic fragments are capable of absorbing toxic contaminants called persistent organic pollutants (POPs) from the environment. Because POPs are lipophilic and have the ability to accumulate in the fat tissues of living organisms for long periods of time, their concentration increases as they move up the food chain [22]. Bioaccumualtion of these chemical compounds may lead to potentially dangerous levels at the top of the food chain. The various processes and how plastics eventually threaten human health are schematized in Figure 3.8. To date, studies into harmful toxicological effects posed by plastics on humans are limited, so the main problem currently is that we don't yet know how big the risks are.

(a) Plastics found in the stomach of a single sea turtle (source: http://www.oceancleanup.com)

(b) Sea turtle entangled in fishing rope (source: http://www.nationalgeographic.com)

(c) Bird with stomack full of plastic (source: http://www.oceanhealthindex.org)

Figure 3.7: Plastic pollution in the marine environment

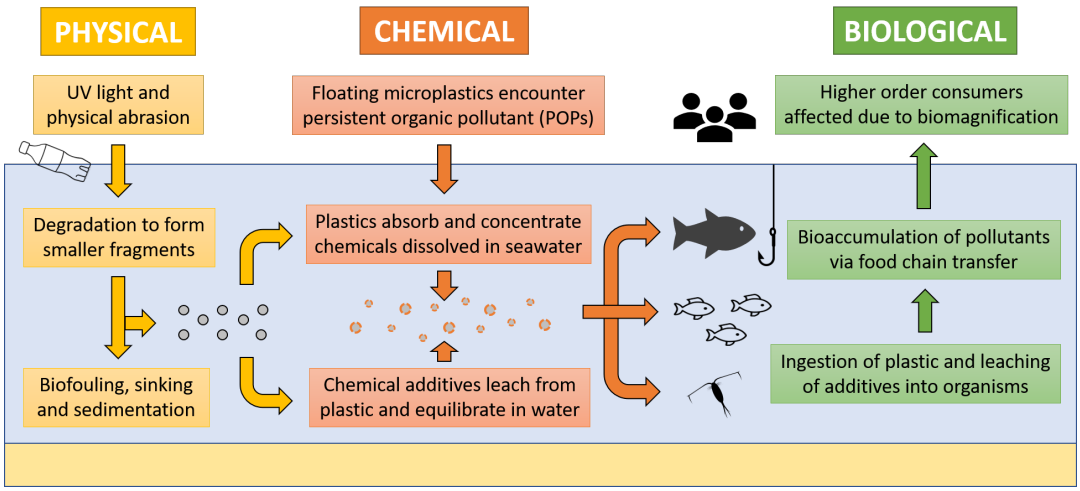


Figure 3.8: Schematization of how plastics eventually enter the foodweb and threaten human health

3.2.3. ECONOMICAL IMPACT

Besides the detrimental impact that plastic pollution cause as mentioned above, there are some economical consequences. For example cleanups, for which equipment, personnel and facilities are needed, cost a lot of money. Also the problem directly affects the tourism sector, which is often the main driver for (local) economies in developing countries. Tourists want to go to places where the beaches and waters are clean, so the number of tourist visitors will most likely reduce at holiday destinations where plastic pollution dominates the natural environment. It is hard to quantify the total economic impact in terms of costs, but according to a report by UNEP, the damage done to marine ecosystems alone already costs USD 13 billion per year. In 2008 marine debris was estimated to have cost the tourism, fishing and shipping industries of the 21 Asia-Pacific Economic Cooperation (APEC) member economies USD 1.3 billion in that region alone [24].

3.3. WASTE GENERATION AND MANAGEMENT

As described in the previous sections, plastic can have large impact on communities and the environment. It is required to understand waste generation and waste management in order to identify shortcomings in waste treatment in Bali and its surroundings.

3.3.1. WASTE GENERATION

The amount of waste generated is influenced by industrialization, urbanization, economic development, habits of citizens and the climate [3]. At this point cities globally produce 1.3 billion tonnes of solid waste per year. With the current trend this volume is advancing to 2.2 billion tonnes by 2025 [3]. Globally most waste is generated by higher income countries, as is displayed in Figure 3.9. By 2025, a large increase in waste production is expected which will be dominated by lower middle income countries. Over the following 20

years the rate of increase in waste production will even double in these lower income countries [3]. In order to cope with this increase in waste generation it is important that waste management evolves accordingly, especially in lower income countries where collection rates are generally poor. Due to environmental, health and economical impact, as described in the previous section, proper waste management is required for every municipality.

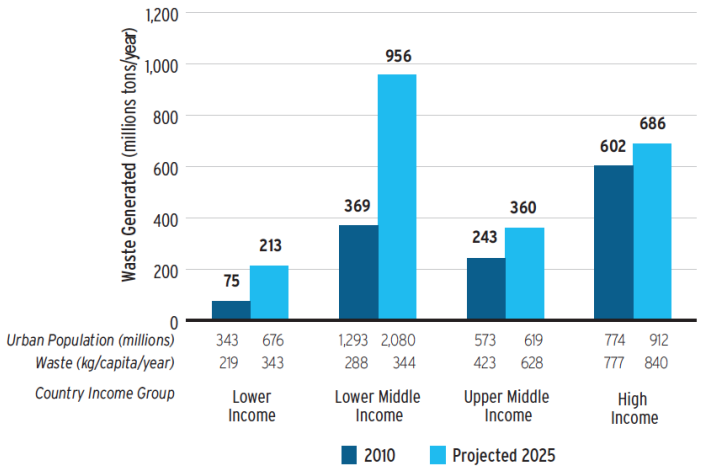


Figure 3.9: Waste production for different country incomes classes [3]

3.3.2. WASTE COMPOSITION

The composition of waste can officially be classified in six types of waste. These types are summarized in Table 3.3. The composition of waste is dependent on a variety of factors, such as culture, economic development, governing climate and energy sources [3]. The composition of waste globally and of low income countries is given in Figure 3.10. Generally low income countries have a high percentage of organic waste compared to higher income countries.

Type	Originates
Organic	Food rests, wood, leaves, flowers, etc
Plastic	Straws, bottles, packaging, bags, lids, cups, toys, slippers, rubber, etc
Paper	Books, bags, boxes, notepads
Glass	Bottles, light bulbs, glasses, windows
Metal	Cans, construction metals, foil,
Other	Textile, leather, laminates

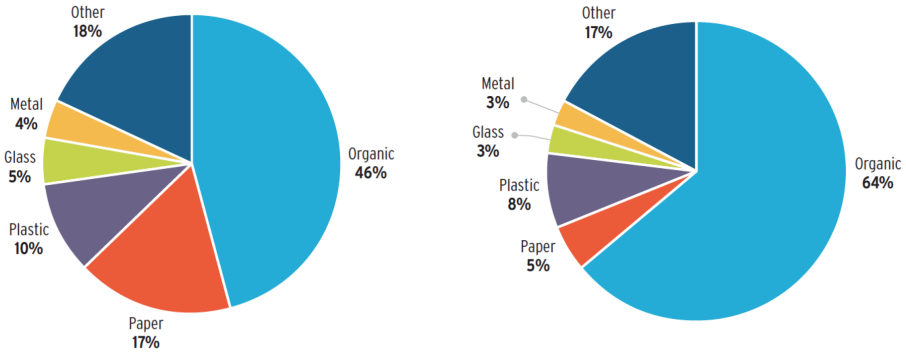
Table 3.3: Various classifications of waste and some examples [3]

3.3.3. WASTE MANAGEMENT

After generation it is desired to manage this waste properly in order to reduce negative impacts, which is generally the responsibility of the government. Waste management consists of several steps. These are discussed in the following sections.

WASTE COLLECTION

Waste collection is defined as the collection of all sorts of solid waste, that are captured after the production process. Waste collection is an essential aspect regarding public health in cities. Collection rates have a wide range over the world from 41% in lower income countries to a overwhelming maximum of 98% in high income countries [3]. The following waste collection methods are globally used[3]:



(a) Composition of waste globally

(b) Composition of waste in low-income countries

Figure 3.10: Composition of waste [3]

- **House collection**
  Waste services will collect garbage at every household. This method of collecting costs relatively a lot of effort.
- **Contracted service**
  The municipality hires a firm who produces the collection schedules and pick-ups.
- **General bins**
  Individuals drop their waste to general bins, which are placed at fixed places within a neighbourhood. The waste is then picked up from the general bins occasionally.
- **Self delivery**
  Households deliver their own waste to disposal sites.

WASTE DISPOSAL

Subsequent from the collection process the waste will be transported to so called disposal sites. There are five main disposal techniques which are used mainly over the world. These include: disposal at landfill, recycling, incineration and waste-to-energy, dumping and composting. In Figure 3.11 an overview is given of the distribution of various disposal techniques globally.

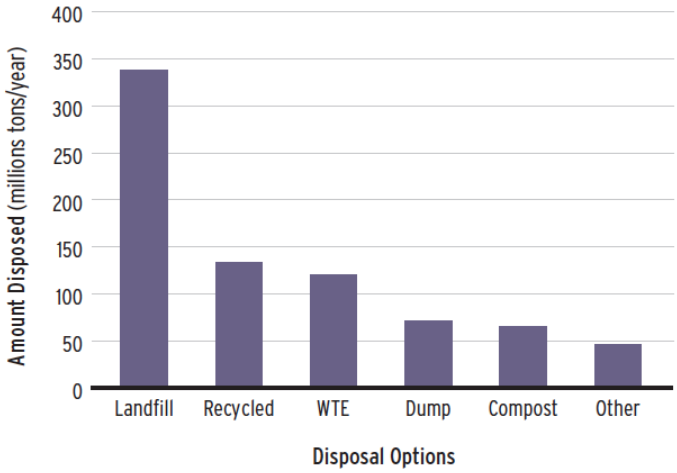


Figure 3.11: Distribution of different disposal techniques used over the world [3]

DISPOSAL AT LANDFILL SITE

The most common disposal type is via landfills. This is a final disposal location for collected waste. Landfills can be controlled in four different ways: semi-controlled dumping, controlled dumping, controlled landfill and sanitary landfill. These categories indicate the organizational structure of the landfill, where a sanitary landfill is considered the most organized. A full description of each of these landfills is given in Appendix F.1. Operational control of a landfill is of great importance as the landfill emits so called LFG (landfill gas). This gas contains a lot of methane which is a harmful greenhouse gas [25]. Methane gasses emitted from landfills contribute to 12% of the emitted methane gas over the world [25].

INCINERATION & WASTE-TO-ENERGY

A common waste disposal technique in Europe is incineration. This results in volume reduction of 95 percent. This technique also releases a lot of heat, which can be transferred into energy. This process is called Waste-to-Energy (WTE) [26]. There are three different types of processes which convert waste into energy, these types are: thermochemical, physicochemical and biochemical. This will lead to the following types of fuel: solid fuel, liquid fuel and gaseous fuel respectively. Eventually these fuels will be converted to thermal energy.

COMPOSTING

Composting is a natural process which is used in waste management. First the organic solid waste is separated from the inorganic [27]. Then, the organic waste naturally decomposes over time to compost. Decomposition is the phenomenon where the biodegradable part of organic waste is decomposed by microorganisms that use the organic fraction as a carbon source [27]. This end product can then be sold to consumers. Composting is beneficial for the environment because the organic matter in waste is recycled and the end product saves water by helping the soil to hold moisture. Most of the times composting is performed at the landfill site.

(PLASTIC) RECYCLING

Recycling is the process of recovering materials and reprocessing it into new products. At this moment 9% of the global total produced plastics are recycled [1]. A clear illustration of this distribution are given in Figures 3.12 and 3.13. Plastic recycling is evolving over the years as awareness among environmental impact has increased [28]. There are four main options to recycle plastics: re-extrusion, mechanical recycling, chemical recycling and energy recovery [28]. Appendix F.2 contains an elaborated version of these recycling techniques

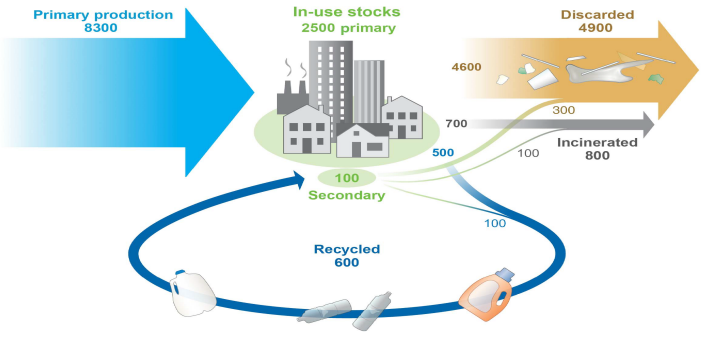


Figure 3.12: Global production, use and fate of plastics from 1950 to 2015 [1].

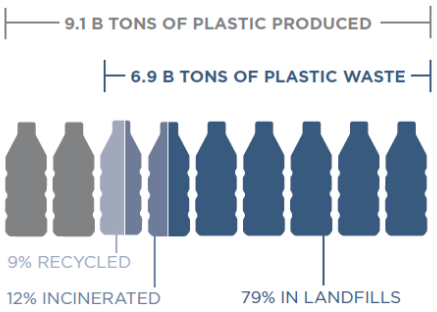


Figure 3.13: Fate of produced plastics [29]

3.3.4. WASTE MANAGEMENT IN DEVELOPING COUNTRIES

The quality of waste management in Western countries is relatively good. In developing countries, like Indonesia, waste management is generally very poor. Waste growth projections in these countries is relatively large and the waste management sector cannot keep up with this growth. Together with the lack of innovation this results in less than 10% of garbage being recycled. The main reasons for poor waste collection rates is bad infrastructure and lack of equipment. Furthermore, waste facilities are often located too far away for citizens, which largely increases the probability of littering in the environment.

4

Area Analysis

An area analysis of Bali (and Indonesia) is described in this Chapter. This area analysis is needed to have a better understanding of Indonesia and the province Bali. The characteristics are explained in Section 4.1. Eventually the characteristics of the island are elaborated in a conceptual model and is described in Section 4.2.

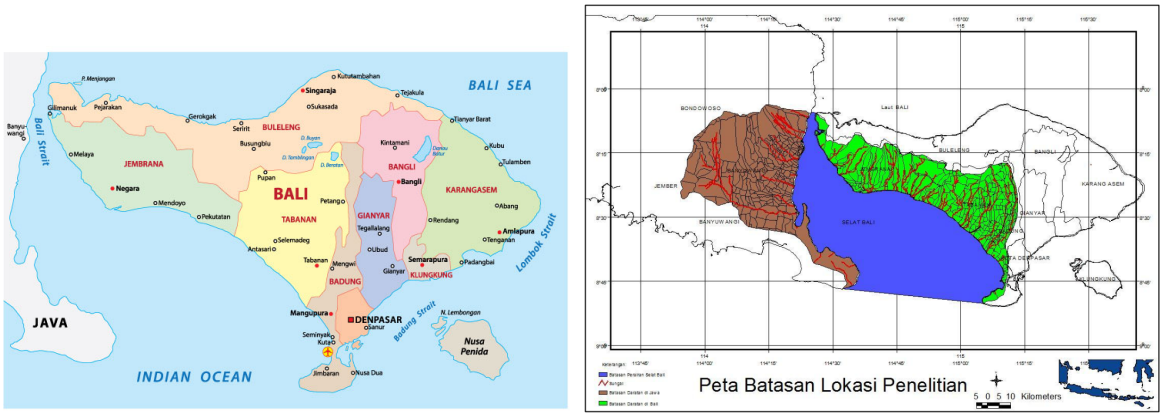
4.1. Characteristics of Bali

4.1.1. Topography

Bali is one of the more than 17000 islands of Indonesia and is a province of Indonesia. The map of Indonesia is displayed in Figure 4.1, with Bali indicated by a red circle. The island is approximately 150 km by 80 km and has a total area of 5600 km^2 [30]. Bali is situated East of Java and the Bali Strait separates the two islands as displayed in Figure 4.2 (a). Lombok is the island East of Bali and the sea narrow is called the Lombok Strait. The two waterbodies North and South of Bali are called the Bali Sea and the Indian Ocean respectively. The tropical island has 9 regencies which are displayed in Figure 4.2 (a). Bali has a large variety of landscapes; there are beaches, cliffs, hills, rice terraces and jungles. Several mountains and volcano's, which are larger than 2000 meters, divide the North and South part of Bali.

Figure 4.1: Map of Indonesia [31]

As discussed earlier in Chapter 2 the input of plastics of the rivers will be investigated in a specific research area. This area will consist of all the river catchment areas on the East coast of Java and the Southwest coast of Bali where the river mouths end up in the Bali Bay. Under the Bali Bay we encompass the ocean at the west of the coastline of Bali. A map of the area in which rivers have an impact on the Bali Bay is displayed in Figure 4.2 (b). When using Google Maps a total of 49 rivers can be observed at the Southwest side of Bali and 15 rivers are located on Java. The total number of rivers is also confirmed by a student report of the Universitas Indonesia [33]. Further research will be performed at the island to assess which rivers are most important to the problem and are fit for measurements. This will be discussed in Chapter 5.



(a) Map of Bali and its regencies [32]

(b) Map of area in which rivers have an impact on the Bali Bay[33]

Figure 4.2: Maps of Bali

4.1.2. CLIMATE

The climate on Bali is considered a tropical monsoon climate which are most found in South of Asia [34]. Monsoon is a wind process where the wind direction changes twice a year. The characteristics of the tropical monsoon climate will be further explained in this section.

TEMPERATURE

The daily temperature is almost constantly 30 degrees Celsius over the year because of its short distance to the equator. The annual average temperature progression is displayed in Figure 4.3.

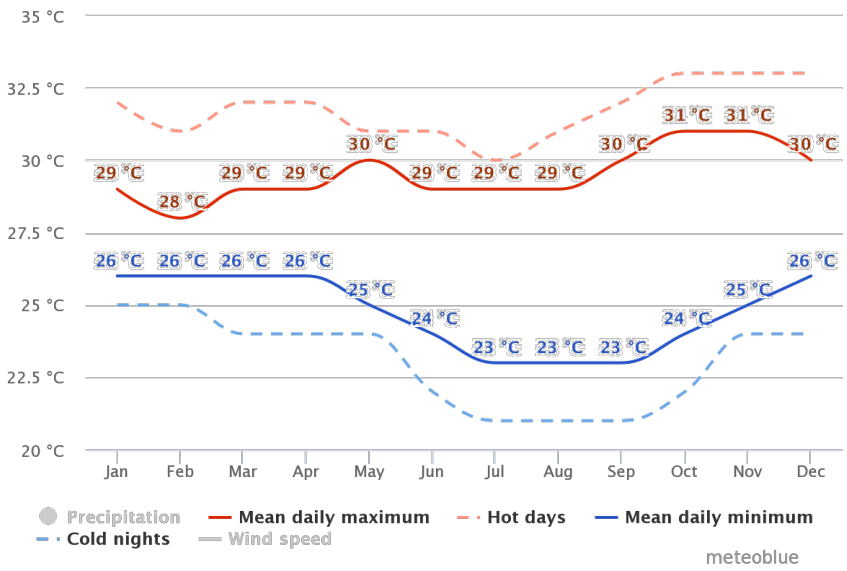
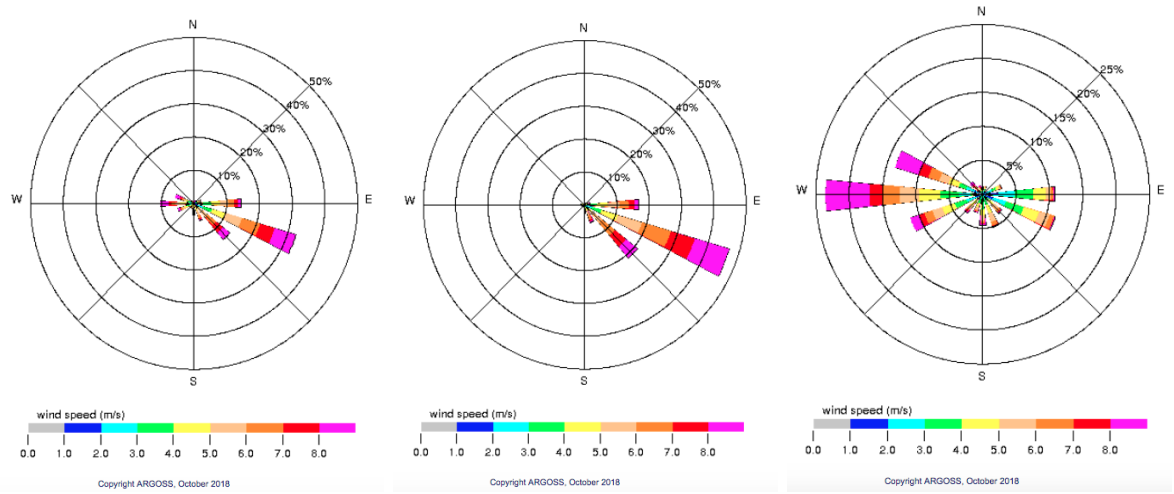


Figure 4.3: Temperature Denspasar, Bali, data from meteoblue.com

WIND CONDITIONS

Wind is really important in the tropical monsoon climate and two seasons are distinguished every year. These are the transitional season and West monsoon season [6]. The wind directions and intensities are displayed in Figure 4.4 for the two seasons. The yearly averaged wind is also shown. The wind direction during the West monsoon season is mainly from the West. The wind is coming from the East-Southeast during the transitional season. These two wind directions are important to remember during the research. In Figure 4.7 the average wind direction is shown in degrees during the measurement period of the research. During this period the



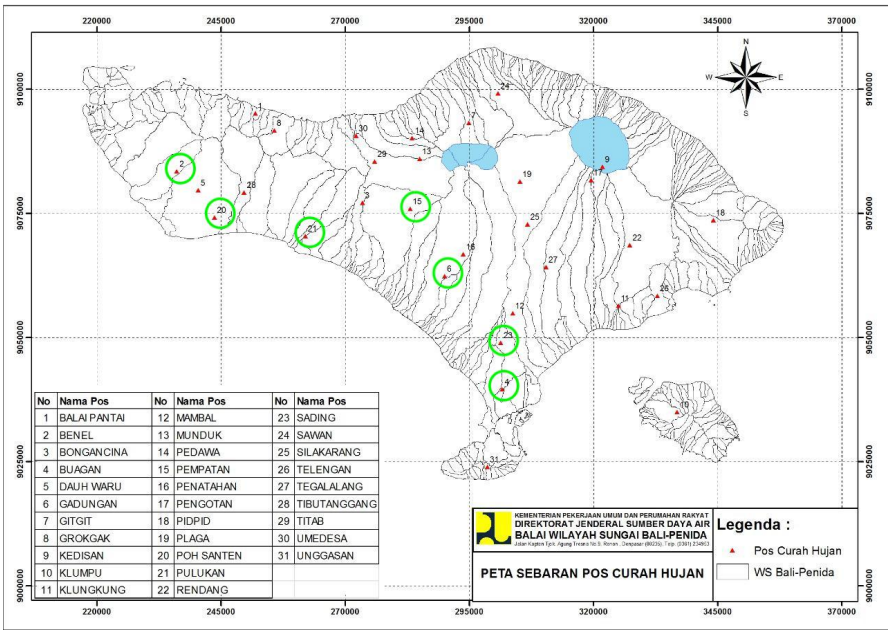
(a) All year average (b) April-October (c) November-March

Figure 4.4: Wind direction at coordinates 9.0S, 115E collected from www.waveclimate.com

wind direction was predominantly from the Southeast which is typical wind for the transitional season. This data is retrieved via Wind Guru[35].

PRECIPITATION

The precipitation data is collected from BWS Bali Penida which is a part of PUSAIR, a similar institute as 'Rijkswaterstaat' in the Netherlands. The data is collected from the following stations 2, 4, 6, 15, 20, 21 and 23 which are displayed in Figure 4.5. The average monthly precipitation is displayed in Figure 4.6. The starting date of the data is different for each weather station. Therefore, two analyses are made, to check if there are differences between the stations. There is some difference, but it is not to large. More precipitation data is available in Appendix A.



No	Nama Pos	No	Nama Pos	No	Nama Pos
1	BALAI PANTAI	12	MAMBAL	23	SADING
2	BENEL	13	MUNDUK	24	SAWAN
3	BONGANCINA	14	PEDAWA	25	SILAKARANG
4	BUAGAN	15	PEMPATAN	26	TELENGAN
5	DAUH WARU	16	PENATAHAN	27	TEGALALANG
6	GADUNGAN	17	PENGOTAN	28	TIBUTANGGANG
7	GITGIT	18	PIDPID	29	TITAB
8	GROKGAK	19	PLAGA	30	UMEDESA
9	KEDISAN	20	POH SANTEN	31	UNGGASAN
10	KLUMPU	21	PULUKAN		
11	KLUNGKUNG	22	RENDANG		

Figure 4.5: Precipitation data collected from the following weather stations indicated by green circles

In Figure 4.7 the precipitation data during the measurement period is shown. Little rain occurs from September until the start of November. Then a sudden increase in precipitation occurs with an average peak of almost 70 millimeters, which also confirms the start of the rainy season described before.

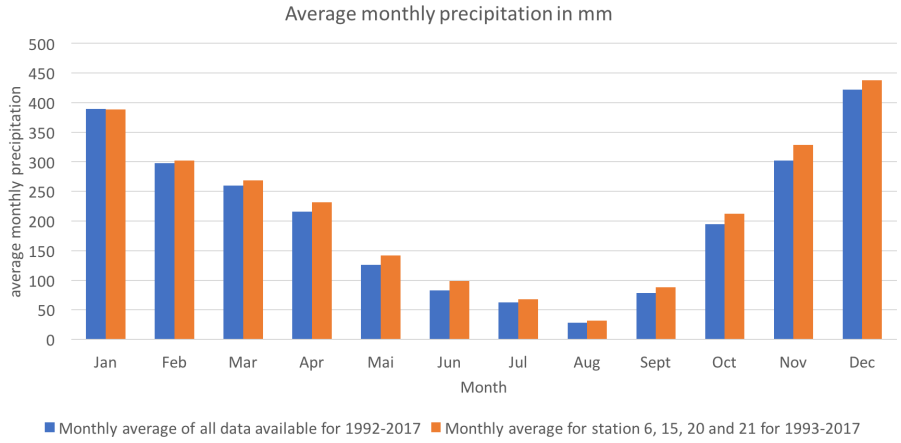


Figure 4.6: Average monthly precipitation in West Bali

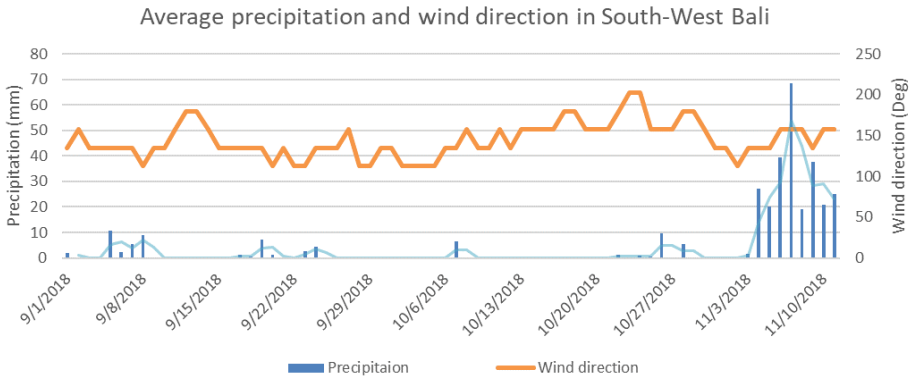


Figure 4.7: Precipitation and wind data during measurement period.

4.1.3. HYDRAULIC PARAMETERS

Hydrodynamic forces can introduce water flow over the entire water column. These water flows are capable of transporting marine plastic debris. Our oceans and seas are not just a still body of water, but are constantly exposed to forces that induce motion of the water mass. Important drivers for ocean currents are:

- Temperature variations
- Salinity variations
- Wind forcing

Winds stir the surface layer of the ocean and are the main driver for current patterns at the ocean surface [36]. These winds induced currents do not penetrate much below 100 m, so in deep water other factors play a role [36]. Deep water currents are driven by pressure gradients, which are caused by changes in salinity and/or temperature. In coastal zones local currents are often dominated. These currents are induced by waves, tide and local wind conditions, but also the coastline alignment (e.g. bay shape) and presence of coastal canyons play a role. Below the important hydraulic parameters in the area of interest are discussed.

SEAS OF INDONESIA

In this section the oceanography and currents of the Indonesian Seas are being discussed, as these currents are a main driver for transport of plastic within this area [37]. Indonesia is enclosed by the Pacific Ocean at its East side and the Indian Ocean at the South side. Both oceans introduce fluxes directed into or outgoing from the Indonesia seas, which links the Pacific to the Indian Ocean. As the focus lies on the conditions in the Bali Bay these flow patterns are beyond the scope of this project. Yet, to better understand the Indian seas and its place

in the global ocean scheme, the seasonal oceanographic conditions in both oceans are included in Appendix F.

The Seas of Indonesia are surrounded by many islands and host complicated underwater trenches, basins, channels, ridges, shelfs, and sills. These factors and the fact that it is connected to both the Indian Ocean and Pacific Oceanc results in complex flow pathways and large water volume transport. The flow that passes through Indonesia is called the Indonesian Throughflow (ITF). The ITF pathways and a rough estimate of the volume transport is depicted in Figure 4.8. Averaged over the year 10 Sv (= 10 million m^3/sec) moves from the Pacific to the Indian Ocean via the Indonean Seas. Circulation and transport in the Java- , Makassar- and Flores/Banda Strait vary along with the tropical monsoon climate. In this area surface water flows along with the prevailing wind direction [37]. So during West monsoon water from the Java Sea is 'blown' into the southern Makassar Strait, whereas during the transitional season the prevailing ENE winds will blow water from the Bandda Sea into the southern Massar Strait. Also current reversal in the Java Sea could occur [37].

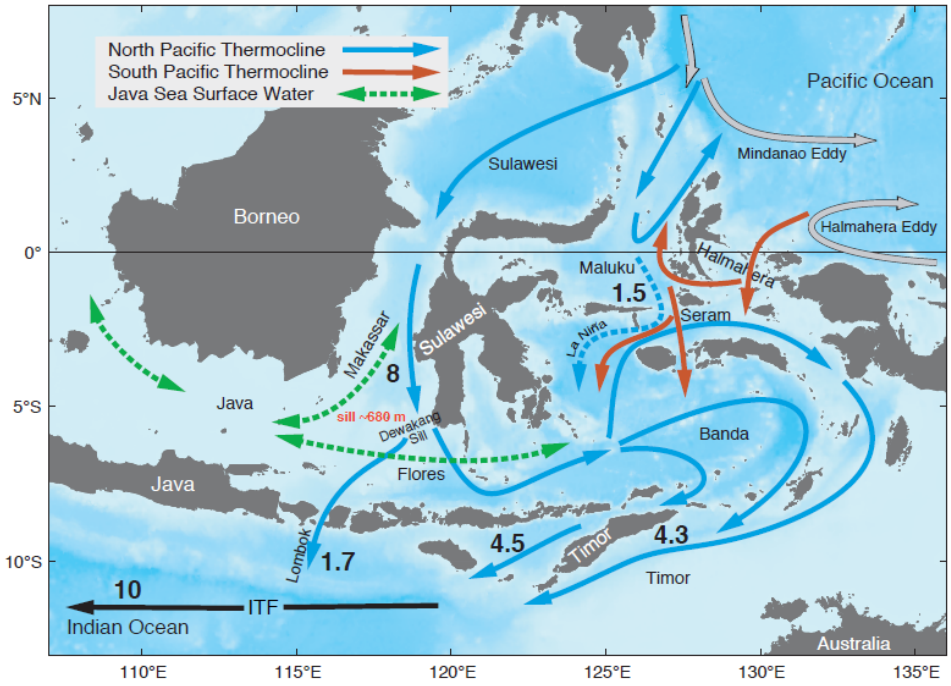


Figure 4.8: Indonesian throughflow pathways and estimates of total volume transport (in Sv = 10^6 m3/sec) [37]

TIDE

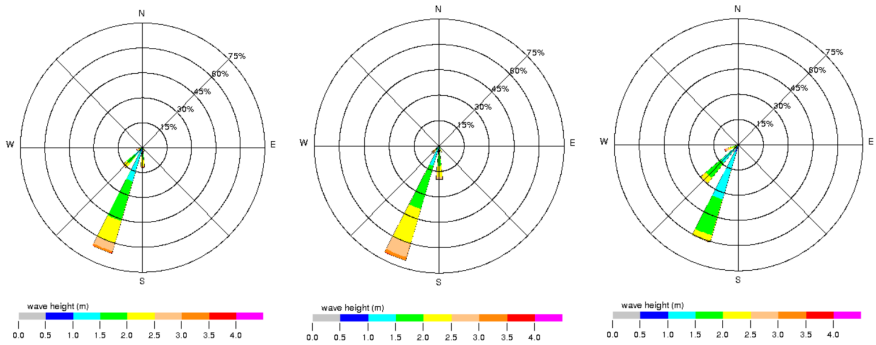
The type of tidal movement in the coastal waters of West and South Bali is a semi-diurnal tide [38]. This means that the tide rises and falls twice per day. Along the coast the spring tidal range is around 2.5m [39]. Therefore, the Southwest coast of Bali qualifies as a Meso-tidal regime (mean spring tidal range between 2-4 m). The type of tidal wave in the wide area of the Bali Bay is a progressive wave, whereas it behaves as a standing wave in the narrow part more North in the Bali Bay [40]. This means that the tidal range is largest at the Southern boundary, and decreases in amplitude as it travels North.

WAVES

The wave climate in Bali is categorized as Monsoon climate. In Figure 4.9 the wave conditions at the entrance of the Bali Bay is given. Here it can be seen that the dominant wave direction does not vary over both seasons, and large swells are experienced all year long, though, the highest waves occur in summer under the influence of the SW-monsoon.

BATHYMETRY

A map of the bathymetry of the Bali Bay is shown in Figure 4.10. The shape of the seafloor and coastline could be important to better understand physical features in the Bali Bay.



(a) All year average (b) April-October (c) November-March

Figure 4.9: Offshore wave conditions at coordinates 9.0S, 115E collected from www.waveclimate.com

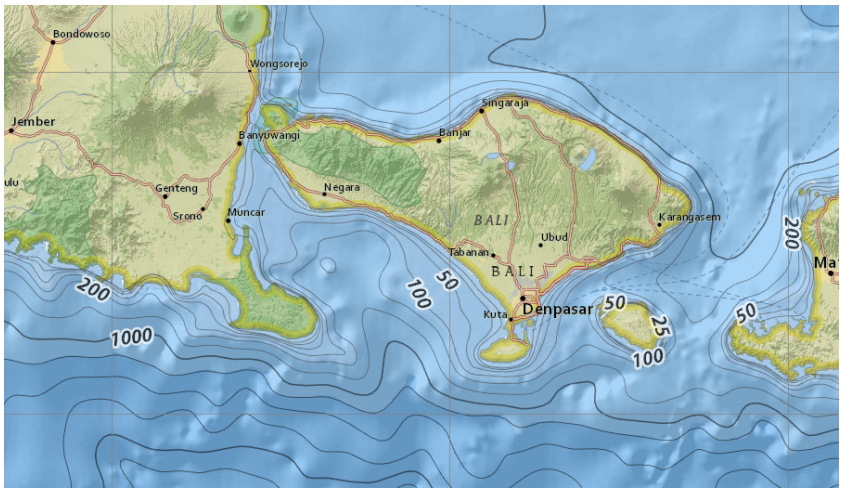


Figure 4.10: Bathymetry of Bali Strait (source: maps.ngdc.noaa.gov)

4.1.4. TOURISM AND ECONOMY

Tourism started to increase immensely in Bali in the late 60's after a large expansion of the airport enabling access for intercontinental aircraft [41]. The number of tourist increased from 30 000 in 1970 to 600 000 in the late 1980's [41]. A lot of hotels were established in the South of the island which led to an increase of inequalities between the North and the South. In 2017 around 5.7 million tourists visited the island and this number is expected to increase even more in the future [42]. The economy of Bali used to strongly depend on agriculture and craftsmanship, but nowadays tourism is the largest driver as it is estimated to represent 60 – 70% of the economy [43]. The economy is not diversified and this large dependency makes Bali vulnerable. This phenomena was observed when the active volcano Agung erupted, which led to temporary closure of the international airports and scared off tourists to plan a trip to Bali.

4.1.5. POPULATION AND CULTURE

Indonesia is currently the fourth most populated country in the world with 267,700,000 inhabitants, of which 87% practices Islam as their main religion. Bali is considered as the Hindu island in Indonesia where around 84% of the 4,292,200 inhabitants is Hindu. Around 13% practice Islam and the remaining 3% consist of Christians and Buddhists [42]. People in Indonesia are free to practice any religion and also on Bali the different religions go along with each other fairly well. Also, discrimination by religion is punished severely in Indonesia. Before Bali experienced mass tourism, almost the entire population worked in agriculture for the production of rice and other agrarian products. Furthermore, the traditional Balinese culture is focused mainly on different kinds of art such as dance (Barong and Kecak), shadow play (wayang) and craftsmanship such as weaving of traditional Batik fabric and woodcarving.

4.1.6. LEGAL SYSTEM INDONESIA

The legal system of Indonesia is rather complex as it inherited influences from three different sources of law; Dutch colonial law, Islamic law and the customary or 'adat' (meaning 'traditional' in Bahasa) law. After the proclamation of independence in 1945 the constitution of the republic of Indonesia was formed, which was still largely comparable to the former Dutch colonial law with influences from both Islamic law and adat law. Adat laws are basically unwritten laws, being still of great importance to rural communities. Besides the constitution, the legal system consists of several other legislative branches. The official hierarchy of the legal system in Indonesia is as follows: [44]

1. **1945 Constitution of the Republic of Indonesia (UUD 1945)**
   This is the highest organ of the Indonesian legal system and every other shall have to comply with this level. Since 2009 also an Environmental Law (Law No. 32) has been added to the constitution, which was established to protect the environmental situation to deteriorate further.
2. **Peoples consultative assembly (MPR)**
   The MPR consists of two bodies; the House of Representatives (DPR) and the Regional Representative Council (DPD) and combined they have the ability to pass laws, amend the constitution and, if in compliance with the constitution, dismiss the President and Vice-President.
3. **Law and Governmental regulation in Lieu of Law (UU-Perpu)**
   Laws are established after mutual agreement is achieved by both the DPR and the President. In a situation of great urgency however, the President has the right to establish a new law, which in term can not conflict with higher legal authorities.
4. **Government Regulation (PP)**
   Regulations are set by the President and always have to comply with a law of a same subject so that the laws are working properly.
5. **Presidential Regulation (Perpres)**
   The word Perpres is rules and also these are issued by the President, only now they are made at the President's own discretion. These rules are implemented to support the power of higher legal organs.
6. **Regional Regulation (Perda)**
   Indonesia consists of 34 provinces, which all have a number of regencies and cities. These regencies are divided in districts and these consist of several villages. These five factions are led by governors, regents, mayors, *camats* and *kepala desa's* respectively. Also they all have their own Regional House of Representatives (DPRD) which in accordance with the head of the local government sets the rules for regional laws. The Environmental Law No.32 also stated that Regional Governments maintain autonomy in terms of environmental regulations.

ENVIRONMENTAL LAW

According to the International Comparative Legal Guide the basis for environmental policy in Indonesia is:

> *"Environmental protection in Indonesia is principally regulated by Law No.32 of 2009 on The Management and Protection of the Environment ("Environmental Law"). Under the Law on Regional Governments (Law No.9 of 2015), which grants regional autonomy to regional Governments, including with regard to the protection of the environment, implementing regulations of the Environmental Law are formulated on national as well as regional level."*

This indicates the regional governments have their autonomy regarding environmental regulation while keeping the national environmental law in consideration. Each province and regency has its own institution that supervises environmental issues in his region. Their task is to monitor and control activities that may harm the environment, and to implement environmental policies that were formulated by the Ministry of Environment [45]. Every province and regency eventually performs their task differently from eachother.

4.2. CONCEPTUAL MODEL

The research questions were discussed in Chapter 2 and one of them reads: 'What are the main drivers of the plastic waste accumulation in the Southwest?' A conceptual model will be introduced to understand the plastic problem and to get an answer to the main research question. To accomplish that, first a good schematization needs to be given to understand the research area. This is done by splitting up the area into

various element, which are described in Section 4.2.1. Afterwards, the schematization needs to be turned into an actual conceptual model which shows the interaction between these elements. How this is accomplished will be explained in Section 4.2.2.

4.2.1. SCHEMATIZATION OF RESEARCH AREA

A schematization of the research area is displayed in Figure 4.11. Different components are presented in the schematization and these elements will interact with each other later on in the conceptual model. Each component will now be briefly introduced and discussed.

DIRTIEST BEACHES

The waste accumulation is especially large in the Seminyak, Kuta and Jimbaran area during the West monsoon season. This area is indicated in Figure 4.11. Around thousand trucks are needed during these rainy months to clean the accumulated waste at their beaches.

RURAL BEACHES

The rural beaches located more towards the North and are displayed in Figure 4.11. Little is known about the waste accumulations at these areas and site visits must reveal the state of these beaches.

RIVER INPUT BALI AND JAVA

The rivers in Southwest Bali and Java are discussed in Section 4.1.1. In this model trash is disposed along the riversides. These rivers are able to transport waste into the ocean and are an important element in the model.

OCEAN SURFACE

The water body is in motion all the time. The tide and wind cause currents which are able to move the waste around the research area. It will be the central element in the model as it interacts with the rivers, beaches, and the Indian Ocean and Java Sea.

THE BOUNDARY CONDITIONS

In the North a boundary is set at the smallest part of the Bali Strait which is about 2.5 kilometers wide. The southern boundary is separating the bay and the Indian Ocean and will be indicated as South boundary in the model.

BOTTOM

A part of the plastic waste might sink to the bottom of the ocean and will stay there. Bottom waste can also flow back to the surface again.

TRASH DISPOSAL AND CLEANUPS

Mismanaged waste is one of the reasons why waste will end up in rivers and on beaches. On the other hand, beach cleanups are regularly organized at Bali and will take waste out of the system. This element should therefore be taken into the conceptual model too. Furthermore, the waste management system on Bali will be investigated, as it currently seems incapable of capturing all the waste on Bali. By mapping the waste management system it can become clear were it is under-performing.

4.2.2. SCHEMATIZATION TO CONCEPTUAL MODEL

The components of the model were explained in Section 4.2.1, but the interactions between these elements are not yet discussed. The schematization of Figure 4.11 is transformed to the conceptual model as displayed in Figure 4.12. The interactions are displayed by arrows in the model. The arrows can be directed one way or both ways. The arrows are numbered and further described in Table 4.1.
This conceptual model will give insight in the movements of the plastic waste in the research area. All the components and arrows will be researched and after the investigation the main drivers can be indicated by the model. After the model is elaborated it will give insight in where efficient interventions can be applied. A side note needs to be made regarding the conceptual model. There are more components in reality such as wildlife, who swallow plastic particles, and fishing boats dumping waste of their vessels. It is assumed that these kind of components are relative small and do not have large contribution to the model. Therefore, these elements are neglected such that the model does not get too complex.

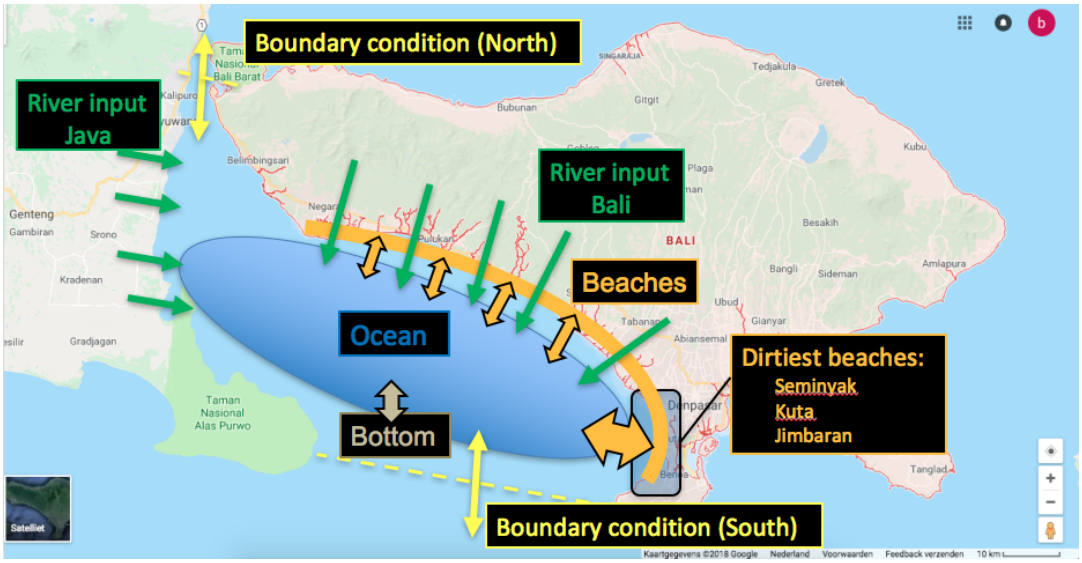


Figure 4.11: Overview of the components in the area of interested

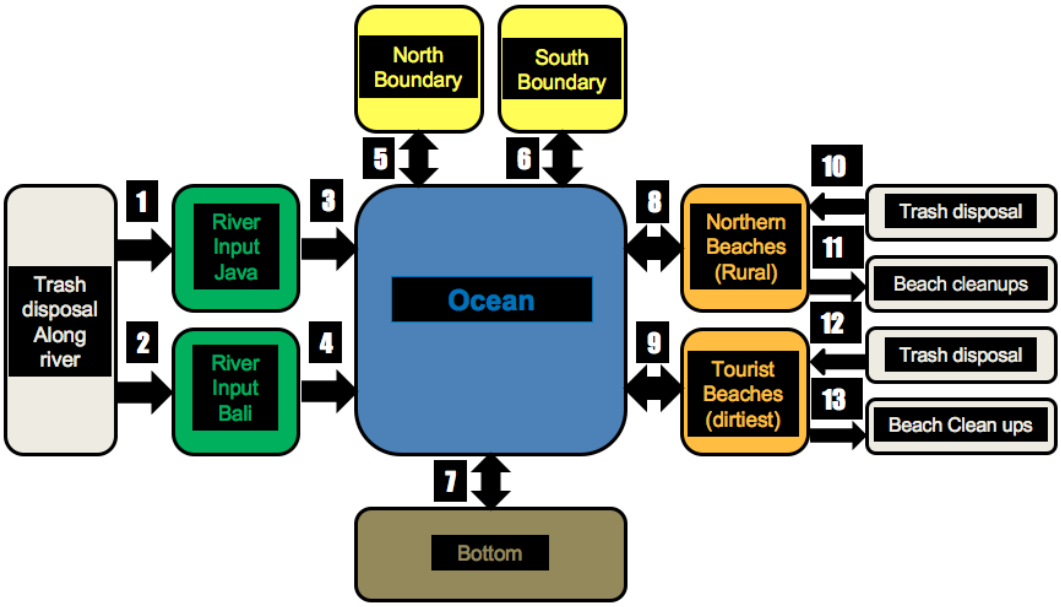


Figure 4.12: Conceptual model of the research area

Arrow(s)	(Possible) directions	description
1 & 2	one way	Inhabitants dump trash often along or in rivers and is an input for plastics in the river system.
3 & 4	one way	When plastic particles are in the rivers it will be transported downstream, towards the ocean.
5 & 6	both ways	Plastic particles are able to travel from the ocean component into the North boundary (Bali Strait) and South boundary (Indian Ocean). There is also the possibility that plastic is coming into the system via these boundaries.
7	both ways	A part of plastics in the ocean might sink to the bottom, but is also able to come back to the ocean surface.
8 & 9	both ways	Plastics can wash ashore on the beaches, but can also flow back into the ocean.
10 & 12	one way	Tourists, fishermen and inhabitants could dump trash when visiting the beaches.
11 & 13	one way	Beach cleanups are often organized on Bali which results in an extraction of plastics out of the system.

Table 4.1: The description of the arrows in the conceptual model

5

METHODOLOGY

5.1. INTRODUCTION

In this chapter the methodology will elaborate which steps are required to answer the research questions. In Section 4.2 a conceptual model was introduced. All the components, inputs and outputs need to be researched and this will be done according to a specific methodology. First the methodology for the ocean, boundaries and bottom component will be treated, where a number of key parameters mainly have to be defined and investigated. Second will be the river research in which the selection of rivers will be explained along with the measurement execution and some key parameters. Next, the research on beaches will be elaborated following similar a similar path as for river research. Lastly the method for the waste quantification and social aspect of the project will be described.

In Table 3.1 a description is made of the various life cycle steps of plastics. Within the case area it is almost impossible to research the plastic pollution problem, and potential solutions, along the complete plastic life cycle. Therefore research is focused on a part of the life cycle where the impact is relatively large. This accounts for steps 4 and 5 in Table 3.1, which describe disposal of plastic and plastic behavior in the environment.

For this report it is important to note that only macro plastics will be considered. In Figure 3.1 in the literature study the official categories of plastic are given that are acknowledged internationally. However, in field experiments with plastic waste it can be difficult to recognize the kind of plastic that has been found. For this reason the following plastic categories are considered for the project scope:

- HDPE (high density polyethylyne)
  - Cups, lids, plastic cases
- LDPE (low density polyethylene)
  - Plastic bags
- PET (polyethylene terephthalate)
  - Plastic bottles, fishing rope
- PP & PS (polypropylene & polystyrene)
  - PP: plastic straws
  - PS: Styrofoam, plastic cutlery & tableware, clamshells
- Multilayer plastics (mostly combinations of PP & PE)
  - Packaging

A visual description of these categories is included in Appendix D.1.

5.2. OCEAN, BOUNDARIES AND BOTTOM

5.2.1. METHOD

Each of the elements ocean, boundaries and bottom will be further analyzed in order to determine their interaction with other components within the system. The goal is to determine per element whether it

interacts as an input or output. A quantification will be left out of the analysis as this would require complex and expensive field measurements, such as investigation of floating litter by boat in the Indian Ocean. As the area of interest is mainly influenced by local conditions, it is expected that only limited excising and/or public research is available. Therefore information will also be gathered by conducting interviews with experts and locals. Based on their expertise and by considering the resources available, the distribution of plastic debris in open waters will be specified.

5.2.2. KEY PARAMETERS

As discussed on Section 4.1.3, the main driver of ocean surface currents is wind. Closer to the coast and near shelf's other factors, such as tidal current and waves, can also induce currents that are capable of transporting marine litter. All parameters and their relation to marine litter transport are briefly discussed below. General hydrodynamics will be used as input in the model. Via literature study and interviews the local conditions during both seasons will be analyzed.

WIND

The propagation of marine litter at the ocean surface is strongly related to the wind direction and magnitude.

TIDE

Asymmetric tides lead to residual currents in both longshore and cross-shore direction. Furthermore, the emptying and filling of the Bali Bay and the phase lag between the tide in the Bali Strait and the Java Sea can give rise to large tidal currents in the inlets. Large tidal currents can also occur around structures on the open coast.

WAVES

Waves can cause complex current patterns in the coastal zone. Oblique waves can also induce alongshore currents [46].

GEOMETRY OF THE AREA

The coastline is a boundary for water flow and can cause divergence and/or concentration of currents near shore. The coastline alignment therefore influences the propagation of marine litter.

5.3. RIVER MEASUREMENTS

5.3.1. RIVER SELECTION

In Chapter 4 the area of research shows that a lot of rivers end up in the Indian Ocean at the South coast of Bali. In Figure 4.5 these rivers were shown, however not all rivers are qualified for research. Therefore a requirement list was made to narrow down the number of rivers:

- For safety reasons, all river measurements will be conducted from hard structures like bridges. Contact with contaminated water should be avoided at all times. Besides that, the team members should be able to work safely on the bridge without much traffic
- A site should be chosen close to the river mouth
- Easy access to the water from the river banks in case equipment has to be recovered
- On the river banks there should be enough space to perform field work but also sorting and weighing
- A river should have a substantial cross-section and depth as the equipment can't be used in small creeks
- Flow velocity should not be larger than $1 m/s$ as turbulence will hamper the measurements

After the river selection is narrowed down enough a trip is organized in order to visually inspect each river and determine which are suitable for measurements. The goal is to maintain 3-5 rivers that are fit for measurements.

5.3.2. KEY PARAMETERS

In order to characterize the real-time properties of a selected river a number of key parameters is required. It's important to note that all fieldwork is performed from a bridge which also includes the acquisition of river properties.

CROSS-SECTIONAL AREA

Water flows through a specific cross section which is defined by the bathymetry and the distance between two river banks at the surface. Rivers are hardly ever prismatic which makes defining the bathymetry difficult. As the selected rivers will be considerably deep at certain segments the cross sectional area will be determined using a sonar tool. First the distance between the river banks is measured with measuring tape. Then the width will be divided in segments with equal width and indicated on the bridge by tape. The final step is to measure the depth in each segment, which is carried out with the floating Deeper Pro+ sonar tool by deployment from the downstream side of a bridge. With these depths an approximation can be made of the bathymetry and thus also the river cross-section.

FLOW VELOCITY

The flow velocity combined with the cross-section will provide an approximation of the river discharge. This parameter will be measured using the same segments as for the water depth. During the project a SEBA F2930 flow meter was provided by BWS Bali Penida. With this device the flow velocity was measured in every segment at 20cm below the surface. This is done at the start and end of the river measurement so that an average flow velocity could be computed. However, a velocity profile is never uniform so this might result in a certain error in the river discharge.

OTHER PROPERTIES

Wind is an important factor for particle movement at the surface and is registered several times during a river measurement with a GM816 digital anemometer. By doing so, a range and an average value for wind speed is obtained. Furthermore the precipitation in the river catchment area is important to record as this will give extra information about the river discharge. This data is provided by the institute BWS Bali Penida.

(a) Flow velocity meter (b) Ocean Cleanup trawl

Figure 5.1: Equipment used during the project

5.3.3. METHOD RIVER MEASUREMENT

The fieldwork at river sites consists of two measuring methods that will be applied to estimate a flux of waste in a specific river. The two variants provide completely different numbers of flowing particles but together they represent an estimation of waste that flows through the river.

TRAWLING

This method is designed to obtain a composition of waste flowing through a river. The method uses a floating frame with nets that can be deployed from hard structures. The operation time is then noted and simultaneously particles are counted that flow into the trawl. This method will be repeated several times to obtain more averaged data. After a trawling session collected material first has to be sorted in organic, plastic and other waste. This is then weighed and the plastic material is taken back home to sort according to the 5

categories that were mentioned in Section 5.1. By doing so, more data on the origin of the material is obtained and a difference in dry and wet weight can be observed. The equipment for this method is provided by The Ocean Cleanup and is shown in In Figure 5.1. In a heavily polluted river, waste could accumulate very fast in the trawl or the trawl could topple, so it is of great importance to monitor this method very carefully.

VISUAL COUNTING

As mentioned earlier, a river is divided in segments and this was indicated by colored tape. In this method the tapes indicate longitudinal imaginary lines in a river between which a surveyor will observe and count the particles that pass this segment during 2 minutes. This will be done successively for every segment and will eventually give a first estimate of waste flowing through a river at the top layer. Besides counting particles flowing through segments the same will be done for particles flowing into the trawl during 2 minutes. During a river measurement this method will be repeated several times for every segment to obtain an final average for passing particles in a river.

5.3.4. MEASUREMENT EXECUTION

At a river site the following sequence of actions will be performed:

1. Measuring the river width and bathymetry.
2. Measuring flow velocity.
3. During the time at the river site wind velocity will be measured several times.
4. The camera is placed at a chosen vantage point and switched on.
5. A quick observation will indicate in which section most debris is flowing in the river
6. The trawl is fixed to the bridge and deployed in the 'busiest' section. During the trawling session multiple visual counting sessions are performed in each river segment as well as the trawl segment. A trawling session is terminated after a certain amount of time that is determined on site.
7. After each trawling session, the collected waste is separated in organic, plastic and other waste. After weighing the wet amounts of collected material number 5, 6 and 7 are repeated several times
8. After performing multiple trawling and visual counting sessions the camera is switched off and removed from the bridge.
9. Lastly number 1 and 2 are repeated once more.
10. Plastic material is taken back home for further sorting. Other waste is disposed properly.

5.3.5. DATA PROCESSING AND ANALYSIS

The rivers are investigated by using the trawl, the visual counting method and the determination of key parameters of the river. After the data is gathered for all these aspects, the data is analyzed. A plastic flux will be determined to get a guesstimate of the river input in the conceptual model as described in Section 4.2. This analysis is further elaborated in Section 7.4.3.

5.4. BEACH MEASUREMENTS

The enormous amounts of plastic washing onto the beaches of Bali are of great concern to local businesses and communities. To get a clear picture of this aspect, local data from beach cleaning institutions will be analyzed. As we are already measuring plastic from rivers during that time, it seems highly relevant that there is also data of plastic on beaches during that same period. This data will be obtained by doing monitor sessions at specific locations along the shore.

According to P. G. Ryan *et al.* (2009) it is important to perform beach surveys consistently on a global scale in order to efficiently compare data. This is a difficult task since no beach stretch is exactly the same; they vary in width, composition, hydrodynamic conditions etc. In order to follow a more standardized and structured procedure the survey and monitoring guidelines of marine litter, as provided by UNEP/IOC [47], have provided an important tool. A short summary of these guidelines follows in the next chapters.

5.4.1. BEACH SELECTION

Suitable beaches need to be identified and selected. In Section 4.2 the case area is described. Here the Southwest coast of Bali is chosen as the desired sub-region from which the surveys are performed. Within this area at least 1 beach must be selected, preferably more, on which beach surveys will be executed. Beach survey locations are selected according to various criteria:

- Minimum length of 100 meters
- Clear access to the sea, no blocking of coastal structures such as breakwaters and jetties
- Accessible to survey teams year round
- Preferably, survey site should not be subject to litter collection activities. Otherwise the periodical activity and timing of these cleanups should be known and taken into account
- Preferred to select various beaches that are subjected to different litter sources. Such consist urban coasts (mostly subjected to terrestrial input), rural coasts (mostly subjected to oceanic inputs) and beaches close to river inputs

As stated in the bullet point summary it is preferred to research three different types of coastal areas, being a rural, urban and river coast. Each of these 3 coast types are dominated by different types of waste. The rural area is dominated by ocean inputs, the urban area is dominated by terrestrial input and the river area is dominated by river inputs. By measuring at each of these locations and comparing them with each other and the river measurements an indication of the composition and total contribution of oceanic, terrestrial and river waste can be found.

5.4.2. METHOD

For the beach research a flux rate survey will be used as method. When performing a flux rate survey the considered beach stretch is cleaned initially, then over a given period of time the next amount of litter is measured. This way a quantity of trash can be given per unit beach length per unit time. When periodic maintenance occurs, it is critical to identify the time period in between cleaning sessions, and to perform the next surveys accordingly. This will prevent influence on the measurement. Flux rate surveys are most fitting for the current research objective since they can be performed in between litter collection activities and are morally favorable as the beaches are actually cleaned during each survey.

5.4.3. SURVEY EXECUTION

In case the survey is done for the first time on the considered beach stretch it is preferred to start the first measurement when plastic pollution is relatively low, before the start of the rainy season, as this will become the baseline measurement from which later measurements can be compared with. As the rainy season progresses new measurements must take place, when comparing this to the baseline measurement a correlation can be found between precipitation and plastic pollution on beaches.

MAPPING OF AREA

With the use of a location template, as shown in Appendix G.2, the measured area can be mapped. Here the length and width of the beach section can be described, the positioning of it's sea- and land-side and its orientation. Distinctive benchmarks and their distance to the survey area can be drawn on the map. In the next survey all this information is used to identify the same beach stretch. When defining the beach length it is important that the measured length of each beach stretch is advised to be around 100 meters. This is most efficient, finding balance between effort and aerial coverage. In beach stretches where waste amounts are relatively high, smaller beach stretches are preferred.

Next, general data of the depositional environment must be recorded. This data is recorded using the survey shown in Appendix G.2. Examples of data that must be considered are wind data, visitors passing, nearby rivers, towns and beach curvature.

WASTE COLLECTION

After mapping the area the survey team can start collecting waste along a beach stretch. First the beach stretch is marked out by drawing lines in the sand that are parallel to the coastline, see Figure 5.2. In between these lines there should be around 2 meters distance. Next, surveyors will carry a waste bag for either plastic, organic or other waste and will then collect particles for their specific category in one of the drawn lines of beach. It is preferred to finish one line at the time in order to prevent confusion. In the case the cleanup team is larger, more lines can be done simultaneously.

At the end of a survey the weight of each of the three waste classes is measured and is registered on the survey form, see Appendix G.2. Both organic and residual waste can be disposed afterwards in garbage bins and

should be disposed outside of the measurement area, preferably in another town. This ensures that in case the garbage bins are disposed in to the rivers, it will not affect the survey area. In case proper waste management facilities are available, waste will be disposed here. The plastic waste will then be taken home for secondary sorting. Data from the first beach survey will serve as a reference as the surveys later on will show the actual waste accumulation in a certain time period. The goal is to measure at least 3 times per beach section.

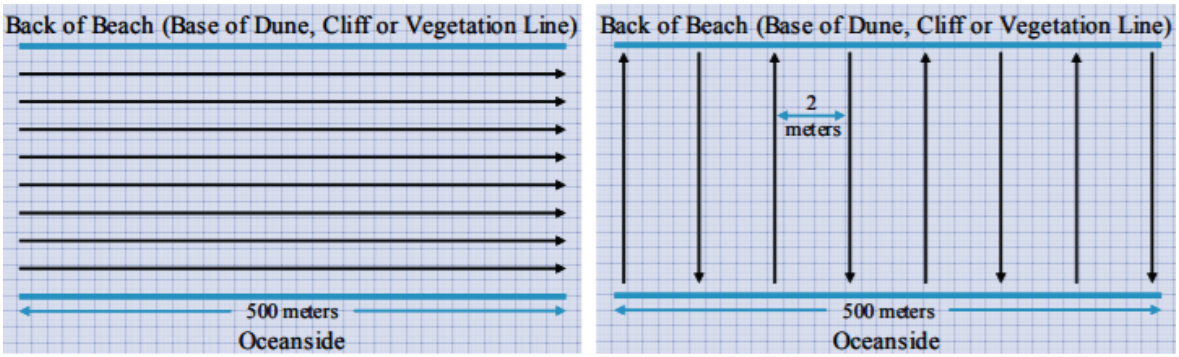


Figure 5.2: Two types of beach surveys; on the left parallel lines to the coast are formed by the survey member and on the right survey members form lines perpendicular to the coast [9]

5.4.4. KEY PARAMETERS

In order to determine the amount of (plastic) waste that accumulates per meter beach for a given period the following equation is used $A = M/(T\ x\ L)$. A short description of each of these parameters involved follows.

- **A**: Accumulation of plastic waste per meter
- **M**: Mass of waste that is found during a survey
- **L**: Length of beach stretch used for the survey
- **T**: Time in between two cleaning events

5.4.5. DATA PROCESSING AND ANALYSIS

To gain insight on the composition of the litter ending up on the beach the litter will be separated on different properties. This will be monitored with the use of a classification table given in Appendix G. The composition of the litter is of importance as this can be compared with future accumulated litter on the same stretch of beach and the litter from rivers respectively. Thereby certain assumptions could eventually be made on the origin of the beach litter encountered during the survey. If it is possible to identify the origin of production of the plastic debris, it will be categorized accordingly. If compared to the local available plastic products, assumptions can be made on the degree of plastic from other locations. Furthermore the accumulation of waste per meter beach per hour will be calculated for each beach location.

Each of the three beach types; terrestrial, river and rural, will be compared with each other in terms of accumulation of waste and composition. It is expected that terrestrial beaches are dominated by terrestrial inputs, river beaches are dominated by river inputs and rural beaches are dominated by ocean waste. By comparing the composition with each of the beach types something can be said on what types of plastic come from land, rivers or the ocean and how fast these develop on the beaches.

5.5. SOCIAL STUDY & WASTE MANAGEMENT

5.5.1. INTRODUCTION

It is essential to gain more insight on the local waste management system, the mentality of consumers towards different types of waste and the degree of waste that ends up in the landfills of Bali. This section will focus on elaborating how to acquire this type of data and will consist of two disciplines; waste management and a social study that focuses on the attitude of locals towards waste in general.

5.5.2. WASTE MANAGEMENT

STAKEHOLDER ANALYSIS AND WASTE MANAGEMENT SYSTEMS

In the preparation phase of the project, a clear hierarchy of the waste management could not be determined. Much of the required data are not publicly available, or are in Bahasa. Therefore local contacts are an important source of information. In order to investigate the local waste management system, an overview of the stakeholders is therefore necessary. Also site visits and in field inspections will be performed in order to better understand the actual situation in Bali. Once the hierarchy is know, sources for data on waste quantities will be investigated, so that a (rough) quantification can be made.

WASTE QUANTIFICATION

To quantify and characterize the waste generation of a particular area the same method as Jambeck *et al.* will be applied. Solid waste generation data will be combined with waste characterization information in order to determine the amount of plastic waste in Bali.

5.5.3. HUMAN ATTITUDE TOWARDS WASTE

The second aspect of this section focuses on the social aspects of human behaviours towards littering in the area. To gain knowledge on the human attitude towards waste management and waste in general a survey has been set-up. The survey consists of seventeen questions, in which the cultural differences have been taken into account in the questioning. The survey is included in Appendix G.3. These questions can be placed into 4 categories. A short summary of these categories follows below:

- **General questions**
  These questions are represented by question 1 to 4 in the survey. Here the gender, age, education level and job type are specified. This is important for follow up questions such as differences in waste handling, awareness and motivation.
- **Waste handling**
  These include question 6, 7 and 8. Asking if the subject separates his/her waste, how they generally dispose and what happens with their waste afterwards. This information provides a greater understanding of personal waste handling.
- **Motivation and awareness**
  Represented by questions 5, 9, 11, 12, 13, 14 and 16. Here information is retrieved on motivation of the subject by asking if the subject cares about what happens with their waste and if they are actively involved in preventing plastics from reaching the ocean. Also questions are asked concerning the awareness of the subject. Asking if they know what happens with their waste, understand which types have negative impact on the environment, how much is recycled in Indonesia and the effect of plastics on the ocean. With this information the understanding and intrinsic motivation of the considered individual is assessed.
- **Individual questions**
  The final category contains some individual questions, represented by question 10, 15 and 17, such as how much he or she would pay for an improvement on their waste handling services. This gives insight on the given value and attitude towards waste handling as well as the motivation to improve on the matter. Question 15 is a referral question to question 14, here it is researched how the subject is informed on plastic pollution in the oceans. Question 17 asks about the mail address of the individual, in case he or she would like to receive results of the survey.

SURVEY EXECUTION

The survey will be handed out to locals across the Southwest of Bali. Because a wide variety of locations will be visited a lot of the subjects will not or barely be able to communicate in English. It is therefore required to have some basic knowledge of Indonesian Bahasa. Having help by local people will greatly improve the communication with subjects and therefore also speed up this aspect. The goal is to take at least 200 surveys in order to retrieve reliable and workable data.

SURVEY DATA

When the surveys are performed all data will be transferred to Excel. When all the information of each individual survey is transferred to excel the data can be analyzed by using Excel programming methods. A few examples of which aspects will be analyzed are shown in the table below:

- The distribution of the general data of all the subjects will be determined. What percentage is female, which education level, what profession etc.
- Charts for each of the individual questions will be defined.
- Each subject will be given a grade on his/her motivation. Depending on the answer more or less points on the intrinsic motivation of the subject are given. The amount of points for each subject are calculated with an Excel code. The more points that are scored for this category, the more motivated this individual is considered to be towards waste handling. The data can then be categorized according to gender, age etc.
- Also a grade will be given on the awareness of each subject. Again, the more points a subject scores the more aware he or she is considered to be towards plastic pollution and waste handling. This data will then also be categorized.
- Waste handling questions of each survey are recorded and categorized as well.
- Figures on the willingness to pay can be defined.

5.5.4. DATA ANALYSIS AND PROCESSING

When all the data is gathered from interviewing local institutions, local inhabitants and the conducted survey this will be processed to create a clear picture of the current dynamics of the waste streams and the stakeholders involved in waste management in general. Also stakeholders who have a more specific interest in plastic on the beaches, rivers and ocean will be indicated. Furthermore, from the survey the awareness and willingness of the Balinese population to contribute to a solution of the problem will be summarized and transformed into graphical illustrations. Finally, combining the gathered data on waste management, generation of plastic and local awareness on the impact of waste, a clear reason why so much plastic ends up in the rivers and ocean can be composed. Therefore the plastic stream illustrated in the conceptual model in Figure 4.12 can be elaborated. When the full methodology has been followed, the results can be inserted into the conceptual model which eases the search for an efficient solution for plastic pollution in Bali.

5.6. ALLOCATION OF RESULTS IN CONCEPTUAL CODEL

In the following Chapters (6 - 9) the results of every component as discussed above are treated separately. In Chapter 10 all results are allocated to the conceptual model, which gives an overview of the movement . Figure 5.3 shows in which chapter the various elements are being discussed.

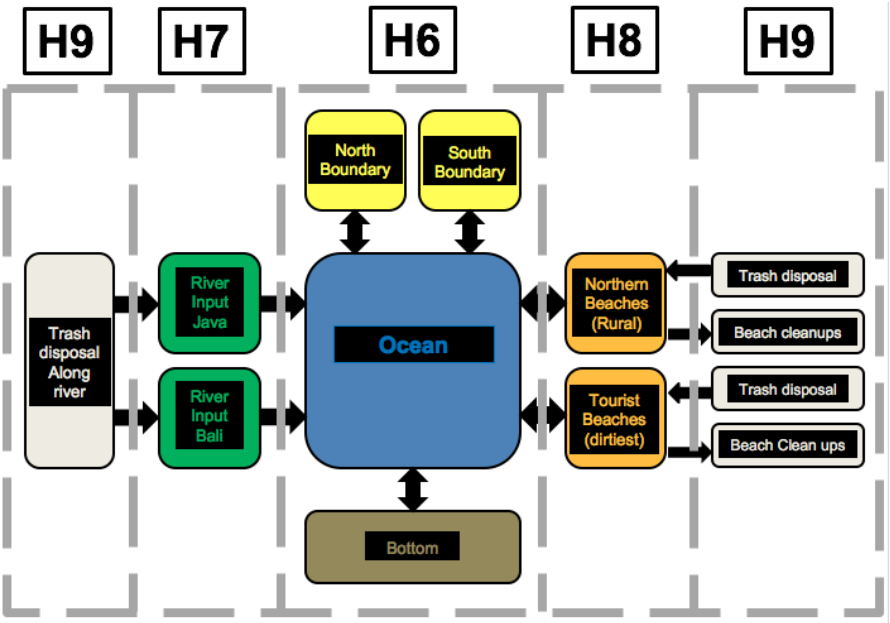


Figure 5.3: Allocation of results in the conceptual model

6

OCEAN, BOUNDARIES AND BOTTOM

Unfortunately, to our knowledge, there is hardly any historic data available of currents monitored in the coastal waters of Southwest Bali or in the Bali Strait. We found out how the local surface currents behave in and around the Bali Bay after our interview with Professor Hendrawan (accompanied by two students from Udayana University) at Udayana University. Prof. Hendrawan is an expert in numerical modelling and he has conducted tracer studies which showed if particles could enter the Bali Bay through the Bali Strait and through the South boundary. He is currently working on the papers '*Marine Debris Mapping in the Coastline of Bali Island*', and '*Marine Debris Mapping and their movement in Nusa Penida Island and its adjacent area*'. For these papers, he and other researchers have started to collect data on marine debris by conducting surveys at various rivers and beaches in Bali and Nusa Lembongan. This data will be used to set up a numerical model that can simulate marine debris in these areas. Yet unfortunately they can not provide us with the data as sampling and data processing is still in process. The entire interview at Udayana University is included in Appendix C.2. All other elements will be analyzed in a qualitative matter, in which mainly our own reasoning and information from the interview will be compared and/or combined.

6.1. OCEAN SURFACE

The ocean surface is the central element in the conceptual model. For convenient reasons we also refer to this area as the Bali Bay. As discussed in Chapter 4, the main driver for ocean surface currents is wind. Yet, closer to the coast other forces can cause additional currents in the upper part of the water column. In our interview with Professor Hendrawan, he states that the tidal forcing does not play a role in the transport of plastic waste in our research area. During West monsoon the wind blows from West to East, thus onshore directed (see Figure 4.4). This means that the marine plastic debris is 'pushed' ashore, assuming that the propagation of litter follows the characteristics of the surface currents. Furthermore, due to the coastline alignment the currents bend in alongshore direction as they approach Bali's coast. This causes a flow from North towards South, which is the reason why most of the debris ends up in Kuta area. Professor Hendrawan and the two students from Udayana University agree on this matter as they mentioned that wind is the main driver for transport of plastic in the Bali Bay. Furthermore they mention that some of the waste washes ashore at the Western coastline, but most of it ends up in Kuta. For reading convenience the part of the interview where they make this statement is included in Table 6.1 below.

	...Discussion about their numerical model that simulates marine debris in Bali's coastal waters and where the plastic debris originates from...
Respondent 3 (student)	Because of the flow of the water and the flow of the currents along the coastline, most of them (marine plastics) end up in Kuta because it's in the South side. Some of them do attach to the Western coastlines but most of them attaches more South.
Interviewers	Because of the shape of the island right? And this transport, is it mainly wind driven?
Respondent 1 (Prof. Hendrawan)	Yes, and it is only wind. No tide. That's why the West monsoon will be the big boom for the trash.

Table 6.1: Part of the interview where Prof. Hendrawan and students explain the driving mechanisms in the Bali Bay

Husrin *et al.* also agrees on this matter and states that strong wind from the West towards East during West monsoon causes a concentration of currents along the coastline of West and South Bali. So both Husrin *et al.* and Professor Hendrawan confirm that wind is the main driver for the transport of plastic waste in the Bali Bay, and that currents near the coast bend towards the South during West monsoon.

During transitional season the wind direction shifts and the magnitude of the wind decreases, see Figure 4.4. Under the assumption that the relation between wind and plastic transport remains the same during both seasons, plastics that end up in the ocean will be transported away from Bali's coast by the prevailing ESE wind. Though, still some debris washes ashore due to waves. The influence of waves is active in the surf zone, where breaking waves impose an onshore directed flow in the upper part of the water column.
In Figure 6.2 the direction and flow near the coast is indicated with dashed orange arrows, whereas the flow in the Ocean Surface element is represented by thick blue arrows.

6.2. BOUNDARIES

First of all, it should be determined whether the water flow at the boundary is either depicted into the system or out from the system into the Java Sea or Indian Ocean. Second of all, should the water flow be directed into the system, it should be checked whether plastic debris is capable of entering the domain. The directional flow at the boundaries are represented by the yellow arrows in Figure 6.2.

6.2.1. NORTH BOUNDARY

According to Husrin *et al.* strong currents can be identified entering the Bali Strait in Southward direction during West monsoon season. During this season surface water from the Java Sea is 'blown' towards the East, as already discussed in 4.1.3. As this current passes coastal areas of various islands, it is most likely that plastic debris is distributed along with the flow. Yet, since the section of the North boundary is very narrow (2.5km) it is assumed that only a small amount will flow from the Java Sea towards the Bali Strait into the system. Prof. Hendrawan stated that his numerical model proved that plastics can enter the Bali Bay through the Bali Strait, but this will only account for a small part of the total waste in the system (see Appendix C.2). Therefore, this inflow is presented by a small arrow in Figure 6.2 (a).

During transitional season it is unclear whether a residual flow is experienced. But if we look at how the surface currents North of the strait behave, we see that the prevailing ESE winds will push debris away from the Bali Strait. Therefore we assume that, even when there would be a significant residual flow into the Bali Strait, there is no input of plastic waste. Also, we assume that a significant outflow is unlikely as the ENE winds will 'push' litter in this area ashore on the Java coast.

6.2.2. SOUTH BOUNDARY

Near the south boundary specified in our model an interesting current is identified, which is called the Java coastal current. This current flows in a limited area, very close to the island Java, as can be seen in Figure 6.1. This current flows eastward during West monsoon and reverses in direction between June - August [38]. A further description of this current is included in Figure 6.1.

As a consequence of the Ekman effect, which is related to coastal upwelling and the rotation of the earth, water surface currents are deflected to the left in the Southern hemisphere. In fact, Prof. Hendrawan states that the combination of Ekman and the prevailing wind direction causes an input at the south boundary during West monsoon. During transitional season the winds reverses and the coastal current as well. Ekman will still deflect currents towards the left and is therefore outward directed. This results in an outflow at the South boundary. The transport by Ekman is indicated by the dashed blue arrow in Figure 6.2

6.3. BOTTOM

Plastics have the characteristic of being buoyant, yet under the weight of organisms or accumulation of sediment, plastics can sink to the seabed. Some scientists believe that over 90% of plastics in the marine environment eventually end up on the sea floor [48]. Upwelling on the other hand, is a phenomenon that would cause a motion directed from the bottom toward the ocean surface. In general, debris tends to become trapped at the bottom in areas with low circulation and high sediment accumulation, whereas floating debris

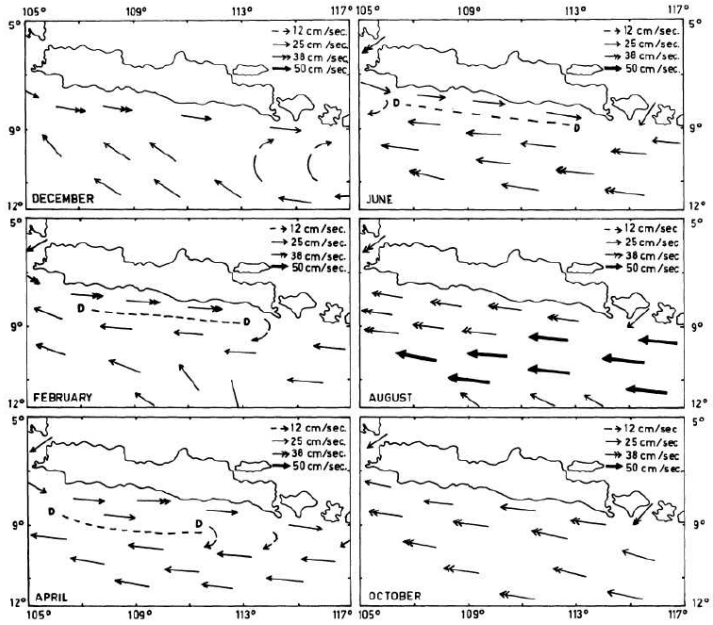


Figure 6.1: This figure shows the current system south of Java. An Eastward coastal current is flowing in a limited area very close to Java during the West monsoon, called the Java coastal current. In April, at the beginning of transitional season, this current decreases in magnitude and eventually reverses further in the transitional season. The rivers of Java are responsible of high volumes of outflow of plastic debris into the Indian Ocean [7]. Therefore, it is assumed that the eastward flow of the Java coastal current can transport considerable volumes of plastic debris towards the Southwest coastal waters of Bali. (source: Wyrtki [38])

accumulates in frontal areas such as eddies and gyres [49]. To determine the ratio and interaction between plastic debris on the seabed and the surface more information is needed on the vertical motion of plastic litter in the water column. Based on the assumption that wind is the main driver for the transport of plastics, the fact that our area is relatively small and exposed to seasonality, we suggest that the area responds as a direct system where only limited interaction between the bottom and surface occurs. To date only limited research has been conducted on this matter. Therefore, we will only focus on plastic litter in the upper part of the water column, and the bottom interaction will be left out of the system.

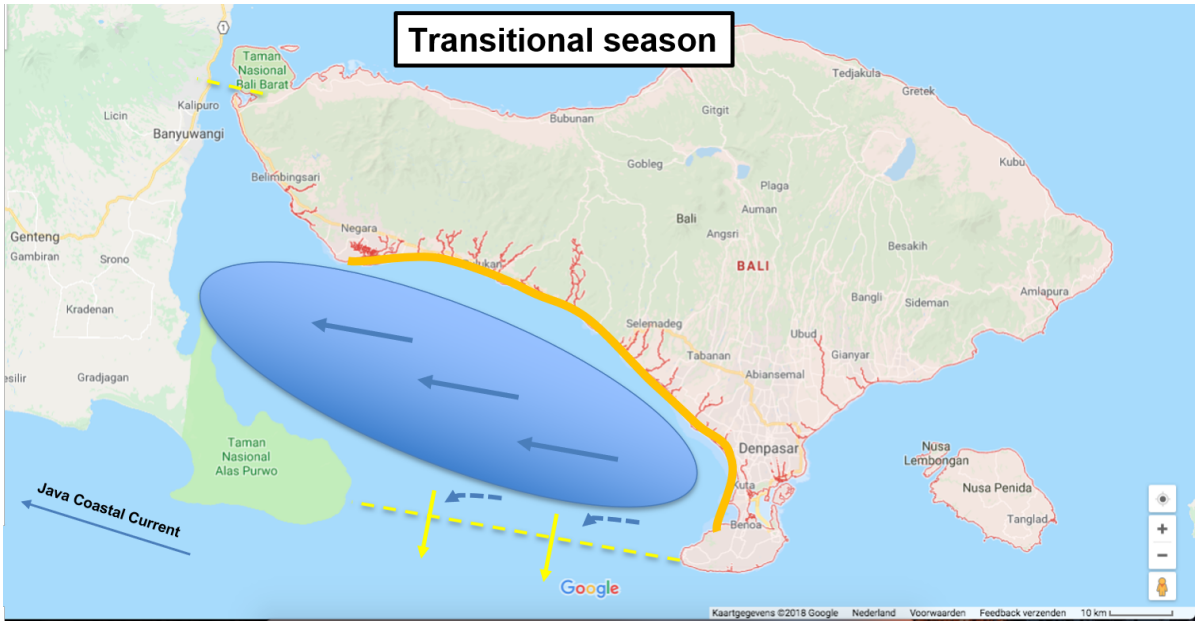
6.4. SUMMARY

A visual summary of our findings are presented below. Figure 6.2 (a) represents the situation during West monsoon season, whereas Figure 6.2 (b) represents the situation during transitional season. It is assumed that marine plastics follow the same track as surface currents. We have tried to analyze the elements in a qualitative matter, in which our hypothetical distribution and interaction of plastic litter with various elements has been supported by experts.

6.5. EVALUATION

The research of these components in the conceptual model proved to be more abstract than for instance the river and beach measurements. It is a preliminary study in the behaviour of plastic in the Bali Bay. In field research with tracers and/or numerical models would be needed to validate the results.

(a) Situation during West monsoon



(b) Situation during transitional season

Figure 6.2: Distribution of plastic debris during both seasons

7

River Research

7.1. Final river selection

The amount of rivers was narrowed down to 8 possible river sites, which were visited afterwards during a field trip. During that trip, the requirements that were stated in Section 5.3.1 finally brought the number of suitable river sites to four. Three of them are located relatively close to Kuta Beach and one is located in Negara, in the West part of Bali. When the first measurement was planned in Negara, the waterlevel had dropped significantly and the company 4Ocean was cleaning the river banks and bed. As a consequence this river was not suitable anymore and had to be released. The final selection of river sites and their corresponding coordinates are shown in Figure 7.1 and Table 7.1.

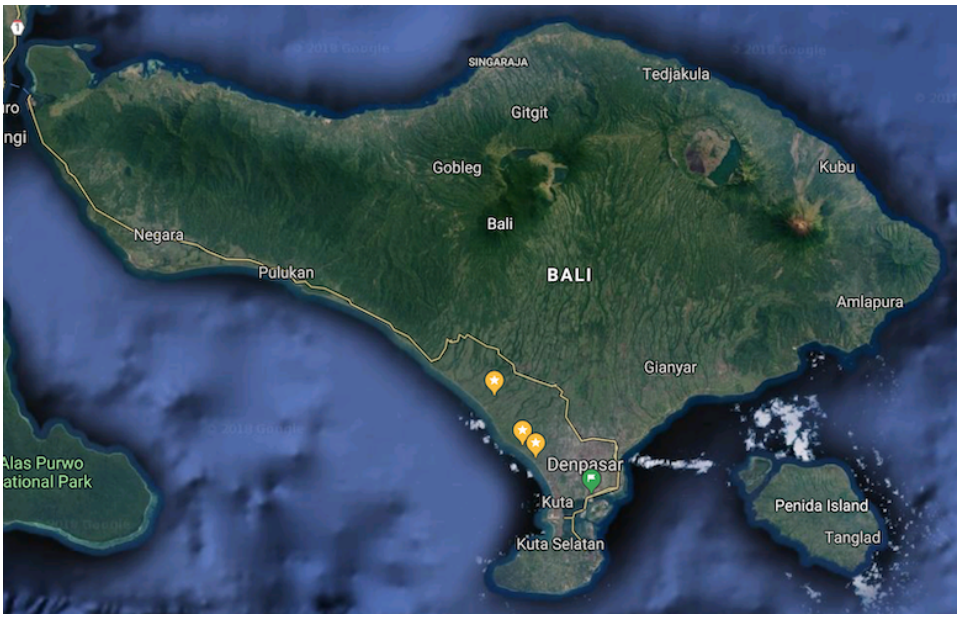


Figure 7.1: Final river selection

River number	River location	Latitude	Longitude
1	Berawa, Canggu	−8.670124	115.143382
2	Pererenan, Mengwi	−8.652355	115.125067
3	Sudimara, Tabanan	−8.583370	115.085478

Table 7.1: Coordinates of selected rivers

7.2. RIVER MEASUREMENTS

7.2.1. PERERENAN

This site is located 300m from the river mouth and most likely has no influence from the tide. The bridge is located in a river bend and spans at approximately 3 meters above the waterline. A little upstream from the bridge a lot of waste was observed on the river banks that have run dry. The river catchment area is densely populated, which also means there could be a lot of input of trash. This was confirmed by locals that passed by while performing measurements. Figure 7.2 shows the measurement site surroundings.

(a) Front view (b) Top view (c) River bank

Figure 7.2: Site overview of Pererenan

7.2.2. BERAWA

The next river site is located in the Southern part of Canggu. There is a walking bridge at approximately 180 meters from the sea and therefore it is expected there is some influence from the tide, although reversed flow was never observed. As the bridge is relatively close to the sea, the river has become wider and shallower. Also this river catchment area is densely populated. Local restaurant employees mentioned the river transports a lot of waste to the ocean during the rainy season due to bad disposal customs of upstream inhabitants. Figure 7.3 shows the height of the bridge with respect to the water level and some surroundings of the area.

(a) Front view (b) Top view (c) River bank

Figure 7.3: Site overview of Berawa

7.2.3. SUDIMARA

The last river site is located in the Tabanan regency, where waste management is far behind compared to the Badung regency. While this regency is less inhabited than previous areas, the river banks and the slopes next to the bridge ends were covered in waste that probably had been disposed by locals. This action was observed several times during measurements. Locals also mentioned the water level can be 3 meters higher in the West

monsoon season. The bridge is located 1700m land inwards from the river mouth and therefore will be no influence from the tide. Figure 7.4 shows the measurement site surroundings.

(a) Front view (b) Top view (c) River bank

Figure 7.4: Site overview of Sudimara

7.3. DATA

A total of 15 river surveys have been performed of which the dates are summarized in Table 7.2 The interval is approximately 1-2 weeks between every survey at each location. Trawling sessions, visual counting and determination of river parameters are performed during the surveys as described in Section 5.3. Precipitation is a valuable parameter for the river plastic flux. A large part of this chapter will divide the results in the two conditions experienced during the research: the dry conditions and the condition after a first heavy rain event. The collected survey data is displayed in Figure 7.5 along with daily precipitation in Southwest Bali.

	Survey 1	**Survey 2**	**Survey 3**	**Survey 4**	**Survey 5**
Pererenan	21/09/2018	03/10/2018	16/10/2018	31/10/2018	07/10/2018
Berawa	28/09/2018	04/10/2018	18/10/2018	31/10/2018	07/11/2018
Sudimara	25/09/2018	05/10/2018	18/10/2018	02/11/2018	06/11/2018

Table 7.2: measurement dates for river investigations

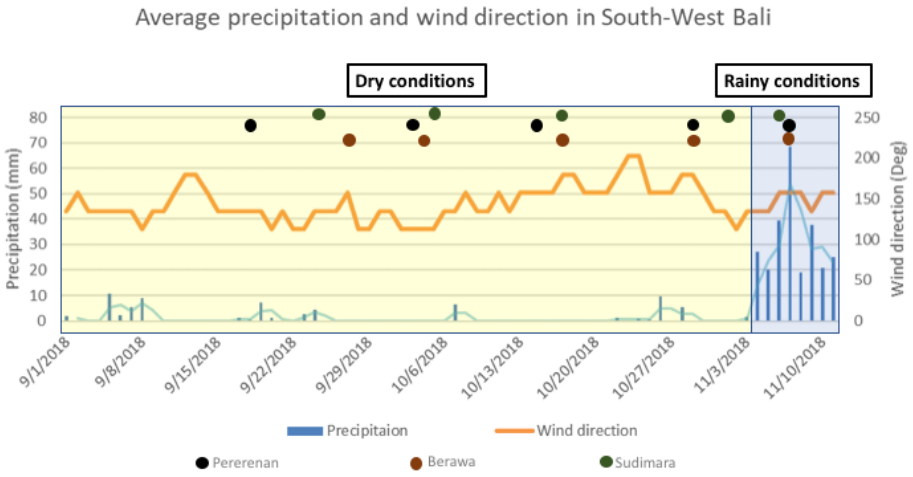


Figure 7.5: Chart with precipitation data, wind directions and performed measurements

7.3.1. PRIMARY SORTING

The manta trawl is used to understand more about the composition of waste and sorts of plastic found in rivers. The number and the total duration of the trawling sessions are displayed in Table 7.3. Only during the fifth survey of each river significant rainfall was observed before or during the survey. The primary sorting is done for each of the rivers and separates organic, plastic and rest waste. The results are displayed In Table 7.4. These values represent the total waste that is caught by the manta trawl at each location. The three rivers are showing quite different results in terms of the primary sorting. Especially Berawa is showing a high percentage of plastic and rest waste compared to the other locations.

	Survey 1		**Survey 2**		**Survey 3**		**Survey 4**		**Survey 5**		**Total**
	total time	#	total time	#	total time	#	total time	#	total time	#	
Pererenan	122 min	2	90 min	2	60 min	1	98 min	2	3 min	1	373 min
Berawa	126 min	2	122 min	2	58 min	1	67 min	1	90 min	3	463 min
Sudimara	81 min	5	63 min	3	83 min	2	60 min	1	80 min	4	367 min

Table 7.3: Total trawl duration and the number of trawl sessions during the surveys

	Pererenan		**Berawa**		**Sudimara**	
	kg	%	kg	%	kg	%
Plastic	0.77	5.2	2.09	37.8	0.87	14.5
Organic	13.83	94.8	2.71	49.1	5.05	84.0
Rest	-	-	0.73	13.1	0.09	1.5
Total	14.60	100	5.53	100	6.01	100

Table 7.4: Primary distribution of wet waste for each river site

The results of the different surveys over time are displayed in Tables 7.5, 7.6 and 7.7. There are some remarkable events noticeable in these results. Survey 5 is showing a significant increase in waste compared to the previous surveys for all the locations. This can be clarified by the large amounts of rainfall during that week. Another observation is at the Pererenan location, where only organic waste is caught in the first four surveys. At Berawa the share of plastic is relatively high during all surveys, which could be explained by the higher population density along the river compared to the other locations. Plastics are always present in the Sudimara location, but the share of plastic compared to the organic waste is significantly lower compared to the Berawa location.

Pererenan	**Survey 1**		**Survey 2**		**Survey 3**		**Survey 4**		**Survey 5**	
	Kg	%	Kg	%	Kg	%	Kg	%	Kg	%
Plastic	-	-	-	-	-	-	-	-	0.765	5.7
Organic	0.11	100	0.96	100	0.045	100	0.105	100	12.610	94.3
Rest	-	-	-	-	-	-	-	-	-	-

Table 7.5: Primary sorting of wet waste for each survey at Pererenan

Berawa	**Survey 1**		**Survey 2**		**Survey 3**		**Survey 4**		**Survey 5**	
	Kg	%	Kg	%	Kg	%	Kg	%	Kg	%
Plastic	0.14	10.1	0.12	63.2	0.01	90.9	0.002	2.4	1.82	46.9
Organic	0.51	37.0	0.07	36.8	0.001	9.1	0.08	97.6	2.06	53.1
Rest	0.73	52.9	-	-	-	-	-	-	-	-

Table 7.6: Primary sorting of wet waste for each survey at Berawa

Sudimara	Survey 1		Survey 2		Survey 3		Survey 4		Survey 5	
	Kg	%	Kg	%	Kg	%	Kg	%	Kg	%
Plastic	0.17	16.8	0.002	0.4	0.03	4.5	0.04	28.6	0.63	16.6
Organic	0.85	83.2	0.48	99.6	0.54	95.5	0.10	71.4	3.1	81.2
Rest	-	-	-	-	-	-	-	-	0.09	2.2

Table 7.7: Primary sorting of wet waste for each survey at Sudimara

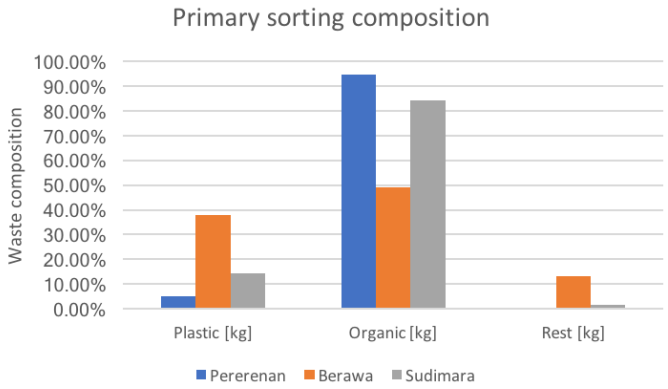


Figure 7.6: Primary sorting of plastic in rivers

7.3.2. SECONDARY SORTING

At home, plastic waste is further investigated in different categories of plastics that were introduced in Chapter 5. The plastic distribution is displayed in Table 7.8 for each location. The total number of plastic is dominated by the categories LDPE, PS/PP and Multilayer plastics, which are all mostly single-use plastics. The weight distribution is showing different results compared to the number of plastics. Here LDPE and Multilayer plastics are dominating and significant amounts of HDPE and PS/PP are found. PET is hardly found and is considered to be the most valuable plastic on Bali, as described in the interview with Eco-Bali (Appendix C).

	Pererenan			Berawa			Sudimara			Total		
	#	kg	%	#	kg	%	#	kg	%	#	kg	%
HDPE (hard)	8	0.08	23.0	2	0.02	4.1	3	0.08	23.4	13	0.18	14.3
LDPE (soft)	19	0.11	30.2	134	0.31	53.3	95	0.16	49.8	248	0.58	46.0
PET	4	0.05	13.8	2	0.01	1.7	1	0.002	0.6	7	0.06	4.8
PS/PP	23	0.05	15.5	30	0.10	17.3	15	0.03	9.6	68	0.19	14.8
Multilayer	15	0.06	17.5	73	0.14	23.6	38	0.05	16.6	126	0.25	20.1
Total	69	0.35	100	241	0.59	100	152	0.33	100	462	1.26	100

Table 7.8: The distribution of dry plastic for all river sites

The plastic distribution and the weight of individual particles are displayed in Table 7.9. The average dry weight of individual particles for the categories are quite similar (2.0-2.8 g) except for the PET particles. These particles have a higher average dry weight of 8.6 gram. The wet weight of the particles is more diverse compared to the dry particles and the fraction wet/dry is in the range between 2.0 and 4.9. Overall, an average wet particle has a weight of 8.1 g and an average dry particle has a weight of 2.7 g.

	Particles #	Weight wet kg	Weight dry kg	Wet particle g	Dry particle g	Fraction w/d -
HDPE (hard)	13	0.37	0.18	5.4	2.8	2.0
LDPE (soft)	248	1.54	0.58	6.2	2.3	2.7
PET	7	0.24	0.06	34.3	8.6	4.0
PS/PP	68	0.37	0.19	5.4	2.8	2.0
Multilayer	126	1.26	0.25	10.0	2.0	4.9
Total	462	3.72	1.26	8.1	2.7	3.0

Table 7.9: The plastic distribution and the individual weight of plastic particles

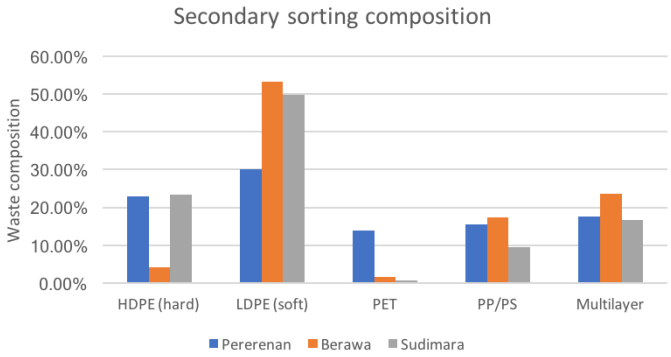


Figure 7.7: Secondary sorting of plastic in rivers

7.4. GUESSTIMATE OF WASTE FLOW

It is hard to make an accurate estimate of the plastic flux in the rivers that were investigated. Therefore, a guesstimate – based on the data gathered during research– is a better definition for the determined plastic flux. Two methods will be used to quantify the plastic flux in the rivers. The first is based on the plastic flux using the cross section of the trawl and extrapolating this plastic flux to the river cross-section. The second method will be based on the average particle weight determined by the trawl. The average weight of an individual particle will be extrapolated using the visual particle counting method, which was described in Chapter 5.

7.4.1. EXTRAPOLATION OF THE TRAWL

The first method is an extrapolation using the trawl. A simple equation is used and is displayed in Eq. 7.1 and all the parameters are explained in Table 7.10. The river is divided into several sections, in which for each section the cross section and flow velocity are determined. The discharge in the total cross section is determined using data of these sections. The discharge in the trawl is also determined. The guesstimate is made by using the data and the equation. The results are displayed in Table 7.11. The total waste flux is between 5.67 and 22.01 kg/h during the dry conditions. The total waste flux is increasing after the first heavy rainfall. This flux jumped to values between 199.86 and 285.07 kg/h. The same increase is seen in the plastic waste flux which is between 0.00 and 3.58 kg/h during the dry conditions and between 47.4 and 93.99 kg/h after the first heavy rain event.

$$J_w = \alpha \frac{M_w}{T_t} \frac{Q_r}{Q_t} \tag{7.1}$$

7.4.2. EXTRAPOLATION OF THE AVERAGE WEIGHT OF INDIVIDUAL PARTICLES

The second method will be based on the average particle weight collected by the trawl. This average weight of an individual particle will be extrapolated by using the visual particle counting method. A simple equation is used and is displayed in Eq. 7.2, with the parameters explained in Table 7.12.
The plastic waste flux is represented by $J_{w,plastic}$ and β is a factor coefficient for unequal waste distribution along the cross section. This value is set at 1.1 for the dry conditions and assumed to be 1.6 after heavy rainfall.

Parameter	Unit	definition
J_w	kg/h	Waste flux through river cross section
α	-	factor for unequal waste distribution
M_w	kg	Total captured wet mass in trawl
$M_{w,plastic}$	kg	Total captured wet mass of plastics in trawl
T_t	h	total trawling duration for location
Q_r	m^3/s	river discharge
Q_t	m^3/s	trawl discharge

Table 7.10: The parameters of Eq. 7.1

	Pererenan		Berawa		Sudimara	
	Normal	After rain	Normal	After rain	Normal	After rain
α[−]	1	1	1	1	1	1
M_w [kg]	1.22	13.38	1.66	3.87	2.20	3.81
$M_{w,plastic}$ [kg]	0.0	0.765	0.27	1.82	0.24	0.63
T_t [h]	6.17	0.05	6.22	1.50	4.78	1.33
Q_r [m^3/s]	0.86	-	0.99	11.62	1.04	20.4
Q_t [m^3/s]	0.03	-	0.012	0.15	0.036	0.205
J_w [kg/h]	5.67	-	22.01	199.86	13.30	285.07
$J_{w,plastic}$ [kg/h]	0.00	-	3.58	93.99	1.45	47.14

Table 7.11: Determination of total and plastic waste flux using method 1

A lot more turbulence was observed in the river after rainfall, therefore it is assumed that particles are spread along the water column. This assumption was needed as only the top 20 centimeters of the water column was visible when performing the visual counting method. The results of this method are displayed in Table 7.13. The plastic waste flux is between 0.0 and 2.8 kg/h during the dry conditions and is in same order of magnitude as the first method. The total waste flux is increasing after the first significant rainfall. This plastic flux jumped to values between 23.2 and 106.9 kg/h which is also in the same order of magnitude as the first method. In Table 7.13 the values plastic waste flux for Pererenan are lacking as the severe rainfall made visual counting and determination of flow velocity impossible.

$$J_{w,plastic} = 30 \cdot \beta \cdot f_{plastic} \cdot p_{waste} \cdot \bar{w}_{pp} \tag{7.2}$$

Parameter	Unit	definition
$J_{w,plastic}$	kg/h	Plastic waste flux through river cross section
β	-	factor for unequal waste distribution
$f_{plastic}$	-	the share of plastic in the waste
p_{waste}	/2 min	average particles along cross section of river per 2 minutes
$\bar{w}_{pp}$	kg	Average weight of a wet particle plastic

Table 7.12: The parameters of Eq. 7.2

7.4.3. GUESSTIMATE FOR RIVER INPUT IN THE RESEARCH AREA

The rivers of Bali and Java have input as stated in the conceptual model as introduced in Chapter 4. With the use of Google Maps, 49 rivers were identified in Bali and 15 rivers in Java. These are the rivers that flow into the Bali Bay. In this section a guesstimate will be introduced to quantify the input during the time of the research; in other words during the dry season until directly after the first heavy rain event. This guesstimate is only based on data gathered during the research and should not be considered (very) accurate. It is just a first interpretation of the extent of plastic entering the Bali Bay from rivers. Based on extrapolations, a range for a

	Pererenan		Berawa		Sudimara	
	Normal	after rain	Normal	after rain	Normal	after rain
β[−]	1.1	1.6	1.1	1.6	1.1	1.6
$f_{plastic}$ [-]	0.00	0.06	0.16	0.47	0.11	0.17
p_{waste} [#/2 min]	10.2	-	27.5	592.2	97.0	355.2
$\bar{w}_{pp}$ [kg]	0.008	0.008	0.008	0.008	0.008	0.008
$J_{w,plastic}$ [kg/h]	0.0	-	1.2	106.9	2.8	23.2

Table 7.13: Determination of plastic waste flux using method 2

plastic flux for the dry period, and a range for the period after the first rainfall is assumed. A range is set to 1-4 kg/h for a plastic flux for a single river during dry conditions and a range of 20-100 kg/h is assumed for a single river after the first significant rain event.

Eventually this leads to an input of 49-196 kg/h for the river input from Bali into the Bali Bay during the dry conditions. The contribution from rivers in Java is 15-60 kg/h during the dry period. The plastic flux is increasing after the first significant rainfall and is estimated to be 980-4900 kg/h for the rivers of Bali and 300-1500 kg/h for the rivers in Java. This leads to a total of 64-256 kg/h of plastic flowing into the Bali Bay during dry conditions. The plastic flux increases to 1280-6400 kg/h after the first heavy rain event has occurred. The total waste flux is estimated at 320-1600 kg/h during the dry season and 9090-19200 kg/h after the first significant rainfall. The guesstimate is displayed in Table 7.14.

	Bali	**Java**	**Total**
Number of rivers	49	15	64
Plastic input single river during dry cond.	1-4 kg/h	1-4 kg/h	-
Plastic input single river after first heavy rain	20-100 kg/h	20-100 kg/h	-
Plastic input of all rivers during dry cond.	49-196 kg/h	15-60 kg/h	64-256 kg/h
Plastic input of all rivers after first heavy rain	980-4 900 kg/h	300-1 500 kg/h	1 280-6 400 kg/h
Dry plastic input of all rivers during dry cond.	16-65 kg/h	5-20 kg/h	21-85 kg/h
Dry plastic input of all rivers after first heavy rain	327-1 633kg/h	100-500 kg/h	427-2 133 kg/h
Total waste input single river during dry cond.	5-25 kg/h	5-25 kg/h	-
Total waste input single river after first heavy rain	180-300 kg/h	180-300 kg/h	-
Total waste input of all rivers during dry cond.	245-1 225 kg/h	75-375 kg/h	320-1 600 kg/h
Total waste input of all rivers after first heavy rain	8 820-14 700 kg/h	2 700-4 500 kg/h	9 090-19 200 kg/h

Table 7.14: The plastic waste flux during dry conditions and after the first heavy rain event for Bali and Java

The plastic fluxes are now determined in kilograms per hour, but values in kilograms per day are required for the conceptual model. It is assumed that river conditions and the plastic flux do not fluctuate during the dry conditions. The determination in kilograms per day is simple and are displayed in Table 8.21 for the dry conditions. The determination of the plastic flow in kilograms per day is completely different for rivers during a flood event. This value is not directly compatible for the conceptual model as the plastic flow from the rivers represents a peak flow. Together with the acquired precipitation data a calculation can be made on the average plastic flow from rivers during a flood event.

In Figure 7.8 the calculation method is visualized. The peak of the plastic flow is known, here the average plastic input after the first large rainfall is used, as well as the rain development during the rainy conditions. For this calculations it is assumed that the plastic flow in the river is heavily correlated with the amount of precipitation. The rain development is simplified and modelled as a triangle, as is shown in the figure. During the flood event, with a period of five days, an average plastic flow of one third of the peak is used. It is assumed no more plastics are transported when the precipitation peak is surpassed, as the riverbanks are washed from most of their plastics.

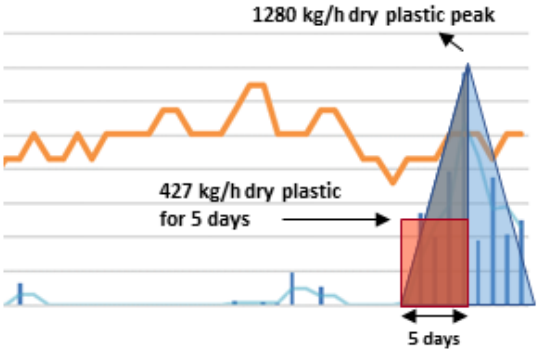


Figure 7.8: Visualization of plastic flow during flood event

	Minimum	Maximum	Average	Per day
Plastic flow river	kg/h	kg/h	kg/h	kg/day
Rainy conditions Bali	109	544	327	2 616 - 13 056
Rainy conditions Java	33	167	100	800 - 4000
Dry conditions Bali	16	65	41	384 - 1 560
Dry conditions Java	5	20	13	120 - 480

Table 7.15: Plastic flow of rivers during dry and rainy conditions in Bali and Java

7.5. EVALUATION

During a river measurement, we would generally spend a few hours on a certain bridge from where we conducted our research. During this part of the project some events were already taken into account in the methodology but also some irregular or unexpected events occurred. In case of a similar future project it is good to know about these events so that everything will run smoothly.

- For safety reasons we decided that we would perform the measurements from a bridge and not enter the rivers themselves as the water is highly contaminated. The selection of measurement sites proved to be more difficult than predicted as some bridges had too much traffic passing and were therefore considered unsafe. Also one bridge caused some limitation in mobility when measuring the flow velocity. At the Sudimara site the bridge was located 8.5 meters above the waterline, which meant we had to lower the flow meter pole by rope, which made the rotor a little unstable in the flow.
- During the fifth river measurement at Pererenan it had been pouring all day and continued throughout the measurement. This caused a flood wave which transported loads of debris. Due to this flood wave the flow velocity was very high which on his turn caused a lot of turbulence. This made measuring the flow velocity and also visual counting impossible, which made this measurement a failure. The impact of such a rain event was something we hadn't foreseen.
- As the equipment was quite large we had to rent a driver to bring us to the site and pick us up when we finished. As traffic in Bali can be very bad for cars, it was sometimes frustrating how long it took to reach a measurement location. Luckily we found rivers considerably close to our house, so that every location was reachable within an hour.
- As already mentioned in Section 7.1 one river site had to be dismissed as there was another company cleaning the river at the same location we wanted to perform measurements. This would obviously bias our measurements and this was not desired. Fortunately we had selected four rivers initially so that we would maintain at least three rivers after this set-back.

- Part of our research was to investigate the contributions of different categories of plastic and to find out their wet and dry weight. Luckily we had an open space in our house where we could dry and separate the collected material. An open space or a nearby laboratory is therefore highly recommended.

8

BEACH RESEARCH

8.1. BEACH SELECTION

As stated in Section 5.4.1 it is preferred to identify three different types of coastal areas, consisting of a rural, urban and riverine coast. With the use of Google Maps the beaches inside the case area were inspected and discussed. Several beaches were identified that would fit in one of the three categories. In Figure 8.1 the various identified beaches are shown.

Figure 8.1: Overview of 8 possible beaches

Then, visual inspections were used in order to determine locally whether or not the beaches are fit for measurement and comply to the beach criteria as stated in Section 5.4.1. During these inspections it was also important to confirm whether the considered coastlines were indeed either rural, urban or river coastlines. These inspections gave three beaches that were found suitable for the beach survey. In Table 8.1 the respective beaches and their location is shown.

Beach number	Beach name	Beach type	Latitude	Longitude
1	Pig Stone Beach, Pangkung Tibah	Rural beach	−8.603940	115.079010
2	Finn's Beach, Tibubeneng	Urban beach	−8.666871	115.139169
3	Nyanyi Beach, Kediri	River beach	−8.631299	115.096326

Table 8.1: Beach Selection

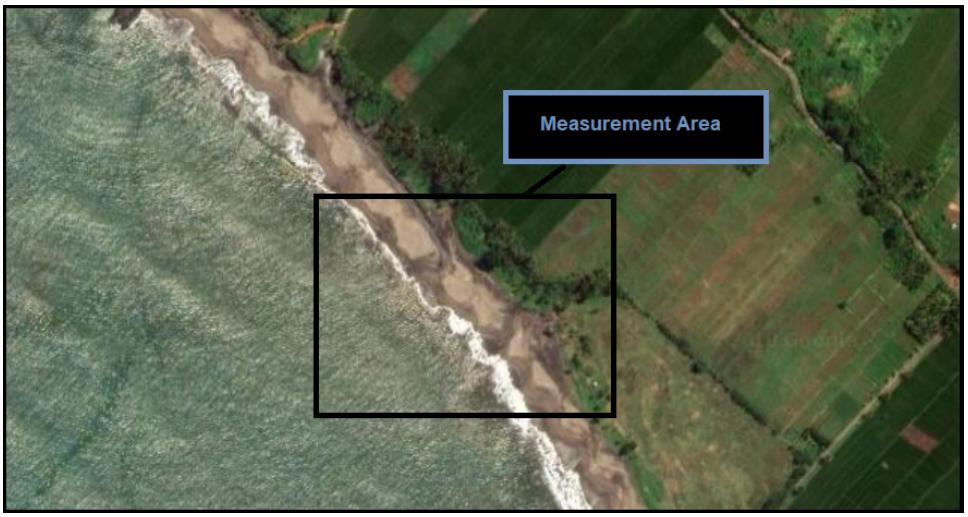
After the visual inspections it was concluded that the urban and river beaches contain far more waste compared to the rural beaches. As the team only has 5 members it is considered too time consuming to perform these measurements with only members of the team. Therefore for the urban beaches contact was made with surrounding beach clubs and restaurants. For the river beaches contact was made with local communities and organizations in order to find volunteers that could join the beach measurements.

8.2. BEACH MEASUREMENT

PIG STONE BEACH

Pig Stone Beach is a rural beach. As can be seen from Figure 8.2 (a) no settlements are surrounding the measurement area. During the visual inspection almost no visitors were seen on the beach. Because of this less dumping of litter by pedestrians is expected. Besides that, river influences and beach cleanups are most likely absent.

The initial cleanup contains relative big amounts of waste as no cleanups occur on Pig Stone Beach. Upon arrival the location template and beach characteristics were filled in. Then the beach section was drawn out and the team started waste collection, walking parallel lines with the waterline. Eventually three measurements were performed on Pig Stone Beach. In Appendix A.16 the litter survey of Pig Stone Beach is displayed, showing weight values for each of the three weight classes.



(a) Aerial view of the measured area of Pig Stone Beach

(b) East

(c) South

(d) Detail

Figure 8.2: Site overview of Pig Stone Beach

FINN'S BEACH

Finn's beach is an urban beach, as it is located in front of various beach clubs and resorts with Finn's Beach club being the biggest. It has a lot of visitors, as it is popular among tourists, and therefore has relatively more terrestrial inputs. Because of these clubs and resorts it is a necessity to clean the beaches regularly. Finn's Beach cleans every Friday, thus a meeting was arranged. From this meeting it was denoted that Finn's Beach

Club performs beach cleanups along a 600 meter stretch of beach, see Figure 8.3 (a). Our project team was allowed to join theses cleanups and measure the different waste types. During these cleanups around 15-20 members would be active cleaning the beaches, which reduced the measurement time significantly.

(a) Aerial view of the measured area of Finn's Beach

(b) East

(c) West

(d) Detail

Figure 8.3: Site overview of Finn's beach

Finn's Beach Club cleans every Friday and thus an initial cleanup was already performed. This is important to take into account when analyzing the data. As Finn's Beach Club was in charge of the measurement, the progress of the measurement was different compared to Pig Stone Beach. As the survey group was much bigger and not used to the measurement method executed by our team, some inconsistencies occurred, these were as followed:

- Not all waste larger than 2.0 centimeters was picked up. Especially large parts of organic waste were left behind.
- The measurement wasn't performed during low tide.
- The beach section was not marked and measured in length. Therefore there are inconsistencies in the measurement area.

Since the measurement area is relatively large the inconsistencies have relatively less effect. However it is important to consider the effects of these inconsistencies when reviewing the data.

In between the Finn's beach cleanups a small cleanup occurred every Tuesday on the same beach stretch. This has to be taken into account when calculating the interval time between each cleanup and eventually the waste flow. Also very small cleanups occur irregularly in between which are not taken into account. This will

result in a conservative estimate of the waste flow.

After the survey, different types of waste were weighed and finally the plastic waste was categorized as is depicted in Appendix A.15. This is done for 3 surveys.

NYANYI BEACH

As Nyanyi beach is very polluted by river inputs, help during the survey was required. The location of Nyanyi beach is quite rural therefore it was hard to find surrounding hotels or restaurants that could provide help. Eventually contact was made with Joshua District, a villa and restaurant complex that also gives workshops about plastic waste. An event was created together with Pantai Project to promote the clean up at Nyanyi beach and eventually 9 volunteers helped during the measurement. Before the measurement a short presentation was given to the volunteers in which the survey method was explained.

(a) Aerial view of the measured area of Nyanyi Beach

(b) Riverbank

(c) East

(d) Detail

Figure 8.4: Site overview of Nyanyi beach

When performing the first measurement of Nyanyi beach, it was decided to make the measurement area relatively small, due to the extensive amount of waste on the beach. Even though the survey was performed with 14 members the research took one hour and 15 minutes and a total of over 140 kilograms of waste was collected. In Appendix A.17 the weight categorization for the three measurements are shown.

8.3. DATA

A total of 9 beach surveys have been performed and are depicted in Table 8.2, showing the date and time interval between each of the surveys. As an initial cleanup was already performed on Finn's Beach Club before the 1st survey, a time interval could already be calculated. In Figure 8.5 the precipitation development is shown, indicating a large increase during the start of November. The wind direction remains relatively constant. In this figure the execution date of each of the measurements is indicated together as well. The final survey at

Finn's Beach Club was performed on 2 November, which was just before the development of the rainy season. The other 2 beaches had surveys performed on 9 November. During this week the first flood event occurred.

	Survey 1		Survey 2		Survey 3	
	Date	Interval	Date	Interval	Date	Interval
Pig stone beach	26/09/2018	-	21/10/2018	597 hr	09/11/2018	455 hr
Finn's beach	12/10/2018	63 hr	19/10/2018	63 hr	02/11/2018	63 hr
Nyanyi beach	19/10/2018	-	03/11/2018	360.5 hr	09/11/2018	360.5 hr

Table 8.2: Dates on which surveys are performed and their time intervals

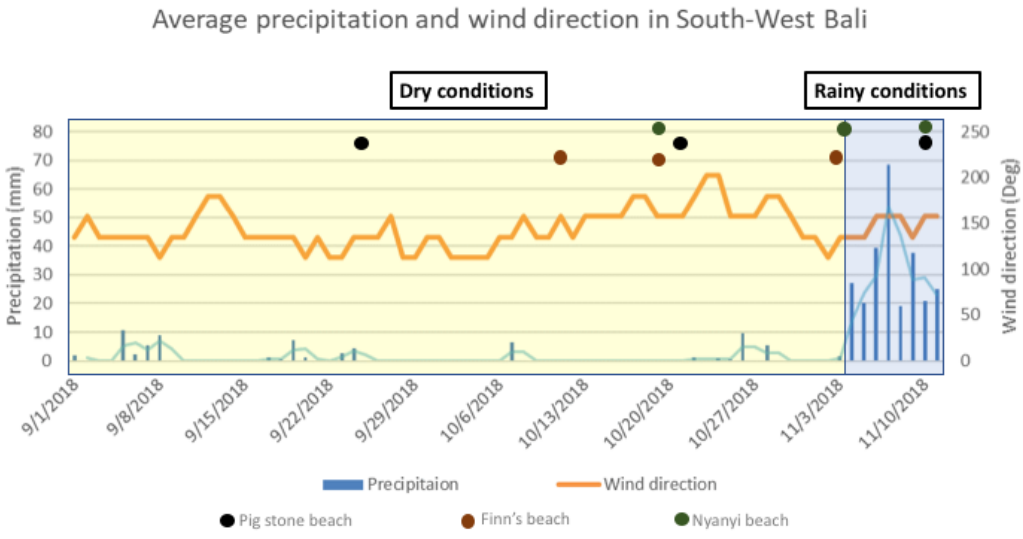


Figure 8.5: Precipitation and wind direction during the beach surveys

8.3.1. PRIMARY SORTING

The primary sorting is done for each of the beaches. In Table 8.3 the results of primary sorting are shown for each of the locations. These values represent the total accumulated waste measured on each of the beach stretches.

Table 8.4, Table 8.5 and 8.6 show primary sorting values for each of the individual surveys for Pig Stone Beach, Finn's Beach and Nyanyi Beach respectively. There is no significant difference between each of the three surveys concerning the primary sorting composition. Apparently, after the first flood event the waste composition after primary sorting remained almost the same. Total accumulated weight does increase after an increase in rainfall. For Nyanyi beach a relative large amount of waste was collected during the 1st survey, as almost no beach cleanups occur and the area has high input of waste from the river.

Figure 8.6 shows the composition of waste at each of the three measured beaches after primary sorting. Interestingly, there is no significant difference between the three beaches. Organic waste is very dominant as the beaches are surrounded by vegetation on the land-side boundary. This results in large pieces of wood and coconuts being spread out on the beach which are relatively heavy and therefore have a large effect on the composition.

	Pig stone beach		Finn's beach		Nyanyi beach	
	kg	%	kg	%	kg	%
Plastic	10.225	12.527	12.305	9.17	21.84	8.43
Organic	69.2	84.78	109.1	81.27	222.5	85.90
Rest	2.2	2.70	12.835	9.56	14.67	5.66
Total	81.625		134.24		259.01	

Table 8.3: Primary sorting of beaches

	Survey 1		Survey 2		Survey 3	
	kg	%	kg	%	kg	%
Plastic	1.82	10.6	3.29	19.0	5.1	10.8
Organic	14.5	85.0	13.6	78.4	41.1	87.0
Rest	0.74	4.3	0.45	2.6	1.01	2.1
Total	17.06		17.34		47.21	

Table 8.4: Measurements for each of the Pig Stone Beach surveys

	Survey 1		Survey 2		Survey 3	
	kg	%	kg	%	kg	%
Plastic	4.39	11.5	3.48	6.9	4.44	9.8
Organic	30.7	80.6	42.8	84.4	35.6	78.3
Rest	3.0	7.9	4.43	8.7	5.41	11.9
Total	38.08		50.71		45.45	

Table 8.5: Measurements for each of the Finn's Beach surveys

	Survey 1		Survey 2		Survey 3	
	kg	%	kg	%	kg	%
Plastic	12.44	8.9	2.28	8.3	7.1	7.7
Organic	115.6	83.0	24.7	90.3	82.2	89.0
Rest	11.23	8.1	0.38	1.4	3.06	3.3
Total	139.27		27.36		92.36	

Table 8.6: Measurements for each of the Nyanyi Beach surveys

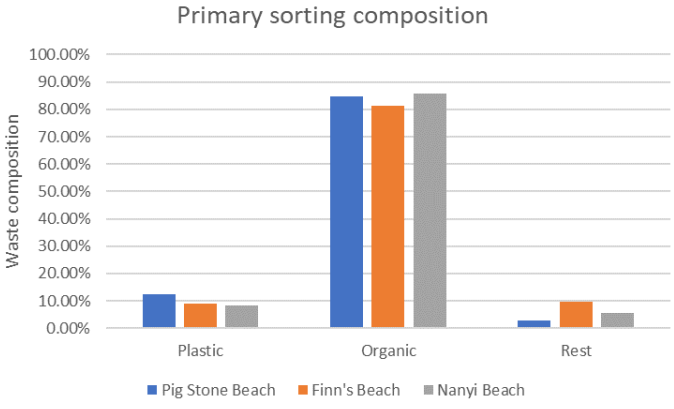


Figure 8.6: Graph of waste composition after primary sorting

8.3.2. SECONDARY SORTING

During secondary sorting the plastic waste is divided into various categories. In Table 8.7 the plastic distribution for each of the locations is shown.

	Pig Stone Beach			Finn's beach			Nyanyi beach			Total		
	#	kg	%	#	kg	%	#	kg	%	#	kg	%
HDPE (hard)		0.78	7.6		1.07	8.7		3.59	16.5		5.44	12.3
LDPE (soft)		0.88	8.6		4.91	39.9		6.07	27.8		11.86	26.7
PET		0.71	7.0		1.32	10.7		0.61	2.8		2.64	5.9
PS/PP		4.47	43.8		2.36	19.2		4.41	20.2		11.24	25.4
Multilayer		3.39	33.2		2.65	21.5		7.15	32.8		13.19	29.7
Total		10.23			12.31			21.83			44.37	

Table 8.7: Secondary sorting of beach surveys

In Figure 8.7 the plastic composition for each of the three measurements is depicted. From the figure it is clear that the plastic composition is very different between the three beaches, despite having similar compositions after primary sorting. This results from each of the beaches having different waste inputs.

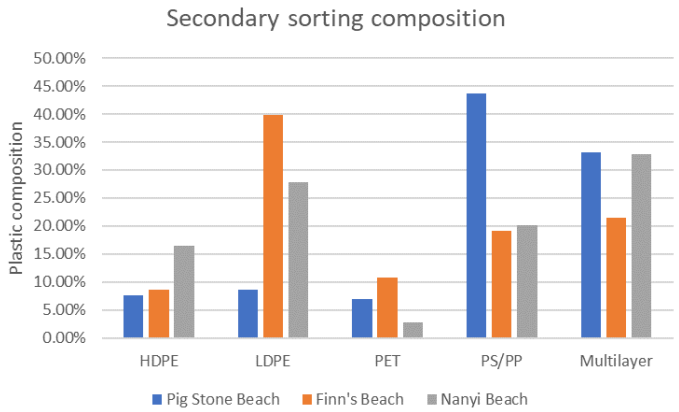


Figure 8.7: Graph of plastic composition after secondary sorting

Pig Stone beach is mainly dominated by PS/PP and multilayer type plastic waste, Finn's beach by LDPE type plastics and Nyanyi beach has a relatively scattered distribution. In other words, ocean inputs are dominated by PS/PP and terrestrial inputs are dominated by LDPE types. As PS/PP type plastics consists of styrofoam. Styrofoam is a popular buoyant material among fishermen and therefore gets disposed in the ocean more often. LDPE and multilayer type plastics are common single use materials and are easily disposed on beaches by visitors.

In Figure 8.8 the composition of Nyanyi beach is compared with the total composition of the river measurements. It shows that the composition of Nyanyi beach and the river measurements are quite similar. This could indicate that plastics from the river indeed directly affect beaches locally.

Slight differences in composition between the river measurements and Nyanyi beach can be contributed to oceanic inputs, as Nyanyi beach also has plastics coming in from the ocean. This can explain why Nyanyi beach is more composed of PS/PP and multilayer plastics. Also, LDPE type plastics are less dominant compared to the river measurements. This might indicate LDPE type plastics are less likely to settle near the beaches, but instead enter the ocean. Figure 8.7 shows that Pig Stone beach is experiencing little LDPE. This might indicate that a part of the LDPE type plastics that enter the ocean won't return to Bali.

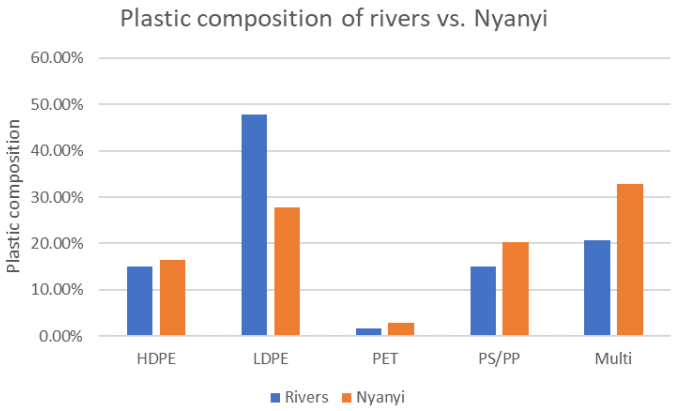


Figure 8.8: Graph of plastic composition of the river measurements compared to Nyanyi beach

Furthermore, for all the locations very little PET was found. This is probably due to the high incentive that is involved with reusing PET. Many recycling facilities on Java pay money for PET waste and therefore lots of PET is collected by individuals. This is also confirmed during the interview with ECO-Bali in Appendix C.3. There are also low values for HDPE. A possible explanation can be that HDPE type plastics often have longer life cycles and therefore get disposed far less into the environment.

8.4. GUESSTIMATE OF WASTE FLOW

8.4.1. WASTE FLOW BEACHES

In Table 8.9 the waste flow is indicated and in Table 8.21 the plastic waste flow is indicated. This is calculated using formula 8.1. This results in a waste flow value that can be easily compared with each of the measurements. Table 8.8 gives an explanation on each of the parameters involved.

$$J_b = \frac{M_t}{T_i}\frac{1}{L_m} \tag{8.1}$$

Parameter	Unit	definition
J_{beach}	g/h/m	Waste accumulation per hour per meter on beach
M_{total}	g	Total captured waste
$M_{plastic}$	g	Total captured plastic waste
T_i	h	Time interval between beach measurements
L_m	m	Length of beach measurement

Table 8.8: The parameters of Eq. 8.1

	Survey 1 g/h/m	**Survey 2** g/h/m	**Survey 3** g/h/m
Pig Stone Beach	-	0.29	1.038
Finn's Beach	1.01	1.34	1.20
Nyanyi Beach	-	1.90	6.41

Table 8.9: Total waste flow in grams per hour per meter for each of the beach surveys

Pig Stone Beach has very low waste flow during the dry period. This can be explained by the fact that the beach is located remotely and only has waste inputs from the ocean. The final survey was performed after a period of rain resulting in an increase of waste flow. Possibly because of excess waste from rivers that entered the ocean.

	Survey 1 g/h/m	**Survey 2** g/h/m	**Survey 3** g/h/m
Pig Stone Beach	-	0.055	0.11
Finn's Beach	0.12	0.092	0.12
Nyanyi Beach	-	0.16	0.49

Table 8.10: Plastic waste flow in grams per hour per meter for each of the beach surveys

Finn's Beach has significant higher waste flows compared to Pig Stone Beach. Higher amounts were expected as the beach also endures terrestrial inputs. However, as stated in Chapter 8.2 more cleanups are performed at Finn's Beach and it is not clear how much waste is collected during these cleanups. Therefore the calculated waste flow at Finn's Beach is an underestimation. As all the surveys at Finn's Beach were performed during a relatively dry period no significant increase in the waste flow can be denoted from heavy rain conditions.

From the table it is clear that Nyanyi Beach has the highest waste flow. This can be explained by the addition of waste inputs from the river. A large increase in waste flow can be seen after the 3rd survey. More rain occurred between the second and third survey, which resulted in more waste inputs from the river.

8.4.2. WASTE FLOW SOURCES

WASTE FLOW

Table 8.11 shows the waste flow and Table 8.12 shows the plastic waste flow during dry conditions and after rain for each of the three sources; ocean, terrestrial and river respectively. It shows that rivers are the most dominant source, especially after rain conditions. Ocean sources start to become more involved when rain conditions increase. A further explanation of the derivation of each of the sources follows in the following chapters.

Source	**Dry** g/h/m	**After rain** g/h/m	**Difference** %
Ocean	0.29	1.038	258
Terrestrial	1.01	0.77	-24
River	1.61	5.372	234

Table 8.11: Total waste flow for each of the waste sources

Source	**Dry** g/h/m	**After rain** g/h/m	**Difference** %
Ocean	0.055	0.11	100
Terrestrial	0.12	0.09	-25
River	0.16	0.49	206

Table 8.12: Plastic waste flow for each the waste sources

OCEAN

The ocean waste flow is directly derived from the Pig Stone waste flow, as Pig Stone is mostly dominated by ocean inputs. The dry conditions cohere with the 2nd survey and the wet conditions cohere with the 3rd survey.

All of the beaches on the South-west coast of Bali are subject to ocean inputs. Therefore the whole beach stretch is used in order to extrapolate the data. The total beach stretch of the case area is calculated with the use of Google Maps. In Figure 8.9 the total beach length is mapped and calculated to a total of 92.42 km. Southern located beaches accumulate more waste than the northern part as the flow is coming in more perpendicular. This is not taken into account in the calculation.

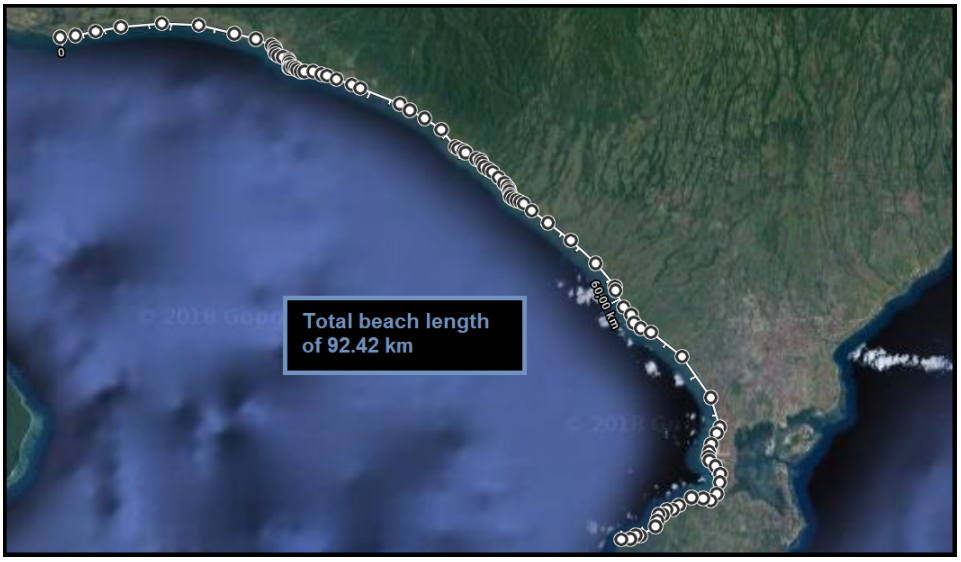


Figure 8.9: Total beach length in case area

Now that the total beach length is known, a total waste accumulation as a result of ocean inputs can be calculated for dry and after rain conditions. This is simply done by multiplying the oceanic waste flow per meter with the total beach length, as is shown in Table 8.13 for total oceanic waste flow and in Table 8.14 for plastic oceanic waste flow.

	Per meter g/h/m	**Beach length** m	**Total waste accumulation** kg/h
Dry	0.29	92420	26.80
After rain	1.038	92420	95.93

Table 8.13: Total oceanic waste flow in case area

	Per meter g/h/m	**Beach length** m	**Total plastic accumulation** kg/h	**Daily plastic accumulation** kg/day
Dry	0.055	92420	5.0	120
After rain	0.11	92420	10.2	245

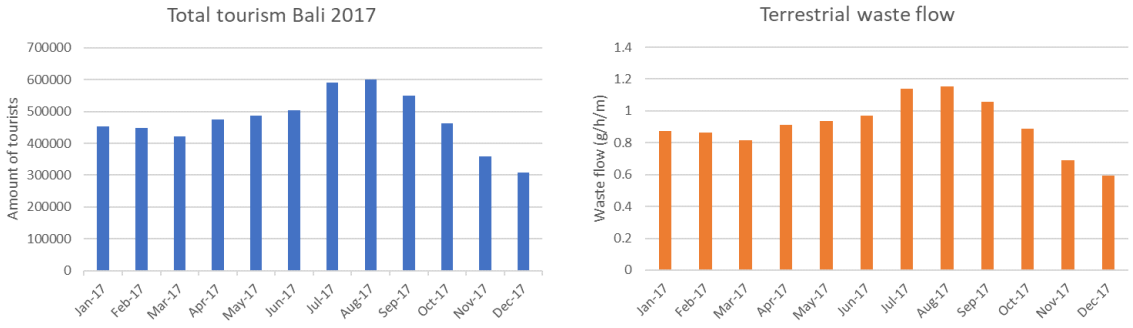
Table 8.14: Plastic oceanic waste flow in case area

TERRESTRIAL

The terrestrial waste flow is derived from Finn's Beach waste flow. First the average waste flow during dry conditions is calculated between the three surveys. Then the oceanic input is subtracted from this value as Finn's Beach endures both terrestrial and ocean inputs. The result is an estimate of the total waste input from terrestrial sources for the month of October, as this is the period on which the measurements took place. As there are no rain measurements of Finn's Beach an assumption has to be made.

It is assumed that the terrestrial waste input is directly correlated to the tourism in Bali. Figure 8.10 (a) shows the tourism development over the past year and Figure 8.10 (b) shows an estimation of the terrestrial input over a year. As the average terrestrial input, in grams per hour per meter, during the month October is known a calculation can be made on the other months. For this calculation it is assumed that the tourism distribution in 2017 is roughly the same as in 2018.

In order to compare the terrestrial data with other source inputs a distinction is made between a dry and after rain value. According to Section 4.1.2, West monsoon season starts in November and ends in March, whereas the transitional season starts in April and ends in October. An average value for a terrestrial waste flow is calculated for each of the two seasons and is represented in Table 8.15.



(a) Tourism per month in Bali in 2017 [42]

(b) Terrestrial waste flow per month in Bali

Figure 8.10: Tourism and terrestrial waste flow

Urban beaches are mainly focused around Kuta, Seminyak, Canggu and Jimbaran. Via Google Maps the total urban beach stretch is measured. A visualization is given in Figure 8.11. The total urban beach length is estimated to be around 16.72 km. Now, the total terrestrial waste flow in the case area per month can be calculated. This is given in Table 8.15. The total plastic terrestrial waste flow is given in Table 8.16.

Figure 8.11: Total urban beach length in case area

	Per meter g/h/m	**Beach length** m	**Total waste accumulation** kg/h
Dry	1.01	16720	16.87
After rain	0.77	16720	12.80

Table 8.15: Total terrestrial waste flow in case area

	Per meter g/h/m	**Beach length** m	**Total plastic accumulation** kg/h	**Daily plastic accumulation** kg/day
Dry	0.12	16720	2.0	48
After rain	0.09	16720	1.50	36

Table 8.16: Plastic terrestrial waste flow in case area

RIVER

The river input is derived from the waste flow values of Nyanyi beach. As Nyanyi endures both river and ocean inputs the dry ocean waste flow was subtracted from the dry Nyanyi waste flow and the same was done for rain conditions.

From Section 4.1.1 it is denoted that there is a total of 49 rivers in the case area. It is assumed that all of the beaches that surround such a river can be considered a river beach. Taking in mind the visual inspections at Nyanyi Beach it is assumed that around 500 to 1000 meters of surrounding beach is affected by a river. An upper and lower boundary for the total waste flow is calculated and shown in Table 8.17 and for the total plastic waste flow in Table 8.18. In Table 8.19 the average plastic accumulation from river beaches is shown in kilograms per day, which will be used in the conceptual model.

	Per meter g/h/m	**Beach length** m	**Total waste accumulation** kg/h
Dry	1.61	24500	39.45
After rain	5.372	24500	131.61
Dry	1.61	49000	78.9
After rain	5.372	49000	263.22

Table 8.17: Total river waste flow in case area

	Per meter g/h/m	**Beach length** m	**Total plastic accumulation** kg/h	**Daily plastic accumulation** kg/day
Dry	0.16	24500	3.92	94
After rain	0.49	24500	12.0	288
Dry	0.16	49000	7.84	188
After rain	0.49	49000	24.01	576

Table 8.18: Plastic river waste flow in case area

	Average plastic accumulation kg/day
Dry	141
After rain	432

Table 8.19: Average plastic river waste flow in case area

TOTAL

The total waste flow in the case area is depicted in Table 8.20 and the total plastic flow is shown in Table 8.21. The plastic flow consists of around 10% of the the total waste flow.

	Minimum kg/h	**Maximum** kg/h
Dry	83.12	122.57
After rain	240.34	371.95

Table 8.20: Total waste flow in case area

	Minimum kg/h	**Maximum** kg/h
Dry	10.92	14.84
After rain	23.7	35.71

Table 8.21: Plastic waste flow in case area

COMPOSITION DIFFERENCES IN RIVERS AND BEACHES

Interestingly, there is a big difference between the composition of plastics in the river and the composition of oceanic plastic input. As is described in Section 8.3.2, Figure 8.7 indicates the plastic composition between the three different beaches, representing an oceanic, terrestrial and river source.

As less than a quarter of all the plastic from the rivers ends up on the beach during dry conditions the rest, presumably, ends up in the ocean. From Figure 8.7 it is observed that oceanic inputs are dominated by PS/PP (Styrofoam) and multilayer plastics and river inputs are dominated by almost 50% LDPE type plastics, see Figure 8.8. Ocean inputs provide relatively small amounts of LDPE, despite large quantities being transported into the ocean via the rivers. This big difference in composition and quantity indicates that large amounts of LDPE plastics, consisting of plastic bags and other single use plastics, remain in the ocean or end up on Java or other coastal areas or the bottom of the sea. This might shift when the wind direction changes during the west monsoon.

8.5. EVALUATION

Some challenges were faced during the beach research. A short summary is given below together with some advise for potential follow up studies.

- Sometimes the beaches were so polluted that extra survey members were required. This was done by creating clean up events together with local restaurants or hotels or joining existing beach cleanups.
- In order to speed up the cleanup process it is advised to use certain tools. After joining a local cleanup session the team noticed that certain materials such as grabbers and garden rakes were very efficient.
- Nyanyi and Pig Stone beach were located quite remotely. For such locations the roads are sometimes in bad shape. This often requires to walk a little extra to the survey site.
- During beach cleanups locals might want to know what is going on and who is invading their space. Try to have an open attitude and speak a little Bahasa. They will often really enjoy the conversations and will be very friendly.
- Southern beaches accumulate more waste from oceanic inputs compared to Northern located beaches due to the alignment of the beaches towards the incoming flow. In order to better understand the differences between waste accumulation from ocean sources it is advised to research the waste accumulation in Northern beaches and Southern beaches and analyze this data extensively.
- In order to better understand the effects of West monsoon wind and waste accumulation on the beach from ocean inputs it is advised to perform more research on the composition and quantity of beach waste during the West monsoon season and compare those with data from the transitional season.

9

WASTE MANAGEMENT AND SOCIAL STUDY

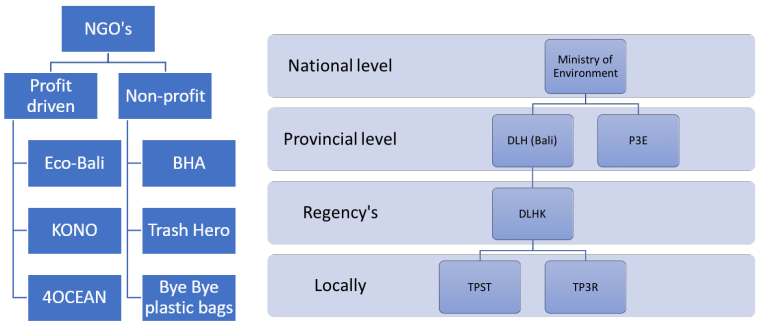
9.1. WASTE MANAGEMENT IN BALI

In order to assess the waste management system in Bali, local research was required. Also, to gain more information on waste streams in Bali, interviews have been conducted with representatives of waste management facilities. These interviews, together with data acquired from local partners, are an important source of information in the waste management research.

9.1.1. STAKEHOLDER ANALYSIS

In the waste management sector on Bali several important stakeholders are identified. There are a great number of companies, foundations, hotels and individuals that are actively trying to reduce mismanaged waste in Bali. A list of NGO's regarding waste management on Bali is given in Figure 9.1 (a). What has been noticed in the analysis is that everybody has more or less the same goal, reducing plastic pollution, but they are all just doing their own part, there is no collaboration.

Within the government various stakeholders are acting at different levels; National-, Provincial-, Regency- and Local level. The hierarchy of the governmental stakeholders is presented in Figure 9.1 (b). In Appendix F.5 a full list of stakeholders and a detailed description is included. A problem that is encountered is the lack of coordination of data between governmental institutes. There is no clear system for data exchange between one division of the government to the other division. This has been experienced first hand as we tried to gather data regarding waste production on Bali.



(a) NGO stakeholders (b) Governmental stakeholders and their hyrarchy

Figure 9.1: Overview of important stakeholders regarding waste management on Bali

9.1.2. WASTE MANAGEMENT SYSTEM

Mr Warta, Director of Environment at the Bali Hotel Association (BHA), assisted us in gaining knowledge about the governance structure and how it works with funding for waste management. The entire interview with Mr Warta is included in Appendix C.5.

AUTONOMY AND WASTE MANAGEMENT BUDGET

The local governmental budget varies per regency and the local income mainly consists of the local taxes payed in the regency. The autonomy is at the regional level. This means that every regency has their own budget, and they decide what expenses are being made with this budget. This budget consists of 2 parts:

- Central government; The central government of Indonesia has an allocation of things such as healthcare and education. The budget received from the central government depends on the population of the area.
- Local income; The local income mainly consists of local taxes. When expenses are made, 10% tax is applied. So, for example, when tourists book a hotel or have dinner at the restaurant, 10% tax is applied and this will be payed to the regional government.

This information is gathered through our interview at BHA. For reading convenience, the part of the interview where Mr. Warta gives us this information is included in Table 9.1 below.

Interviewers	I still have one more question. How does it work from the government with regulation, legislation and funding and how is this structured from Indonesia to the islands. You said, for example, that the local government of Badung regency has a lot of money but where does this come from?
Respondent	The local government budget consist of 2 parts. One is from the central government. You have a special allocation for things that cover public services like education and healthcare.
Interviewers	So Badung gets more because
Respondent	(interrupting) I think in that part it's a bit equal, it depends on how large the population of your area is. The other part is what they call the local income from the tax. Badung is where, I think, 80% of the hotels in Bali are located. When guest stay in the hotel they pay 10% tax, this one goes to Badung. That's why Badung is one of the wealthiest local government in Indonesia, they have a lot of money from this tourism sector. When you eat at a restaurant they charge you 10%, that goes to local government. It's not to Bali but only to the local government, by law, because Badung is central government. The autonomy is in the regency level, so this level can do whatever they want to do with the local tax that they collect. That's why they have a lot of money to spend on promoting the tourism, cleaning tools and whatever they want.
Interviewers	Is there also a division for waste management services?
Respondent	Yes, they do have their department like DHLK, and DHLK Badung has more money then, for example DHLK Denpansar, so they can buy more trucks and excavators. That's why, when Kuta has waste emergency, Badung can deploy a lot of equipment.

Table 9.1: Interview with Mr Warta, Director of Environment at the Bali Hotel Association (BHA)

ACTUAL SITUATION IN BALI

As follows from the stakeholder analysis in Section 9.1.1 there are a lot of parties who are involved with the waste management system of Bali. Within the system in Bali a clear difference in operation between urban areas and the more rural areas has been identified. Every regency has its own DLHK, a regional governmental institute who manages the local TPST and TP3R facilities within a regency (see Figure 9.1 (b)). TPST and TPST3R are locations where waste is gathered and segregated before it is disposed in a landfill. At a TPST mixed waste is brought in, after which it will be transported in bulk to the landfills. At a TPST3R facility, the mixed waste is being separated into three categories: organic, plastic and other. The plastics, in their turn, will be divided into recyclable and non-recyclable. Since the autonomy as at the regional level, they are being held responsible for their own waste handling (by law).

It is suggested that waste management systems in the rural regencies are far behind compared to for instance Badung, as they have a lower budget. In order to confirm this statement and to map the actual waste management systems, inspection on site has been performed. Also, to get more information on waste streams in Bali interviews have been conducted with representatives of the facilities. These interviews have been included in Appendix C. A diagram of the various waste streams, showing how waste is being distributed from input towards is presented in Figure 9.3. This diagram also gives more insight on how the element 'Trash

disposal' in our conceptual model behaves in the system.

Our site visits confirmed the statement about the difference between rural and touristic regencies. The infrastructure to the rural area is often of bad quality and also their waste management varies from urban areas. A lot of rural villages, located more in the North and inland, are very traditional an handle their own waste because the government can not handle the whole regency. Often the chief of a community decides what happens with the waste and most of the times it will be incinerated or dumped locally. But it is not only the rural areas that lack in quality. During our inspection we encountered many uncontrolled dumping sites, often next to riverbanks. To give an general idea of our site inspections, in Bali look like, illustrations of waste management facilities and (un)controlled dumping sites are included in Figure 9.2. Due to the fast development and economic growth in the urban areas of Bali the generation of solid waste has strongly increase. This development has been a big problem for local and regional authorities. On top of that there is a relatively low expertise concerning waste management [50]. In the past everything used to be organic and banana leaves were used instead of plastic packaging. Inhabitants would just throw everything away as it only consisted of degradable material. Now, some locals kept the same habit, while most of the waste is not degradable anymore. This has also been emphasized by Mr. Warta when we asked him about traditional waste management in Bali. He stated:

> *"In the past everything is organic and when you buy something everything is wrapped in banana leaf. So our parents or grandparents used to do that and just throw away everything because it's all degradable. But now, with the same habit which is passed down from generation to generation, we treat everything the same way like we're throwing the banana leaf. So that's the problem. People who doing that sometimes are just feeling innocent. "No I'm doing fine, I'm just throwing rubbish"."*

So not only is there a lack of facilities and quality, but also the social aspect is strongly contributing to trash disposal in the environment. Summarizing, 3 main challenges towards establishing proper waste management systems can be specified:

- Limited budget
- Low expertise
- Social attitude towards littering

(a) Suwung Landfill, Denpasar (b) Eco-Bali facility, Badung (c) TP3R facility, Seminyak

(d) TPST facility, Denpasar (e) Bank Sampah, Denpasar (f) Local beach dumpsite, Negara

Figure 9.2: Different types of waste management facilities in Bali

WASTE STREAMS

In Figure 9.3 the different transport streams of generated waste in Bali are outlined. These paths are based on different interviews, given in Appendix C and visual inspections on site. The most waste ends up at the landfill unrecycled through the DESA and TPST service.

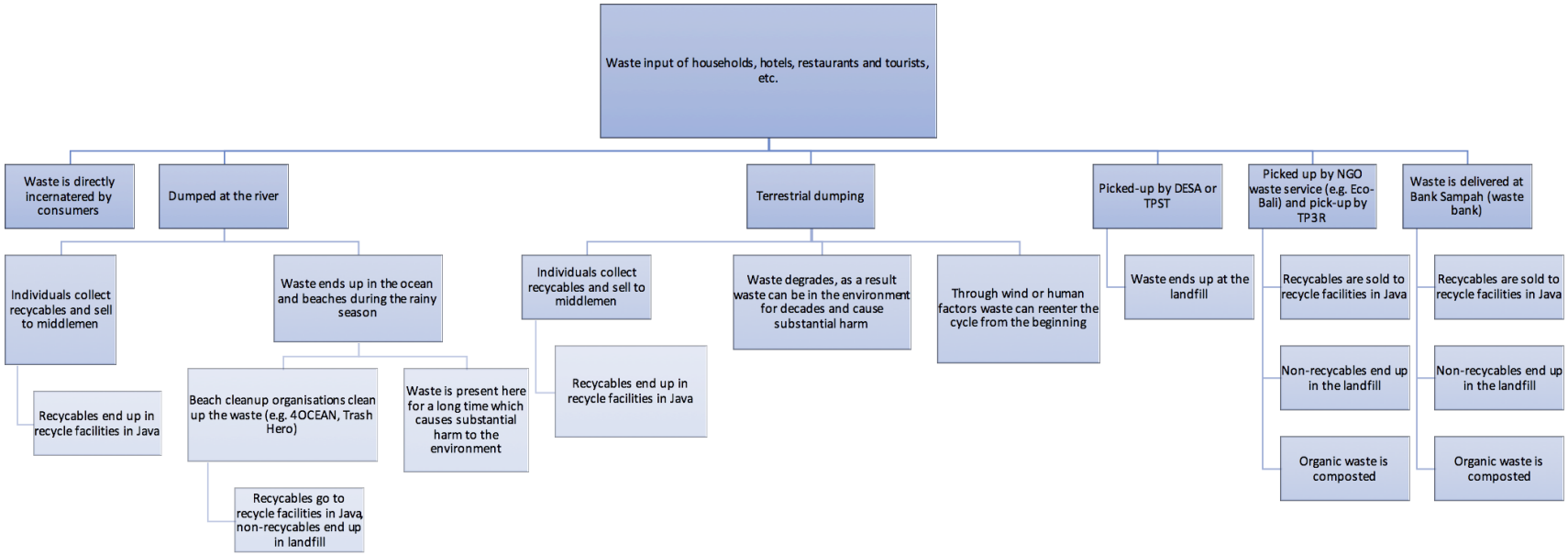


Figure 9.3: Waste streams within Bali

9.2. WASTE QUANTIFICATION IN BALI

Now that waste streams from rivers and onto beaches have been identified, the next step is to quantify the total waste generated in the research area.

WASTE PRODUCTION

The regencies that are involved within the case area are Jembrana, Tabanan and Badung. Their respective waste production in cubic meters per day is shown in Table 9.2. The values are from 2016 but are expected to have grown in 2018. Therefore calculations with these numbers resulted in a conservative estimate. For a detailed map with locations of these regencies Figure 4.2 can be consulted. Also an estimation of the waste production in kilograms per day is shown. This way the data can be compared with the waste flow from the rivers and beaches. Here an average compressed density of 450 kg/m^3 is used [51]. Figure 9.4 shows that 19% of the total weight of waste in Bali is plastic. This results in a calculation of the total dry plastic waste that is transported to the landfills per day.

Regency	Waste 2016 m^3/day	Waste 2016 kg/day	Plastic waste 2016 kg/day
Tabanan	866.87	390 092	74 118
Jembrana	545.99	245 696	46 682
Badung	723.09	325 391	63 824
Total	2135.95	961 179	184 624

Table 9.2: Waste transport rates per regency towards the landfill, retrieved from Appendix A.2

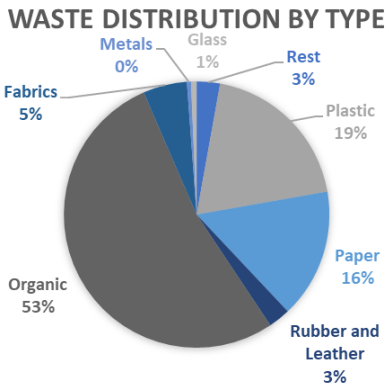


Figure 9.4: Distribution of waste types in Bali [17]

TOTAL WASTE PRODUCTION CASE AREA

In order to determine the total waste production also information on the amount of mismanaged waste must be acquired. After meetings with DLHK information was retrieved on the waste treatment in the Badung regency. In Appendix A.3 a data flyer from DLHK is shown. Here it is stated that around 10% of the waste in Badung is not processed and ends up in the environment instead of the landfill. Incineration is assumed to be a relatively small amount and is therefore neglected. As Badung is the most developed regency in Bali it also has better waste management facilities compared to the other regencies. During field trips it was observed that more remote regencies lack in waste collection, seeing more trash being disposed along the road and rivers. An example is the trash disposal in Negara, in the Jembrana regency, as can be seen in Figure 9.2. Mismanagement of waste in Tabanan was observed as well but not as servere compared to Jembrana.

In Table 9.3 calculations are made on the amount of mismanaged waste in each of the regencies. In Tabanan the mismanagement of waste is assumed to be 25% of the total waste disposal. This is 40% for Jembrana.

Regency	Managed plastic waste 2016 kg/day	Mismanagement %	Total plastic waste kg/day	Plastic in the environment kg/day
Tabanan	74 118	25	98 824	24 706
Jembrana	46 682	40	77 803	31 121
Badung	63 824	10	70 916	7 092
Total	184 624	-	247 543	62 919

Table 9.3: Total waste production and plastic production into the environment

9.2.1. GUESSTIMATE OF TRASH DISPOSAL

Table 9.3 shows that a total of 62 919 kg of plastics gets disposed into the environment per day. It is assumed that this waste eventually enters the ocean via local rivers under the influence of heavy rainfalls. This value represents arrow two in the conceptual model, see Figure 4.12, as this data only represents waste disposal in rivers in Bali.

9.3. SOCIAL STUDY

As described in Section 5.5.3 all the survey data has been transferred to Excel. With the use of Excel a variety of charts, graphs and other images were created. These are depicted in Appendix B.

9.3.1. DISTRIBUTION OF SURVEY SUBJECTS

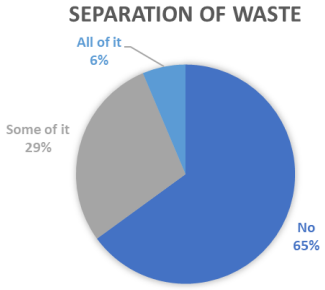
A total of 224 surveys were conducted in Bali representing a wide variety of subjects. In order to get a better understanding of the variety and distribution of the subjects a few charts and figures where created, these are depicted in Appendix B. Here it shows that the gender distribution is distributed quite evenly, with around 54% males and 42% females. The subjects are predominantly 18 to 35 years old, representing 67% of the total group. Most of the interviewee's had finished a high school degree, amounting to 53%. Interestingly, 24% has finished a lower degree (no study, elementary school or middle school) and 20% a higher degree (college or university). A wide variety of job descriptions was found, varying from students, governmental work to farmers or housewife's. Similar job descriptions where listed together in order to compress the list. Most of the subjects work in the service (tourist) industry or are students.

WASTE HANDLING

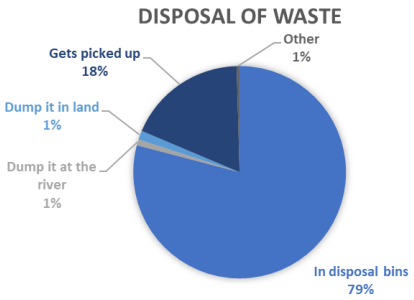
In Section 5.5.3 the various types of questions are described. Question 6,7, and 8 focus on waste handling of the individual.

In question 6 it was asked whether the subject separates his or her waste. This question was asked in order to understand whether locals care enough and are aware enough about the impacts of the different types of waste. In Figure 9.5 (a) the answers to this question are shown. A surprising 65% does not separate their waste and 94% does not or barely separate their waste. This is a very large amount and shows that most of the subjects are not aware or motivated enough to handle their waste properly. On the other hand very limiting services are provided by the government and they barely motivate any form of waste separation for individuals. Recycling facilities in Java do pay for recyclables and some locals earn money by collecting PET or PP/PS, as is explained by ECO-Bali in Interview C.3. Often large hotels or resorts are very conscious on their waste production. An example is the Bali Hotel Association initiative, described in Interview C.5. These groups might represent the final 6%.

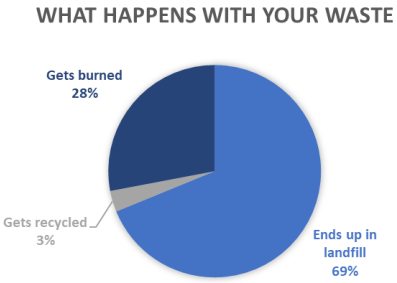
As a lot of waste was found near rivers or in land during visual inspections it was expected that a lot of locals are dumping their waste in these areas. Therefore question 7 was introduced in the survey, here it was asked how the individual disposes his or her waste. In Figure 9.5 (b) the resulting chart is shown. Most of the subjects, 79%, says they dispose their waste in disposal bins. What is very interesting is that only 2% says that their waste is being disposed in land or into the rivers. This is very contradicting to what has been seen during visual inspections and what has been discussed during several meetings with waste management authorities. Possibly the subject is aware of the negative effects of their waste disposal and is ashamed to admit this. Or, the small percentage that disposes their waste incorrectly does this in very large amounts. On the other hand



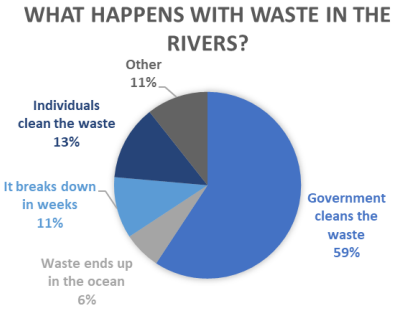
(a) Separation of waste



(b) Disposal of waste



(c) What happens with waste



(d) What happens with the waste in rivers

Figure 9.5: Various chart results from the survey

waste is often managed by village chiefs as government services are limited and/or cannot reach rural villages. Waste then gets collected by local village facilities, but then get disposed into land or rivers as landfills or other waste services are simply too remote. The general public may dispose their waste in disposal bins or has it collected, but local waste management may dispose it into the environment in the end resulting in great quantities of waste in rivers and land. Finally, the question demands one answer. The interviewee will most likely choose the option that coheres with his or her most dominate waste disposal method, neglecting other options completely which is not an accurate assumption.

Because a lot of waste handling is done locally by the villages a follow up question was asked whether the subject knows where his or her waste will end up. This may provide information on the waste handling of remote villages and/or their awareness on the matter. In Figure 9.5 (c) the results are shown. Interestingly none of the subjects thought that their waste ends up in the ocean or on land, despite the large amounts of plastic that are cleaned up daily from Bali's beaches during the rainy season as well as lots of encounters of plastic and other types of waste on river banks and on land. This might mean that the individuals are very unaware of their waste treatment or are ashamed to admit so. On the other hand the question provides the interviewee to only answer one option. Again, this might result in the subject to answer the option that is considered to him or her the most dominant completely neglecting the other options.

AWARENESS AND MOTIVATION

The awareness and motivation of the subjects is tested in two ways. First, by analyzing each of the awareness and motivation questions individually. This tells something about the awareness and motivation of the complete survey group concerning specific subjects. Secondly, a grading system is build both for awareness and motivation with the use of an excel program. For various questions awareness and motivation points where given depending on the answer. With the grading system the overall awareness and motivation of each individual is assessed. Then, these individuals can be compiled into groups according to age or gender after which they can be compared easily with one another.

INDIVIDUAL QUESTIONS

In question 9 it was asked whether the individual cares what happens with his or her waste, see Appendix B. It shows that 68% of the subjects only cares a little bit or not at all, a very large amount. This shows that most locals are barely motivated to change anything about the current situation and a lot of education is required to change this. This also degrades the argument of shame, which has been used before in Section 9.3.1. Apparently the subjects are not afraid to admit they don't care and are either not aware of its effects or simply do not care.

Question 11 asks the subject what happens with waste in the rivers. As a lot of waste is dumped along river banks it is important to research if the subjects are aware of its effects, which might identify whether this type of dumping occurs out of sheer unawareness or carelessness. The results of this question are shown in Figure 9.5 (d). Around 59% of the subjects think the Government cleans this waste. This is not the case as government facilities are already lacking to pick up waste in most villages and cleaning riverbanks involves even more implications. This shows a lack of awareness and also indicates a motive for locals to dump around riverbanks. However, 6% indicates that most of the waste in rivers ends up in the ocean. Showing that some awareness around the matter does occur.

The following question aims on asking the individuals what types of waste have the most negative impact. Most subjects answered plastic, total of 77%, and the second most popular answer was glass with 19%. Both materials degrade very slowly and can have negative impacts on the environment. Surprisingly, most of the subjects seem to be aware of plastic materials being negative to the environment, or at least the most negative. However, as was concluded from question 9, most people appear not to care. Education and motivational campaigns are necessary to change this mindset along future generations. In question 13 it is questioned how the subject is informed on the notion that plastics have negative effects. Almost 40% indicates that it follows from their education and 30% indicates they got informed by family members. This shows that education on plastic pollution seems to work. Question 14 asks what is negatively impacted due to plastics in the ocean. Most subjects answered that the environment suffers the most with 78%. However, 9% answered agriculture to be affected the most. This shows a great lack of awareness among these subjects. Finally, in question 16 it is asked whether the subject tries to prevent or mitigate plastics from entering the ocean. Total of 22% answered no and 36% answered rarely. Only 20% of the subjects tries to consistently prevent plastics from entering the ocean.

GRADING SYSTEM

Now that each of the questions has been analyzed individually a general analysis on the awareness and motivation will be performed. As explained previously an excel program is used from which calculations are made on each subjects awareness and motivation score. All of the results are shown in Appendix B.

First the total amount of awareness and motivation points where calculated. In Appendix B.1 it is shown that the average awareness score contains 3.12 with a range between 0 and 11. Appendix B.2 shows that males seem to score higher than average with a score of 3.46, which is 11% above the average score, compared to females which scored 2.92 points and 6% below average.

The average amount of motivation points scored is 4.30 points with a range between -2 and 11. For some answers negative points where contributed as the answer would indicate deep unmotivated behavior. Male and females seemed to score almost the same with only a slight edge to the male score with 4%. This is not considered to be significant enough to constitute any conclusions from.

Next, the effect of age was assessed on awareness and motivation scores. In Appendix B.3 the average awareness and motivation score of each age group is shown. As the data pool for older age groups is significantly less it was decided to form two groups, young and old respectively, in order to have better comparable data. The young group consists of subjects between 0 to 35 years old and the old groups contains of subjects who are older than 35. The young age group scored on average 3.54 awareness points, whereas the old age group scored 2.04 awareness points. A significant difference of 74%. Contributing factors to this difference can be educational campaigns that are performed at schools around Bali. Organizations such as Eco-Bali perform such programs, as is shown in Interview C.3. Also the high amount of university students in the young age group possibly results in a greater understanding of the plastic pollution problem.

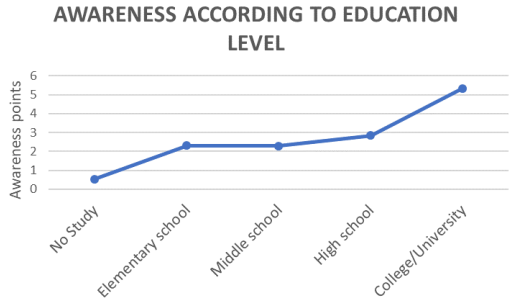
When looking at motivation points the young age group has an average score of 4.74, whereas the old age group scores 3.27 on average. A significant difference of 45%. As the young age group is significantly more aware they are possibly also more motivated to contribute to reducing the plastic pollution problem.

Following up, the effects of education levels on awareness and motivation scores was assessed. In Figure 9.6 (a) the development of the awareness score is shown as the education level increases. Subjects that did not have any study background had on average an awareness score of 0.55, which is 82.51% lower than the general average. As can be seen from the figure, higher education levels have higher awareness scores. With college/university degree subjects scoring on average 5.34 points, which is 71.41% higher than the general average. As expected a higher education level results in a better understanding of the plastic pollution problem.

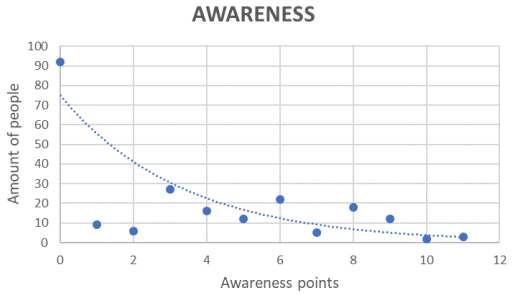
The same approach was taken for the motivational score. In Figure 9.6 (c) the development of the average motivation score according to the education level is shown. Surprisingly, subjects that did not endure a study level scored relatively high with an average of 5 points. A possible explanation is the low data pool that is available among people with no study background, which contains 11 subjects. Subjects with an elementary school background score the lowest with an average of 2.69 points, scoring 37.32% below average. Individuals with a college or university background score on average 6.52 points, which is performing 51.87% above average. This is expected as increased awareness along higher education levels triggers an increased motivation.

In order to better understanding how the subjects performed Figure 9.6 (b) was created. Here the awareness distribution is shown together with a trend line. From this figure it is clear that most of the subjects score around zero, constituting of over 90 people, and this drops for higher scores.

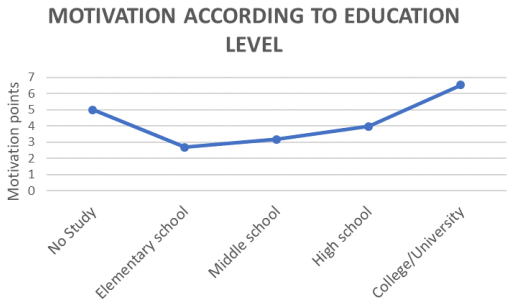
In Figure 9.6 (d) the motivation distribution is shown. Most people have a motivation score of 5. Interestingly, no subject has scored 0 motivation points.



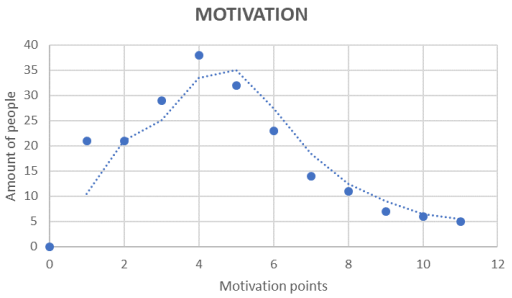
(a) Graph of the average awareness points scored according to the education level



(b) Graph of the awareness distribution



(c) Graph of the average motivation points scored according to the education level



(d) Graph of the motivation distribution

Figure 9.6: Awareness and motivation graphs from the survey

9.3.2. WILLINGNESS TO PAY

In Appendix B shows that around 46% of the subjects are not willing to pay for an improvement in their waste handling. Figure 9.7 shows the willingness to pay distribution, which indicates most people do not want to pay and those that are willing to pay generally pay low amounts. Around 80% of the subjects do not want to pay more than 40000 rupiah on a monthly basis. With an average wage of 2 297 968 rupiah [52] in Bali this only accounts for 1.74% of the average salary. This is quite low and shows that their is almost no willingness to pay for an improvement on waste management.

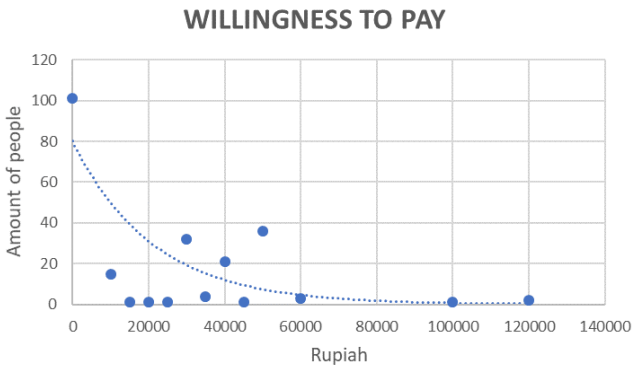


Figure 9.7: Willingness to pay distribution

9.4. EVALUATION

During research about the waste disposal, attitude towards waste, and waste management on Bali we encountered some challenges which are valuable to be aware of in case of a further or similar research. These experiences are summarized in this Chapter.

- During meetings with governmental institutes it became clear that their data on waste generation, waste composition and waste that ends up on their landfills are not very accurate. The main reason for this is that they only have just started with monitoring these amounts. Furthermore, the differences in budgets per regency for monitoring lead to differences in accuracy.
- At the start of the research, institutes were mainly contacted through mail. However, responses were either delayed or never arrived. This is due to the fact that in Bali contact is mainly made through cell phones.
- Some institutes are distant towards providing data and information, as they see their findings as something of value.
- During the survey it was difficult to communicate the survey to locals, as a lot of locals are not able to read Bahasa or understand English. As a solution several individuals were hired who were able to communicate with locals and explain the survey questions.
- The survey was constructed in English, when it was translated to Bahasa, some questions did not make sense to people. Therefore, it is important that the survey is checked by a native speaker to see if the questions are still coherent. Also check if the survey is not offensive towards local culture.

10

Conceptual Model Results

10.1. Final conceptual model

Every element in the conceptual model has been investigated and the connection between all these elements will be analyzed in this Chapter. The results are summarized in the conceptual model that has been introduced in Chapter 4. Two conditions have occurred during the measurement period of the team: The dry condition and the first flood event. Figure 10.1 presents the final outcome of the model for the dry conditions and Figure 10.2 for the first flood event. The arrows in the models are presented in kilograms of plastic per day. Both models endure the same wind conditions. The direction of the wind was predominantly from the Southeast. This direction is typical for the transitional season as discussed in Chapter 4. West monsoon conditions haven't occurred during the measurement, therefore no results during this season are available. As a consequence the conceptual model isn't applicable for the West monsoon season. However, it was possible to create an area overview of the main drivers and plastic flows for both seasons without quantifications, namely the transitional and West monsoon season. These Figures are presented in Appendix E.

10.2. Model remarks

After introduction of the conceptual model in Chapter 4 some adjustments were made along the way. As not all components could be researched within the scope of the project.

Trash disposal rivers Java

As no data is available on waste management in Java, estimates could not be made on the amount of plastic waste that is mismanaged in this area. Therefore this value is unknown.

River input Bali to ocean and beaches

During the beach measurements also the effect of local rivers was analyzed. This has resulted in a new arrow in the final conceptual model. The river input from Bali splits of in a part that ends up in the ocean and a part that ends on the beaches. The calculation is based on the data received from Section 8.3. Here a calculation was made on the accumulation of plastic waste on the beach as a result of direct river input. The rest of the plastic flow from the river is assumed to enter the ocean. For rivers from Java it is assumed that all of the plastic flows into the ocean as little data is available on local beach accumulation.

North boundary

The North boundary is not taken into account as this area is relatively small and therefore has limited impact. Also Prof. Hendrawan stated negligible amounts of litter would enter through the Bali Strait. Furthermore, during the transitional season it is hard to specify the residual flows, as is discussed in Chapter 6. The boundary is thus considered to be a neutral element and is therefore not displayed in the model.

Bottom

Bottom interaction is considered to have minimal impact and is not taken into account into the revised model as described in Chapter 6.

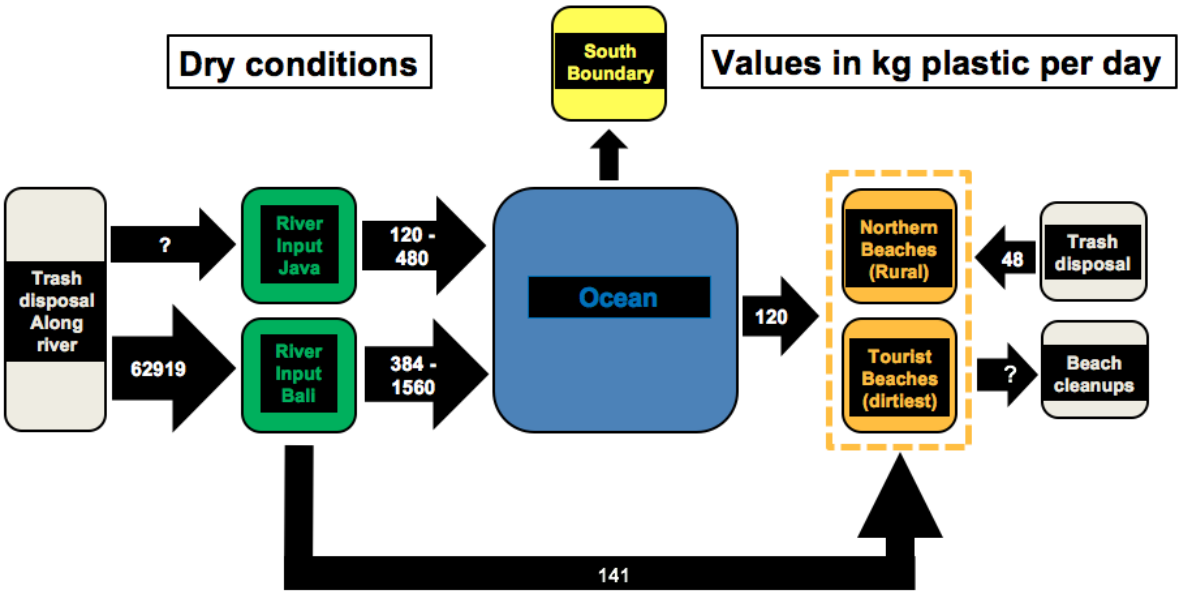


Figure 10.1: Conceptual model during dry conditions in the Transitional season

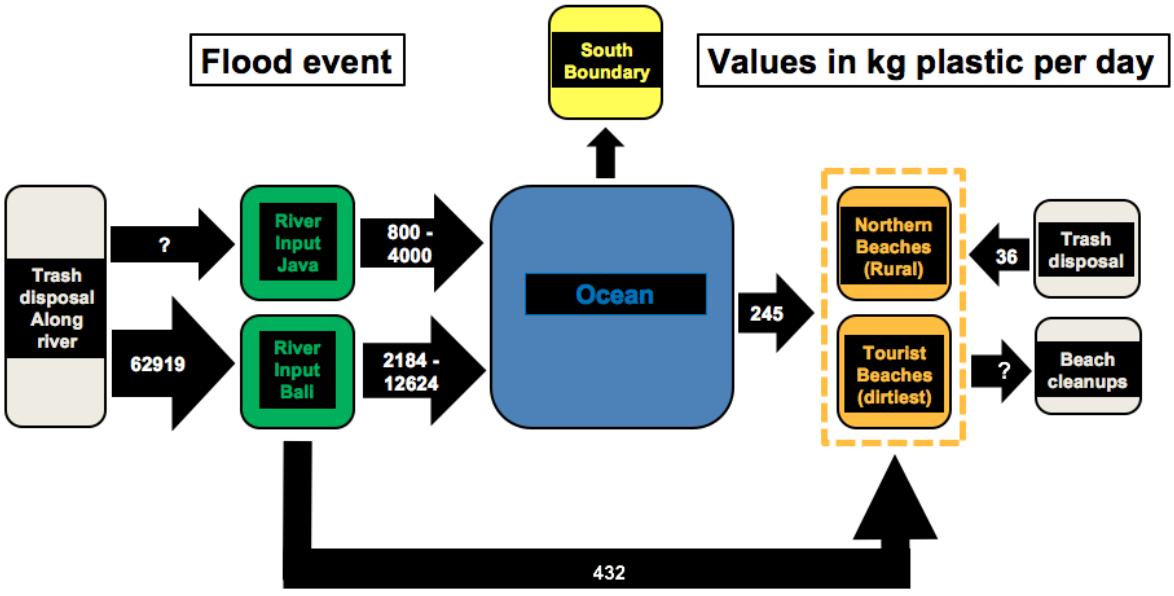


Figure 10.2: Conceptual model during a flood event in the Transitional season

BEACH CLEANUPS

Various beach cleanup initiatives were contacted, as well as governmental facilities and organizations that are involved in processing waste from the beach cleanups, in hopes to retrieve data on this matter. However, little to no data is recorded and therefore no estimates could be made on the amount of plastic that is cleaned from the beaches per day.

10.2.1. SUGGESTED RELATIONS

TRASH DISPOSED ALONG THE RIVER COMPARED TO DRY RIVER TRANSPORT

It is estimated that during dry conditions 62 919 kilograms of plastic gets disposed daily along rivers in Bali. However only a small amount, between 525 - 1801 kilograms per day, is transported into the ocean or beaches. This low conversion is due to the limited rainfall during the dry season. As the rivers are relatively shallow and the discharge is quite low a lot of waste remains on the riverbanks, where it slowly accumulates over time.

INCREASED PLASTIC TRANSPORT IN RIVERS DURING FLOOD EVENT

During the flood event a significant increase in plastic transported is observed. As the water depth and discharge increases, accumulated waste on the riverbanks and riverbed start to interact with the river and is eventually taken by the river, which transports waste downstream towards the ocean. However, still a large quantity of disposed trash along rivers in Bali is not involved in the transport.

LOW PLASTIC TRANSPORT FROM OCEAN TO BEACH

Figure 10.1 shows relatively large amounts of plastic enter the ocean, but a significant smaller amount then gets transported to the beaches. This is due to the wind conditions during the transitional season. The wind is predominantly from the Southeast, see Figure 8.5. During the West monsoon the wind will be coming from the West. It is expected that ocean inputs will rise significantly during this period.

DIRECT BEACH ACCUMULATION BY RIVERS

During dry conditions between 8-27 percent of the plastic transport in rivers is accumulating directly on local beaches. This percentage has decreased during the observed flood event to 3-17 percent. This reduction could be caused by increased flow conditions. More forcing is involved and therefore waste gets spewed deeper into the ocean. Together with the Southeast wind conditions it becomes more difficult for waste to travel back towards the beach.

11

Conclusion and Recommendation

11.1. Conclusion

In Chapter 2 our research questions were outlined. This section is dedicated to answer those research questions based on our findings.

What are the main drivers for the plastic waste accumulation in the Southwest of Bali?

A conceptual model is created to identify the main drivers for plastic accumulation at the beaches in the Southwest of Bali. The main outcomes are large quantities of trash in the environment throughout the year and even larger inputs of plastics via rivers into the ocean during the large rain events. Meteorological properties are then an important factor in further distribution of these plastics.
Bali experiences two seasons, a transitional season and the West monsoon season. Generally, these seasons collide with the dry season between April and October and the rainy season between November and March respectively. Increased precipitation and a predominating wind direction from the West are experienced during the West monsoon season. Wind predominantly from the Southeast combined with hardly any precipitation is observed during the transitional season. An accumulation of land dumped waste is experienced in the environment of Bali during these dry conditions. When the rainy season begins, a lot of the accumulated waste in the environment, such as river banks, is flushed and will finally find its track to the bigger rivers. These rivers, in their turn, transport large quantities of (plastic) waste to the ocean. Wind is the main driver for the distribution of plastics inside the Bali Bay. As the prevailing wind is from West to East during the West monsoon, which often collides with the rainy season, the waste that ends up in the Bali Bay gets 'pushed' ashore by wind. Due to the geometry of Bali's coastline, currents near the coast bend towards the South. This is the reason why most of the waste eventually ends up at the popular tourist beaches in Bali.

What is the distribution and composition of plastic waste on Bali?

A great variety of plastics is found in Bali's rivers and beaches. Single use plastics such as plastic bags and packaging (LDPE and Multilayer plastics) are commonly found in Bali. The lifetime of these products are usually very short. High amounts of LDPE were found at popular beaches, where there is a lot of littering by tourists and local inhabitants. Rivers provide a large source of LDPE and Multilayer plastics. After rivers have flushed their waste in the ocean, only a small amount of LDPE returns to the beaches. Apparently large quantities of LDPE plastics remain in the ocean, sink to the bottom or leave the case area. This might shift during the West monsoon. Plastic input from the ocean largely consisted of PS/PP and Multilayer plastics. The increase in PS/PP is a result of fishermen who dispose a lot of Styrofoam in the ocean. Overall very little PET was found in the environment. Many locals are involved in collecting PET as they can be exchanged at recycle facilities for a small fee.

How does the waste management system in Bali currently look like and is the system lacking?

The governmental autonomy in Bali is at the regional level. This means that every regency has their own budget, and they decide what expenses are being made with this budget. This budget consists of two parts; one part is money received from the national government, and the other part results from local income. The local income mainly consists of local taxes payed in the regency. This causes large variations between regencies as the more rural areas enjoy less tourism and therefore their income on local taxes is much smaller than in urban areas.

Bali can be divided into 9 regencies and every regency has its own DLHK, a governmental institute who manages the local waste facilities within their regency. Rural regencies tend to have a more lacking system in terms of waste management, simply because they have less money available. But it is not only the rural areas that lack in quality. All over the island, both in rural and urban areas, many uncontrolled dumping sites have been encountered. In the past, Balinese inhabitants were using mainly organic material and banana leaves were used for wrapping food instead of plastic packaging. Inhabitants would throw everything away as it only consisted of degradable material. Nowadays, some locals kept the same habit, while most of their trash is not degradable anymore, resulting in accumulation of waste in nature.
The amount of solid waste in Bali has exponentially increased over the last decade. This has increased the difficulties concerning the establishment and management of proper waste systems. On top of that, they have relatively little expertise about waste handling. So in order to improve the waste management systems in Bali, 3 main challenges can be specified:

- Limited budget
- Low expertise
- Social attitude towards littering

ARE LOCALS AWARE OF PLASTIC POLLUTION IN BALI AND ARE THEY MOTIVATED TO IMPROVE ON THE MATTER?

A survey is conducted to provide insight on personal waste management of local inhabitants, their awareness of the problem and their motivation. As shown in this survey most subjects understand that plastics have a negative impact on the environment, but often are not willing to act accordingly as separation of waste barely occurs. A main concern is the lack of understanding of local waste management. Many of the subjects do not realize that large quantities of their waste end up in the ocean and eventually the beaches. As a result there is a lack of motivation to improve on the matter. Most subjects are barely willing to pay for an improvement in their waste management. On the other hand Balinese people have great (personal and/or financial) issues and therefore plastic pollution isn't high on their agenda. This is very comprehensible as Indonesia is still classified as a lower middle income economy and is relatively new to large scale plastic usage. However, it was found that higher educated subject had a significant higher level of awareness and motivation. Younger subjects are also more aware and motivated, as many educational programs on plastic pollution are recently held in schools. This shows an improvement on the local attitude towards plastic pollution for future generations.

WHICH EFFICIENT SOLUTIONS CAN BE PROVIDED TO MITIGATE PLASTIC POLLUTION?

Four solutions are proposed to efficiently improve the plastic problem in Bali.

Interception from rivers
The high concentrations of plastic waste in Bali's rivers indicates the possibility of engineering solutions to mitigate marine plastic littering, and prevent that these plastics end up on Bali's beaches. It will be most efficient to trap and collect litters at locations with high distributions. However, this also has some risks. First of all, large quantities of debris, including organic, plastic and rest waste, are experienced during flood events. These could damage the structure or, even worse, form a blockade in the river, forcing the river to flood its banks. Secondly, fish and other living organisms could be hindered by the system. Studies on the type of structure, mesh size, structural strength, duration and timing for trapping litter, and costs are required for designing catchment devices in the river. Social costs should also be considered as many locals earn a living from waste collection activities.

Improving waste management
On different levels of the waste management system (from household storage to disposal facilities) improvements can be implemented. Actively involving local residence is an essential step to establish solutions that fit into Bali's society.
It has been identified that the budget framework for waste management systems is unequally distributed over the regions in Bali. Insufficient resources are available in the more rural areas and more financial support from the National government could improve situations in this area. This should be combined with activities to change the mindset of locals towards waste disposal.
There are a lot of NGO's involved in reducing plastic pollution, and many of them are significantly contributing to improvements in the waste system. Yet, they are mainly acting on their own and the know-how and experience is seldom communicated and transferred to others with similar responsibilities and/or goals. Better

collaboration between these institutes could not only result in more efficiency but could also reach out to a larger public.

Education
Anti plastic initiatives and awareness messages are found quite often in Bali. However, often these programs are focused on tourists in order to communicate a pro-active message. The intent is good but the problem is addressed towards the wrong group. In order to reach locals more efficiently, a regional awareness campaign focused on locals is required, in the native language. From the survey results we observed that higher educated subjects performed better on awareness and motivation scores. Therefore an organized education program should be provided in schools to teach kids about waste and plastic from a young age. Currently some NGO's like Eco-Bali and ByeByePlasticBags organize small scale education programs to teach kids about plastic pollution. This should however become a standard part of every kids' education in Indonesia, especially in remote areas where waste management is lacking the most.

Communication and combined goal
Restaurant owners, beach clubs and locals all suffer economically as tourist income decreases due to plastic pollution. Besides that, negative impacts on the environment and public health are of great concern as we are still in the dark on many consequences. This has resulted in a wide variety of groups being actively involved in beach cleanups, awareness programs and recycling initiatives. However, after many interviews with various stakeholders such as governmental institutions, recycle organizations, beach cleanups, restaurant owners, beach club owners, locals and universities it became clear that most of the parties involved barely communicate with one another. Also they aren't working together efficiently in the search for an actual solution for the problem. A lot of organizations clean up beaches regularly, but do so without giving a notice to other parties or recording data. Obviously this is not an efficient approach and does not tackle the problem at its source.
In order to prevent the necessity of daily beach cleanups in the future, an organized communication network is required along which various stakeholders can exchange information and work towards a common goal. In this way the critical beaches can be designated and a prediction can be handed out on the severity of plastic washing ashore, based on wind and rain data.
Beach cleanup initiatives and the hotel and restaurant industry could then organize a shared schedule, in which every beach cleanup and its initiator is indicated on a certain beach stretch. This prevents double work which currently happens frequently and costs money and time. Then data of the beaches should be recorded, collected and analyzed. This results in large scale data collection in an effective manner with all stakeholders working towards a common goal. However, it seems very unlikely that all these stakeholders would cooperate so intensively on short notice. Therefore it would be very helpful if there would be an organized framework initiated by a 3rd party which has enough authority to establish and monitor the activities.

11.2. RECOMMENDATIONS

To better understand how the plastic pollution in Bali works and to get this problem under control a lot more extensive research is required. During two months we stayed in Bali, we have gathered a lot of data and knowledge about the problem such as the waste management system, governance structure, social attitude and real-time amounts of waste. However, designing an actual solution requires much more time. A short summary of recommendations for follow up studies and activities are given below.

- A big factor in the plastic pollution problem is the lack of waste management. More research on possible solutions that improve waste collection rates, recycling and reduction of plastic usage are advised.
- During fieldwork trips we found a lot of plastic wrappings of sweets that are put into Hindu offerings. These offerings are put on sacred statues and temples, but also on bridge crossings and streets. A lot of these offerings end up in the environment. By replacing these plastic sweets, the offerings would be fully organic which at least prevents these sweets ending up in nature.
- Another remarkable thing was how many single-use plastic bags are used daily in Bali. If one would buy a pack of gum, every cashier would either put it in a plastic bag or ask if you'd want one. The ease of giving out a plastic single-use bag should therefore become less convenient. For instance by putting a tax on these bags, as has happened in The Netherlands.
- In order to design a catchment device that intercepts plastics from the river, research on the type of structure, mesh size, structural strength, duration and timing for trapping litter, and projected costs

are required. Denpasar already has three of these structures in a channeled river but their design and functionality are questionable.

- This research provides data on the waste flow in the case area during dry conditions and a single flood event. In order to better understand the effects of the change in wind direction from South-East to Westerly wind, and the increase in rain conditions it is advised to perform similar measurements research during the west monsoon.
- Further research must be performed on beaches along the entire Southwest coast to quantify the ratio between accumulation of (plastic) waste in the Southwest and more Northern beaches of Bali.
- More research is also required on how the waste composition changes between rural, urban and river beaches as the wind changes during the West monsoon. Research could indicate whether more wind driven plastics are observed after this shift.

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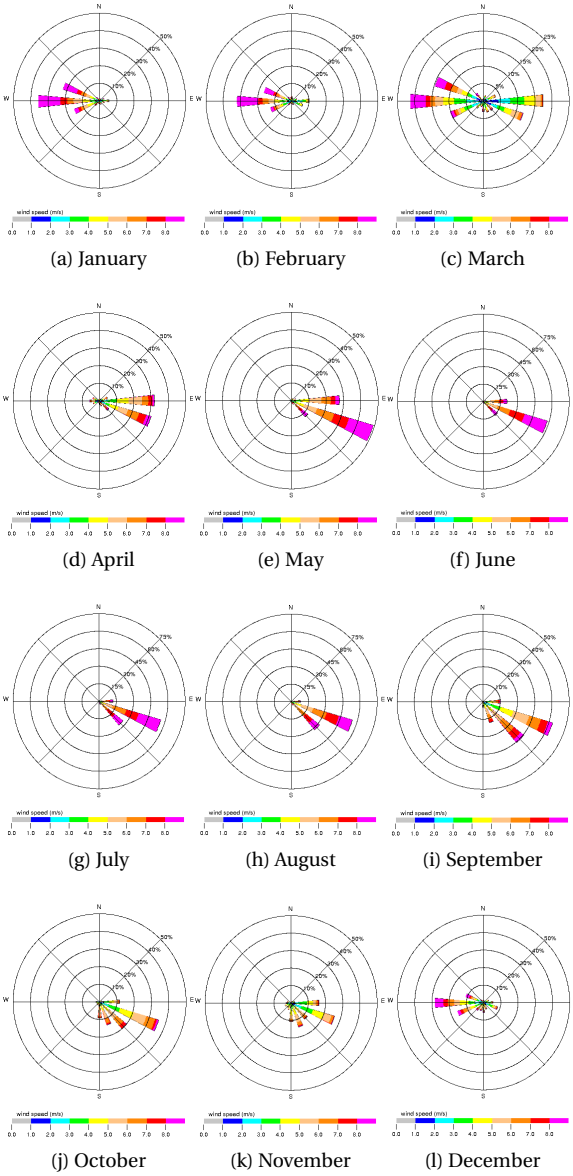
A

DATA

A.1. WIND DATA



(a) January (b) February (c) March

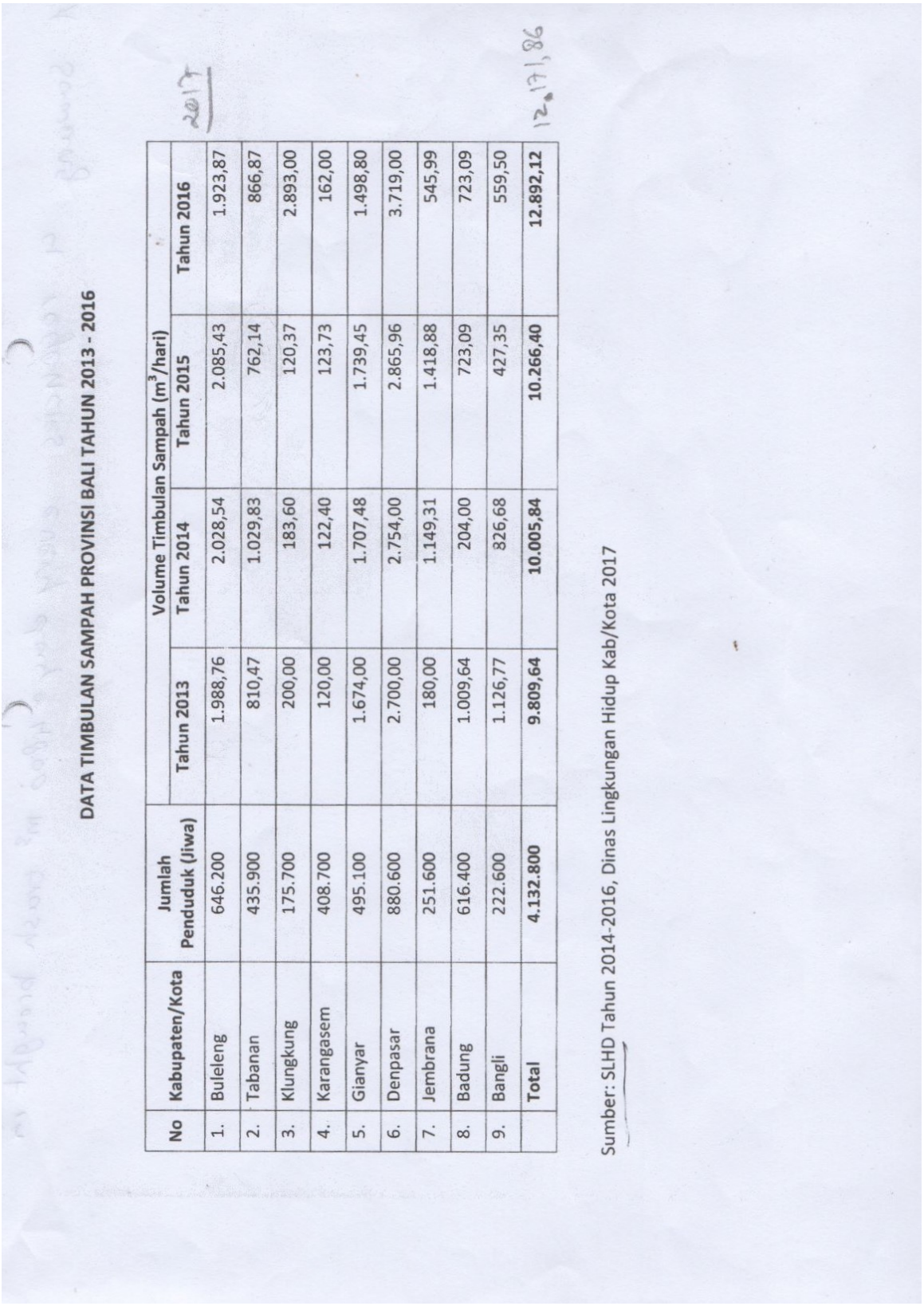
(d) April (e) May (f) June

(g) July (h) August (i) September

(j) October (k) November (l) December

Figure A.1: The wind roses for each month of the year by using the data of wave-climate.com

A.2. NUMBERS REGARDING WASTE MANAGEMENT

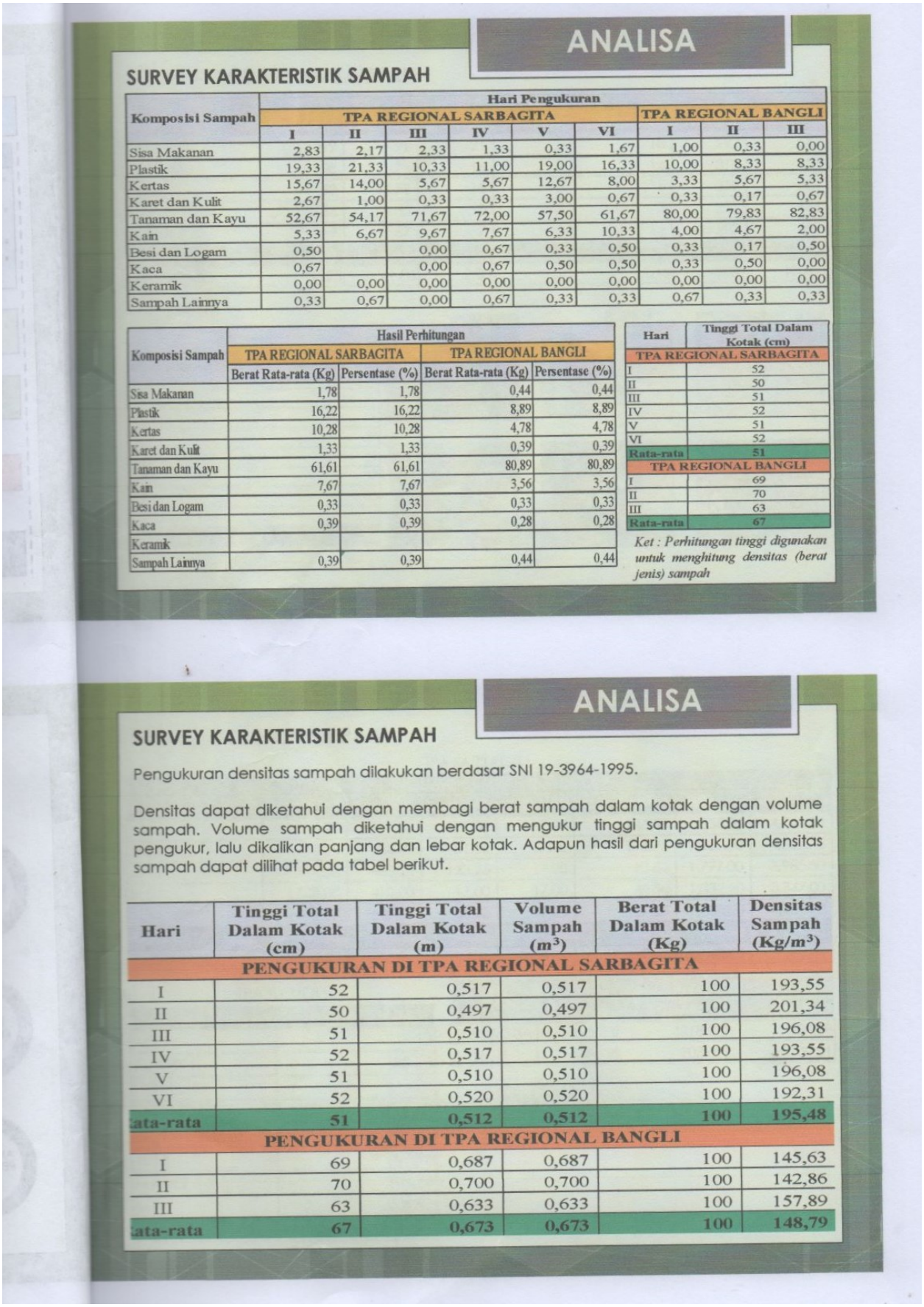


DATA TIMBULAN SAMPAH PROVINSI BALI TAHUN 2013 - 2016

No	Kabupaten/Kota	Jumlah Penduduk (Jiwa)	Volume Timbulan Sampah (m^3/hari)			
			Tahun 2013	Tahun 2014	Tahun 2015	Tahun 2016
1.	Buleleng	646.200	1.988,76	2.028,54	2.085,43	1.923,87
2.	Tabanan	435.900	810,47	1.029,83	762,14	866,87
3.	Klungkung	175.700	200,00	183,60	120,37	2.893,00
4.	Karangasem	408.700	120,00	122,40	123,73	162,00
5.	Gianyar	495.100	1.674,00	1.707,48	1.739,45	1.498,80
6.	Denpasar	880.600	2.700,00	2.754,00	2.865,96	3.719,00
7.	Jembrana	251.600	180,00	1.149,31	1.418,88	545,99
8.	Badung	616.400	1.009,64	204,00	723,09	723,09
9.	Bangli	222.600	1.126,77	826,68	427,35	559,50
	Total	**4.132.800**	**9.809,64**	**10.005,84**	**10.266,40**	**12.892,12**

Sumber: SLHD Tahun 2014-2016, Dinas Lingkungan Hidup Kab/Kota 2017

Figure A.2: Waste generation data per regency in Bali, provided by DLHK



ANALISA

SURVEY KARAKTERISTIK SAMPAH

Komposisi Sampah	Hari Pengukuran								
	TPA REGIONAL SARBAGITA						TPA REGIONAL BANGLI		
	I	II	III	IV	V	VI	I	II	III
Sisa Makanan	2,83	2,17	2,33	1,33	0,33	1,67	1,00	0,33	0,00
Plastik	19,33	21,33	10,33	11,00	19,00	16,33	10,00	8,33	8,33
Kertas	15,67	14,00	5,67	5,67	12,67	8,00	3,33	5,67	5,33
Karet dan Kulit	2,67	1,00	0,33	0,33	3,00	0,67	0,33	0,17	0,67
Tanaman dan Kayu	52,67	54,17	71,67	72,00	57,50	61,67	80,00	79,83	82,83
Kain	5,33	6,67	9,67	7,67	6,33	10,33	4,00	4,67	2,00
Besi dan Logam	0,50		0,00	0,67	0,33	0,50	0,33	0,17	0,50
Kaca	0,67		0,00	0,67	0,50	0,50	0,33	0,50	0,00
Keramik	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Sampah Lainnya	0,33	0,67	0,00	0,67	0,33	0,33	0,67	0,33	0,33

Komposisi Sampah	Hasil Perhitungan			
	TPA REGIONAL SARBAGITA		TPA REGIONAL BANGLI	
	Berat Rata-rata (Kg)	Persentase (%)	Berat Rata-rata (Kg)	Persentase (%)
Sisa Makanan	1,78	1,78	0,44	0,44
Plastik	16,22	16,22	8,89	8,89
Kertas	10,28	10,28	4,78	4,78
Karet dan Kulit	1,33	1,33	0,39	0,39
Tanaman dan Kayu	61,61	61,61	80,89	80,89
Kain	7,67	7,67	3,56	3,56
Besi dan Logam	0,33	0,33	0,33	0,33
Kaca	0,39	0,39	0,28	0,28
Keramik				
Sampah Lainnya	0,39	0,39	0,44	0,44

Hari	Tinggi Total Dalam Kotak (cm)
TPA REGIONAL SARBAGITA	
I	52
II	50
III	51
IV	52
V	51
VI	52
Rata-rata	51
TPA REGIONAL BANGLI	
I	69
II	70
III	63
Rata-rata	67

Ket : Perhitungan tinggi digunakan untuk menghitung densitas (berat jenis) sampah

ANALISA

SURVEY KARAKTERISTIK SAMPAH

Pengukuran densitas sampah dilakukan berdasar SNI 19-3964-1995.

Densitas dapat diketahui dengan membagi berat sampah dalam kotak dengan volume sampah. Volume sampah diketahui dengan mengukur tinggi sampah dalam kotak pengukur, lalu dikalikan panjang dan lebar kotak. Adapun hasil dari pengukuran densitas sampah dapat dilihat pada tabel berikut.

Hari	Tinggi Total Dalam Kotak (cm)	Tinggi Total Dalam Kotak (m)	Volume Sampah (m^3)	Berat Total Dalam Kotak (Kg)	Densitas Sampah (Kg/m^3)
PENGUKURAN DI TPA REGIONAL SARBAGITA					
I	52	0,517	0,517	100	193,55
II	50	0,497	0,497	100	201,34
III	51	0,510	0,510	100	196,08
IV	52	0,517	0,517	100	193,55
V	51	0,510	0,510	100	196,08
VI	52	0,520	0,520	100	192,31
ata-rata	51	0,512	0,512	100	195,48
PENGUKURAN DI TPA REGIONAL BANGLI					
I	69	0,687	0,687	100	145,63
II	70	0,700	0,700	100	142,86
III	63	0,633	0,633	100	157,89
ata-rata	67	0,673	0,673	100	148,79

Figure A.3: Waste composition [17]

A.3. RIVER SURVEYS

A.3.1. PLASTIC RESULTS

Net:	Single	Loc.	1	Primary waste sorting						Secondary plastic sorting												
Date	Time	Length [min]	U [m/s]	Plastic		Organic		Rest		PET		PP / PS		HDPE (hard)			LDPE (soft)			Multilayer			Comments
				kg	cm^3	kg	cm^3	kg	cm^3	#	kg	#	kg	#	kg	cm^3	#	kg	cm^3	#	kg	cm^3	
21/09/2018	12:55	60	0.11			0.065																	
	14:03	62	0.11			0.045																	
03/10/2018	10:43	30	0.12			0.86																	Groot stuk palmboom in trawl
	11:20	60	0.12			0.1																	
16/10/2018	11:11	60	0.1			0.045																	
31/10/2018	09:04	54	0.12			0.085																	
	10:03	44	0.05			0.02																	groot stuk hout uit trawl gevallen
07/10/2018	09:03	3	?	0.765		12.61				4	0.048	23	0.054	8	0.08		19	0.105		15	0.061		extreme regenval
TOTAL		373	0.10429	0.765		13.83		0		4	0.05	23	0.054	8	0.08		19	0.105		15	0.061		
				5.24%		94.76%					13.79%		15.52%		22.99%			30.17%			17.53%		

Figure A.4: Plastic overview of location Pererenan

Net:	Single / Double	Loc 2		Primary waste sorting				Secondary plastic sorting												
Date, Trawl	Time	Length [min]	U [m/s]	Plastic	Organic		Rest	PET		PP / PS		HDPE (hard)		LDPE (soft)			Multilayer		Comments
				kg	kg	cm^3	kg	#	kg	#	kg	#	kg	#	kg	cm^3	#	kg	
28/09/2018	12:54	70	0.04	0.08	0.41		0.71							6	0.01				
	14:16	56	0.04	0.06	0.10		0.02							3	0.00		1	0.00	
04/10/2018	12:29	60	0.04	0.00	0.03		0.00							1	0.00				
	13:36	62	0.04	0.12	0.04		0.00			1	0.00			2	0.00		1	0.00	
18/10/2018	15:05	58	0.03	0.01	0.00		0.00			1	0.00						1	0.00	
31/10/2018	14:00	67	0.03	0.00	0.08		0.00										1	0.00	
07/11/2018	13:03	30	0.44	0.36	0.25		0.00	1.00	0.01	11	0.09			29	0.08		9	0.00	
	13:43	30	0.54	1.10	1.03		0.00	1.00	0.00	13	0.01	2	0.02	64	0.10		31	0.07	
	14:32	30	0.52	0.36	0.78		0.00			4	0.00			29	0.13		29	0.06	
			0.50																
TOTAL	single	463		2.09	2.71	0.00	0.73	2.00	0.01	30.00	0.10	2.00	0.02	134.00	0.31	0.00	73.00	0.14	
				37.83%	49.03%		13.14%		1.7%		17.3%		4.1%		53.3%			23.6%	

Figure A.5: Plastic overview of location Berawa

Net:	Single / Double	Loc 2		Primary waste sorting				Secondary plastic sorting												
Date, Trawl	Time	Length [min]	U [m/s]	Plastic	Organic		Rest	PET		PP / PS		HDPE (hard)		LDPE (soft)			Multilayer		Comments
				kg	kg	cm^3	kg	#	kg	#	kg	#	kg	#	kg	cm^3	#	kg	
25/09/2018	11:50	15	0.13	0.00	0.05	0.00								3	0.00				
	12:16	15	0.13	0.00	0.09	0.00								1	0.00		1	0.00	
	12:44	15	0.13	0.02	0.13	0.00								3	0.01		2	0.00	
	13:07	15	0.13	0.14	0.51	0.00								13	0.01		1	0.00	stuk hout in trawl
	13:32	21	0.13	0.00	0.07	0.00											1	0.00	
05/10/2018	11:14	22	0.13	0.00	0.21	0.00								1	0.00				
	11:52	20	0.13	0.00	0.14	0.00													
	12:25	21	0.13	0.00	0.14	0.00													
18/10/2018	09:10	46	0.11	0.00	0.30	0.00								1	0.00				
	10:04	37	0.11	0.02	0.24	0.00	0.00							3	0.00		2	0.01	
02/11/2018	11:41	60	0.11	0.04	0.10	0.00	0							1	0.01				
06/11/2018	11:34	20	0.48	0.13	0.40					2	0.00			15	0.05		9	0.02	
	12:04	20	0.48	0.18	0.33			1.00	0.00					22	0.05		14	0.01	
	12:34	20	0.81	0.033	0.23		0.09			4	0.01			18	0.01		3	0.00	
	13:05	20	0.96	0.30	2.15					9	0.02	3	0.08	14	0.02		5	0.01	
			0.12																
			0.6825																
TOTAL	single	367	4.1	0.871	5.052	0	0.089	1	0.002	15	0.03	3	0.08	95	0.162	0	38	0.054	
TOTAL	double	0		0.00	0.00		0.00	0	0	0	0.0	0	0.00	0	0.00		0	0.00	
				14.49%	84.03%		1.48%		0.6%		9.5%		23.4%		49.8%			16.6%	

Figure A.6: Plastic overview of location Sudimara

A.3.2. RIVER PARAMETERS

Waterdepth

Perrenan	Date	point on bridge [m]	0	1	3	5	7	9	11	13	14
1	21/09/2018	Water depth[m]	0	-0.9	-1.8	-1.8	-1	-1.1	-0.7	-0.5	0
2	03/10/2018	Water depth[m]	0	-1.3	-1.6	-1.4	-0.8	-1.1	-0.7	-0.4	0
3	16/10/2018	Water depth[m]	0	-1.1	-1.5	-1.6	-0.7	-1	-0.6	-0.5	0
4	31/10/2018	Water depth[m]	0	-0.8	-1.9	-1.9	-1.1	-1.4	-0.8	-0.7	0
5	07/10/2018	Water depth[m]	Not possible to measure due to extreme conditions, approximately 1 meter water increase								

Laguna	Date	point on bridge [m]	8	10	14	18	22	26	30	34	38	42	44
1	28/09/2018	Water depth[m]	0	-0.8	-1	-0.9	-0.9	-0.9	-1	-1	-1	-1	0
2	04/10/2018	Water depth[m]	0	-0.6	-1	-0.7	-0.6	-0.9	-0.7	-0.8	-0.7	-0.7	0
3	18/10/2018	Water depth[m]	0	-0.5	-0.8	-0.7	-0.6	-0.8	-0.7	-0.8	-0.8	-1	0
4	31/10/2018	Water depth[m]	0	-0.4	-0.7	-0.7	-0.7	-0.8	-0.7	-1	-0.9	-0.9	0
5	07/10/2018	Water depth[m]	0	-0.9	-1.2	-1.1	-1	-1	-0.9	-0.9	-0.9	-1	0

Tanah Lot	Date	point on bridge [m]	6	7	9	11	13	15	17	19	21	23	24
1	25/09/2018	Water depth[m]	0	-1.1	-1.2	-1.6	-1.9	-1.4	-1.2	-0.7	0	0	0
2	05/10/2018	Water depth[m]	0	-0.9	-1.3	-1.5	-1.3	-1.1	-1.1	-0.7	0	0	0
3	18/10/2018	Water depth[m]	0	-0.9	-1.1	-1.5	-1.8	-1.2	-1.1	-0.7	0	0	0
4	02/11/2018	Water depth[m]	0	-1	-1.2	-1.5	-1.8	-1.2	-1.1	-0.7	0	0	0
5	06/10/2018	Water depth[m]	0	-1.4	-2.4	-2.8	-3	-2.4	-1.8	-1.4	-0.5	-0.1	0

Figure A.7: Overview water depth rivers

Cross section

Perrenan	Date	ML	1	2	3	4	5	6	7
1	21/09/2018	Surface[m2]	1.8	3.15	3.2	2.45	1.95	1.5	0.85
2	03/10/2018	Surface[m2]	2.1	2.95	2.6	2.05	1.85	1.45	0.75
3	16/10/2018	Surface[m2]	1.85	2.85	2.7	2	1.65	1.35	0.8
4	31/10/2018	Surface[m2]	1.75	3.25	3.4	2.75	2.35	1.85	1.1
5	07/10/2018	Surface[m2]	Not possible to measure due to extreme conditions, approximately 1 meter water increase						

Laguna	Date	ML	1	2	3	4	5	6	7	8	9
1	28/09/2018	Surface[m2]	2.6	3.7	3.7	3.6	3.7	3.9	4	4	3
2	04/10/2018	Surface[m2]	2.2	3.3	3	2.8	3.1	3.1	3	2.9	2.1
3	18/10/2018	Surface[m2]	1.8	2.8	2.8	2.7	2.9	3	3.1	3.4	2.8
4	31/10/2018	Surface[m2]	1.5	2.5	2.8	2.9	3	3.2	3.6	3.7	2.7
5	07/10/2018	Surface[m2]	3	4.4	4.4	4.1	3.9	3.7	3.6	3.7	2.9

Tanah Lot	Date	ML	1	2	3	4	5	6	7	8	9
1	25/09/2018	Surface[m2]	1.7	2.55	3.15	3.4	2.95	2.25	1.65		
2	05/10/2018	Surface[m2]	1.55	2.5	2.8	2.6	2.3	2	1.6		
3	18/10/2018	Surface[m2]	1.45	2.3	2.95	3.15	2.65	2.05	1.6		
4	02/11/2018	Surface[m2]	1.6	2.45	3	3.15	2.65	2.05	1.6		
5	06/10/2018	Surface[m2]	2.6	4.5	5.5	5.6	4.8	3.7	2.55	1.25	0.35

Figure A.8: Overview Cross section rivers

Velocity

Perrenan	Date	ML	1	2	3	4	5	6	7
1	21/09/2018	Surface[m2]	0.07	0.10	0.11	0.03	0.00	0.00	0.00
2	03/10/2018	Surface[m2]	0.09	0.12	0.11	0.01	0.00	0.00	0.00
3	16/10/2018	Surface[m2]	0.06	0.10	0.09	0.00	0.00	0.00	0.00
4	31/10/2018	Surface[m2]	0.05	0.12	0.13	0.03	0.05	0.00	0.00
5	07/10/2018	Surface[m2]	Not possible to measure due to extreme conditions, approximately 1 meter water increase						

Laguna	Date	ML	1	2	3	4	5	6	7	8	9
1	28/09/2018	Surface[m2]	0.028	0.0375	0.034	0.044	0.041	0.044	0.0505	0.0505	0.041
2	04/10/2018	Surface[m2]	0	0.031	0.041	0.034	0.041	0.0375	0.0405	0.0375	0.034
3	18/10/2018	Surface[m2]	0.03	0.04	0.03	0.04	0.04	0.04	0.05	0.05	0.04
4	31/10/2018	Surface[m2]	0	0.047	0	0.057	0.041	0	0.017	0.0375	0.0345
5	07/10/2018	Surface[m2]	0.202	0.596	0.099	0.543	0.5175	0.2675	0.318	0.0795	0.4425

Tanah Lot	Date	ML	1	2	3	4	5	6	7	8	9
1	25/09/2018	Surface[m2]	0.086	0.1275	0.031	0.0825	0.031	0.063	0.066		
2	05/10/2018	Surface[m2]	0.0955	0.1245	0.028	0.102	0.034	0.0535	0.044		
3	18/10/2018	Surface[m2]	0.0695	0.1085	0	0.0695	0.031	0.0535	0.0505		
4	02/11/2018	Surface[m2]	0.089	0.1055	0.014	0.0855	0.0475	0.0695	0.057		
5	06/10/2018	Surface[m2]	0.252	0.805	0.9145	0.958	0.6805	0.4835	0.2335	0.06	0

Figure A.9: Overview velocity rivers

Discharge

Perrenan	Date	ML	1	2	3	4	5	6	7	Total	
1	21/09/2018	Q[m3/s]	0.13	0.31	0.34	0.07	0.00	0.00	0.00	0.84	
2	03/10/2018	Q[m3/s]	0.19	0.37	0.28	0.03	0.00	0.00	0.00	0.86	
3	16/10/2018	Q[m3/s]	0.10	0.29	0.24	0.00	0.00	0.00	0.00	0.64	Average
4	31/10/2018	Q[m3/s]	0.08	0.38	0.43	0.09	0.12	0.00	0.00	1.11	0.86
5	07/10/2018	Q[m3/s]	Not possible to measure due to extreme conditions, approximately 1 meter water increase								

Laguna	Date	ML	1	2	3	4	5	6	7	8	9	Total	
1	28/09/2018	Q[m3/s]	0.07	0.14	0.13	0.16	0.15	0.17	0.20	0.20	0.12	1.35	
2	04/10/2018	Q[m3/s]	0.00	0.10	0.12	0.10	0.13	0.12	0.12	0.11	0.07	0.87	
3	18/10/2018	Q[m3/s]	0.05	0.11	0.10	0.12	0.12	0.13	0.16	0.17	0.11	1.06	average no rain
4	31/10/2018	Q[m3/s]	0.00	0.12	0.00	0.17	0.12	0.00	0.06	0.14	0.09	0.70	0.99
5	07/10/2018	Q[m3/s]	0.61	2.62	0.44	2.23	2.02	0.99	1.14	0.29	1.28	11.62	Rain

Tanah Lot	Date	ML	1	2	3	4	5	6	7	8	9	Total	
1	25/09/2018	Q[m3/s]	0.1462	0.325125	0.09765	0.2805	0.09145	0.14175	0.1089	0	0	1.19	
2	05/10/2018	Q[m3/s]	0.148025	0.31125	0.0784	0.2652	0.0782	0.107	0.0704	0	0	1.06	
3	18/10/2018	Q[m3/s]	0.100775	0.24955	0	0.218925	0.08215	0.109675	0.0808	0	0	0.84	average no rain
4	02/11/2018	Q[m3/s]	0.1424	0.258475	0.042	0.269325	0.125875	0.142475	0.0912	0	0	1.07	1.04
5	06/10/2018	Q[m3/s]	0.6552	3.6225	5.02975	5.3648	3.2664	1.78895	0.595425	0.075	0	20.40	Rain

Figure A.10: Overview discharge rivers

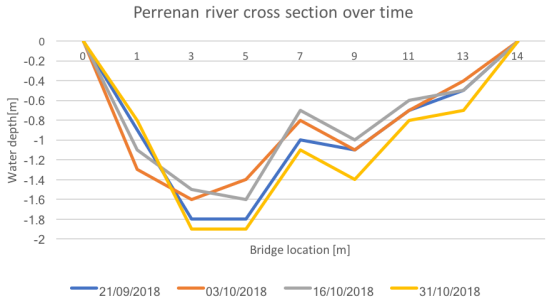


Figure A.11: graph of cross section over time Pererenan

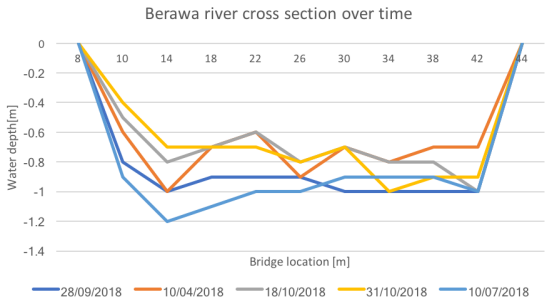


Figure A.12: graph of cross section over time Berawa

A.4. BEACH SURVEYS

A.4.1. SORTING OF WASTE

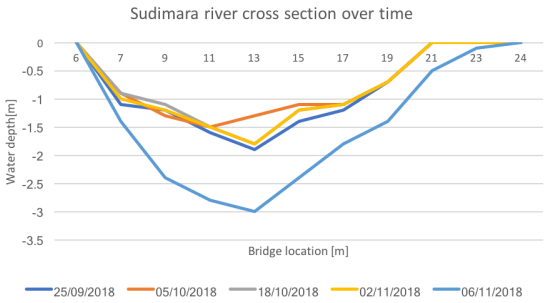


Figure A.13: graph of cross section over time Sudimara

Particle Counting

Perrenan	Date	ML	1	2	3	4	5	6	7	Total	
1	**21/09/2018**	Average #/2min	3.3	0.1	4.8	0.1	0.4	0.2	0.3	9.20	
2	**03/10/2018**	Average #/2min	4.89	3.56	1.11	0.11	0.56	0.56	0.00	10.78	
3	**16/10/2018**	Average #/2min	5.90	1.00	0.70	0.40	0.50	0.20	0.00	8.70	Average
4	**31/10/2018**	Average #/2min	5.31	3.06	2.38	0.38	0.31	0.38	0.13	11.94	10.15
5	**07/10/2018**	Average #/2min	Not possible to measure due to extreme conditions, approximately 1 meter water increase								

Laguna	Date	ML	1	2	3	4	5	6	7	8	9	**Total**	
1	**28/09/2018**	Average #/2min	0.25	5	4	4.75	3.75	3.5	7	15.50	12.50	56.25	
2	**04/10/2018**	Average #/2min	0.6	0.2	0.4	0.2	1.4	8.2	8.6	5.00	2.40	27.00	
3	**18/10/2018**	Average #/2min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	5.50	6.00	average no rain
4	**31/10/2018**	Average #/2min	0.10	0.00	1.80	1.40	0.50	1.80	4.60	5.40	5.20	20.80	27.51
5	**07/10/2018**	Average #/2min	17.40	81.60	21.80	134.40	77.80	109.80	60.00	43.80	45.60	592.20	Rain

Tanah Lot	Date	ML	1	2	3	4	5	6	7	8	9	Total	
1	**25/09/2018**	Average #/2min	8.75	52.25	0.00	31.25	8.50	29.50	65.50			195.75	
2	**05/10/2018**	Average #/2min	17.00	47.20	1.80	24.00	7.60	9.80	0.00			107.40	
3	**18/10/2018**	Average #/2min	3.13	16.75	0.00	3.75	1.14	5.71	0.43			30.91	average no rain
4	**02/11/2018**	Average #/2min	2.13	14.75	2.14	9.14	2.00	20.71	2.86			53.73	96.95
5	**06/10/2018**	Average #/2min	35.4	68.6	7.6	112.8	90	27	9.4	4.4	0	355.20	Rain

Figure A.14: Overview average particle counting rivers

Survey date : *12/10/2018* BeachID: *Finn's Beach* Survey #: 1

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
11.3		0.36	1.07	1.235	0.65	1.07	2.995
19.4							
TOTAL [KG]: 30.7		0.36	1.07	1.235	0.65	1.07	2.995

38.1

Survey date : *19/10/2018* BeachID: *Finn's Beach* Survey #: 2

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
24.6		0.48	0.43	0.65	0.32	1.6	4.43
18.2							
TOTAL [KG]: 42.8		0.48	0.43	0.65	0.32	1.6	4.43

50.7

Survey date : *02/11/2018* BeachID: *Finn's Beach* Survey #: 3

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
19.7		0.48	0.86	0.76	0.1	2.24	5.41
9.5							
6.4							
TOTAL [KG]: 35.6		0.48	0.86	0.76	0.1	2.24	5.41

45.5

Figure A.15: Data record of Finn's beach measurements

Survey date : *26/09/2018* BeachID: *Pig Stone* Survey #: 1

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
7.2		0.17	0.195	1.02	0.23	0.2	0.74
4.4							
2.9							
TOTAL [KG]: 14.5		0.17	0.195	1.02	0.23	0.2	0.74

17.0

Survey date : *21/10/2018* BeachID: *Pig Stone* Survey #: 2

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
4.0		0.47	0.67	0.81	0.23	0.18	0.45
4.6			0.93				
3.7							
1.3							
TOTAL [KG]: 13.6		0.47	1.6	0.81	0.23	0.18	0.45

17.3

Survey date : *9/11/2018* BeachID: *Pig Stone* Survey #: 3

5. Primary sorting							
Org		**PET**	**PS / PP**	**Multi**	**HDPE**	**LDPE**	**Rest**
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
10.2		0.065	2.67	1.555	0.315	0.495	1.01
10.7							
7.7							
6.1							
6.4							
TOTAL [KG]: 41.10		0.07	2.67	1.56	0.32	0.50	1.01

47.2

Figure A.16: Data record of Pig Stone beach measurements

Survey date : *19/10/2018* BeachID: *Nyanyi Beach* Survey #: 1

5. Primary sorting							
Org		PET	PS / PP	Multi	HDPE	LDPE	Rest
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
8.6		0.48	2.51	5.28	1.32	2.85	4
9.4							6.5
8.3							0.73
5.435							
9.2							
8.2							
3.8							
10.6							
7.45							
6							
6.9							
4.5							
6.4							
4.2							
1.5							
2.8							
4.2							
1.6							
4							
2.6							
TOTAL [KG]:	115.6	0.48	2.51	5.28	1.32	2.85	11.23	139.3

Survey date : *3/11/2018* BeachID: *Nyanyi Beach* Survey #: 2

5. Primary sorting							
Org		PET	PS / PP	Multi	HDPE	LDPE	Rest
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
5.4		0.125	0.565	0.6	0.47	0.515	0.375
1.9							
9.8							
7.6							
TOTAL [KG]:	24.7	0.13	0.57	0.60	0.47	0.52	0.38	27.3

Survey date : *9/11/2018* BeachID: *Nyanyi Beach* Survey #: 3

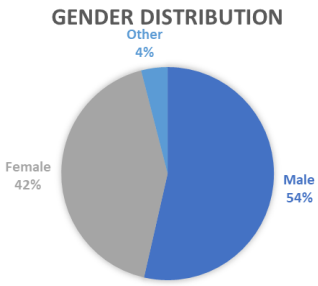
5. Primary sorting							
Org		PET	PS / PP	Multi	HDPE	LDPE	Rest
[kg]	#	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]
82.2			1.335	1.265	1.8	2.7	3.06
TOTAL [KG]:	82.2	-	1.34	1.27	1.80	2.70	3.06	92.4

Figure A.17: Data record of Nyanyi beach measurements

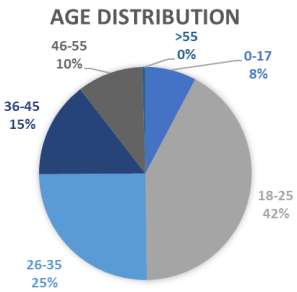
B

SURVEY RESULTS

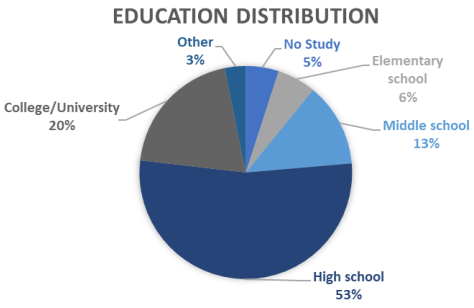
B.1. CHARTS FROM SURVEY



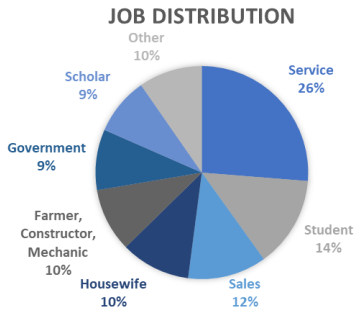
(a) Gender distribution



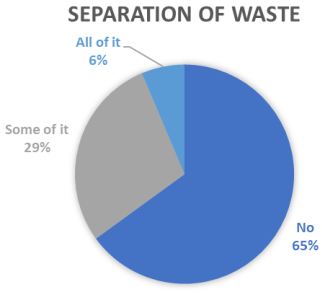
(b) Age distribution



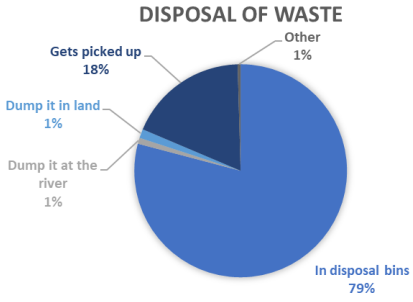
(c) Education distribution



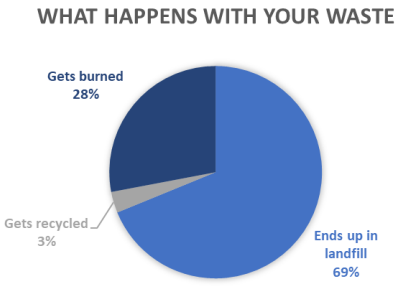
(d) Job distribution



(e) Separation of waste

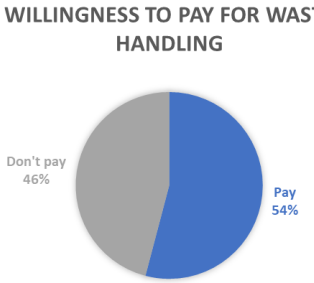


(f) Disposal of waste

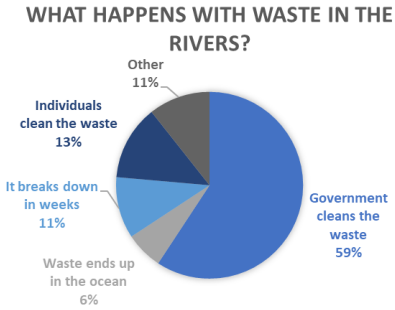


(g) What happens with waste

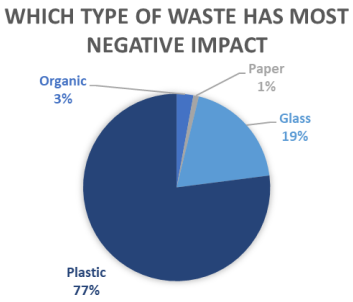
(h) Care what happens with waste



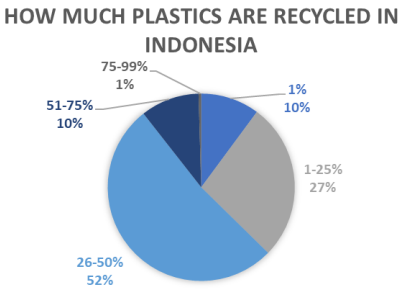
(i) Willingness to pay for waste handling



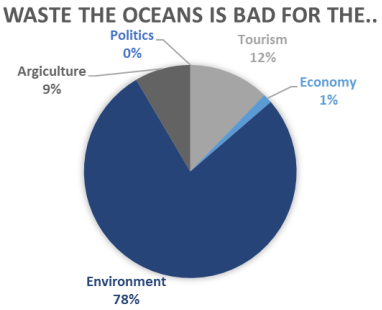
(j) What happens with the waste in rivers



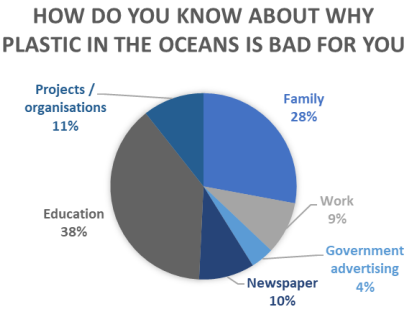
(k) Which waste types have the most negative impact



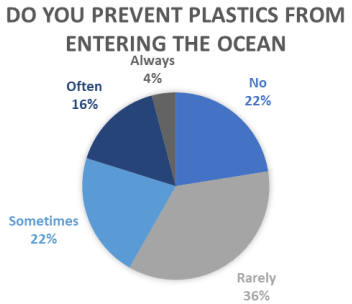
(l) How much of plastics are recycled



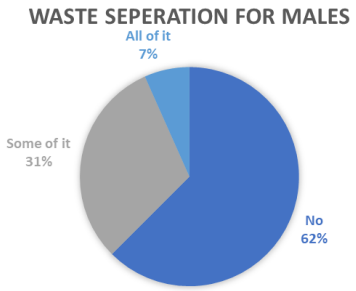
(m) Plastic in the ocean is bad for the..



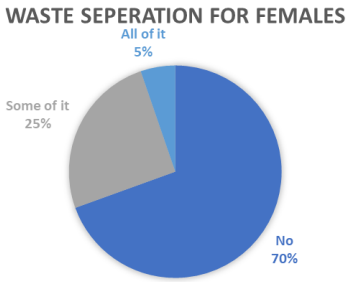
(n) How do you know about the effects of plastics in the ocean



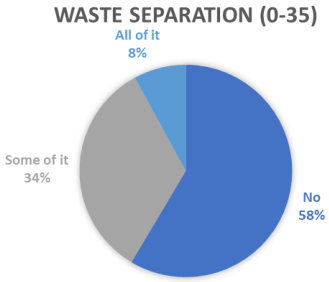
(o) Do you prevent plastics from entering the ocean



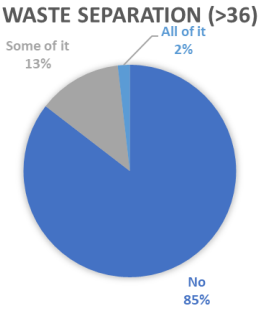
(p) Waste separation according to males



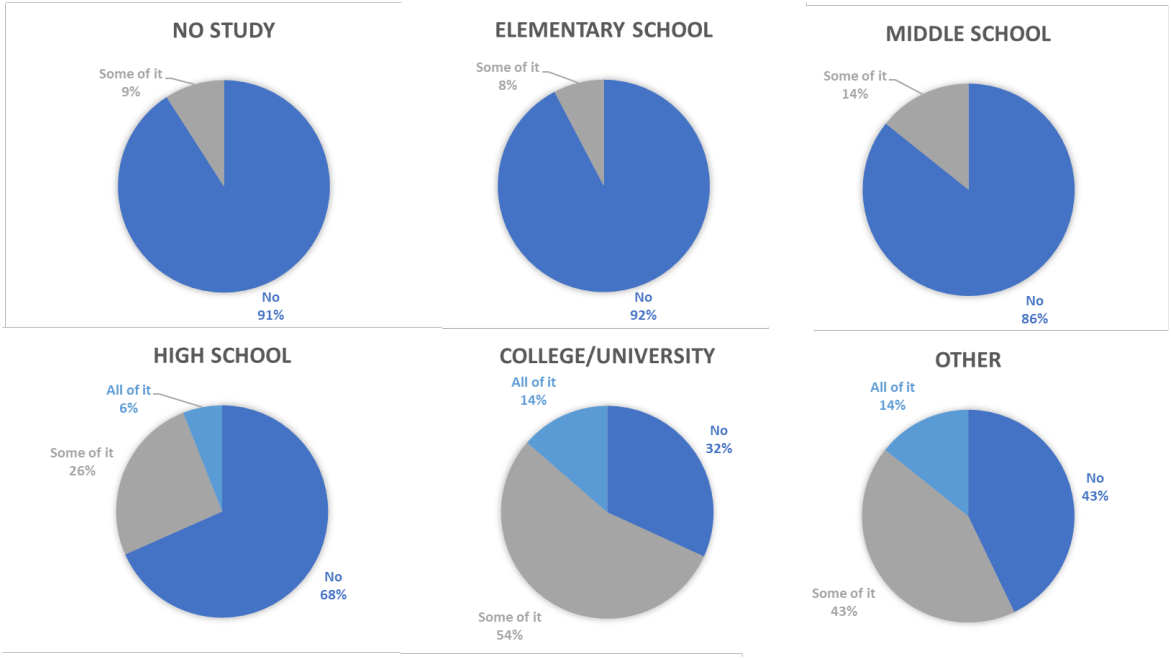
(q) Waste separation according to females



(r) Waste separation according to the young demographic

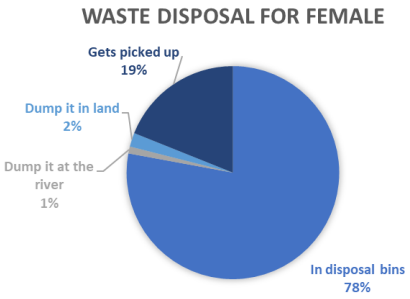


(s) Waste separation according to the old demographic



(t) Waste separation according to education level

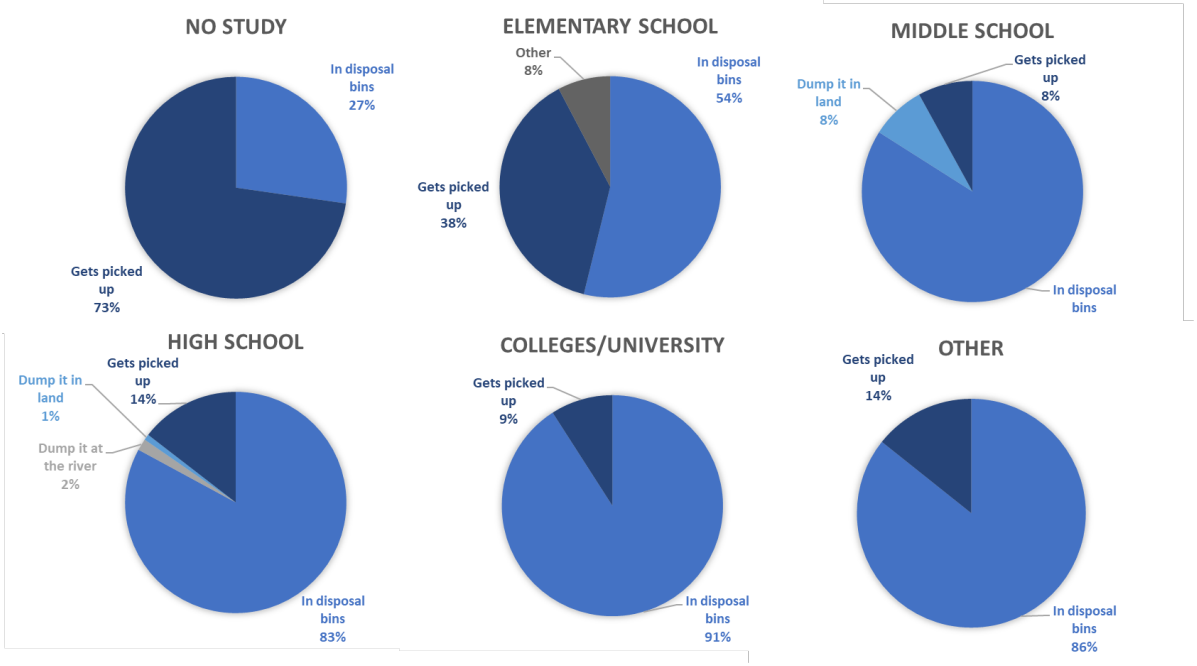
(u) Waste disposal according to males



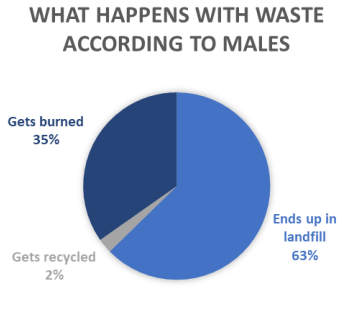
(v) Waste disposal according to females

(w) Waste disposal according to the young demographic

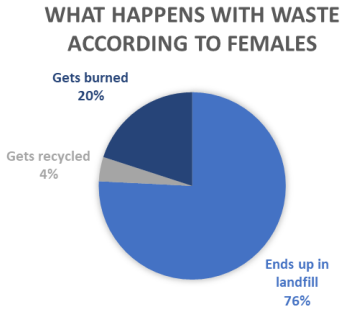
(x) Waste disposal according to the old demographic



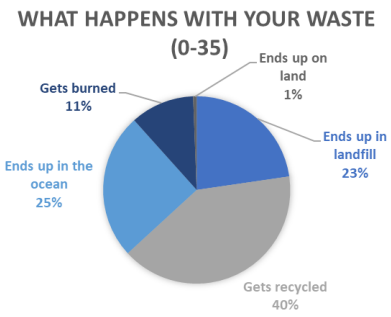
(y) Waste disposal according to education level



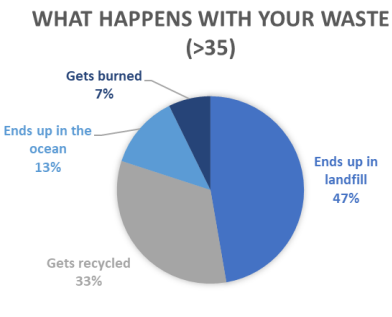
(z) What happens with waste according to males



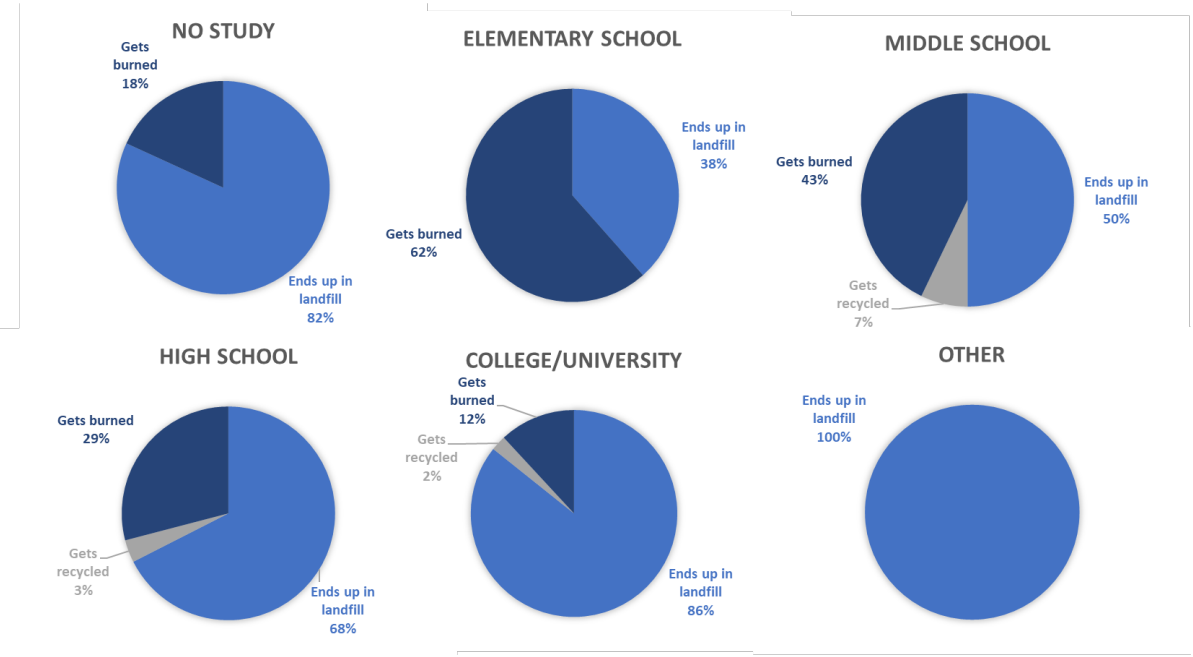
() What happens with waste according to females



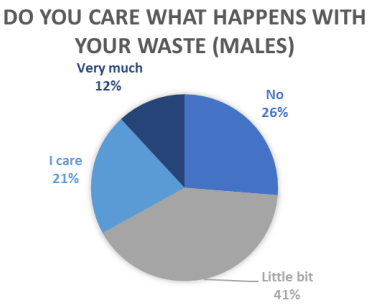
() What happens with waste according to the young demographic



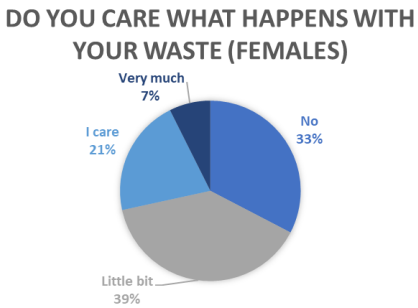
() What happens with waste according to the old demographic



() What happens with waste according to education level



() Care what happens with waste according to males



() Care what happens with waste according to females

	Average	Minimum	Maximum
Awareness points	3.12	0	11
Motivation points	4.30	-2	11

Table B.1: Average awareness and motivation points scored per subject

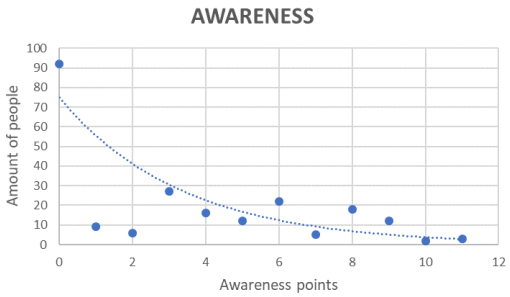
	Average	Minimum	Maximum
Awareness points male	3.47	0	11
Awareness points female	2.92	0	11
Motivation points male	4.74	-2	11
Motivation points female	3.27	0	11
	Difference	Percentage	
Difference in awareness male and female	+0.55	+19%	
Difference in motivation male and female	+0.17	+4%	

Table B.2: Awareness and motivation points for young and old

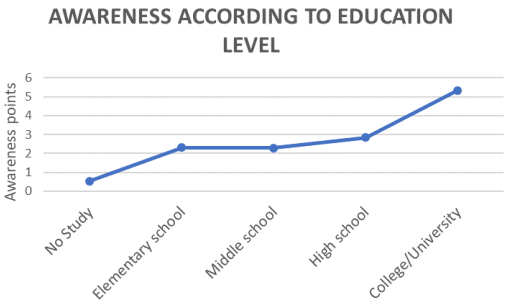
	Average	Minimum	Maximum
Awareness points young (0-35)	3.54	0	11
Awareness points old (>35)	2.04	0	8
Motivation points young (0-35)	4.74	-2	11
Motivation points old (>35)	3.27	0	11
	Difference	**Percentage**	
Difference in awareness young and old	+1.5	+74%	
Difference in motivation young and old	+1.47	+45%	

Table B.3: Awareness and motivation points for young and old

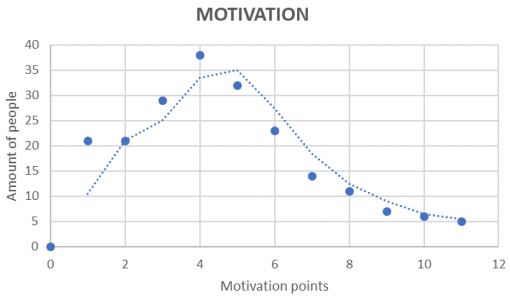
B.1.1. DATA



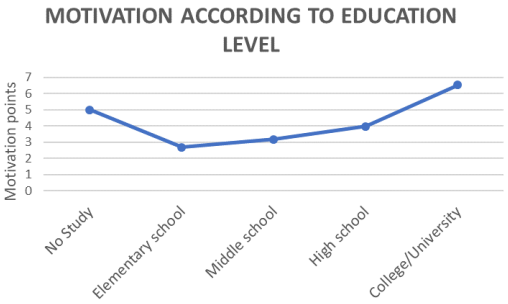
(a) Graph of the awareness distribution



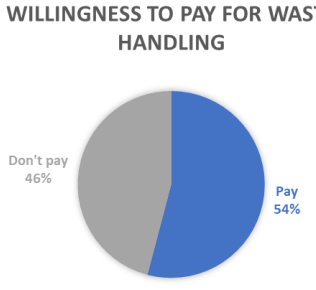
(b) Graph of the average awareness points scored according to the education level



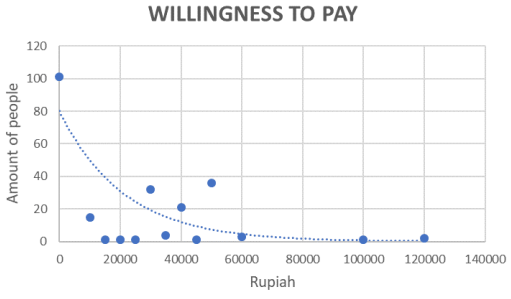
(c) Graph of the motivation distribution



(d) Graph of the average motivation points scored according to the education level



(e) Willingness to pay



(f) Distribution of the amount of rupiah the subjects are willing to pay

C

INTERVIEWS

C.1. WASTE MANAGEMENT SERVICE TPST 3R SEMINYAK

Transcript	Waste Management Service TPST 3R Seminyak
Date	Monday October 1st 2018
Interviewers	Bas van Wijland & Joris Memelink
Interviewee	Mr. Komang Rudhita Hartawan
Location	TPST 3R Office in Seminyak, Badung regency, Bali, Indonesia

Start of interview

Interviewers	Could you tell us a little about this facility and what kind of activities you undertake on a daily basis?
Respondent	First I would like to, this name is TPST 3R Seminyak. We have 16 trucks here.
Interviewers	So this is only for the Seminyak area?
Respondent	Yes only for Seminyak area. And then we start work at 3 o'clock in the morning for pick-up trash from hotel, villa, restaurant
Interviewers	And the clients all have to pay a fee to have their trash picked up?
Respondent	Yes, they about, the local people, they pay for 40.000 for one month and then restaurant, hotel between 150.000 until 4.000.000. And then in the afternoon we start in 4 o'clock, then only 4 truck. In the afternoon is special for pick-up garden waste from the hotel
Interviewers	And do you tell your clients to separate their garbage?
Respondent	Yes, yes specially for hotel and villa, they already separate.
Interviewers	In organic and non-organic?
Respondent	No, we call it: the rubbish from the room, dry and wet. In dry we have three: garden waste, room and then kitchen waste. In the hotel, only there. And then when we come here for the un-organic we separate up there (pointing at the separation site at the facility), and the garden waste we make the compost.
Interviewers	So all the un-organic waste like plastic, metal, lamps get separated in this facility?
Respondent	Yes all, I can show you (Mr. Hartawan shows us a price list on his computer of all the kinds of waste he encounters)
Interviewers	So all these materials are being sold back to the people?
Respondent	Yeah to the public in Surabaya
Interviewers	And they pick it up here, or?
Respondent	Yes they pick it up here (Mr. Hartawan explains some more about waste categories)
Interviewers	Ok so you separate it here and put it in big bags and sell it to people in Surabaya because there they can recycle the material?
Respondent	Yes
Interviewers	They can only recycle in Surabaya?
Respondent	For the glass bottle already in Bali, but for plastic, PO or PE sonly in Surabaya
Interviewers	And are there more districts who do this? For instance this is Seminyak
Respondent	Special is for Badung, they will make everyone in it, one village one facility
Interviewers	And that is similar like this?

Respondent Yes like Seminyak, now they already they making between 10 and 15, but still, new one but still building, not running
Interviewers So this is the only facility running at the moment and they have plans to make more?
Respondent Special for Badung government they will make one village one TPST
Interviewers Do you know when those facilities will be finished?
Respondent I think next year
Interviewers So then, and is this TPST financed by government?
Respondent The first time, everything total from private investment. From our Desa Banjar (village), the first time in 2003, in December. And then in 2005 government support us, specially from Badung Provincy and then from Jakarta, this building is from Jakarta.
Interviewers Is that because the most economic activity in Badung, it needs to be clean?
Respondent Yes, because Badung is big tourist attraction, it very important to make Badung clean.
Interviewers And in other area's, so not Badung but more in the North for example?
Respondent Denpasar already have two, Denpasar, but sometimes is running, sometimes is off
Interviewers But more in the North, like Tabanan, is trash also being picked up?
Respondent Tabanan people just start for themselve, buy some truck, not from government. They come so see what we do here.
Interviewers So the local people, I mean clients from Seminyak, only the clients that pay, then your trucks will pick up their trash?
Respondent Because from Adat (Adat is een soort stamhoofd in een dorp/regio: heeft veel macht en iedereen moet naar hem luisteren). So the local people must use this TPST
Interviewers Where does the waste come from that goes to the landfill in Denpasar
Respondent Suwung Denpasar that is only waste from Denpasar and Badung, for Suwung
Interviewers And government trucks pick this up to bring to the landfill?
Respondent The trucks from government, they only pick up the rubbish in the Raya Seminyak (Main street in Seminyak)
Interviewers And in the main street there is a waste collection point then?
Respondent They use the big truck to pick up the waste, but only in main street.
Interviewers So the people that live far from the main street..
Respondent Ah, they use us.
Interviewers But not everybody can use your trucks right?
Respondent Everybody must use us if they not use main street because we have regulation from Adat, is not from government. In Bali the role from Adat is very strong, stronger than government. That is local culture.
Interviewers So you listen more to your Adat then you do to a governor.
Respondent Yes but he always is in coordination with the government.
Interviewers What is your idea about, you know when we drove all the way through the South coast and we checked every time there was a river, everywhere we saw trash in the river and aside of the road. How do you think that is happening?
Respondent Now we, in our government we already we have a rule for that. If people throw trash in the river they get a punishment.
Interviewers But only if somebody sees right, and it's very hard to see somebody do it?
Respondent Yes very hard to see.
Interviewers And also maybe some Adats care less about the trash.
Respondent Yes if all the Adats in Bali be like Seminyak, I think maybe in five years Bali island is clean.
Interviewers When actually did the problem start with the crazy amounts of plastic waste on Bali?
Respondent When I was maybe 10 years old, on the beach was no plastic, only organic. And then maybe 10 years ago was start. But the worst was 5 years ago, then you can not see the sand. I have support from Coca-Cola in 2007 they give us the special tractor for the beach.
Interviewers Oh so you can pick up the trash from the beach?
Respondent Yeah to pick up the rubbish but not the sand. In Indonesia only two, one here, one in Kuta beach.
Interviewers So you also clean up the beach?
Respondent Yes off course that is our field, all our field is not only the villa, but also the beach.
Interviewers And do you think the trash, the plastic is coming from Bali or also from other islands?

Respondent	I think not all, I think half from Bali, half from outside. And outside specially from Java. Because we I see the product maybe half not from Bali. We have a research from 2008, from University Udayana, says half from Bali.
Interviewers	If you do a big clean up in November/December on the beach, do you also record how much waste is collected?
Respondent	Start from November until March and then between 250 and 300 trucks with trash.
Interviewers	300 trucks? And do you keep record of how many kilo's of waste?
Respondent	No I don't keep about how many kilo's, only trucks. Maybe in one day 5 trucks but the first time maybe start from 2 trucks. And then in December/January for one day maybe 15 trucks.
Interviewers	And one truck is how big?
Respondent	One truck 7 cubic meter. Because then we use the government trucks. 300 trucks in 4 months. I hope this year is not so many..
Interviewers	Do you have like numbers of how many trucks u used in that year for cleaning the beach?
Respondent	I have records start from 2009, so in 2009 260 trucks. In 2014 boom-booming with 290 trucks, that was the worst.
Interviewers	And you keep track of each day?
Respondent	Yes each day.
Interviewers	But do you still remember how many trucks for example were used on 20 december?
Respondent	No, no we only record totally. But this in Seminyak only, 3 kilometers only. Kuta is same story, Legian is 6 kilometer, Kuta is 8 kilometer.
Interviewers	So for Seminyak it's 260 trucks but for Kuta it may be 4 to five times that?
Respondent	Yes more
Interviewers	But do they do the same as you do in Seminyak?
Respondent	Not the same. In Legian start clean up in 2008 and Kuta start in 2006.
Interviewers	2014 was the worst year, and in 2015 and 2016?
Respondent	Maybe 250, 260 trucks. I hope this year maybe 200.
	End of interview

C.2. UDAYANA UNIVERSITY

Transcript	Udayana University
Date	Monday October 15th 2018
Interviewers	Bas van Wijland & Joris Memelink
Interviewee 1,2 & 3	(1) Prof. Hendrawan, (2) Miss Argeswara & (3) Mr. Damar
Location	Faculty of Marine Science and Fisheries, Jimbaran, Badung regency, Bali, Indonesia
	Start of interview
Interviewers	We thought we would make some boundaries first, the research area is not too large, and we started in the North with the Bali Strait and here in the South with the South boundary. And we thought ok, first the input in this area will be the rivers, which will then go in the ocean off course. And from the ocean, with all the currents and the tide, it will move from the ocean to this area or it could go to the bottom or out of the boundaries over here.
Respondent 1	Did you make it by a numerical model?
Interviewers	No we're not going to do that because we will do a project with numerical models in our master thesis and this is a multidisciplinary project so we will more investigate how it works than that we will go into detail with models. So we are more quantifying the sources and getting a feeling than that we're going to model it. What we want to do is tell something about every arrow, what is happening over there. We started with rivers already, we have some devices which we use to measure input in rivers.
Respondent 1	What do you mean input in rivers, the trash?
Interviewers	Yes, we made a selection of rivers, mainly big rivers that have like a lot of input from villages. So we have a selection of 3 rivers now.
Respondent 1	How is the method to measure the rivers?

Interviewers Actually we do three things. We measure the parameters of the river, so cross-section and flow velocity. Then visual counting, quite an easy method which we learned from The Ocean Cleanup.

Respondent 1 I did before in each river in this area, and already counting the debris along the coastline also for three months. And in the river we did two time. And trapping the trash use a net for an hour. We already collected data but not published yet so i can't tell everything. And we also use a numerical model how they move, how they move from the Indian Ocean and this strait but not published it yet. We surveyed the bridges for months since 2014, still continue till now, collecting the data and off course we will find a lot of trash here in December, January, February. But actually not only here but spreading also to the west.

Interviewers We couldn't find any information about these beaches. We visited them and we saw plastics already.

Respondent 3 It was literally this year and last year that we started the project, that why there isn't any data.

Interviewers So you're still processing it?

Respondent 1 Yes. We have 50 stations here, all in Bali, and we also have in Lembongan. Totally we have 70 or 80 station. Every month we're collecting data.

Interviewers So these stations are all connected to this faculty?

Respondent 1 No, to my project. Also river, I have 8 rivers 2014 until 2015. And now we already completed 5 rivers, big rivers. We already counted upstream unto downstream we have 5 to 7 station in every river, randomly.

Interviewers And you also use this method?

Respondent 2 No we use the CSiro Australian river method.

Respondent 1 CSiro methodology. We count it in the river bank.

Interviewers And how does that method work?

Respondent 1 We count it in the river bank. In 2014 we counted in the river flow by the net. And I think this underestimates, because most of the garbage thrown in by the people traps in the river bank. After the rainy season coming, then it will be flushed. So we want to estimate how much garbage is in the side. Then the possibility will be flushing out to the ocean. So that's why we counting in the river bank, before the rainy season coming. We already did river flow, just finished last month. We have a big river survey in Mati river. But we have selected river with different characteristic; with dense population, tourism activity,

Interviewers And also rivers with for instance less tourist activity so you do all kinds of rivers.

Respondent 2 Yeah so we can differentiate between them.

Respondent 1 Different characteristic. But unfortunately we can not talk about the data, now we still processing, numerical model still processing and river survey still processing, coastline still processing. So we have three kinds; river survey, coastline survey and modelling the movement of the garbage in the ocean. How they move, seasonally, and how the characteristic.

Interviewers So that will finally give a result about how much of the waste from the river banks is ending up on the beach?

Respondent 1 Yeah actually we have but we are still writing.

Interviewers Do you also look to the different types of plastic?

Respondent 1 Yes sure, we do different types; soft plastic, hard plastic, textile also

Respondent 3 We have our own classification sheet.

Respondent 2 So we use the CSiro Australian method and they already have a work sheet with the different kind of plastic and now we're adding the brands as well.

Interviewers So these river surveys, like the banks and the river flow you did during every month of the year?

Respondent 1 No, for river we did only before the rainy season coming, so last month we already completed, otherwise we have a bias.

Interviewers That's one of the things we want to show, the difference between the extent of plastic in rivers itself between the dry season and the rainy season. But we're already seeing that it has been so dry lately and the rainy season starts maybe end of November but our project ends in the start of November. So we will have data of the dry season but we won't have the data from the rainy season so we are trying to collect data about how much is ending up on the beach right here during the rainy season.

Respondent 1 For this beach, we already collected for one and a half years, for Kuta Beach every month.

Interviewers And how do you collect this?

Respondent 1 We do trans-sect NOA methodology

Respondent 3 So like on the coastline, a length of 500 metres, every 5 meters we have a line trans-sect towards the shore. And then we do visual surveys, I think 1 meter to the right and 1 meter to the left. Specifically for Kuta Beach because it was considered a hot topic.

Respondent 1 So we already have the characteristic how then before the rainy season coming and after.

Interviewers And you conduct those surveys every?

Respondent 2 In 2015 we did it, only at Kuta Beach.

Interviewers And how often did you do this?

Respondent 2 Once a month. And we do it evertime before 6am so before the trashguys take it

Respondent 1 So in there, we use 30 to 50 students

Interviewers And they will count particles and also what amounts of plastic and organic etc?

Respondent 2 All kinds of waste that we can find in our trans-sect, so including cigarette buds, plastic and then metals.

Respondent 1 Yes, several types of plastic.

Respondent 2 Mostly off course it's plastic but we also take data of the metals and everything.

Respondent 1 But for the macro debris, we only take between 2.5 and 30 centimeter and we also just note the parts bigger than 30 centimeter.

Interviewers Ah so you also don't consider microplastics for the survey?

Respondent 2 We do like bottle caps, you still count those, because there are many.

Interviewers Yes we do the same.

Respondent 3 It's like out of the boundary, specifically for Kuta beach, because we are targeting macro plastic.

Interviewers It would've taken you ages if you had to count the microparticles as well.

Respondent 3 Exactly.

Respondent 1 We do microplastics already

Respondent 2 We investigate plastics inside the fish and in sediment

Respondent 1 And also in the seawater

Respondent 3 We just finished gathering data for the dry season and then in January we're going to take the wet season data.

Interviewers It's very good that finally there is an institute that finally collects this data because we met with a lot of governmental institutes, but none of them collects important data.

Respondent 2 Yes it's because we're doing scientific research.

Interviewers We had a meeting last week at DLHK Badung and the day before they had a meeting with the other DLHK's, like from all the regencies and they finally reached an agreement that they should start to collect data.

Respondent 1 Several subjects, Kuta Beach, numerical model and also coastline characteristics of debris and we are supported by Australia.

Interviewers By which Australian institute is that?

Respondent 1 Research centre of Australian government.

Interviewers They support this research

Respondent 1 Yeah only the technical supports, training for the people, and giving the direction how to do research.

Interviewers That's very good.

Respondent 2 It's a big project so we have to wait, you know a while, before we give the data to the government. He's planning to it this year even though we did it, you know, a few years ago, but it's a big project

Interviewers We're also wondering what is your opinion about the origin of the plastic in Bali because many people have think that it's coming from Java or even from Sulawesi.

Respondent 1 Did you hear those guys from the World Bank that they said the plastic is coming not from Bali but from outside Bali?
Interviewers Well most people say at least half of the trash is coming from other islands.
Respondent 1 Bad opinion
Interviewers Yes we think so too because we drove all the way to Negara and we saw literally every bridge and every river had plastic thrown over or in it.
Respondent 2 Every coastline in this area is dirty actually.
Interviewers So maybe some is but it is very difficult for particles come all this way and reach the beach.
Respondent 1 The garbage from my model, the garbage from here (pointing to South Bali) and also here (pointing at East of Java), yeah most of them will send it into Kuta Beach.
Interviewers But there is some coming from other islands then?
Respondent 2 From this model most of them ends up in Kuta Beach, and only a small percentage is from other islands.
Respondent 3 Because of the flow of the water and the flow of the currents along the coastline, most of them end up in Kuta because it's in the South side. Some of them do attach to the Western coastlines but most of them attaches more South.
Interviewers Because of the shape of the island right? And this transport, is it mainly wind driven?
Respondent 1 Yes, and it is only wind. No tide. That's why the West Monsoon will be the big boom for the trash
Respondent 2 But people in this area, because they are coastal communities, they also throw their trash at the beach. Because I've seen them do it, like diapers and everything.
Interviewers We also saw the same thing. Like this little ridge at the beach and then they just throw it over.
Respondent 2 There is a lot of input from the coastal communities.
Respondent 1 I think we have similar interests.
Interviewers Only you have some more time and a lot more experience.
Respondent 1 We will do survey for the river, each river from Tabanan to Jimbaran.
Interviewers I think we have experienced a lot of those coastal communities more west care way less about handling trash than they do in Badung regency. So then it's going to take a long time before people will start handling waste properly.
Respondent 2 In this area (West Bali) they also have the same problem.
Respondent 1 We just came back from the field yesterday.
Respondent 2 Most of the people in the South already know that they have to put their waste at least in the bins, even though they're not that segregating. But in the North and the West they are not aware yet.
Respondent 3 I think on the East to, but the only difference is the tourism activities are all focussed on diving and other activities in the water that they know not to throw trash into the water as it will affect their revenues.
Interviewers Is the data from the beach surveys, is there any possibility we could look into that. Like the countings.
Respondent 1 The methodology you mean?
Interviewers More into the quantities that you have observed.
Respondent 1 You can see one of our survey in 2017, just look at how the solution.
Respondent 2 Our first marine debris survey we looked into the difference of the number of trash we found in the Kuta area compared to other sides of Bali. So that were coastal surveys performed doing the Csiro method, we told you about before. So we pull a transect of some meters, we did that around Bali. And with that data we can see the difference in abundance of trash around the island compared to Kuta.
Interviewers Ok do you have an example of such data you collected?
Respondent 1 This is a sample of Penida island.
Interviewers And those are the survey points? The bigger the circles the more trash was found per square meter?
Respondent But that's only for Penida island. I can give you the pictures.
Interviewers Oh, that would be great.
Respondent 2 We don't have the picture for whole Bali.

Respondent 3 I think because we just finished a couple of weeks ago that one of our friends is still doing the visualization so the only thing we have now is the Penida one we showed you.
Respondent 1 We have one of November last year and we started February this year doing every month survey for whole Bali Island.
Interviewers So you have not finished this research yet.
Respondent 2 Hopefully we will finish this research in March next year, just for the data sampling. And that's why I said it's a big project so it's going to take a while. For data sampling we're doing it from February until March so we're aiming for one year.
Interviewers And for the survey in 2017 you also did the survey every month?
Respondent 1 No just only one month.
Respondent 2 That was a trial. And then we started to do it monthly in February.
Interviewers Are there any papers published yet on how the currents move annually? Like South of Bali?
Respondent 1 The sea current you mean?
Interviewers Yes
Respondent 1 I only have a small area, like the Benoa bay, and close to the Kuta beach, not a large area.
Respondent 2 We have one published paper, but only for Kuta beach.
Respondent 1 And also in Lombok strait, I work last time in 2014 for Lombok strait.
Interviewers And any other publications that you know of, maybe not from your team?
Respondent 3 I mean, he is the pioneer in here so yeah. In this area no but probably in other area's in Indonesia, I don't know, they might have done studies about the currents or numerical models but here it's just the ones that he has done.
Interviewers And so basically the only data there is on amounts of plastic on the beach during one year would have come from here right? Because you are the only institute actually collecting data.
Respondent 3 Oh here as in you mean the faculty, Yes.
Interviewers There is no other..
Respondent 2 I think there are other institutions but they don't do it like regularly.
Respondent 1 Many in here do clean up but they don't collect data. If they have for only one time we can not talk any more because the data is not enough.
Interviewers You mean they collect the data inconsistently?
Respondent 2 We don't have the plastic input data for Kuta beach but we have published the hydrodynamics around Kuta beach.
Respondent 1 Actually we already completed the model for the Bali Strait here, all of here, but only in Bahasa.
Interviewers A lot is in Bahasa!
Respondent 3 Because mostly the undergraduate thesises are done by the students here.
Interviewers Did you already graduate actually?
Respondent 2 No we are in our last year now.
Interviewers So this research is for your thesis also?
Respondent 2 Yes it's for our final research project.
Respondent 1 Actually she and he will do it for microplastics.
Interviewers Cool.
Respondent 3 I'm assuming you already graduated?
Interviewers No this is actually our last project before we start our master thesis. So after we come back we start our master thesis and then it's going to take like 9 months before we graduate.
Respondent 3 We really want to help but it's just difficult as we are still in progress.
Interviewers The feeling I had so far is that there is not so much trash coming in the boundary over here, the North boundary, right?
Respondent 1 Yes well from the hydrodynamic, generally, the hydrodynamic we completed for the North West Monsoon, there is some material coming from there. But also some of material is coming from here (From South of Java) is the residual current is very strong from here (which then enters the South Bali bay area). If we put material here (pointing to the area's North of Bali strait), not so much is coming over here.
Interviewers There is some but..
Respondent 1 Some, but not so much.
Interviewers So almost everything is coming from Bali then?

Respondent 2 Yes most likely

Respondent 1 Yeah, so the first, actually if the garbage already stay in the inner of this strait, most of them will move into the Kuta beach. But the garbage close to the coastline will generally go to this one (pointing at area's West from Kuta Beach). So we completing the resident time and also the residual current.

Interviewers You do this with tracers or something?

Respondent 1 Yes GPS tracer. Not to show the mechanism, but we put the floating material with GPS just to validating our model.

Interviewers To see the trajectory?

Respondent 1 Yes the validating the trajectory of the model.

Interviewers So you put in all the data from the area and then you run the model and it shows the plastic is moving like this and then you validate the model with the GPS tracers?

Respondent Yes exactly

Interviewers During West Monsoon the current and wind is mainly directed towards Kuta right? So if there would be trash here (South of Java), do you think it could enter the Bali Bay.

Respondent 1 Yes that's possible. If we understand about the Ekman transport I think that will happen. Because Ekman is to the left in the Southern Hemisphere and then the wind is from this side so it will go around.

Interviewers How do you think, if you would quantify these sources (Bali strait and South Java) by the extent of plastic, how much would these inputs contribute to the plastic problem.

Respondent 2 Like the influence?

Interviewers Yes, like how much plastic would come in here (northern boundary) and how much would come in from this side (southern boundary)? Would there be a lot more coming from this boundary or is it kind of the same?

Respondent 1 We were counting it by the model. We make a percentage, not quantity but just percentage of how much of the material we put in the North part and the South part will be coming in to the Bali bay area.

Interviewers So you would check what percentage of material would enter through the Bali Strait and what percentage travels around this tip of Java. And is that percentage kind of the same?

Respondent 1 Not same, most of them is in the South. Because in here (North of Bali Strait) most of the material is travelling this way (to the East).

Interviewers And do you know these percentages by heart from your studies?

Respondent 1 I forgot the exact percentages.

Interviewers But at least there is more trash coming in from the South boundary than from the North?

Respondent 1 Yes, even if you are running the global model by Australia you can see also some particles coming up into this strait.

Interviewers The global model?

Respondent 1 Yes, I forgot the real name but Australia government online we can put some particle in here or in Indian Ocean, and then we can select the coordinate, how wide the area and how they move.

Interviewers And then it shows the trajectory?

Respondent Yes, but the last model I think 2000. And this model I used the average wind of last 5 years. The residual current here is very strong going to the North.

Interviewers Is there more known about this phenomenon (current changes direction when transitional season changes into West Monsoon)? So this is Java, because this report is pretty old it's from '74. It's not a model but it did indicate the change of direction in the mean current.

Respondent 2 It's amazing they could do this back then.

Respondent I think he is the pioneer for to also the hydrological research.

Interviewers I've read a paper that four very polluted rivers are in Java.

Respondent 1 I think that's in the West of Java.

Interviewers Actually two are in the South, one near Surabaya and one more in the West.

Respondent 2 There is this guy who went to the West Java government, I think he was from Australia, and he got the government and some of the military people to actually clean the river. So I think that one now is actually cleaner than it was maybe during that research.

Respondent 3 But it is true that Java has a lot of polluted rivers.

Interviewers That's why we are interested in the phenomenon about the currents close to the coastline, if it's changing over the year.
Respondent 1 Well it is the general characteristic of the current.
Interviewers And do you have more details about this?
Respondent 1 Well yes but that is only from our models.
Respondent 3 We didn't publish anything about this yet.
Respondent 1 I'm sorry but in 11 I have another meeting. But if you have any question you can send in my Whatsapp or you can discuss with our students.
Interviewers I think we came a couple of months to early because you will finish this big research in March right?
Respondent 3 Yes then we just finish our surveys so after that we still need to investigate and process everything.
Interviewers And will this be in English or Bahasa? I think in English right?
Respondent 2 Yes it will be in English because it's such a big project.
Respondent 1 Also this project was supported by WWF so it is required in English.
Interviewers If there would be NGO's or clean up services that collect the weight data, who would that be?
Respondent 2 There are actually so many small ones but I think that actually collect data would be 'Bye Bye Plastic Bags' and 'Plastic Detox' and may be 'Trashhero'. Eco-Bali is also a big organization.
Interviewers Of Eco-Bali we know they didn't have data of weights. They do a lot but they didn't gather data.
Respondent 2 Yes they are like a private waste management facility.
Interviewers Ok so we will try to meet with Trashhero and Plastic Detox then to see if they have any data.
Respondent 2 Trashhero organizes cleanups every week but we don't know if they also record how much they gathered.
Interviewers Yes you also have 4Ocean who cleans the beach every day but they don't collect anything.
Respondent 3 There is a lot of clean ups but mostly it's just cleaning and no further actions are taken.
Interviewers Also I was wondering, have you experienced or seen with your own eyes that it has become less over the years, the trash on the beaches i mean?
Respondent 2 I don't think so.
Respondent 3 I personally haven't seen a decrease in plastic waste. But both of us aren't from here, we have just studied here, but over the course of 4 years that we have been here, I don't think there is a significant decrease in the plastic pollution. Every year during the raining season the beaches get covered in trash and it's not really noticable that it has become less than previous years.
Respondent 1 I just completing study to investigate the effectiveness of recycling place in Badung regency and yeah I think the recycling place isn't effective here. Because you know TPST?
Interviewers Yes we have visited the TPST in Seminyak.
Respondent 1 We studied what the effectiveness of TPST. We investigate 22 TPST in Badung regency and all have the problem, the most of the problem they receive the mixed garbage, plastic with organic.
Interviewers Yes so they have to separate everything at the facility which is way too time consuming right?
Respondent 1 Yes. Second is from financial problem. Third is the labor; no one want to work in the TPST because high risk, especially for Balinese people. We don't have regulation specifically for TPST.
Interviewers To us it very much looked like everybody is working separately on the same problem so there is no organized idea and also management for what to do with all the waste. I think the TPST take like only a few percent of all the waste that has been produced and then the other 95% is going to the landfill.
Respondent 2 Have you been to the TPA Suwung?
Interviewers Yes we have been there.
Respondent 2 That's where they put everything.
Respondent 1 The mixed garbage is the most of problem. We need to take separate from the source.

Respondent 2	But there is no regulation yet that people have to segregate their waste so that the TPST doesn't have to do it again.
Interviewers	Thank you very much for your time. It has been very helpful and interesting to talk to you.
Respondent 1	We will keep in touch and we can discuss about later questions.

End of interview

C.3. ECO-BALI RECYCLING

Transcript	Eco-Bali recycling
Date	Monday October 1st 2018
Interviewers	Reinoud de Klerk & Thomas van Welsenes
Interviewee	Paola Cannucciari (Senior Program Manager Eco-Bali)
Location	Eco-Bali recycling, Badung regency, Bali, Indonesia

Start of interview

Interviewers	What happens with the waste collected at the beaches during for example the global beach cleanup?
Respondent	We actually brought it here (Eco-Bali) to check what is possible to recover and to consider the state in which the waste is. If it is not possible to recover it will be brought to the landfill. Talking about the source, if were talking about what gets to the sea it is the stuff which has not been captured by everything else. Everything what is not captured by everything else (waste management in Bali) accounts for people dumping on the side of the rivers, and that is washed out. Unfortunately the problem is that the more we are doing the more waste management there is the more irresponsible people are with their waste. So on the other hand the plastic that we see in the ocean is not coming from directly from what there is in the direct area but is coming from more inland. Inland could be really in the middle or could also be if you go around more on the edges of the more populated areas.
Interviewers	Why does this happen?
Respondent	The reason for this is that first of all we do have regulations on waste management, in 2010 just to give you an idea how recent the first legislation was for plastic, and we were founded in 2006 and there was not much there
Interviewers	Was there a collecting service back then?
Respondent	There was a collecting service but there was not a general legislative rule where it stated that you were not allowed to dump your waste in nature.
Interviewers	But you still see quite a lot of people burning their waste?
Respondent	Because when you are going up the legislation even from the local level as well, there is not really a person who stands up and says let's change this or that. Now slowly they are starting to giving some examples why it is bad to dump your waste and are publishing general awareness videos on social media for people to become more aware that burning and dumping the waste is irresponsible waste management.
Interviewers	But it is not enough?
Respondent	Not really, the current legislation is appointing each village to manage their own waste. The point is that they do not now enough about proper waste management
Interviewers	Eco bali is basically contacting these villages and giving them notes on how to manage their waste?
Respondent	The one we are staying now this village were Eco-Bali is established, this area, goes from here all the way to the sea, it goes up to Finns.
Interviewers	Is it called Badung?
Respondent	No that is more a regency of Bali, look if you
Interviewers	And everyone in this village, all the households use Eco-Bali as a service?

Respondent No, No, No that would be fantastic but unfortunately unsustainable. Because people have traditionally not payed for their waste, so in some areas it is possible for people to afford our service, but in some areas they only can afford 5,000 Rupiah (0,30 eurocent) a month and you can imagine what you can do with that, in terms of waste management. Our service is actually not to expensive it is 150,000 per household per month. Which is about 6,5 euros, but for here it is still not to much, but the traditional households are not used to even pay for their waste management.

Interviewers Is there something you can do to encourage them?

Respondent Yes, we pay for certain recyclables, these are different types of plastics, most of the metals, paper, in some places glass as well, tans, tins and we will pay money for that, definitely. So in villages we create groups who collect all these at households, it is not solving the problem of the waste, but it is a start to get as much recyclables and organic out of the system and it also provides a opportunity to talk to them and create more awareness. Here we also explain them that you can do some composting at your home, so it is a step by step process. Obviously the government has the right to step down and say this, but also for example our business if we say from now on you have to do this and this it is something that is not easy implementable. So to actually have the power to control on this specific level. That is the situation down south. The more we go to the northern part the less waste management is there.

Interviewers We also get the feeling that a lot of locals do not really understand why littering is a bad thing. We tell them to think about the plastic impact on the environment, but they do not see it that much of a problem.

Respondent I do not think if this is completely true, I just came this back this morning from a meeting with for example bye bye plastic bags and uh, and the government wanted to actually join to this commitment to reduce the amount of plastic that is being used, so there are some people with some motivation. However, it also depends were you go, it is currently not the priority in the life of a citizen, even not as high as in Europe. However, again the time that it took in Europe to reach that level of awareness, using a very structured system. It is about who you behave towards waste, this is because you learned when you grew up, this is the way you have to deal with waste. But here they did not have all of this, so this is very hard to attain. If they would do proper waste management by their own spontaneous wish, they would be the most advanced human being in the planet. Because if we take away the legislation and everything created in these kind of situations, I mean, I know lots of people in Switzerland who were dumping their trash because they did not want to pay and there was no police to control it. It is more that people who come here and say Indonesians are terrible with waste management would act exactly the same way is they grew up here. Just to get a better perspective. Nevertheless, I think there is no time to waste in joking around.

Interviewers Yea, because I read that Eco-Bali is doing some education classes to create more awareness on plastic pollution.

Respondent Yes we also have problems some of them are about waste separation at home, also to work together at schools. We also have a program that is still very long, here we provide them classes about how to sort your waste and what kind of waste you have in general. And show them how to do composting and what the benefits are of these. It is really to try to reorganize everything. Besides this, it is important how you present this, the people here love to do competitions. So now we have some competitions with schools, so they are trying to collect as much waste as possible. We do that with schools, but we also do training sessions for businesses for the staff, especially for the tourism industry.

Interviewers Do you know more about the numbers regarding waste in Bali, so how much waste is generated for example?

Respondent O I can tell you that I do not have right now, but let's say that Bali produces more or less 5000 tonnes of waste per day, and that accounts for the residents and the tourist. The residents used to use 0,5 kg waste per person per day, but now that is 0,7 kg per person per day. Because of the different lifestyle and also because the distribution of types of waste used is becoming different.

Interviewers And is this expected to increase even more?

Respondent I do not know if you have seen in the supermarket, but everything here is packed in a plastic box, because those boxes are not always recyclable, because it is often not even PP. There is a whole other compensation which has to be done in terms of using plastic, it is not only important how to collect or to capture. But it is also very important to change how we use plastic over here. This is why there is a whole new governmental regulation were the government has finally set targets for Indonesia in general that the plastic recycling rates need to be increased and that 30% of the plastic should be reduced. At the moment about 50% of the waste is collected, which is I think nothing. So yea, that is the story. Now each regency, Badung, Den Pasar, etc. Each of the regencys has their own dumping site. Have you been up the Suwung landfill?

Interviewers No we haven't really been up there but we have checked the edges. It was to crowded at the site to really go further. But we saw houses near it and people walking there.

Respondent Yea there is a lot of activity there

Interviewers So the regency's have different ways of collecting there waste?

Respondent Yes, of course, the different regency's have different budgets for waste management, and ways to handle their waste. But more or less the system is the same, it only differs in how much money they have, like for example Badung is the richest one.

Interviewers We also wanted to know if there are recycle facilities on Bali?

Respondent No there is nothing on Bali, we sort it here and we send it to Java. For plenty of reasons, one is that land on Bali is respectively expensive, two Bali is a touristic area, it is not meant for Industrial purposes. Three, for the level of amount of waste of the recyclables on Bali is thought to be not enough, a lot of people think that it is not sustainable open a facility. There has also been somebody from Bali province they were making pallets out of soft plastic, and they were not getting enough and transferred to Java as well.

Interviewers So for all these types of waste there is a factory in Java?

Respondent Yes

Interviewers but this is hard to get the recyclables out of the waste, as it is all mixed?

Respondent For the general items that are the most valuable ones to recycle like for example, cans, plastic bottles, cardboard boxes and all that. This is generally pretty good collected, because you can see people on top of the trucks separating them out. But you can imagine that a lot of the paper is wasted and a lot of the soft plastics are not recovered because they are covered in filth. So that is the reason why not everything is recycled.

Interviewers So just to be clear is the cleaning on the beaches just voluntarily?

Respondent As far as I know, yes, but there are a lot of individuals who clean the beaches. But most of the time the whatever business will clean its beach in front about once a day. Also to be fair there is also in Seminyak the organization called Coca-Cola together with Quicksilver they have been supporting local communities by giving them bulldozer trucks to clean the beaches. During this season there is not so much, but later in the time there is a lot of plastic and wood, branches which needs to get taken care of and that has been going on for about 8 years, or something like that. But it is not that the government has appointed someone over there to clean specific parts of the beaches. But it is not mandatory to clean the beaches. Obviously the rivers are not that well either.

Interviewers We also saw one river in Den Pasar who has a sort of plastic filter, I'm not sure if you know if this is happening more in Bali, and if it works?

Respondent The like the iron roster? I think they have a couple of those, but they are always open, because the risk especially during the rainy season that there will be a flood is to high. It does not exactly work.

Interviewers So basically all the waste that the government picks up goes to the landfill?

Respondent No, there are a lot of scavengers in the informal sector who pick up all the recyclables. They do this for profit they can sell recyclables to. It is informal because it is traditional started a sort of company, but it is not really a company, more a activity. They generally have low status, so they do not pay taxes, they do not do anything like that. But they create a lot of money, because they sell it to middlemen who transport it to Java to the recycling facilities.

Interviewers So there is like a drop off point on Bali were they can sell the recyclables?

Respondent Yes, they know that they should contact certain persons to sell their recyclables, and these sell them to the facilities in Java.

Interviewers	Over the course of 12 years that Eco-Bali exists, is the waste on the beaches a local problem because tourists do not find them attractive? Or is there another concern for them?
Respondent	In terms of economic impact, yes it may have some impact, but not so much to be fair Bali is full of people. Nevertheless, of course they can feel it, but for the waste, but during the rainy season there were a lot of people who saw the plastic who said this is not what we were paid for. So yeah, economically they can feel it. Bali will need to be more competitive to maintain there position in tourism as the government is looking at developing new regions for tourism. Also the fact that everything has changed to plastic, for instance 8 years ago when you wanted to have a coffee you bought it and it was in a jar. Also the selling of things in a different way have produced much more waste. In terms of them being aware that it is not a healthy thing, I think that it is still they do not see the problem, but they are getting more aware. However, most people still burn some of their plastic waste so there is still a lot of movement for awareness.

End of interview

C.4. DLHK

Transcript	DLHK
Date	Monday October 8st 2018
Interviewers	Joris Memelink & Thomas van Welsenes & Sebastiaan van Wijland
Interviewee	Mr. Hertawan & Mr. Suantara
Location	DLHK unit 16, Badung regency, Bali, Indonesia

Start of interview

Interviewers	Do you have data of different types of waste being collected?
Respondent	Only plastic and organics. Glass and other types are not recorded. However there is an organization called the Green House that does monitor different types of waste.
Interviewers	How many TSTP facilities in Badung regency?
Respondent	Fifteen are active in the Badung regency. We of DLHK have two functions. Those are recycling and education. These education programs are performed on schools.
Interviewers	When did you start the education program?
Respondent	2 years ago the education program started in elementary schools.
Interviewers	What data is available about waste processing in the regency?
Respondent	(Mr. Suantara provides the team a sheet with various data and explains each of the categories). Cleaning is done everyday on the beaches of Kuta from 6 to 9 in the morning so the beaches are clean for the tourists. This is done from November until March.
Interviewers	You think the 10% of the waste that is not being processed (as indicated on the sheet provided) is due to the government trucks not being able to reach all residents?
Respondent	No, it is being thrown away in the wrong place. For example rivers and land.
Interviewers	A lot of villages handle a lot of their own waste because the government can't manage the whole regency right?
Respondent	Yes, a lot of northern villages in the Badung regency are very traditional and they often throw away their waste in the rivers, burn it or throw it in land. They are the result of the 10% waste that is not being handled.
Interviewers	Do you think plastic travels through the Bali straight?
Respondent	Possibly a little bit but most comes through straight of Lombok and circulates in the Indian Ocean. When the wind direction changes due to the rainy season the plastic from the Indian Ocean travels to Bali's coast.
Interviewers	The cleaning of the Beaches, such as Kuta and Seminyak, are these the responsibility of DLHK?
Respondent	It is a cooperation between different parties. Such as local hotels and restaurants and TSPT's. Also companies like Coca Cola, Danone and Aqua sponsor the clean ups with excavators. The TSPT's work together with DLHK.
Interviewers	Do other regencies have the same construction for their beach clean ups?

Respondent	Not sure as we do not share this information. But Badung is a lot bigger and has the biggest problem so most attention goes to Badung.
Interviewers	Have you noticed a decline in tourists due to the plastic?
Respondent	Not sure but we try to clean as much as we can during the rainy season.
Interviewers	Can you provide more data on the amount of waste that is handled in Badung?
Respondent	Right now not sure, but we can keep mail contact and share information next week.

End of interview

C.5. BALI HOTEL ASSOCIATION

Transcript	Bali Hotel Association (BHA)
Date	Wednesday October 24th 2018
Interviewers	Erik van Utenhove & Thomas van Welsenes
Interviewee	Mr. Warta, Director of Environment
Location	Hotel Primebiz, Kuta, Badung regency, Bali, Indonesia

Start of interview

Interviewers	*...Introduction about our project and how we do our measurements...* We also try to gather information in general about waste in Bali. Like how does it work, for example facilities like EcoBali that picks it up or
Respondent	(interrupting) Oh have you met Paola?
Interviewers	Yes we visited her 3 times already.
Respondent	I think she has a lot of data.
Interviewers	Yes we are already in discussion with them about that, but they don't have all the data that we want. It's hard because a lot of stuff is just not monitored. EcoBali, they handle a lot of waste but they don't really check everything. It's difficult because not even the government institutes check it that much. We went to DLHK and they just started monitoring the amounts this year for the first time.
Respondent	Where?
Interviewers	To DHLK
Respondent	Oh DHLK. Yes yes. I think one of the weaknesses of our government is if we are looking for data there's hardly any because their focus is just to do it. But I believe there is a department for data analysis and collection but it doesn't function very well here. So if you check, for example, how much waste Bali produces 10 years ago compared to now, there is no certain governmental body that can answer that question.
Interviewers	That's I think the biggest issue we faced as well. That's why we tried to get a lot of contacts locally, also with you guys, to get multiple sources and try to get better insight.
Respondent	What data do you think we can help you with?
Interviewers	I spoke to Wiwied and, for example, you guys organize this year on the 15th of September the international cleanup day.
Respondent	Yes we have been doing this since 2013, but its once a year you know. But we collect a lot of data.
Interviewers	I'm not sure if it's possible to share that data with us? Because it is also for multiple regions in Bali and so far we have only looked at the Southwest of Bali. If we could look at other regions as well we can look for comparisons and differences. Because for us it's impossible to do 100's of measurements as we're here only for a limited stay. So that's one of the question I wanted to ask you.
Respondent	I think it's okay. We started with one zone back in 2013 and ever since we keep adding zones. Last year we had 11 zones and this year we have 15 zones, including one in Northwest Bali. We have several data and it's also separated per category. Its okay we can share it with you, I think here is no secret on this.
Interviewers	That would be great.
Respondent	Do you need the data from 2013 as well, just as comparison? The more you have I think the better.
Interviewers	If it would be possible to get all the date that would be excellent.

Respondent Okay

Interviewers You said 15 zones, so that means 15 different places that are measured?

Respondent Yes, we try to expand every time. For example in Kuta we have zones in South of Kuta, Kuta Legian and Seminyak. Every zone have their own leader

Interviewers (interrupting) The leader is a hotel group?

Respondent Hotel group, yes. Actually this International Coastal Cleanup is only one of our programs. As an Association, which is now consisting of 150+ hotels, so me as a director of environment want to coordinate every member. Because we also have some big hotels like Hilton groups, Starwood Marriott and Heritage. They are all very advanced in environmental initiatives. But some of our hotels are independent small hotel, they don't have resources or knowledge on how to participate in this program. So that's my part, to function ourselves, the association, as the bridge and share the knowledge with all the hotels so that they can adopt. Like how to manage energy efficiently, water consumption and waste management. For example we also collect used cooking oil and send it to a company that can process it to bio-diesel The we also collect soap bars that guests used in the room, and reprocess it into a new soap bar and send it to the rural area. So the association plays the part as organizer coordinator.
Actually it's not really the solution for the plastic problem, it's more like an awareness campaign. We invite all the hotel members to join this day. We also invite school children and communities. I think the more people who are aware of the problem that we will face if we don't manage the waste properly, the better. So that's why its not really a solution but it's an education program from Bali Hotel Association to the public.

Interviewers Do you see a shift in mentality? For example, 5 years ago, there were more people throwing their trash at the street compared to now?

Respondent I think from 5 years ago we have a lot of improvement in terms of awareness. I joined the cleanup last month in Sanur, but they don't have a lot of rubbish brought to the shore. Like last 2 years there was so many, but this year it's cleaner. I think the media is very helpful for this, but I think it's still far away.

Interviewers Normally it starts to get really dirty at the beaches around November/December right?

Respondent Yes, like this month (October) until the end of rainy season.
For me I believe to solve this problem is the education on how you treat your plastic. 1) You have to reduce your consumption, and 2) you have to take care how you treat your plastic waste. This month we are going to launch a very small initiative, where our old bed sheets will be send to a foundation that recycles the sheets for re-usable shopping bags. We will give them to our staff so that they can change their habit when they go to the minimart, for example, and that they don't ask for a plastic bag. It is only a small step but It starts small and when it then escalates and everyone is doing it we can reduce the number of plastic bags.

Interviewers We also feel that right now there is almost no data collected on the problem. Collecting data may take a couple years and wont fix the problem directly, but at the end you may find a solution that tackles the problem at the source. Right now cleaning at the beaches is necessary but it's the end of the process. But you want to find a solution at the beginning.

Respondent Yes. So that is why with this campaign, use your garbed bag when you shop, is solving the problem at the source. Beach cleaning is not a solution but it's a campaign.

Interviewers That's like part of our project. We collect the garbage and categorize it to find the source of the problem and determine what the biggest polluter is right now. But at the end the solution has to come from the mindset in particular.

Respondent So your expectation for the outcome of your study is something like a recommendation for Bali?

Interviewers Yes but we will also do a recommendation for a follow-up research in Bali. Right now we are collecting the data and at the end of our research we will have recommendations concerning waste management in Bali. We noticed that a lot of people just throw their trash away near the rivers and at the beach, and with our measurements we hope to find the main drivers for the plastic waste. Then maybe the next group can start designing solutions for waste management systems or river catchment devices. These are just examples but when our research is done we can pinpoint it more.

Respondent How do you manage your plastic waste in Holland?

Interviewers We have different bins for waste categories. Everyone grew up and saw their parents doing it so it's really normal to categorize your waste. Our infrastructure is very excisable and we're only a small country, so at every place the garbage truck can access to collect the waste. I think here (Bali) the biggest problem is that in the more rural villages the garbage trucks can't get there, so they have to manage their waste themselves. And if they don't have the money to buy, like, a garbage truck themselves they just throw it away in the river because that is the easiest way.

Respondent That's what happens. In the past everything is organic and when you buy something everything is wrapped in banana leaf. So our parents or grandparents used to do that and just throw away everything because it's all degradable. But now, with the same habit which is passed down from generation to generation, we treat everything the same way like we're throwing the banana leaf. So that's the problem. People who doing that sometimes are just feeling innocent. "No I'm doing fine, I'm just throwing rubbish". For us, in Bali, rubbish is dirty, so we don't want to talk about it and nobody wants to accept it. So, for example, when the government wants to build a temporary dumpsite people will not accept it. "Don't do it here, do it somewhere else". So who will take care of that? That's the problem also.

Interviewers So its more like a conservative mindset that people don't want to change?

Respondent Correct.

Interviewers I feel like the new generation, though, is getting a lot of educated programs.

Respondent Yes but what happens is when they come out of school they are faced with the reality that their parents are not doing that. At school they get taught to put this plastic bottle in this yellow bin, something like that. But when they get back home, when they do that, ask their parents "do you have a yellow bin?" they say "Don't worry about it, just throw it away". So that is a conflict in the mind of the kids. That's the challenge.

Interviewers Is Bali working more on this education or is the whole of Indonesia that is doing this?

Respondent I saw a lot of initiative from the environmental ministry. Companies like Danone and Unilever are also doing that. But the problem here is that nothing is coordinated, everybody is doing their own part, there is no collaboration.

Interviewers Yes, that's what we have noticed also with the government facilities and with, like, EcoBali and other companies we have talked to. Some don't want to share information because they have conflicting goals or there is no universal goal. Everybody wants kinda the same thing but nobody is communicating like one goal.

Respondent *(interrupting)* And then between one division of the government to the other division, they don't have same data. They all have different data and they don't want to share *(laughing)*

Interviewers Yes they don't share. they always say you have to go there or there.

Respondent Actually the goal for Indonesia set by the government, regarding the environmental ministry, by 2020 Indonesia is aiming to reduce plastic waste by 70%.

Interviewers 17?

Respondent 70

Interviewers Wow!

Respondent But I don't know, what are the practical steps in that. But as a hotel association we like to encourage our members to reduce plastic waste, for example push them to provide refillable bottles in the room instead of the plastic cups and provide a water dispenser on every floor. It's just small things, but maybe it can help. I think real action is required. So that's why we try to push and push our members, okay lets do it and don't want to wait for the government to tell us to do. Just do it, with or without the government. The future of Bali tourism is to keep Bali clean and green.

Interviewers Did you notice that the plastic on the beaches have a negative effect on tourism?

Respondent It's really. But in term of tourist numbers it's always going up. But if you have this negative press coverage it's not good for your brand and it could also create an image that Bali is a cheap destination that don't care about the environment. That's what we worry about.

Interviewers Last year it really exploded in the media right?

Interviewers When there was the "garbage emergency"

Respondent Yes last year. Luckily the local government of Badung regency have a lot of money. They stand by everyday with around 55 people with their excavator. Because today they clean it, the next day everything is back again. It's not only in Bali right, ocean is all connected. Maybe people in Java are throwing rubbish in the river and ends up here because the wind is blowing from the west during rainy season.

Interviewers What are your thoughts, like if you had to say a percentage, how much do you expect that comes from Bali and how much from the ocean?

Respondent It's difficult.

Interviewers Would you say that the majority comes from Bali?

Respondent Maybe.

Interviewers Well that's what we are trying to measure.

Respondent Like yesterday I went up to Singaraja and on the way I see a pile of rubbis, with a red plastic bag, green plastic bag, everything just pilled up on the road side waiting for collection. But I think some of it will just go to the water channel and end up in the ocean. And then this year, maybe end of the year, will end up in Kuta (laughing).

Interviewers Yes, eventually.

Respondent How to stop that? That's the question. Stop from the source. If you have the recommendation or the final result of your study we would love to hear that.

Interviewers Yes, definitely

Respondent Maybe we can implement some. I think it's a good collaboration between the practician and the academics.

..Discussion about data exchange and other contacts in Bali..

Interviewers I still have one more question. How does it work from the government with regulation, legislation and funding and how is this structured from Indonesia to the islands. You said, for example, that the local government of Badung regency has a lot of money but where does this come from?

Respondent The local government budget consist of 2 parts. One is from the central government. You have a special allocation for things that cover public services like education and healthcare.

Interviewers So Badung gets more because

Respondent (interrupting) I think in that part it's a bit equal, it depends on how large the population of your area is. The other part is what they call the local income from the tax. Badung is where, I think, 80% of the hotels in Bali are located. When guest stay in the hotel they pay 10% tax, this one goes to Badung. That's why Badung is one of the wealthiest local government in Indonesia, they have a lot of money from this tourism sector. When you eat at a restaurant they charge you 10%, that goes to local government. It's not to Bali but only to the local government, by law, because Badung is central government. The autonomy is in the regency level, so this level can do whatever they want to do with the local tax that they collect. That's why they have a lot of money to spend on promoting the tourism, cleaning tools and whatever they want.

Interviewers Is there also a division for waste management services?

Respondent Yes, they do have their department like DHLK, and DHLK Badung has more money then, for example DHLK Denpansar, so they can buy more trucks and excavators. That's why, when Kuta has waste emergency, Badung can deploy a lot of equipment.

Interviewers And do they also focus on education, concerning waste management?

Respondent Not yet, to my knowledge. Right now it's only initiative from the private sector, NGO or foundations. Only when there is any special international environmental date, or something ceremonial, the government is doing that.

Interviewers Are there also people that try to approach the government?

Respondent In every meeting where we have the chance to meet the official we voice the concern. Please help, you have the money so you have to spend and this is how you should spend.

Interviewers Isn't there a way to go to them and say, like, we have this project plan or idea and can the Badung regency then support it? Or is it not working that way?

Respondent	I don't have that experience because we always do our own funding. So far we don't have any project that involve big funding. If you work with local NGO there is a chance, if this one connects with their program. But working with government is also complicated, you'll have a lot of paperwork (laughing). The best thing is you know them first and you make your own initiative with your own money and when you're able to show initial success they will look at you. You can not approach them with empty hands. You have to show something. This is what we have done, we want to make it bigger and we need your support.
Interviewers	Is that something you guys want to do in the future? Like as you said, you always start with small projects but maybe make a project bigger and approach the government?
Respondent	BHA will take part but we don't want to do as ourselves. I feel like it's better to work together under one umbrella with stakeholders, because we're just an organization and we don't have a lot of money. We don't want to charge our member for another fee. I want to give them a program and show them what they can do themselves. As a group of hotels, then, we can go to the government and show them what we're doing.

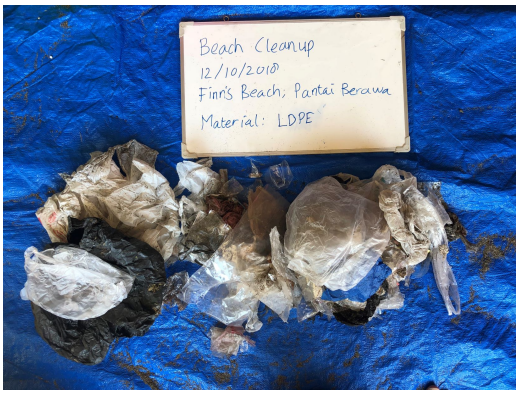
End of interview

D

IMAGERY AND SITE IMPRESSION

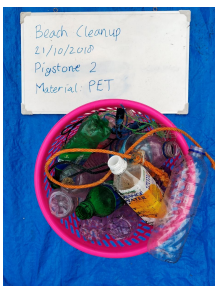
D.1. PLASTIC CLASSIFICATION

(a) HDPE



(b) LDPE

(c) PP & PS



(d) PET

(e) Multi

Figure D.1: Examples of plastics within the classification

D.2. RIVER SITE OVERVIEW

D.2.1. PERERENAN

(a) Riverbank 1 (b) Riverbank 2

Figure D.2: River banks of the location Pererenan

(a) (b) (c)

Figure D.3: Photos of the location Perenan

(a) (b) (c)

Figure D.4: Photos of the location Pererenan

D.2.2. BERAWA

(a) Riverbank 1 (b) Riverbank 2

Figure D.5: River banks of the location Berawa

(a) (b) (c)

Figure D.6: Photos of the location Berawa

(a) (b) (c)

Figure D.7: Photos of the location Berawa

D.2.3. SUDIMARA

(a) Riverbank 1 (b) Riverbank 2

Figure D.8: River banks of the location Sudimara

(a) (b) (c)

Figure D.9: Photos of the location Sudimara

(a) (b) (c)

Figure D.10: Photos of the location Sudimara after heavy rain

D.3. BEACH CLEANUPS

(a) (b) (c)

Figure D.11: Photos of the cleanup at Finns Beach

(a) (b) (c)

Figure D.12: Photos of the cleanup at Nyanyi Beach

(a) (b) (c)

Figure D.13: Photos of before the cleanup and plastic waste collected at the beaches

E

Area Overview of the Conceptual Model per Season

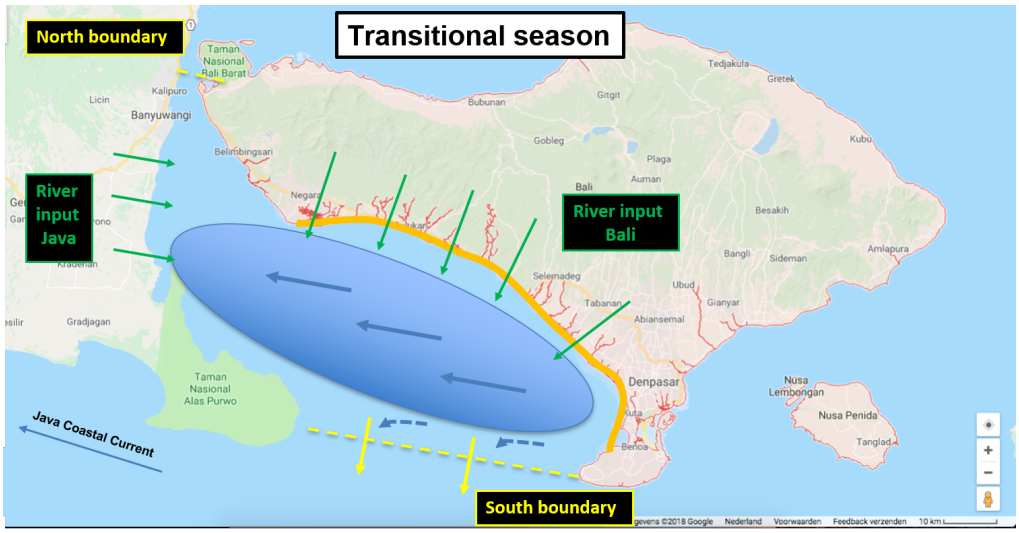


Figure E.1: Conceptual model during Transitional season

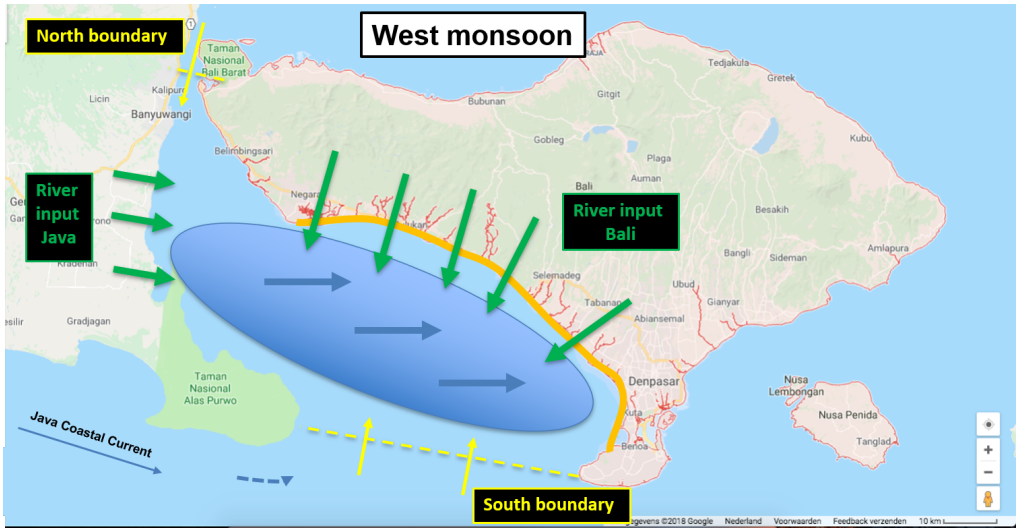


Figure E.2: Conceptual model during West monsoon

F

BACKGROUND INFORMATION

F.1. LANDFILL DUMPING TECHNIQUES

Landfill	Description
Semi-controlled dumping	A semi-controlled dump is a disposal location were there is no engineering done whatsoever on how the dumping should take place. At these kind of sites there is some directed dumping of waste. Due to the unorganized structure of these dumps there is an unlimited release of contaminants and there is no landfill gas management possible. This means that the landfill gas will be directly emitted in the air [25].
Controlled dumping	Controlled dumping is the situation when there is a placement strategy of the waste on specific areas and this placement of different types of waste is registered in a common database. Unless the dumping is used in a more controlled matter than semi-controlled dumping there is still an unlimited release of contaminants. Furthermore, there is no landfill gas management that takes place.
Controlled landfill	There can be spoken of a controlled landfill when next to a placement strategy of the waste and a common database there is a daily cover material. Cover material is useful for multiple reasons including: prevention- or blown off litter, odours in the region, scavenging, infestation, bad aesthetics and the minimization of risk of a fire [53]. Furthermore, there is a clear infrastructure present and surface water is monitored. In this type of structure the landfill is protected to contaminants to some degree. Also passive ventilation or flaring of methane gasses is present which reduces the amount of methane gasses trapped or emitted to the environment.
Sanitary landfill	Waste is registered and placed in a common database over the landfill, there is a daily cover present for reasons metioned at controlled lanfill. Furthermore, there are measures present for the final top cover and closure, there is a clear infrastructure over the landfill. Also there are treatment facilities for liner and leachate in place. When the lifetime of the landfill is expired there is an existing plan for the future of the landfill. Typically in a sanitary landfill the landfill gasses will be flared including energy recovery.

Table F.1: Different classes of landfills [3]

F.2. RECYCLING TECHNIQUES

- **Re-extrusion**
  Re-extrusion, also known as primary recycling is the process where scraps of mostly single-polymer plastics are reintroduced to the extrusion process of similar materials. An example of this is when a

LDPE crate which has been produced, does not meet the requirements. The crate is then shredded into pieces and reused in the extruding process of a new crate made of the same type of plastic [54]. At this point this is the most used recycling technique for plastic solid waste[28].

- **Mechanical recycling**
  Mechanical recycling, known as secondary recycling, is the process where plastic waste is recovered and then reused by manufacturing plastic products with mechanical means. Mechanical recycling can only be utilized on single polymer plastics which include: PP, PS and PE. These type of plastics are complex in structure and are often contaminated. Therefore there are several treatment procedures before plastic waste can be recycled mechanically. Examples are: shredding of plastic, separation of contaminants, separation of plastic based on density, milling of single-polymer together, washing & drying and finally the extrusion process can be performed again [28].
- **Chemical recycling**
  Chemical recycling, also referred to as tertiary recycling, is an advanced technological process which turns plastic materials into small molecules, often liquids and gases. These molecules are then used as materials for the production of innovative petrochemicals and plastics. The word chemical is used because the chemical structure of the polymers are changed. At this point a lot of research is performed on the possibilities of chemical recycling. These processes include gasification, liquid-gas hydrogenation, pyrolysis, viscosity breaking, and steam cracking. Plastic types that are suitable for this kind of recycling consist of PET, PE and HDPE [28].
- **Energy recovery**
  Energy recovery essentially is production of energy in the from of heat, steam or electricity from plastic waste through incineration. This form of recycling is only preferred when other recycling processes fail due to technical or economical reasons. Because plastic is created out of oil the calorific value of plastic is high. This makes the heating value of plastic high, which results into plastic being a reliable energy source. If water and carbon-dioxide are produced during combustion, plastic can turn into fuel, similar to other petroleum based fuels [55].

F.3. OCEANOGRAPHY INDIAN OCEAN

The Indian Ocean represents 20% of the sea area and has an average depth of 4000 m, with depths reaching nearly 7.5 km in the Java Trench. On a large scale 3 distinct circulation systems can be delineated: the seasonally changing monsoon gyre, the Somali Current and the Indian Ocean gyre, consisting of the South Equatorial Current and the West Australian Current.

The Indian Ocean gyre is located south of the equator. This is a steady subtropical gyre rotating counterclockwise all year long. It consists of the westward-flowing South Equatorial Current and the West Australia Current. All currents and their (seasonal) direction are depicted in Figure F.1. Yet, the most remarkable currents in the Indian Ocean occur in the tropical regions of the northern Indian Ocean, where a seasonal reversal current takes place. This area is influenced by monsoon where the direction of currents differ per monsoon period. These variations are due to changes in seasonal wind direction. During Northeast monsoon in the winter (December to April) the current flows from the NE towards Africa [39]. The current reverses during Southwest monsoon in the summer (June to October), flowing from NE towards India [39]. Also with respect to plastic pollution, these currents are of particular interest as they flow along the coastline of the largest polluters in the world, as discussed in Section 3.2.1.

F.4. OCEANOGRAPHY PACIFIC OCEAN

The massive Pacific Ocean covers up a third of the world surface and is the largest body of water on the globe [56]. It is also the deepest ocean with an average depth of 4200 m, and host trenches exceeding depth of 10.9 km [56]. Unlike the Indian Ocean, surface currents in the Pacific Ocean remain the same during winter and summer. The Pacific current consists of two main circulations, which are made up of a few sub-currents. In the north, the North Pacific gyre has a clockwise rotation whereby the North Equatorial Current swings up past the Japanese coast and into the North Pacific Current. This current finishes its circuit as the California Current. The other major circulation is the South Pacific gyre, which sends cold water from the West Wind Drift into the Peru Current, then flows back towards Australia into the South Equatorial Current.

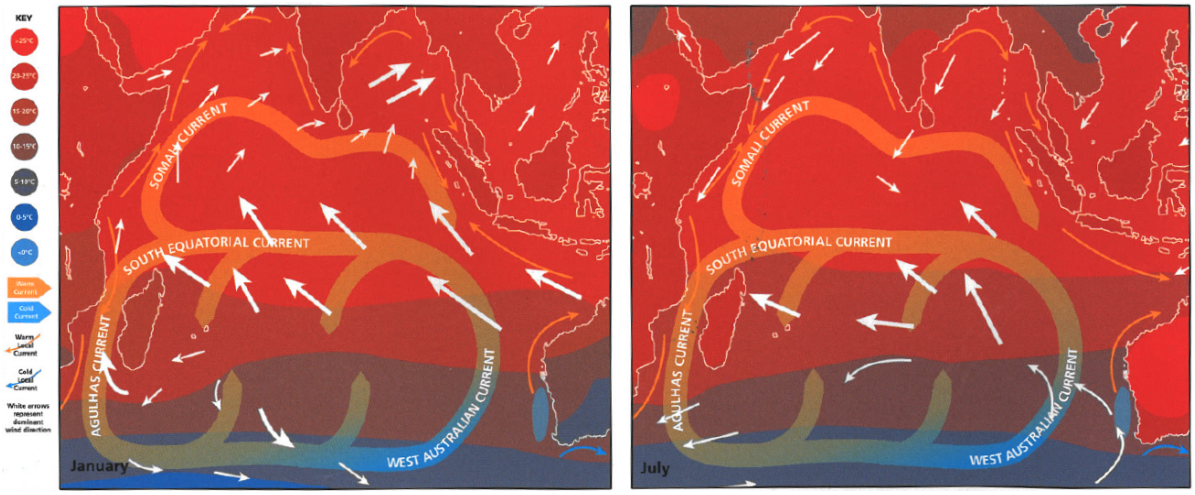


Figure F.1: Temperature, Winds and Currents in the Indian Ocean [56]

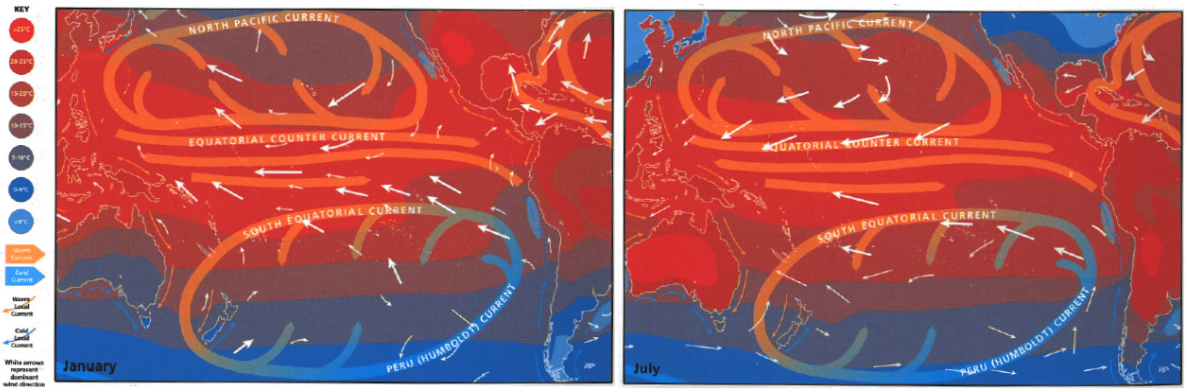


Figure F.2: Temperature, Winds and Currents in the Pacific Ocean [56]

F.5. STAKEHOLDERS OF WASTE MANAGEMENT IN BALI

Institution	Description
DLH	DLH is a governmental institute on the provincial level that is the operational head of the underlying DLHK institutes. DLH is an institution that sets up meetings and different guidelines for the DLHK of the regencies. Furthermore, they gather data on waste generation and processing in the different regencies through DLHK's. During the visit at DLH Bali they were able to provide waste generation values from all the regencies, that are given in Appendix A.
DLHK	DLHK is a governmental institute on a regional level who carries out the waste management in a regency. Every DLHK determines their own interpretation of the management guidelines set by DLH and therefore determines their regencies' management towards waste management. During the visit at DLHK Badung they were able to give different values on the waste generation and management within the Badung regency.
TPA	TPA is another word for a landfill, essentially all the waste of a certain region ends up here. Every regency has its own TPA but TPA Suwung in Denpasar is used by several regencies and is therefore the largest landfill. As of this year, TPA's have to record how many trucks with garbage are being brought in which then has to be reported to DLHK.

TPST & TPST3R	TPST and TPST3R are locations were waste is gathered and segregated before it is disposed in a landfill. At a TPST mixed waste is brought in which will hereafter be transported in bulk to the landfills. At a TPST3R mixed waste is separated, notice that 3R stands for reuse, recycle and reduce. Furthermore, at the TPST3R facility recyclable materials are separated in one of the many subcategories. For example, light bulbs, bottle caps, and plastic bottles will eventually be sold to a recycling facility in Java. An interview with the head of a TPST3R is given in Appendix C.
DESA	DESA is a waste pickup service with trucks, the waste is picked up at assigned disposal locations. These trucks were bought by a local community or village and they bring the waste from the disposal locations to the TPST or TP3R.
Bank Sampah	Bank Sampah literally means 'waste bank' where households, who either can not pay a pick-up service or who do not have a pick-up service available for them, have the possibility to dispose their waste. Households can earn money for their waste if they have separated their garbage into non-organic and organic. The organic waste is then composted and the non-organic waste is further divided into recyclables and non-recyclables. This can be considered as a very viable solution for the waste problem, as households are offered an economic incentive to drop off their waste in an Eco friendly way. The payments for the waste of households is then saved in a 'bank' account, this is why it is called a waste bank.
Households	Households are the main contributor to waste production on Bali and every household has different ways for disposal of their waste. These are further presented in Section 9.1.2
Eco-Bali	Eco-Bali is a mayor institute that is privately owned and has different services regarding waste management, especially in the Badung regency. Eco-Bali provides a waste pick-up service after which they separate and dispose the waste in an Eco-friendly matter. They also create more awareness in several ways among locals regarding the impact of improper waste waste management. Eco-Bali has provided us with information on the waste management system on Bali in general.
Hotels & restaurants	Hotels and restaurants have a strong interest in clean beaches, as their customers require that. Especially the stretches in their vicinity. A lot of these hotels and restaurants organize a public or private beach cleanup to maintain a clean beach for their customers. For instance Finn's beach club organizes a beach cleanup for a large stretch every week. This is were a part of the data for Chapter 8 came from.
4Ocean	4Ocean sells bracelets that are made from recycled plastic and they promise their customers that for every bracelet 0.5 kg of waste is removed from the environment. During field work we encountered them cleaning rivers all the way up to the West of Bali at Negara. Because of the magnitude of the work they do on Bali, they are included in the waste management stakeholder table as an individual stakeholder.
Trash Hero	Trash Hero is an organization who operates all over the world and is substantial in Bali. They create awareness, provide multiple teams who clean the beaches and land, organize waste education for schools and universities and organize better waste handling systems for local communities [57].
Informal sector	The informal sector consists of individuals who pick up recyclable plastics from the streets, beaches, landfills, and many more places. The informal sector removes a significant amount of recyclables from the environment. Individuals sell their recyclables to middlemen who in their turn sell them to the recycle factories in Java.

G

SURVEY TEMPLATES

G.1. RIVER SURVEY [FROM THE OCEAN CLEANUP]

1. Environmental mapping Monitior date: Bridge: Surveyer:

Bathymetry

Start time:

Stop time:

Bridge dimentions

Bridge length	start	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8	ML9	ML10	stop

Navigation frequency

Nr of ships:	U1	U2	U3	U4	U5	U6	U7	U8
Time								
Amount								

River particularities

Description:

Location:

Wind

	U1	U2	U3	U4	U5	U6	U7	U8
Time								
Speed (m/s)								
Direction								

Water level

	U1	U2	U3	U4	U5	U6	U7	U8
ML2 (m)								
ML4 (m)								

2. Visual Counting Monitior date: Bridge: Surveyer:

	Particle count [parts/2min]											Flow velocity [m/s]										
Time	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8	ML9	ML10	ML11	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8	ML9	ML10	ML11

3. Camera's Monitor date: Bridge: Surveyer:

Camera [#]	Location [#]	Start time [T]	Stop time [T]	Noodle time [T]	Comments

4. Trawling + Primary sorting Monitor date: Bridge: Surveyer:

Time	Duration	Location	Velocity	Count	Trawl	Depth	Org	PET		PS		PS- E		PO_hard		PO_soft		Rest	
[T]	[min]	[#]	[m/s]	[#/min]	[s/b]	[m]	[kg]	[kg]	#	[kg]	#	[kg]	#	[kg]	#	[kg]	#	[kg]	#
					S														
					B														
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5. Secondary sorting Sorting date: Surveyer:

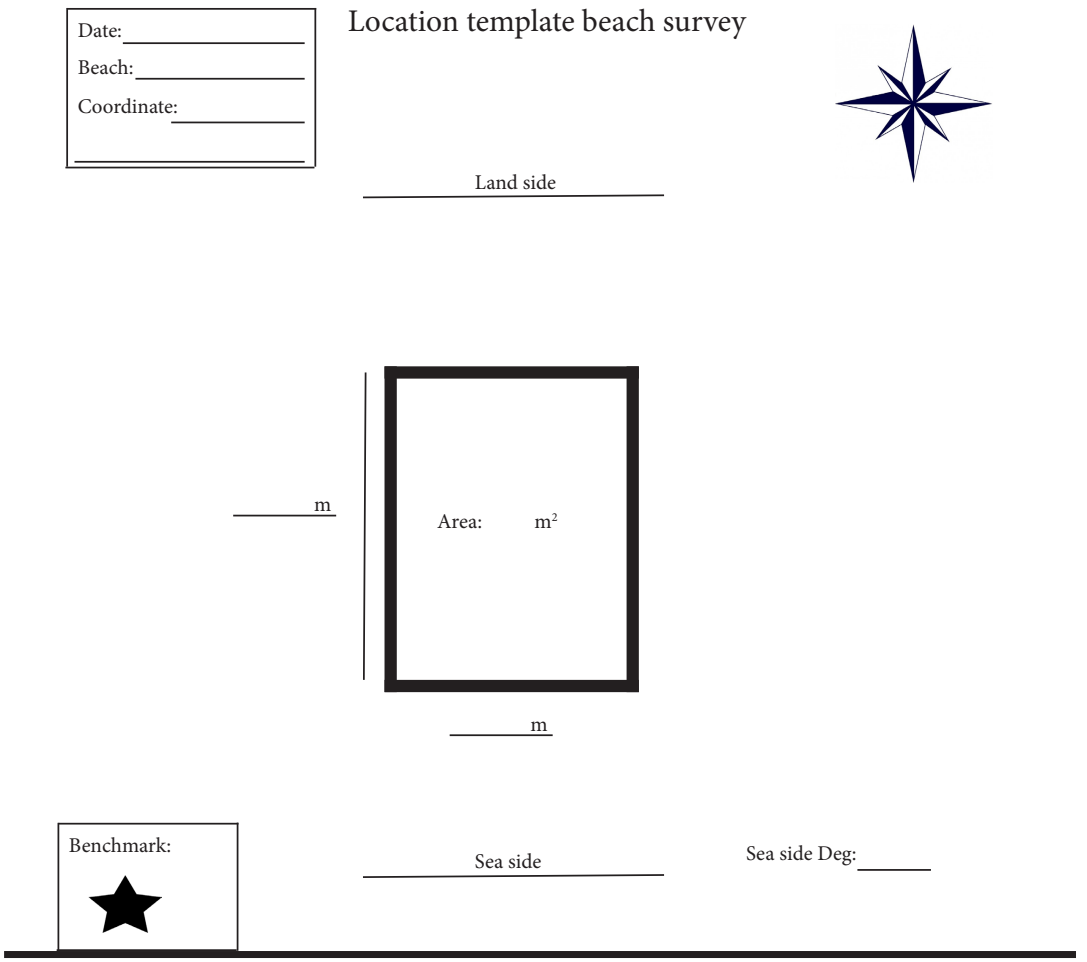
Date sample	Bridge	Trawl	PET		PS		PS-E		PO_hard		PO_soft		Unknown		TOTAL		Comments
			DW	V	DW	V	DW	V	DW	V	DW	V	DW	V	DW	V	
		[S/B]	[kg]	[L]	[kg]	[L]	[kg]	[L]	[kg]	[L]	[kg]	[L]	[kg]	[L]	[kg]	[L]	

G.2. BEACH SURVEY

Survey date: BeachID:

Pantai Project		Orginization	
		Surveyor Name	
		Contact	
		BeachID	
1. GENERAL			*Description*
Survey type	Accumulation / Standing-stock		Type of shoreline survey conducted
Survey date			Date survey was performed
Beach name			Unique name by which the beach is known
Shoreline name			Name of shoreline if beach name is not known
Region			Name of the region where the beach is located
Season			
Date of last cleaning			Date on which the beach was lasted cleaned, either by survey or maintenance cleaning
Storm activity			Has there been any significant storm activity since the last survey
# of persons			Number of persons conducting the survey
2. SURVEY CHARACTERISTICS			
Coordinate at start of shoreline section	Latitude	Longitude	Record as XXX.XXXX at start of shoreline section
Coordinate at start of shoreline section	Latitude:	Longitude:	Record as XXX.XXXX at end of shoreline section
Time start/end	Start:	End:	Begin and end time of survey
Length of sample area			Length of survey area, measured in longshore direction (meters)
Width of beach			width of the beach at time of survey (meters)
Large items	Yes / No		Did you note large items in the surveyed debris? (yes/no)
Quality assurance	Yes / No		Is the sample for quality assurance purposes (yes/no)

Aerial sketch/photo of beach area (location template on next page)



Beach survey location identification:

1. Identify suitable measurement area (preferred length is 100m)
2. Mark measurement area with material on boundaries
3. Make pictures of measurement area, preferably at multiple angles to map the exact area for future measurements.
4. Measure beach length (measure beach width when low tide is at its peak)
5. One longitudinal benchmark at the measurement site with distance (e.g. temple, goryne)
6. Fill in all fields possible in the form Beach Characteristics
7. Fill in all fields possible in the form Location template
8. Start measurement (either parallel lines or perpendicular lines dependent on location)

Survey date: BeachID:

3. SOURCE CHARCTERISTICS			*Description*
Location & major beach usage	URBAN		Select one and indicate the major usage type (recreation, fishing, surfing, boat access or remote)
	SEMI-URBAN		
	RURAL		
Estimated visitors/year			Estimate of number of persons who visit the beach annually
Access			Vehicular (can drive on beach), pedestrian, (must walk), isolated (i.e. need a vessel)
Nearest town	Name:		Name of nearest town
	Distance:		Distance to the nearest town (kilometres)
	Direction:		Direction to the nearest town (cardinal direction, e.g. NE, SSW)
Nearest River	Name:		Name of nearest river. If not relevent write down 0 and go to next section
	Distance:		Distance to the nearest river (or stream) (kilometres)
	Direction:		Direction to the nearest river or stream (cardinal direction, e.g. NE, SSW)
River/Creek input	Yes / No		Whether the nearest river or stream has an outlet directly to this beach (yes/no)
Pipes or drains input	Yes / No		Whether there is an pipe or drain outlet directly to this beach (yes/no)
4. BEACH CHARACTERISTICS			
Slope			Slope of the beach - distance for 1 m of fall from mid point of beach
Aspect			Direction you are facing when you look out at the water (cardinal direction, e.g. NE, SSW)
Prevailing wind			Direction of prevailing wind for the beach system (cardinal direction, e.g. NE, SSW)
Beach curveture			Concave, convex, sinusoidal, straight
Horizontal profile			Horizontal shape of the beach (Linear/Concave/Convex/Mixed)
Total beach length			Length measured along the mid point of the beach (kilometres)
Substratum type			For example a sandy or gravel beach (or pebble, rock etc)
Substratum uniformity			Percentag coverage of the main substrate type named above (%)
Back of beach			Describe the landward limit (Rock wall, Cliff, vegetation, Parking lot)
Offshore reefs	Yes / No		Presence of offshore reefs (yes/no)
Offshore seagrass	Yes / No		Presence of offshore seagrass beds (yes/no)
Tidal Range			Max - min vertical tidal range (metres). You can use tide chart
Tidal distance			Horizontal distance (metres) from the lowtide- to hightide line. Measure on beach during HW & LW
Notes			

Survey date : BeachID:

5. Primary sorting												
Org	**PET**		**PS**		**PS-E**		**PE-hard**		**PE-Soft**		**Rest**	
[kg]	[kg]	#	[kg]	#	[kg]	#	[kg]	#	[kg]	#	[kg]	#

TOTAL [KG]:

TOTAL [#]:

G.3. LOCAL SURVEY ON WASTE PERCEPTION

ENGLISH VERSION SURVEY

Pantai Project

DISCLAIMER Survey No. _____

The purpose of this survey is to measure personal waste management in Indonesia
Your response will be strictly confidential and remains anonymous
These results will be used for a non-profit student project, Pantai Project
Please fill in these results as accurate as possible

1. **What is your gender?** *Please fill in one of the boxes*

   Male ☐ Female ☐ Other ☐

2. **What is your age?**

   0-17 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ >55 ☐

3. **What is your education level?**

   No study ☐ elementary school ☐ junior high ☐

   senior high university ☐ other ☐

4. **What type of work do you do?** *Please write your answer inside the box*

5. **Where are your priorities?** *Please fill in one box per category*

	No Priority	Low Priority	Neutral	High Priority	Full Priority
Work	☐	☐	☐	☐	☐
Family	☐	☐	☐	☐	☐
Health	☐	☐	☐	☐	☐
Environment	☐	☐	☐	☐	☐
Leisure	☐	☐	☐	☐	☐
Education	☐	☐	☐	☐	☐

6. Do you separate your waste in different types (plastic, glass, organic etc.)?

No ☐ Some of it ☐ All of it ☐

7. How do you dispose your waste? *Please fill in one or more boxes*

In disposal bins ☐ Dump it at the river ☐ Dump it in land ☐

Gets picked up ☐ Other (*Please specify in the box*):

8. What happens with your waste? *Please fill in one or more boxes*

Ends up in landfill ☐ Gets recycled ☐ Ends up in the ocean ☐

Gets burned ☐ Ends up on land ☐

9. Do you care what happens with your waste?

No ☐ Little bit ☐ I care ☐ Very much ☐

10. How much would you pay per month to have all of your waste recycled?
Fill in your amount in the box

IDR

11. What happens with waste in the river?

Government cleans the waste ☐ Waste ends up in the ocean ☐

It breaks down in weeks ☐ Individuals clean he waste ☐

Other ☐

12. Which type of waste have the most negative impact?

Organic (Food, wood, plants) ☐ Paper ☐ Glass ☐ Plastic ☐

13. How much of the plastics are recycled in Indonesia?

0% ☐ 1-25% ☐ 26-50% ☐ 51-75% ☐ 75-99% ☐ 100% ☐

14. Plastic in the oceans is mostly bad for:

Politics ☐ Tourism ☐ Economy ☐ Environment ☐

Agriculture ☐

15. How do you know about this? *Refers to question 14*

Family ☐ Work ☐ Government advertising ☐ Newspaper ☐

Education ☐ Projects/Organizations ☐

Other (*Please specify in the box)*:

16. Do you try to prevent plastics from entering the ocean?

No ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

If you wish to receive a summary of the results, please indicate your email:

Thanks for your participation.

INDONESIAN VERSION SURVEY

Pantai Project

PENAFIAN (*DISCLAIMER*) Nomor Survei: _____

Survei ini bertujuan untuk mengetahui pengelolaan sampah pribadi di Indonesia. Kerahasiaan jawaban Anda akan dijaga dan nama Anda tidak disebutkan di dalam formulir survei ini.
Hasil dari survei ini akan digunakan untuk proyek nirlaba yang dilakukan oleh siswa-siswi yang bernama Pantai Project. Mohon berikan jawaban yang seakurat mungkin.

1. **Apa jenis kelamin Anda?** *Mohon centang salah satu kotak di bawah ini*
   Laki-laki □ Perempuan □ Lainnya □

2. **Berapakah umur Anda?**
   0-17 □ 8-25 □ 26-35 □ 36-45 □ 46-55 □ >55 □

3. **Apa pendidikan terakhir Anda?**
   Tidak sekolah □ SD □ SMP □
   SMA □ Perguruan Tinggi (Universitas) □ Lainnya □

4. **Apa jenis pekerjaan Anda?** *Mohon tulis jawaban Anda di dalam kotak yang tersedia berikut ini*

5. **Apa prioritas Anda?** *Mohon centang satu kotak per kategori*

	Bukan Prioritas	Prioritas Rendah	Netral	Prioritas Tinggi	Prioritas Penuh
Pekerjaan	□	□	□	□	□
Keluarga	□	□	□	□	□
Kesehatan	□	□	□	□	□
Lingkungan	□	□	□	□	□
Hiburan	□	□	□	□	□
Pendidikan	□	□	□	□	□

6. Apakah Anda memisahkan sampah Anda menjadi beberapa golongan (plastik, kaca, organik, dll.)?

Tidak □ Beberapa saja □ Semuanya □

7. Bagaimana Anda membuang sampah? *Mohon centang satu atau lebih kotak berikut*

di tempat sampah □ dibuang di sungai □ dibuang di tanah □

Ada yang mengumpulkan □ Lainnya (*Mohon jelaskan di dalam kotak yang tersedia*):

8. **Apa yang terjadi dengan sampah Anda?** *Mohon centang satu atau lebih kotak berikut ini*

berakhir di TPA □ didaur ulang □ berakhir di laut □

dibakar □ berakhir di tanah □

9. **Apakah Anda peduli dengan apa yang terjadi dengan sampah Anda?**

Tidak □ Sedikit □ Saya peduli □ Sangat peduli □

10. Berapa yang bersedia Anda bayar per bulan untuk mendaur ulang semua sampah Anda?

Mohon tulis biaya yang bersedia Anda habiskan di dalam kotak yang tersedia

Rupiah

11. Apa yang terjadi dengan sampah di sungai?

Pemerintah membersihkannya □ Sampah tersebut berakhir di laut □

Terurai dalam waktu beberapa minggu □ Dibersihkan oleh penduduk □

Lainnya □

12. Jenis sampah mana yang paling memiliki dampak negatif?

Organik (Makanan, kayu, tumbuhan) □ Kertas □ Kaca □ Plastik □

13. Berapa persenkah plastik yang didaur ulang di Indonesia?

0% □ 1-25% □ 26-50% □ 51-75% □ 75-99% □ 100% □

14. Plastik di laut paling tidak baik bagi:

Politik □ Pariwisata □ Ekonomi □ Lingkungan □

Pertanian □

15. Dari mana Anda tahu? *Mengacu pada pertanyaan nomor 14*

Keluarga □ Pekerjaan □ Iklan Pemerintah □ Surat Kabar □

Pendidikan □ Proyek/Lembaga □

Lainnya (*mohon jelaskan di dalam kotak yang tersedia)*:

16. **Apakah Anda melakukan upaya untuk mencegah masukknya plastik ke laut?**
Tidak □ Jarang □ Kadang □ Sering □ Selalu □

Jika Anda ingin mendapatkan ringkasan dari hasil survei ini, mohon tulis alamat email Anda:

Terima kasih atas parisipasi Anda.

Figure G.1: Bahasa version survey

H

SAFETY REPORT

Safety and security plan

This document provides the information about safety and security during the performance of the multidisciplinary project by the Pantai Project team.

General information

Group members	Thomas Michel van Welsenes Johan Frederik Sebastiaan van Wijland Joris Roeland Memelink Reinoud Paul de Klerk Erik Jacob Fulco van Utenhove
Country	Indonesia
Location of residence	Canggu, Bali island
Office space	Uduyana University Jl. Raya Kampus UNUD, Kampus Bukit Jimbaran, Kuta Selatan, Kabupaten Badung, Bali 803611, Indonesia
Contact in Bali	Sila Dharma (siladharma@unud.ac.id)
Purpose of trip	Multidisciplinary project MSc Hydraulic Engineering program
Start of project	06-09-2018
End of project	06-11-2018

Points of attention during our trip

Special points of attention during our trip are mainly the times we must travel. During our project in Bali we have to travel to our office space. We will probably travel on scooters or motorcycles. Because the traffic rules will be followed differently than we know in the Netherlands, we have to be very careful during these movements.

Personal behavior

We should adapt to a certain level to the local culture, to prevent any aggression as result from miscommunication. We already have a list of Indonesian emergency words which are useful when in a difficult situation and we also plan to learn some Bahasa Indonesia through Duolingo. Furthermore, we should not drink too much and go out during the night. As during this time, the most accidents occur.

Group rules of engagement

We planned rules in our group that should prevent any accidents or illnesses. At all times never should anyone be outside our home alone, so we always should minimal be with two persons during trips. Secondly you always need to be attainable through the cellular network in case of any emergency. Furthermore, we agreed to the risk reduction measurements and made our boundaries clear regarding these points so we are on the same level regarding safety, hygiene and appearance.

Risk Analysis

Threat	**Probability**	**Impact**	**Risk Reduction measurements**
Corruption	High (4), corruption is something, which is embedded in Indonesia.	Low (1)	Stay low key, don't wear anything expensive what could lead to assumptions of wealth which could trigger exploitation.
Traffic accident	Medium (3), Traffic in Indonesia is known to be unsafe. Especially in the weekends as there are a lot of people who drive under influence.	High (4)	Increase the amount of awareness during participation in traffic. Don't travel more than necessary. If we have to travel with a taxi, only with taxi's we trust.
Illness	High (4), There are a lot of diseases, which you could get if you're not careful.	High (4)	Always check if water bottles are sealed and watch out with uncooked food. Also we brought malaria emergency pills and we are properly vaccinated.
Theft	High (4), People don't have a high income, they could see us as an easy way to earn money.	Medium (3)	Stay low key, don't wear anything expensive what could lead to assumptions of wealth. Prevent being out during nighttime too much, always stay together with the group. Only drive with taxi drivers we trust

Contingency planning

During an incident, so one of the threats becomes reality we have a plan with several steps.

During the incident

Step 1: Check if our group is complete and everyone is in good condition.

Step 2: Stay calm; be clear that we don't oppose a threat to our offenders to avoid waking any aggression.

Step 3: Consider CARE, so firstly stay calm, accept this is happening to us and observe the situation, release our valuables if they ask for it and look for any things during the situation we could identify later.

Step 4: We should consider anything we could do to make the situation safer, but not play the hero as this could seem as a threat to the offenders. Also you should check if you should involve the police as this can have a negative effect on the situation.

After the incident

Step 5: Two should contact in order of the S&S checklist (stated in the last page). The other two should write down all details of the incident, this way every detail can be told the best later as people tend to forget detail during stressful conditions.

In the event of an emergency or incident during your stay abroad

1. Call the emergency number of the insurance company Chartis (AIG): **+31 10 4535656** and have the TU Delft travel insurance policy number ready: **60.10.4117**
2. Call the emergency number of the embassy/consulate which you have noted down,
3. Inform the TU Delft control room: **+31 15 278 1226**
4. Inform your TU Delft supervisor and/or your faculty international office.
5. Inform your parents and local supervisor

Keep this information with your important papers and in your phone!

Step 6: Evaluate if the police should be involved (This is goes during the S&S checklist)

Step 7: Evaluate the accident with the group, and give each other the support needed.

H.1. SAFETY EVALUATION

Before initiation of the project a safety report was created to be prepared properly in case unwanted events occurred. However, when arrived on location, there were some additional safety measures identified. The most important operations that increased our safety during the research and accommodation are summarized here, some aspects can be used for future research in countries with similar circumstances.

- Preparations with regard to safety were done through the following topics: special points of attention, personal behaviour, group rules of engagement and a risk analysis. The risk analysis contained basic potential hazards conveyed with the probability and impact of these threats. See Appendix H.
- It was decided that during river measurements, no direct contact with water should occur, as the rivers in Bali are generally very polluted. This would significantly reduce the chances on an infection and sickness.
- At home a lot of plastic from beaches and rivers had to be separated by hand which meant physical contact had to be made with trash. There was a high possibility these particles were covered in dirt and rotting substances so it was required we would wear gloves and disinfect hands properly afterwards
- As traffic jams are a part of life in Bali our main transportation vehicle was a motorbike. This improved our mobility when we had to travel towards Denpasar for an interview. However, it also made us vulnerable as traffic can be chaotic and only helmet were available for protection. An accident could then result in bad injuries so we had to be extremely careful when driving around. During the project it appeared that if you'd just drive slowly and pay attention to other people, driving a motorbike was safe.
- A taxi was used to travel to the river and beach measurement sites. For these measurements a lot of equipment had to to be brought to and from the sites which would make travelling on a motorbike unsafe.