2016

# Bali Polymer Accumulation

## PLASTIC ACCUMULATION IN A VILLAGE ENVIRONMENT

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# Contents

# Introduction

## *Project purpose*

This project is intended to gather data on the accumulation rates of different types of waste polymers in a rural environment in Indonesia. In order to prepare for this goal and ensure relevant data collection, research was done into Balinese infrastructure and culture, waste management and mixed solid waste (M.S.W.) breakdown, as well as polymer waste identification. This project hopes to answer the following question:

How much and what kinds of polymer waste accumulate in one week in a case study village in Bali?

# Literature review

## *Waste accumulation*

### General

Solid waste tends to be divided into the following categories: paper and carboard, organic waste, metal, glass, wood, textiles, and plastic. (Alwaeli, 2012) Of these categories paper and cardboard, metal, glass, wood, textiles and even organic watse can be reprocessed, reused, or recycled for a lower cost than processing new material. Plastic on the other hand is often more costly to gather, sort, clean, and reprocess than it is simply to produce; and unlike paper and cardboard, wood, and organic waste, it is not generally biodegrade. Plastic accumulation comes down to an interaction between low production costs, and high waste processing costs.

### Polymer

In 2009 plastics made up approximately 12% of the total waste generated in the EU. (Alwaeli, 2012) Average per capita mixed solid waste production is approximately 2.8 Kg per day. (Helmi, 2012) Keeping both of these things in mind each person in Bali likely produces approximately 336 grams of polymer waste per day, 2.352 Kg per week, 10.192 Kg per month, 122.304 Kg per year. Of those amounts 80% is likely to consist of thermoplastic waste; those thermoplastics can be reclaimed as material or energy, however to be financially viable a clear understanding of the scale of accumulation and the breakdown by plastic type would be required.

## *Bali Specific Issues*

### Rural

In many parts of the developing world centrally regulated waste management systems are poorly implemented or altogether missing. For example because the people of Nepal have a greater demand for other public services, waste management has been afforded a low priority and in many municipalities has been poorly implemented.(ADB, 2013) Most of Indonesia is similarly lacking organised waste management infrastructure. While official landfills exist, that does not mean that small villages will have the resources to gather and deliver their waste to these locations. For example Bali alone produces approximately 20,000 cubic meters of mixed solid waste per day. Of this amount only 25% reaches a legally sanctioned landfill.(Helmi, 2012) In Ghana because of lacking infrastructure and education pertaining to plastic waste disposal, accumulating waste often

finds its way into water supplies where it accumulates.(Abota, 2012) Similarly in Bali plastic waste is washed from the streets into the canal and aquaduct system built during dutch occupation which supplies water from the center of the island out in gravity fed channels to the mangrove swamps and eventually the sea. Rapid population growth has also contributed to strain on local resources. In Bali between 1990 and 2012 the resident population nearly doubled, from 2.7 million to 3.9 million. The tourist population of Bali comparatively has spiked from approximately 1 million annually to 2.6 million in the same timeline.(Helmi, 2012)

## Cultural

Balinese traditions remain in many ways exactly as they have been for hundreds of years, however recent changes in consumption habits and economic shifts from agricultural living to metropolitan development are having a significant impact on life for the Balinese. Products that prior to 10 years ago would have been bought in bulk in paper, metal, or glass packaging now come in large rolls of single use metalized multi-layer film sachets. These packets include snacks, candy, dish soap, shampoo and conditioner; additionally this form of packaging, which is illegal in places like Singapore because of the massive waste they generate, often bear names like Indofoods and Unilever. Bali has a law on the books which establishes producer responsibility for plastic waste, however without appropriate enforcement this law has no impact.

Three times every day every Balinese household will weave offering baskets out of banana leaf for the Gods of the island and place small amounts of rice, fruit, even coffee inside them. Traditional materials for these offerings, every day food preparation and construction, were almost entirely biodegradable. In modern times however the low cost availability of polymers, in part due to Indonesia's booming petrochemical industry, have flooded island life with plastic bags, food containers and wrappers, toys, tools, gadgets, and other miscellaneous polymers. Now it is rare to find an offering that does not have a plastic wrapped candy sitting in it. At the end of the day the offerings are swept into the gutter, bottles and containers from household waste are thrown out on the street, construction debris and broken tools and appliances are buried near the construction site, and regularly polymer waste is swept into little piles to be burned in the jungle. The Balinese are extremely resourceful and will reuse glass bottles, and bits of metal, they will pass hand-me-down clothes through many owners and repair whatever they can; however without a clear value or use, they are not culturally or logistically prepared for any scale of plastic waste accumulation.

## Waste Management

According to a 2012 estimate, each person on the globe produces an average of 1.2 kg of mixed solid waste per day. (Hoornweg & Bhada-Tata, 2012) While this number is likely to be lower in Bali due to cultural influence and low overall consumption, this is still a significant amount of waste. Organized waste management in Bali effectively only exists in Denpasar. The government has regulated a few official landfills, however a 2012 article in the Jakarta post clearly cited several illegal dump sites on the island of Bali. These sites are being used to supplement feed for pigs and chickens, and additionally becoming the sites of "scavenger hamlets" of Javanese supporting their families on whatever can be salvaged from the site. (Helmi, 2012)

Several organizations exist on the island that work as recyclers. These organizations are mostly concerned with separating waste in order to acquire material for products such as glass bottles for cutting and repurposing or certain multilayer films for use in making upcycled consumer bags. A company called PT Enviro-Pallets has specialized in using multilayer films and contaminated material to produce durable recycled plastic pallets for logistical and industrial use. This demonstrates a value for a material that otherwise is not recyclable on Bali.

A loose organization of Javanese scrap peddlers exist on Bali as middlemen, crisscrossing the island on motor scooters, purchasing pre-sorted plastic waste from locals for resale to vendors who transport the material to Java for reuse and recycling.

# Project

## *Materials*

### M.S.W.

The mixed solid waste that was collected in this project included polymer film such as that found in food wrappers, 3D polymers such as bottles and straws, a minor amount of metal glass and textiles, and a few token examples of e-waste and pharmaceutical waste in the form of batteries, compact fluorescent lightbulbs and a few blister packages of old medication. As waste is defined as anything that would generally be thrown away, participants were instructed to collect only the things they would not repurpose, with the exception of bio-waste such as diapers, needles, or sanitary products.

Image 1. An example of M.S.W. prior to sorting.

### Safety equipment

Equipment intended to protect anyone sorting waste from harm.

Inventory:

Gloves

Heavy gloves 5 pair, neoprene gloves 5 pair, nitrile gloves mediumx100 largex100

Masks/ filters

Adjustable masks with filters x5, spare filters x4

Coverings

Disposable bunny suits x16, shoe covers x100, rubber boots 4 pair

Eyewear

Safety glasses x5

## Sorting equipment

Equipment intended to simplify the sorting process, organization, and cleanup.

Inventory:

Area preparation

Tarp 5m by 5m

Duct Tape or masking tape one roll

Scissors 1 pair

Separation

Bags 100 by 120cm x40

Zip ties x50

Markers gold, silver and black 1 of each

## Field testing kit

Intended to be as stripped down and basic a field identification kit as possible.

Inventory

Lighter

Knife

Pliers

UV light

Ethanol

Copper piece

## Collected Waste

## *Methods*

### Planned vs. actual collection procedure

A detailed account of the initial plan for collection and the different methods by which the plan was altered due to unforeseeable circumstances is included as an attachment.

The collection of materials was accomplished by going household by household in the village of Keliki to recruit participating households. Each of these households collected waste for the project according to project guidelines and held this material aside for pickup. Participating households were instructed to collect waste according to the project protocol, meaning things that would be thrown away during the collection period with the exception of biological waste. Each household was provided garbage bags and were told a bit about the background of the project.

The population of Keliki is approximately 4000 people and at an average of 15 people per extended family household that makes 266 households. Calculating 1.2 kg of mixed solid waste per day by 15 people per household by 7 total days of collection, comes to 126 kg of MSW per household per week. A team of 5 people working 7 hour days for the one week sorting period would result in approximately 245 human working hours; considering a waste sorting rate of 10 kg MSW per hour would allow a maximum of 2450 kg of MSW to be sorted. Meaning that ideally the participation of approximately 19 households was required for the project. In the end we recruited 8 households that had no tourist contact, 5 households with tourist contact, 8 local shops or warungs, and 1 hotel.

At the end of the collection period each bag was labelled with a bag number and data pertaining to the household type, the number of residents, the number of children (residents under the age of 10) was collected. Each bag of waste was weighed and the weights were recorded in correlation to the bag number that was written onto each bag with a black sharpie or silver paint pen. Bags of waste were brought to the sorting area and waited under a canopy to protect them from the elements as best as possible.

### Sorting

This project was designed with stringent safety requirements, and while I could not provide protective footwear to anyone helping me sort, gloves, safety glasses, bunny suits, and particulate masks were provided. Unfortunately I could not convince anyone else to use them. What I assumed was a cultural difference turned out to be simple practicality, the humidity and heat were so great that wearing the gear for more than 15 minutes would have been inhumane.

The area was prepared with a large plastic tarp. Each bag of waste would be reweighed to confirm our numbers before being opened and laid out. Then a group of volunteers who were both available and wanted to help with the project and I sorted the material into woven baskets.

Image 2. An example of M.S.W. after sorting.

## MSW breakdown

According to instruction participants were to collect anything that they would throw away, with the exception of bio-waste. It turns out that the Balinese throw out very little, most bio-waste is set aside for composting, most metal and glass can be reused; in fact, much of the plastic that I had expected to see was sorted aside for sale to scrap peddlers. Most of the material consisted of polymer films, however there were examples of glass, metal, paper, much of which could still have been sorted for scrap value. We also recovered a few items that would be classified as e-waste and pharmaceutical waste; these were set aside as they should be specially disposed of. Most of the items appeared to be result of everyday waste accumulation; some was evidently included as it was convenient to be rid of it. Plastics were separated primarily according to physical characteristics. Film plastics covered any plastic that is a thin malleable sheet, such as a bags or cling wrap. 3D plastics include anything that maintains a rigid 3D shape, bottles, forks, clips, etc. Non-plastics included everything else, these were not separated into sub categories but were weighed as their own category.

## Polymer breakdown

The categories of plastic films are as follow: LDPE mixed consisting of mostly shopping bags. Metalized multi-layer were primarily food and hygiene product wrappers. Printed multi-layer materials generally include ink layers but do not have a reflective aluminum element. Clear plastics are mixed and may represent many types of plastic. Contaminated plastics show wear indicating that they may have been exposed to the elements for a significant period before the collection began; these were given their own category as I do not believe they represent accumulation from the collection period.

The categories of 3D plastics were similar but kept simpler: 3D mixed plastics consisted of any molded or thermoformed non-film plastic. However, as some examples appeared to be extremely weathered, contaminated plastics was included again as a separate category. Styrene was given its own category as well because it was so bulky and different compared to the weight to size ratio of other plastics.

## Data collection

Once waste had been sorted into different categories it was put back into bags to be weighed.

Material was weighed in a large black plastic bag which had a tare weight of 100g. This tare was considered and compensated for during the weighing and recording process.

### Identification procedure

While separation categories were simplified to speed up sorting, initially the project was intended to have an element of on-site identification. As most of the techniques I researched included a degree of empirical uncertainty I kept my focus on separation by observable material properties and took samples from several categories for analysis at the lab. A description of the different methods initially intended is included below.

## Observational methods

### *Transparency/ Translucency*

The transparency or translucency of a piece of plastic can give you information as to a likely identification. If a plastic is transparent it is likely to be PET, PP, PVC, or PS. If a plastic is either translucent or opaque it may still be PP, PET, or HIPS, but may additionally be HDPE, LDPE, or LLDPE. (Manrich, 2009)

## Physical methods

### *Bend/Breaking*

Bend a sample piece of plastic waste and observe whether or not white stress markings appear. Plastics that will generally show white stress markings include PP PS and PVC, while HDPE and PET will not discolor. (Manrich, 2009) Bending or stressing a thin plastic to its yield point may cause either deformation or a brittle shattering break, this tends to be a simple means of seperating transparent PP which bends and deforms from PS which shatters.

### *Hardness*

LDPE and HDPE are generally easily scratched by a fingernail, where most other plastics like PP will generally not be marked. Furthermore LDPE is significantly more malleable than HDPE. (Manrich, 2009)

## Chemical testing

### *Burning*

Combustion testing of a piece of plastic can be very useful. The coloration of the flame produced from burning different plastics will differ in coloration from one another. Additionally the odor and pH of the smoke , and whether the plastic self-extinguishes will give you significant criteria for determining plastic makeup. A simple method of halogenation testing can be performed by heating a copper wire in a flame before touching that wire to a piece of plastic, by returning the wire to the flame to burn off the melted plastic residue you can determine the presence of chlorine or other halogens by looking for the indicative green coloration of the flames.

### *Density*

Simple comparative density testing of plastics can be performed by taking small slivers of material and suspending them in solutions of salt and ethanol. Using charts available in many of my references you can then determine which plastics sink and float in each solution giving an idea of the molecular density of the suspended samples.

### *Solubility*

Solubility testing can differentiate between different plastics as well by taking small samples of plastic and testing whether or not they dissolve in different solutions. Most plastics are relatively chemically inert, depending in part on their degree of polymerization however in many cases specific solvents will break apart different plastics while leaving others alone. This observable property in conjunction with known outcomes allows identification.

# Results

## *Total Polymer accumulation by weight*

Each of the plastic types was sorted and weighed individually as each source was divided, then the weights of each type were added together and compared to the final weights of the total amount of each material.

| Material type | | Sums | Final |
|---|---|---|---|
| LDPE mix | | **5.9** | **6** |
| Metalized | | **3** | **2.9** |
| Printed multi-layer | | **2.4** | **2.1** |
| Unprinted clear | | **3.4** | **3.1** |
| Contaminated | | **3.2** | **3.2** |
| | **total film** | **17.9** | **17.3** |
| 3-D mix | | **3** | **3** |
| 3-D contaminated | | **0.9** | **0.8** |
| Styrene | | **0.1** | **0.1** |
| | **total 3D** | **4** | **3.9** |
| Nonplastic | | **4.9** | **4.7** |
| | **total** | **26.8** | **25.9** |

Table 1. Material breakdown by type and weight.

## *Averages per person*

By dividing the amounts of M.S.W. produced by each source in one week, by the total number of residents in each source type, the per capita numbers become clear.

| Source type | Total weight | adults | children | people | per person |
|---|---|---|---|---|---|
| Tourist linked | 4.4 Kg | 32 | 16 | 48 | .0916 Kg |
| Non-Tourist linked | 4.1 Kg | 41 | 12 | 53 | .0773 Kg |

Table 2. Weekly accumulation of material per capita.

Warungs produced an average of 2.587 Kg of M.S.W. per week.

## *Waste by type*

Data pertaining to waste accumulation was collected in the form of weights. As each material type was separated, individual waste type weights were collected based on their source so that that material accumulation could be analyzed against sources. The following charts show the waste breakdown by source.

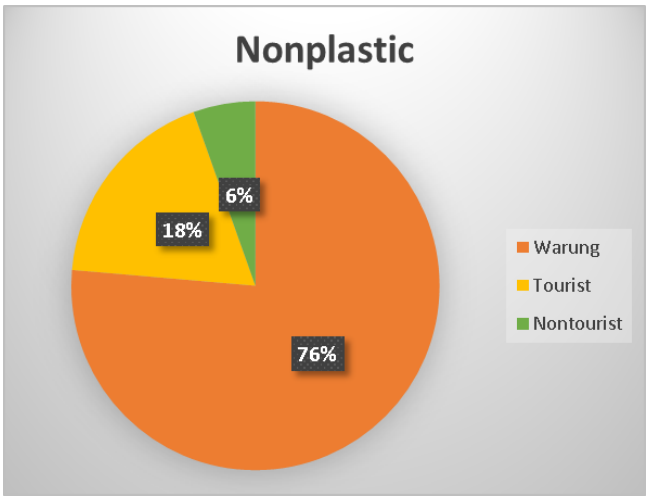


Figure 1. Nonplastic material breakdown by source.

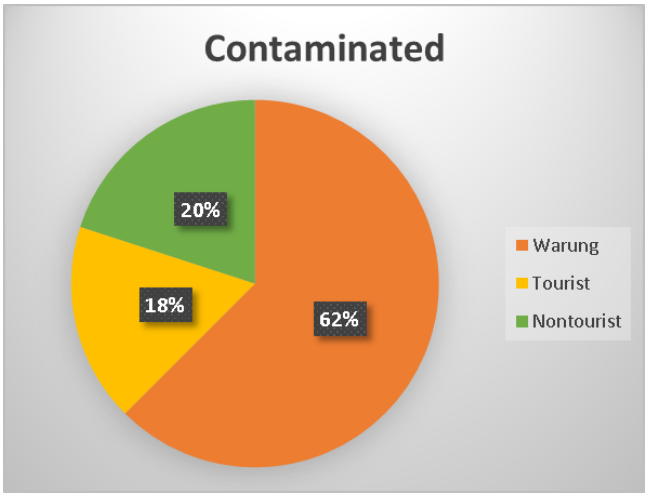


Figure 2. Contaminated film material breakdown by source.

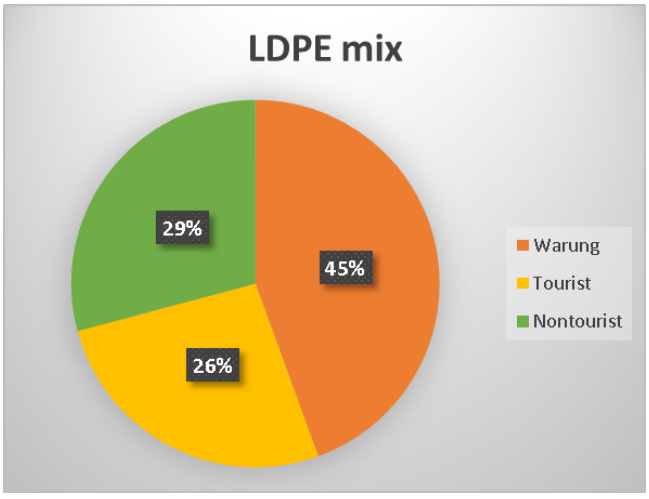


Figure 3. LDPE mixed film material breakdown by source.

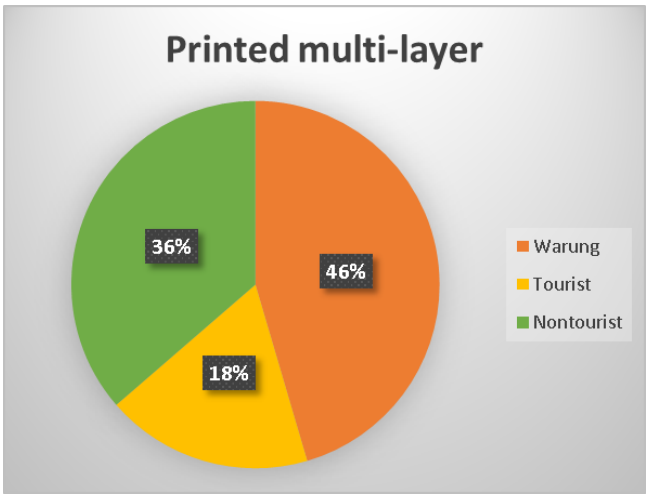


Figure 4. Printed multi-layer film material breakdown by source.

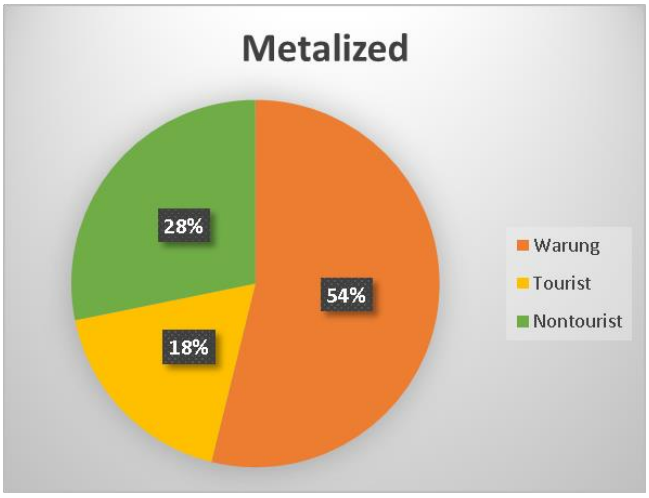


Figure 5. Metalized multi-layer film material breakdown by source.

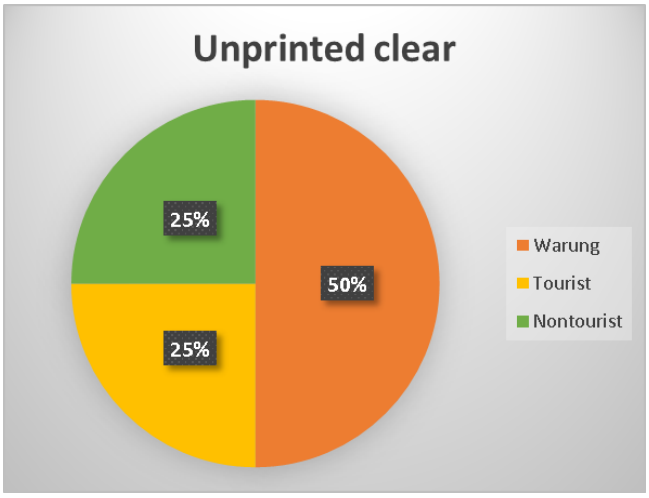


Figure 6. Unprinted clear film material breakdown by source.

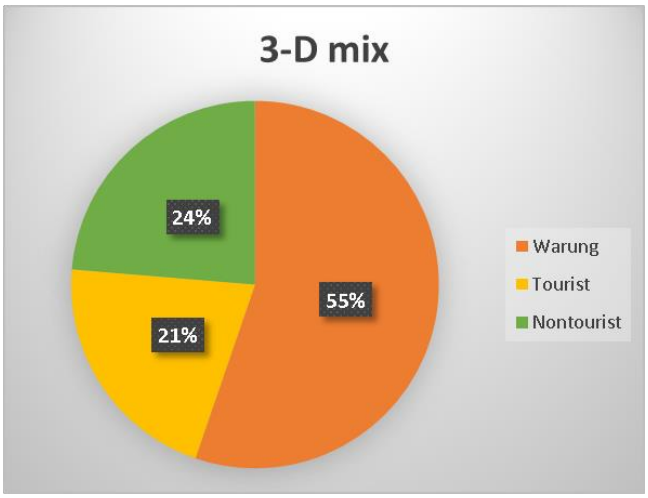


Figure 7. 3-D mixed material breakdown by source.

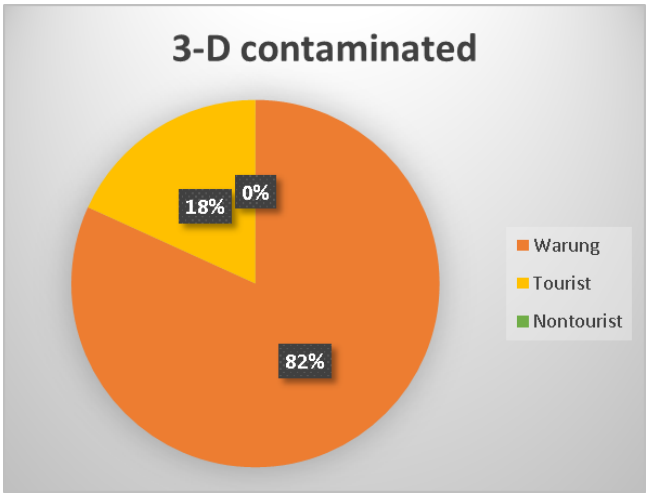


Figure 8. 3-D contaminated material breakdown by source.

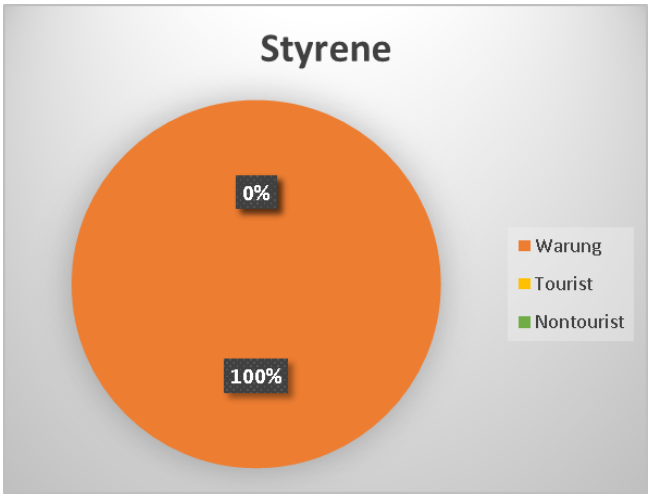


Figure 9. Styrene material breakdown by source.

# Discussion

## *Metalized multi-layer film*

While most types of polymer waste can find a collection and resale value, there are exceptions; the most notable of these is metalized multi-layer film. Some facilities exist that attempt to reclaim materials and value from waste such as printed circuit boards however these facilities are unable to process metalized multilayer films and are not up to international standards regarding waste water and runoff.

However the major limitation to the existing network of waste management organizations and material resellers is that certain materials such as multi-layer plastic films and metalized multi-layer plastic films do not fetch a high enough price to warrant collection. This is in part because these multi-layer films are difficult to recycle; they are made up of many different kinds of plastics, as well as inks, and aluminum, in the case of metalized films. As recycling generally depends upon separation of different plastics in order to confirm consistent melt properties this adds a significant obstacle.

## *Sources of error*

The most significant sources of error to this study were the size of the collection group and the duration of the project. By extending the collection times and scaling up the amount of households being surveyed data resolution would be greatly improved and potential error from these sources would be reduced.

Upgrading certain items of equipment to be specifically scaled to the project would also be helpful. For example the luggage scale that was used while being particularly utilitarian had very poor accuracy when measuring small amounts of waste. A scale that was designed to display grams and kilograms accurate from .01 grams to 20 kilograms would be more than sufficient. Minor discrepancies between initial weights as added together from individual source weights and final weights of all material gathered together could be eliminated with higher precision. The chart below demonstrates this difference, much of this is due to evaporation of liquids and in the case of the LDPE mixed films the addition of a bit of storm water, as it's bag was closest to the windy edge of the overhang. The general trend of weight reduction may also be due to biological interference. Small vertebrate and significant arthropod activity going into and out of the collected waste bags in search of food and one another caused much of the material to be stripped of any accumulated food particles. The bag of printed multi-layer coming from Western influenced households in particular housed a small colony of ants with pupae, this colony had moved out by the time all of the printed multi-layer had been accumulated together.

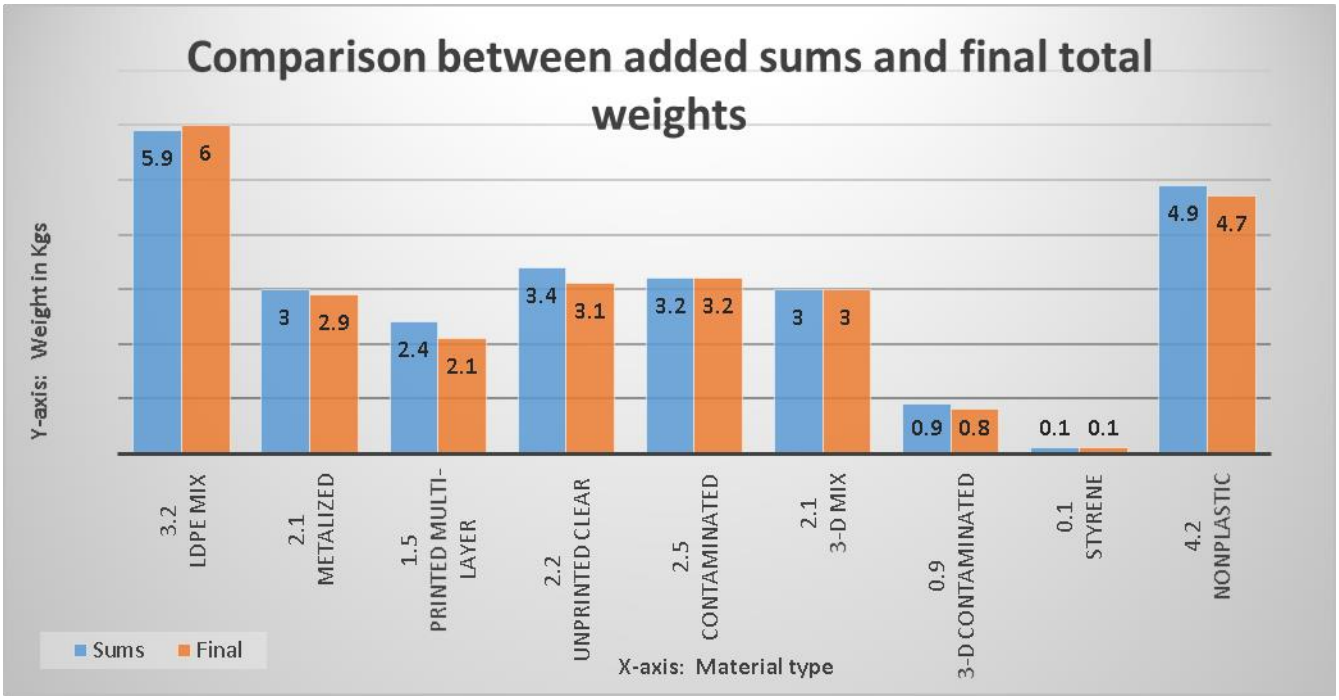


Figure 10. Comparison of accumulated sum totals vs. final total weights.

Additionally the scale had difficulty recording weights under 400 grams so in order to get accurate readings a 1 Kg hand weight was strapped to the bag of waste. This would push the scale past its minimum threshold. For example, a 200 gram bag would display a low weight reading when weighed, with the 1 Kg weight strapped to it the scale would read 1.2 Kg. The 1 Kg would be removed from the total weight in order to give an accurate reading. This proved to be a minor nuisance, and did not impact readings.

During sorting some bags of waste material turned out to be contaminated with biological material. As I could not convince any of the other participants to wear any more than gloves I did not wish to increase the risk to anyone kind enough to participate. In the cases in which biological contamination or sharps were found in a bag I immediately stopped work, put on the full safety gear to repack the bag which would then be removed from the study. A significant amount of data was lost; however this was required for the projects ethical standing. As an interesting note the data which was removed would have had a significant effect on final averages, the biologically contaminated material that was removed was much denser than an equivalent volume of mixed waste as can be seen below. Accidentally including this biological material would have been a significant source of error.

| | Totals before exclusions | | Remaining after exclusions | |
|---|---|---|---|---|
| | Weight | Avg. per person | Weight | Avg. per person |
| Tourist linked | 14.3 Kg | 0.2014 Kg | 4.4 Kg | 0.0916667 Kg |
| Non-Tourist linked | 5.3 Kg | 0.0898 Kg | 4.1 Kg | 0.0773585 Kg |

Table 3. Weekly accumulation per capita, with and without biological contamination.

### *Potential revisions to future studies*

Ideally future studies could expand this study by taking in multiple larger and longer duration case studies. If this study was used to create a streamlined kit and method that could be replicated in multiple locations simultaneously, it would vastly increase the amount of data brought in for analysis and provide an open source starting point for comparatively similar studies in other regions.

## Conclusion

The results of this project demonstrate that overall the accumulation of polymer waste is extremely low, the buildup appears to be visible because of lacking education regarding the availability of existing infrastructure and infrastructure that is unable to deal with all types of polymer waste. The actual Balinese polymer accumulation was significantly lower than expected, additionally a wide margin exists between accumulation in households living traditionally and tourist linked households. Based upon observations made in the village of Keliki the greatest sources of polymer waste appear to be centered around warungs, schools, and temple festivals.

The materials that are most difficult to process on the island are metalized multi-layer polymer films and biologically contaminated polymers such as the sodium polyacrylate found in diapers. Processing and collecting infrastructure would need to keep these materials in mind. Ideally any collection infrastructure would also keep in mind the inclement weather on the island and the need to keep water from accumulating in collection bins, to keep the material dry and reduce mosquito breeding areas as they pose a malarial and dengue fever risk.

While the issue of polymer accumulation in rural environments is daunting, with proper study it would not be impossible to design a saleable practical solution to it that could be adapted to different cultural and environmental needs.

# Acknowledgments


## *Pak Dewa and Ibu Jero*

Without whom the idea for this project would never have occurred. Their tireless coordination in the village of Keliki made this project a success.

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Without whom direction and motivation in this project would have been lacking. Her patience and experience in ecological projects were a major factor in the success of this project.

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Who were patient enough to host the project in Keliki as well as providing space and refreshments for participants sorting waste.

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For providing the background and education required as well as significant research and project materials involved in this project.

## *Anu Neuvonen*

Who always believed that I could be an engineer and accomplish the goals of this project. Her unwavering support has meant everything to me.

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# Attachments

## *Initial planning and preparation*

### Advance preparation

In the months leading up to this project, under the supervision of Valeria Poliakova, I researched similar studies found in other parts of the world, waste accumulation numbers in Indonesia, and polymer waste identification. The goal of this research was to uncover existing pitfalls and problems similar research encountered for planning purposes, to outline rough expected numbers for the project to work with, and to simplify the planning of field identification and sorting. In the final weeks, the focus shifted from individual research and planning, to involving other Arcada staff and students in a review process that allowed their input regarding the overall project plan, potential sources of error, and resource allocation. This was accomplished through several small meetings with staff members, several polymer film sorting sessions under the direction of Liuba Nikiforova, and a presentation of the overall motivation and project plan intended to generate feedback.

Other considerations in packing and preparations of equipment took into account availability of materials on the island, air travel regulations regarding liquids and other substances, and overall baggage weight restrictions. This process ultimately led to a very compact and functionally robust kit of safety, testing, and presentation equipment; as well as an overall plan that was flexible in order to account for unforeseen difficulties, and a basic breakdown of sorting categories that might provide valuable data despite regional variances in polymer blends and additive combinations that might complicate assured identification.

### Day 1

On arrival in Bali, make contact with Pak I Dewa in order to review and confirm the expectations and planning of the case study and suggest revision whenever necessary. Contact should be made with the local school and Banjar in order to determine the best location for/availability of a meeting and presentation point for a coffee get-together. Flyer designs should be finalized, translated, printed, and placed in order to give villagers plenty of time to familiarize themselves with the idea and spread notice by word of mouth. Once these tasks have been taken care of, review, translation, and finalization of the presentation can be focused on before the get-together.

### Coffee get-together

The purpose of this meeting with local Balinese villagers would be to impress upon them the importance of proper waste disposal, familiarize them with basic waste information, and finally to recruit them to collect their waste for this project. The meeting would also facilitate the distribution of waste collection bags and collection protocol handouts to representatives of volunteer households. The get-together was additionally meant to assess the interest of potential volunteers for the sorting phase of the project.

This get-together would consist of a brief presentation to disseminate information, followed by a question and answer session. This would likely entail an auditorium, seating, power for my projector and laptop, and a screen of some kind to project onto. A translator would have to work with me as my Bahasa and Balinese are insufficient to the task. As the title suggests coffee was to be provided in addition to a combination of local and Finnish snacks.

### Interim activities

Once the collection period had begun time would be allotted with which waste management services, recyclers and local industry could be contacted for interviews, and information regarding the accumulation of polymer waste in Bali on the whole and locally in villages like Keliki could be gathered. Additionally this would allow me to confirm which types of plastic can be recycled on the island, and which materials will have appreciable value for separation and collection at the village level. Local trouble spots and accumulation centers would also be a target of investigation during this period. Finally any local groups focused on the reuse, reduction or cleanup of wastes would be interviewed about any trouble materials that cannot be easily dealt with on the island and the potential next steps that can be taken both for the village and after this case study has concluded.

### Collection

This collection period was meant to allow time for collection of accumulating waste. At the end of this period Dewa and I planned to collect the waste from villagers and bring it back to the sorting area to be weighed sorted and weighed again. While collecting the waste from each local household we would interview to confirm specific data about the number of residents, their ages, and whether they had any direct contact from tourism.

## *Revision and alteration*

As many of my initial numbers were based on rough estimates, getting more accurate numbers from Dewa allowed me to make some revisions. Additionally unforeseen cultural differences and environmental factors forced an expected amount of change from the initial plans. This is the reason that so many of the plans were kept flexible initially.

### Immediate revisions

### Actual Day 1

Dewa was able to immediately provide information regarding the population and distribution of the people in the village of Keliki, altering many of the calculations I had made based on inaccurate initial assumptions. In a stroke of luck for this case study, Pak Dewa, who is the son of a previous village headman and was well acquainted with almost everyone in the village and able to converse freely and casually. This is significant because in Keliki not everyone is fluent in Bahasa Indonesia, the local language. Many villagers prefer to converse in Balinese; to complicate matters further, there are three different dialects of Balinese appropriate to the caste of the speaker and listener, which are functionally different languages. For practical purposes this meant that all of my plans of regarding the translation of flyers, handouts, and presentations would prove ineffective in communicating with a large group, and the existing project plans were revised.

### Coffee get-together and presentation

Because of language issues, the coffee get-together turned out to be impractical. Additionally the culture does not lend itself to dissemination of information through message boards; most vital information is related person to person through speech. I continued to revise and develop my presentation retuning it to an audience

of students at the local secondary school which would allow me to present in English, however I did not get the opportunity to present to them as their schedules were filled with examinations during my visit.

Because we could not recruit participants as we intended to, Dewa and I instead determined to go household by household recruiting families to participate in the waste collection. The population of Keliki is approximately 4000 people and at an average of 15 people per extended family household that makes 266 households. Initially I did my calculations based on an estimate of 9 people per household. Calculating 1.2 kg of mixed solid waste per day by 15 people per household by 7 total days of collection, you come to 126 kg of MSW per household per week. With a team of 5 people working 7 hour days for the one week sorting period we would have approximately 245 human working hours; considering a waste sorting rate of 10 kg MSW per hour we would be able to sort a maximum of 2450 kg of MSW. That meant that we would require the participation of approximately 19 households to meet our goal.

In the end we recruited 8 households that had no tourist contact, 5 households with tourist contact, 8 local shops or warungs, and 1 hotel. Instructions were given to collect anything they would throw away, with the exception of bio-waste such as diapers, needles, or sanitary products. They were provided garbage bags and were told a bit about the background of the project.

## Interim activities

During the collection week I met with a local recycler and visited his facilities. Olivier of Peduli Bali was happy to discuss polymer accumulation in Bali and the economics of waste collection. His facility was focused on removal of material from the waste stream for the purposes of resale and reuse for artistic and consumer products. I visited a nearby landfill and documented the conditions workers experienced and investigated which materials were reclaimed. It turns out that the vast majority of plastics that make their way to these facilities are sorted out for their material value; multi-layer and metalized multi-layer film was not sorted out and simply remained in a pile of waste.

I did my best to contact several other companies including PT Enviropallets an operation that claims to be able to take mixed polymer waste including metalized and multi-layer films and thermoform this waste into reusable industrial freight pallets. I was not able to confirm this impressive claim because my calls and e-mails were not returned. I had also originally planned to take a little time to investigate the mangrove swamps at the edge of the island in order to document accumulation and consider potential plastic traps that could catch refuse with minimal environmental impact; I was not able to fit this excursion into my trip due to time constraints.

One potential use for shredded multi-layer film is as a filler material in bricks. By mixing it with wet cement it becomes an additive in the resulting concrete, which is comparable in its properties to concrete bricks made with the traditional filler material of volcanic sand. There is a cultural problem however; the Balinese have ceremonies for all of their building materials, intended to restore balance to nature and appease any spirits of chaos that might have been unleashed by say cutting down a tree or mining a stone. They have no appropriate ceremonies for plastic; because of this Balinese are unwilling to use polymer composite bricks in any dwelling. They might consider using them in infrastructure or animal housing, but there is very little market for these bricks even at a savings from the traditional option. Because of this, a project making these composite bricks failed some years ago. During the collection interval I visited a small pyramid made from the remaining stock of composite bricks.

## Collection

Collection of the material went as planned for the most part. At the end of the collection period Dewa and I came to collect bags of waste and as we collected each back we labelled it with a bag number and took down data pertaining to the household type, the number of residents, the number of children (residents under the age of 10) and of course bag weight. Each bag of waste was weighed and the weights were recorded in correlation to the bag number that was written onto each bag with a black sharpie or silver paint pen. Bags of waste were brought to the sorting area and waited under a canopy to protect them from the elements as best as possible.

## *Additional pictures*

Additional picture 1. Sorting material with Dewa and volunteer team.

Additional picture 2. Dewa speaking to a participating household.

Additional picture 3. Dewa and Paul sorting material.

Additional picture 4. Weighing material and gathering data.