Plastic upcycling

holistic study of a sustainable plastic brick

Masterthesis

im Studiengang

Master Höheres Lehramt an beruflichen Schulen für

Fahrzeug- und Fertigungstechnik

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an der Pädagogischen Hochschule Weingarten

Trash Waste Solutions

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Aspach, 26.07.2021, Marina Seeger

Summary, abstract

The Master's thesis is a mixture of education, survey and risk analysis.

To include the aspect of education was a personal concern for me, which is the reason I created and supported a project working group consisting of students from the PH Weingarten (Weingarten University of Education). This group produced environmental education material, which will then be distributed to the local partners of Trash Waste Solution in Siladen and to other NGOs that carry out environmental education.

In addition, a survey was conducted to find out the opinion of the population on the recycled brick and to include their concerns in the subsequent research. The population is in favour of the Precious Plastic Brick but has concerns. Most concerns were expressed about the fire behaviour of the Brick. They also have concerns about that the Brick do not stand up to the demand of the environment, its practicable use, that it will harms the environment and that it will outgas hazardous substances.

The main focus is on the extensive investigation of the Precious Plastic Brick, which examines it for its hazards to humans and determines the material properties. The Precious Plastic Brick is produced by mechanically recycling of household waste. Either polypropylene (PP) or high-density polyethylene (HDPE) can be used as the basic material. The necessary machines and moulds were developed by Precious Plastic.

All the tests carried out were financed on a donation basis. Particularly noteworthy is the laboratory Lehmacher | Schneider from Osnabrück with its CEO Mr. Schneider who carried out the UV examination and the FILK Freiberg Institute with the laboratory manager for emission tests Mr. Bernd Matthes who carried out the emission tests. In conclusion, the Brick has a lot of potential to be one of many solutions to recycle plastic waste in a meaningful way. To ensure the safety of people living in a Precious Plastic house, final fire behaviour tests are necessary. This includes investigating whether and in what form a fire barrier such as plastering can be installed. The results of the tests are listed below in a material data sheet. This was created as a representative of the Brick made of PP.

Material Data sheet

Product Name

Precious Plastic Brick

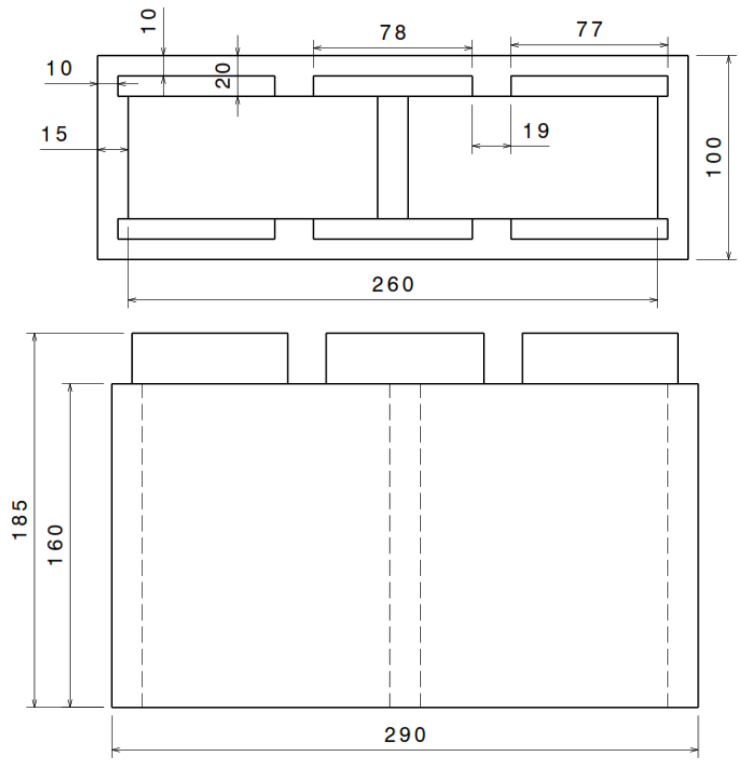
Description

Brick made from recycled Post Customer Polypropylene waste. Each brick consists of approx. 1.8 kg of recycled plastic without the addition of additives or fillers. The bricks are placed on top of each other in a staggered manner. To achieve a straight finish, there are bricks with single, double and triple plugs.

Professional use:

To build a house with it, a load-bearing base frame, e.g., made of wood, is required. The bricks are placed on top of each other and thus form the walls as filling material. To ensure fire protection, a fire barrier, e.g., plaster, must also be applied on the outside and inside. This also protects the bricks from UV radiation.

Size and Dimensions Standard Triple Plug Brick



Width [mm]	290
Depth [mm]	100
Height [mm]	160 (without plugs)
Weight [kg]	1,8
Material	PP

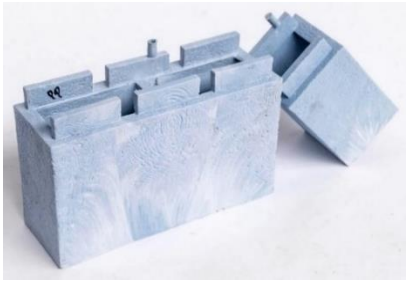


Figure 1 left Sketch Brick with dimensions (Marina Seeger) and right below Brick (Precious Plastic, 2021)

Environmental aspect

The Post-Customer Waste that would otherwise end up in a landfill is transformed into a building material. The bricks can be made anywhere in the world and the equipment and drawings are freely available to anyone via the Precious Plastic website. https://community.preciousplastic.com/how-to/make-extruded-plastic-bricks

The bricks have very good properties in terms of earthquake resistance, and they are water resistant. They do not endanger the environment if they are used properly. This includes protection from UV radiation by e.g., plaster.

Properties

Emissions/ Outgassing

Emission tests were carried out on the PP base material (shredded PP household waste from Sulawesi, Indonesia) of the brick according to the following methods of the automotive standard: VDA270, VDA275, VDA277, VDA278. The material has no emissions of concern in terms of odour, VOC, fog value, total carbon and formaldehyde.

Heavy metals analyse

The PP base material was examined using AAS (atomic absorption spectroscopy). The sample was tested for Pb (lead), Sb (antimony), Mn (manganese) and Cd (cadmium). The base material did not contain any of the mentioned substances in critical quantities.

Tensile Test

The maximum tensile stress of a test specimen injection-moulded with 800 bar from PP household waste from Constance is 22.93 N/mm² (average; without weld line). The recycled material (injection moulded at 800 bar) loses 25% of its tensile strength compared to the unrecycled material (injection moulded at 1200 bar, average; without weld line.) and exhibits brittle fracture behaviour.

Pressure test

- The PP Brick breaks at a maximum force of 271.28 kN, which corresponds to a weight of approx. 27.66 tonnes. Brittle fracture
- The HDPE brick breaks at a maximum force of 113.4 kN, which corresponds to a weight of approx. 11.56 t. Breakage after cracking

Both bricks can thus withstand enough force to meet the requirements of a building material for single-storey houses. The tests carried out with UV-irradiated bricks also showed no problems with regard to their load-bearing capacity.

Fire Behaviour

UL94 Vertical Flame Tests were carried out which neither the PP material nor the HDPE material passed. Test specimens according to UL94 Vertical Flame Standard were held under a 20 mm high burner flame for 10 seconds. Subsequently, 4 out of 5 samples burnt off. The samples emitted burning drops. To meet the requirements of NFPA 220 "Type 5 - Wood framed " the Precious Plastic Brick needs an attached fire protection.

Weathering of the brick (due to UV radiation and climate change)

The HDPE and PP brick were tested according to DIN 75220 Z-OUT and were exposed to a radiation energy of 480 kWh/m². Both bricks became brittle on the surface and decomposed into microplastics, the damaged depth is approx. 0.1-0.2 mm. For this reason, the brick needs UV protection.

A water absorption test was also carried out. The brick absorbed between 0.28 and 0.57% water (in a water bath over a period of 10 days). This value is not in a critical range.

Motivation

"**About 82 %** of the plastic waste in the sea comes from Asian countries like Thailand, China, **Indonesia**, India or Vietnam."

(Schulz C. , 2019) (Foundation, Ellen MacArthur, Januar 2016)

"Of the 6.9 billion tonnes of plastic waste generated world-wide by 2015, about **9 % was recycled**, 12% incinerated and 79% landfilled or disposed of in the environment. "

(Schulz C. , 2019) (BUND, 2.Auflage, Juli 2019)

"About 36% of global plastic production results in **packaging** material. 14% is used for textiles and about **16% for buildings** and other construction work."

(Schulz C. , 2019) (UNEP, 2018)

The facts show how high the need for action is to get the environmental pollution caused by plastics under control. Owing to the circumstances that there is not so much plastic waste on the streets and floating in the lakes in Germany forgets how big and significant this problem is. Many Germans are unaware that Germany also ships plastic waste to Malaysia, for example. In 2016 alone, Germany exported around 11 per cent of its packaging waste abroad. (Groß, 2018). In 2018, the figure was even just under 13 per cent. (BUND, 2019).

In the summer of 2017, I visited Krui, Sumatra for the first time and was shocked by the state of plastic waste pollution on the beaches and in the water. It was immediately clear to me that I wanted to do something about it. For this reason, I organised two beach clean ups with friends there. A year later I came back to Sumatra and in the meantime the project was continued by a local hostel owner, and we got together and went to the schools to give lectures on why it is important to dispose of plastic waste properly. Afterwards we went to the beach together with the children to do a beach clean-up.

Re-cycle plastic – Turn the one-way street into a cycle

A process becomes holistic by conceiving it as a cycle. In nature, there are only cycles, for the reason that sustainability would not work otherwise. The production of plastic was not conceived as a cycle. In retrospect, we try to make it one. The solutions will never be perfect because the whole system was not designed as such. Producing plastic manoeuvred us into a one-way street and the solutions are sometimes very complicated to get out of. The top priority is to conceptualise sustainable plastic cycles. Banning single-use plastic by the government, promoting compostable plastic and the simplest and most effective form: Reducing plastic.

In this master's I deal with the attempt to turn the one-way street into a cycle. The cycle continues until more sensible measures take effect and no more plastic has to be recycled.

Figure 2 holistic upcycling Process 1) (Seeger, 2017) 2) (Trash Waste Solution, Natalie Blanc, 2019); 3) (Precious Plastic, 2021); 4) (Dickens, 2021) 5) (kdekiara)

To find a topic for my master's thesis I did some research on the internet and found the Trash Waste Solution. "Trash Waste Solution (TWS) is a non-profit association founded in

2019 with headquarters in Switzerland. Our vision is to free the underwater world from waste and to protect it sustainably." (Kurath, 2021) The association tries to do its part to reduce pollution by taking the simplest possible measures. TWS has set up a plastic upcycling plant in Sulawesi to produce Precious Plastic bricks. This plant was produced according to the freely available Blueprints of the NGO Precious Plastic.

My assignment from TWS is to test the Precious Plastic Brick via the Trash Waste Solution for its health hazards to humans, and to determine its material properties. In other words, a risk analysis. From this, I try to conceptualise a circle that involves the education of the local people in Sulawesi, and the opinion of the people. The circle in Figure 1 represents a holistic solution to reduce plastic input into our nature through the use of a recycled brick. It takes education to create space for the problem, and it takes the brick to act as a concrete solution. In my view, there is no solution to the problem of plastic pollution in the environment without education.

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List of Abbreviation

AAS	Atomic absorption spectroscopy AAS
Brick	Precious Plastic Brick
HDPE	High Density Polyethylene
NGO	Non Government Organisation
PH	Pädagogische Hochschule Weingarten
PP	Polypropylene
PVC	Polyvinylchloride
RWU	University of Applied Science Ravensburg-Weingarten
SVOC	Semi volatile Organic Compounds, SVOC
TWS	Trash Waste Solution
UK	United Kingdom
VVOC	Very Volatile Organic Compounds

1 Introduction

TWS is setting up a low-tech plastic recycling plant in Sulawesi in May 2021. This will operate according to Precious Plastic's open-source process, which is based on a very simple conventional injection moulding process. The next section introduces TWS and their plant, followed by the concrete target definition and procedure of this master thesis.

1.1 About the TWS

"TWS is a non-profit association founded in 2019 and headquartered in Switzerland. Our vision is to rid the underwater world of waste and to protect it sustainably. We want to understand the big picture of the problem and get to the root of it. We want to prevent further input of waste into the environment by recycling and preventing waste at source within the framework of a circular economy. The solutions are to be planned together with the local population, managed by them and supported financially and structurally by our NGO in Switzerland. In the short term, we will start with simple projects that allow for quick solutions with high impact. Our project will start in North Sulawesi, Indonesia, where the beautiful underwater world needs immediate protection. For this, we will develop concepts for complete material cycles (plastics, compost, metal, non-metal, etc.) and bring holistic disciplines, such as training in environmental awareness and generating local jobs in the recycling business [...] In the medium/long term, we would like to develop holistic Zero Waste concepts that significantly reduce the current amount of waste, prevent as much waste as possible from ending up in landfills and recycle the waste produced, i.e. add it back to the material cycle as a secondary product (recycling and/or organic recovery). To this end, synergies of actors at all levels (civil society, private sector and politics) are being promoted". (Kurath, 2021)

1.2 Presentation of the project Pilot plant for low-tech plastic recycling in North Sulawesi

This master thesis deals with the project of the Trash Waste Solution pilot plant for low-tech plastic recycling with the Precious Plastic Concept in North Sulawesi, Indonesia. Through TWS, a pilot plant for the upcycling of hard plastic packaging is being set up and managed in the city of Manado in the north of Sulawesi. TWS is aiming for a holistic concept, so the plastic waste collected from the households will be sorted, shredded, and heated. The heated mass will be injected into a mould that will create a brick for building houses. "The feasibility study (AS-IS study) of TWS, which was prepared by the core team with a 3-month stay in Indonesia, serves as a basis. Also important is the Master Thesis `Approaches to reduce marine litter - a baseline study in the pilot region of North Sulawesi, Indonesia` (2018, Julia Giebel / Hochschule Magdeburg-Stendal), an East Java Recycling report from Holland and the support from Sam Ratulangi University in Manado." (Kurath, 2021). TWS's feasibility study established the basic pillars of the project

Concrete construction of the Precious Plastic plant to be installed in Manado in April 2021

The Precious Plastic Plant is an arrangement of semi industrial machines therefore it is no hobby level but also not industrial. They are designed user-friendly and easy to be replicated. All parts of the machines can be downloaded as open-source blue prints and there is an instruction where to buy and find parts. The machine can be built anywhere in the world. In the beginning of the project the output was household products, so the developer of Precious Plastic started to push the boundaries to more useful products. In the fourth. Iteration they designed a machine to get raw material as output c.f. (Precious Plastic, 2021). That is where they developed the Brick to build walls and houses. The TWS decided to go for the Brick solution because there is a great need for building materials. The cost of the entire system which TWS purchased from Precisi is approx. 7500€. This includes cost for Shredder Pro, Extrusion Pro and 4V Brick Mould. Appendix 2 contains a detailed description of the machines required, which are briefly presented here.

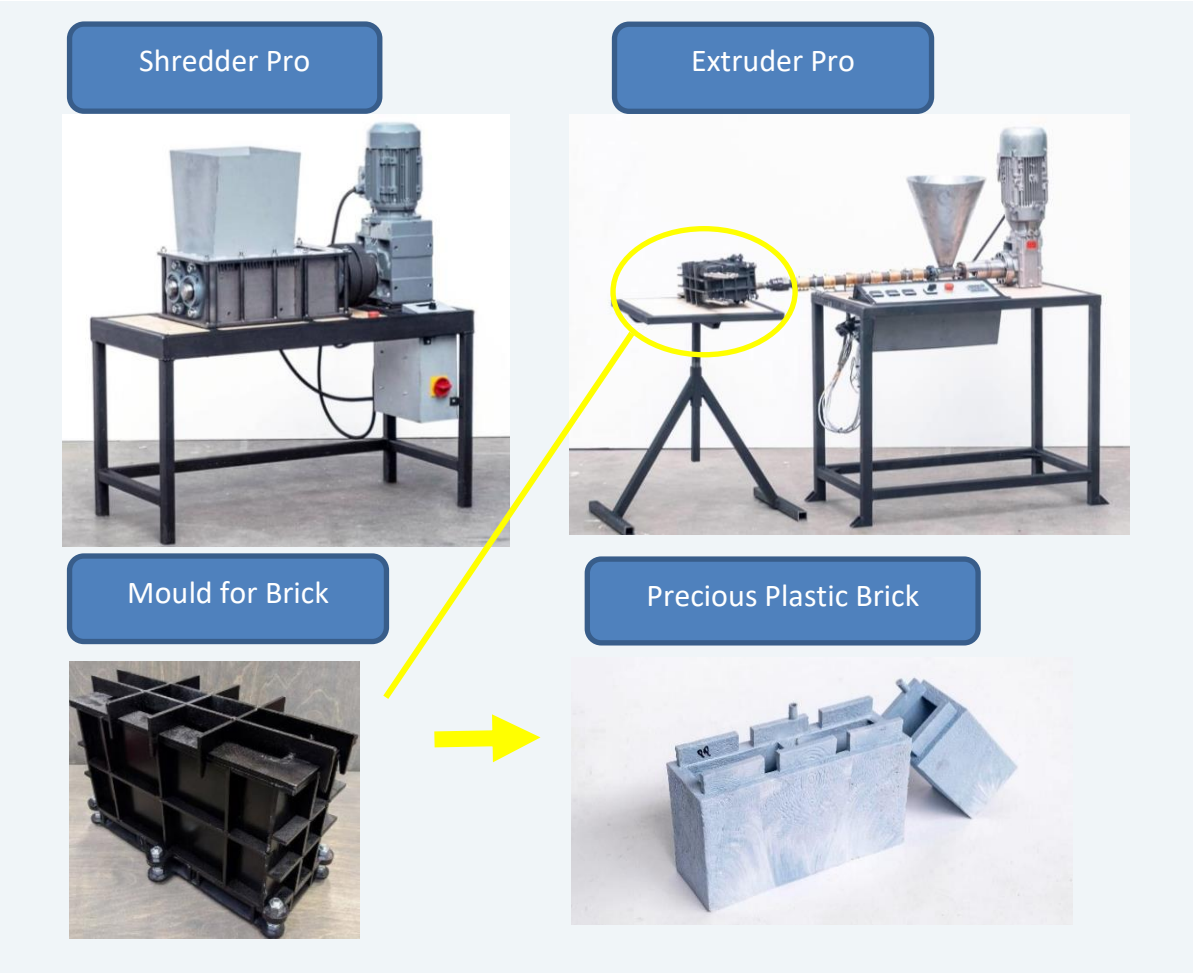
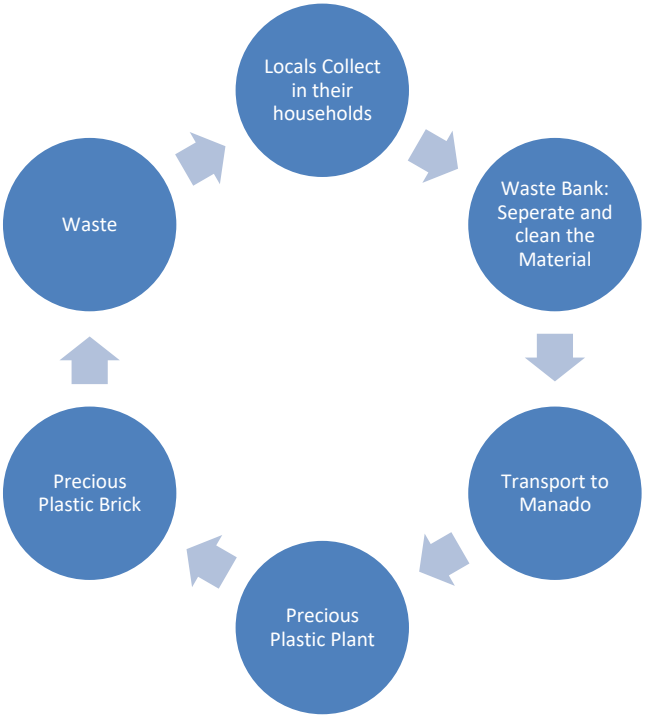


Figure 3 Precious Plastic Plant (Precious Plastic, 2021)

Target expectation of the project Pilot plant for low-tech plastic recycling "Precious Plastic" in North Sulawesi, Indonesia

From an economic point of view, the process of the Precious Plastic plant will not be profitable. However, it is much cheaper and easier to purchase and maintain than a comparable plant that would be economically viable. The comparable plant is from Conceptos Plásticos. This company sells bricks made of plastic and has already built several houses in Colombia from them. There are no known problems regarding the use of the bricks. Due to the simple variant of the Precious Plastic plant, it can be set up and operated with little financial effort and know-how. In addition, the pilot plant is to be used to assess and scale up the process for the recycling of plastics.

TWS has chosen a brick as the product of the upcycling process, which is used to build walls and houses. The decision in favour of the brick is based on the fact that a lot of energy in Manado is used to build houses and huts, and the demand for building materials is therefore high.



The aim of the TWS project is to generate a holistic product cycle and raise public awareness and attention to plastic in the Ocean.

Figure 4 Lifecycle Precious Plastic Brick

Local people bring their recyclable materials to a waste bank. There, the materials are processed and separated. The population receives a payment. TWS obtains its raw material from the waste bank. This virtually eliminates the possibility of contamination and the associated dangers of the basic material. In the next step, it is transported to Manado where it is processed into a product, the brick. It would also be possible to dismantle and rebuild it at another location. Ultimately, the brick should be recyclable at the end of its life cycle. The basic material is not collected, sorted and processed directly by the beach clean ups. The risk of not being able to determine the exact plastic would be too high. For example, PVC often contains hazardous additives such as plasticisers and can hardly be distinguished from PP.

1.3 Target expectation master's Thesis and Procedure

This Master's thesis takes a holistic view of the risks and hazards associated with the use of Precious Plastic Bricks. Due to the high demand for sustainability, a concept is also to be developed on how to promote the awareness of the population towards plastic in the sea. The aim is to develop a didactic and methodical concept for educating children about plastics in the sea. The target group are local children of Siladen between 6 and 12 years. The results of the master's thesis will then be available as open-source material on the internet, so that anyone who wants to manufacture the Precious Plastic Brick can inform themselves about the dangers and risks. The environmental education materials produced will also be made available.

Table 1 Concrete target expectation

Chapter	What is to be done	Output
2. Environmental education	Create a didactic and methodical concept for education and awareness of plastics in the sea with a project group from Environmental Education Course of the PH Student project group consists of: Anita Gerhart; Franziska Schmitteckert; Katharina Kober; Ann-Katrin Speidel	Didactic and methodical concept for education and awareness of plastic in the sea
3. Public opinion about the Brick	Generate a Public Opinion about the Brick: 1. Identify and uncover local people's opinion and concerns about the Bricks. Thru a survey conducted in Siladen and Manado 2. Identify the global Opinion and concerns about the Brick thru the YouTube Video "Why the world needs recycled plastic bricks (and how to make one yourself!)" from Recycle Rebuild	Discussion of the survey results and Comparison of global and local opinion

4. Brick-requirements	Defines the requirements for the Brick. Includes: Application area, Load case, Environmental influences (in the Application area) such as UV radiation, ambient temperature, and humidity. Presents other existing recycling Brick projects	Product requirement document
5. Examination of base material	Identify, investigate, and evaluate the process for obtaining shredded Post-Consumer Waste (Base Material)	Guidance document for the production of PP Base Material
6. Preparation Examination	Preparation Examination • Pointing out previous studies • Define and justify the tests to be carried out • Production and evaluation of the materials to be tested	Concrete test conditions and manufactured test specimens made of HDPE and PP
7. Examination and Evaluation of Precious Plastic Brick and Test Specimen	Testing Properties of HDPE and PP Bricks and Test specimen All divided in: The health hazard and the hazard of material failure Chapter contains: Experimental description; Results; Evaluation	Data sheet with mechanical properties of the brick (Located in the Summary, Abstract)
8. Summary and outlook	briefly presents the results of the individual chapters and relates them to each other. Gives an assessment of the Precious Plastic concept and shows how to proceed with the Precious Plastic Brick.	

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The milestone plan gives an indication of what action is planned and when. Environmental education, public opinion about the brick and the preparation of the investigation can take place before the actual examination.

Table 2 Milestone plan

	März				April				Mai					Juni				Juli				August				
	CW 9	CW10	CW 11	CW 12	CW 13	CW 14	CW 15	CW 16	CW 17	CW 18	CW 19	CW 20	CW 21	CW 22	CW 23	CW 24	CW 25	CW 26	CW 27	CW 28	CW 29	CW 30	CW 31	CW 32	CW 33	CW 34
	01.03-07.03	08.03-14.03	15.03-21.03	22.03-28.03	29.03-04.04	05.04-11.04	12.04-18.04	19.04-25.04	26.04-02.05	03.05-09.05	10.05-16.05	17.05-23.05	24.05-30.05	31.05-06.06	07.06-13.06	14.06-20.06	21.06-27.06	28.06-04.07	05.07-11.07	12.07-18.07	19.07-25.07	26.07-01.08	02.08-08.08	09.08-15.08	16.08-20.08	23.08-27.08
Precious Plastic Plant in Sulawesi					arrival of the plant			try to do a Brick	Motor of injection moulding machine too little power																	
2. Environmental education	Research and clarify requirements through interviews with contact																									
Project Group				Create group		organize Group		create																Results	Pub-lishing results	Inte-grate in Thesis
3. Public Opinion about the Brick							research		Conducting the survey in Sulawesi, inverstigate the YouTube Video					Results			Evaluate								
6. Preparation Examination						research and create																				
7. Testing properties																										
7.1 The health hazard														Testing				Results			Evaluate				
7.2 The hazard of material failure																										
7.2.1 Tests that can be carried out at the RWU														Testing				Results			Evaluate				
7.2.2 UV weathering test											Test can be carried out when they have space					Results		Evaluate							

2 Environmental Education

Chapter 2 deals with environmental education. Within the framework of this thesis, environmental education material for the island of Siladen, which was selected by the TWS as a target region, is to be created. A project group from the environmental education course at the PH Weingarten is being set up to produce the material. The output of this chapter is a comprehensive didactic educational concept. The approach is as follows:

First, it is clarified why environmental education is necessary, then it is shown which environmental education material is needed in Siladen. In the next step, the project of environmental education in Siladen is defined and a call is made in the study programme of environmental education at the PH. This group of students will then be supervised until the goal of producing the environmental education material is reached. As a follow-up to the Master's thesis, the material will be distributed to the TWS staff in Siladen and to other voluntary organisations worldwide such as Greenpeace and greenbook.org.

2.1 The need for environmental education

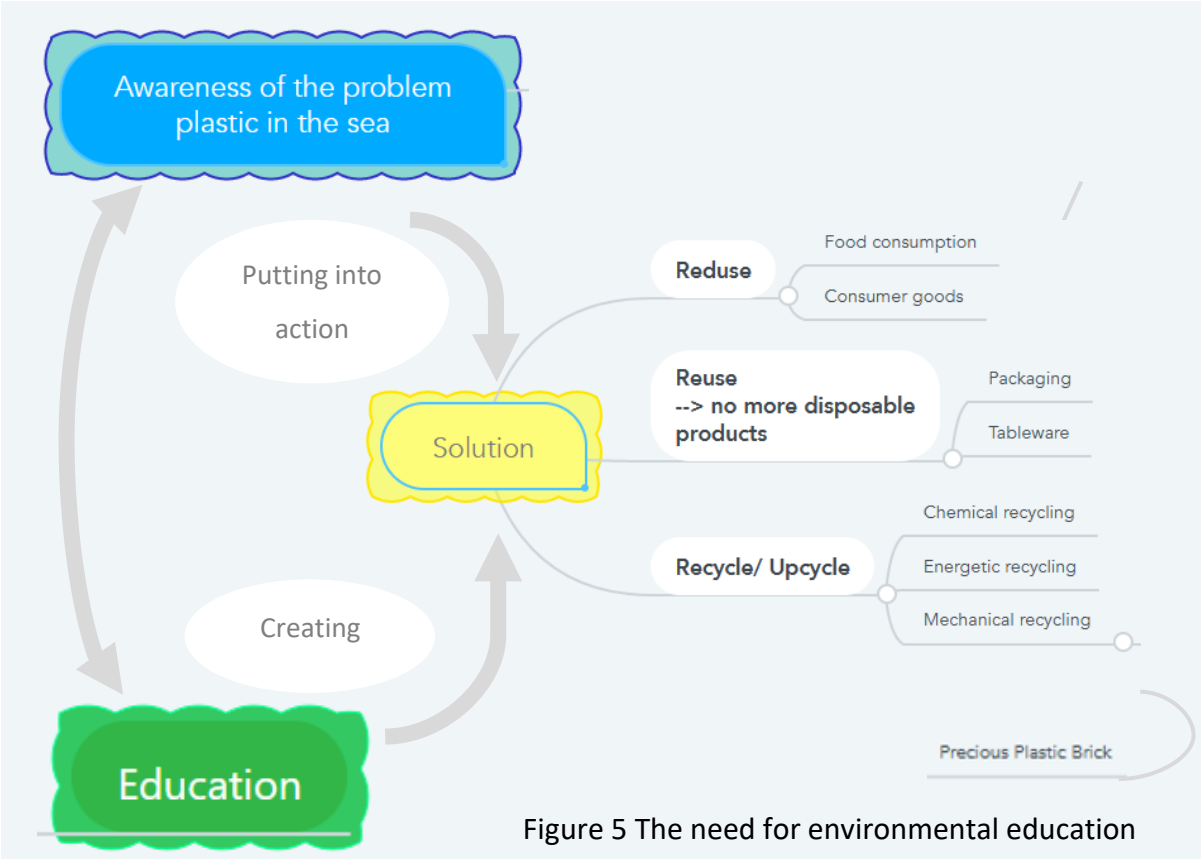


Figure 5 The need for environmental education

The global problem of the acute influx of plastic into the sea must be solved. Knowledge alone is not enough to understand the problem as such. Many people in Germany know that there are enormous amounts of plastic in the sea, but only a few are really aware of this problem. Awareness is necessary to act purposefully.

> "Thirdly, "awareness" is understood as a property of mental states. A distinction must be made between two meanings in which "be-conscious" is applied to mental states as a singular predicate. On the one hand, mental states are described as conscious if their contents are available for reflection and behavioural control. In this sense, not only intentional states such as beliefs, but also sensory states such as sensations can be "access-conscious". On the other hand, mental states are conscious when we take cognisance of their experiential qualities and experience what it is like to be in that state." (Metzinger & Schuhmacher, 1999)

Access to awareness of the problem is found through education. At the same time, awareness of the problem leads to education. Education in itself can lead to solutions, but consciousness is needed to put these solutions into action.

The solutions themselves are simple: Reduce, Reuse and Recycle or upcycle. They are listed according to their effectiveness.

1. The simplest measure and therefore the most effective is to reduce consumption. Here it is important to save or reduce what has the greatest impact on the environment. For example, it helps the environment by far more to reduce your meat and fish consumption than to buy a bamboo toothbrush every now and then.
2. The next measure is reuse. The goal is to stop using disposable items.
3. Recycling is at the bottom of the list of measures. Of the three, it is the costliest. However, this does not make it any less relevant. It can be recycled in various ways, and research is always developing new possibilities. The mechanical recycling of post-consumer waste in the form of Precious Plastic Bricks finds its option here as a solution.

2.2 Clarify what educational material is needed in North Sulawesi

2.2.1 Guideline-based interview with Ana Fonseca, local contact in North Sulawesi

Persons present at the interview: Ana Fonseco, Markus Kurath, Marina Seeger

Date: 15.03.2021 20:00 European Time

Table 3 Fact Survey with Ana Fonseca and Guideline-based Interview

Fact Survey of the person to be interviewed	
Name	Ana Fonseco
Task in the Area of North Sulawesi	Experience Manager of the Siladen Resort and Spa https://www.siladen.com/our-team/
Intersections with the education of local children	No direct Intersections.
Measures the person has already taken	Ana is very committed to imparting knowledge regarding the awareness of plastic in the sea to children. She has already given several lectures and presentations in Siladen about the topic as well as organized Beach Clean Ups. She has also taken the children on dolphin tours to make them aware of what they are trying to protect. Also, they did a puppet Show to transfer Information's. The resort has given the children T-shirts with the slogan "Save the oceans". The children chose this slogan themselves.
Conditions on site to carry out a learning unit	Presentations were made by her and other Siladen Resort and Spa staff at the church or resort. The Local School has no technical equipment to show videos or presentations. In the church there is a projector. The course unit is taught in Indonesian.
Information about the children to be taught	The learning unit should be created for children from 6 to 12, because the school in Siladen takes all classes up to the age of 12 together in extracurricular activities

	The attention span of children is very short. Maximum 10 minutes The level of education of the children is very low and not comparable with European standards.
Leading question	Answer
What do you think is needed in terms of environmental education in schools? In relation to awareness around plastic in the sea	"I am running out of presentations and videos. I can't find any suitable material on the internet for the children in Sulawesi. It would be helpful to get very simple and child friendly educational material. The material should be kept very simple and limited to a few simple key statements" Explicitly she would like to have: - More Videos she can show - Presentation and videos should not last longer than 10 min - Graphic Support - Presentation should be fun and easy for the children - Games e.g., Puppet Show - The material should have a stimulating effect on the children - A presentation for the local teachers, as they also need education regarding plastic in the sea Markus Kurath would like to see a video with a cut open seabird, where you can see that the bird has plastic in its stomach.
How would you describe the level of education in schools? In terms of all subjects and standards in the school	The level of education in the school in Siladen is at a very low level. It is much lower than in the city of Manado in North Sulawesi. There are very big local differences in education in North Sulawesi. The education level of teachers is also very low. For this reason, educational materials for teachers should also be produced as part of the project. Because if the children have questions after the learning unit, the teachers can answer them as well.
We want to develop a didactic methodical concept in the	Presentation and Video (video TWS with turtle from website Rio Facebook)

form of e.g., an environmental day (presentation for education, beach clean-up) The presentation aims to educate the children and make them aware of the problem of plastic in the ocean. What elements do you think should be included?	- Beaches clean up (should last around half an hour / hour, care should be taken to ensure that the children wear shoes.) - Separation of the waste →and tell them why it is important to separate. - Separation of: recyclable material • Paper (some keep it and sell it) • Glass • Cans • Hard Plastic - non-recyclable material
What explicit material do you think should be included in the presentation?	Local examples from Siladen Pictures and videos are meant to show Siladen and its reefs.

Summary

Environmental education material in Siladen is urgently needed. The material should be kept very simple. Educational material should also be prepared for the teachers at the local schools. The learning units should not be longer than 10 min. Children from 6 to 12 years participate in the environmental education units. The educational level of the children in Siladen is very low, which is why simple, short, stimulating material is optimal.

2.2.2 Inventory of existing material

Ocean Warriors - Plastic in Paradise

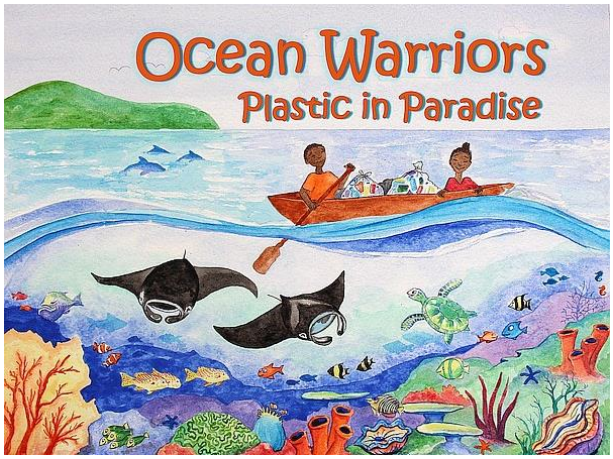


Figure 6 Ocean Warriors- Plastic in Paradise (Friendly Drifter - Education Initiatives, 2017)

The Ocean Warrior Plastic in Paradise Book is written by Cath Witten in 2017 and published by Friendly Drifter. The TWS organisation recommended this book because the content is very well designed and the problem of plastic in the sea is explained with the help of a story. The learning unit to be designed should be similar to this style. The book is not used because the funds of the TWS are not sufficient to distribute it in Sulawesi.

> "Ocean Warriors Plastic in Paradise is a children's book about two young siblings who rescue a turtle by preventing it from ingesting a plastic bag found floating in the ocean. The pair then recognize the dangers that plastic has on the marine life, the damage it causes to our oceans and beaches, and they work together to find solutions." (Friendly Drifter - Education Initiatives, 2017) The Price of the Book is on the Friendly Drifter Website for $20.00.

A Plastic Ocean

The film "A Plastic Ocean" (Leeson, 2016) by Craig Lesson, produced by Plastic Ocean Limited, lasts 100 minutes and shows the problems of plastic in the sea and what it means for marine life and for humans. In Sulawesi, Ana Fonseca and the Siladen Spa Resort team usually only show the trailer (A Plastic Ocean - Trailer, 2016), which lasts 2 minutes. The trailer is available with Indonesian subtitles, the main movie is not. The main movie is not available as an open

source for private people, it costs 7 $ to download the movie for hosting a screen in your school or company you can contact Plastic Ocean Limited and get it for free.

The 2 min trailer is very impressive and contains harrowing images. No concrete content is conveyed, but only awakening images are shown. For this reason, I think the trailer is from an environmental education point of view too short. There is a 3.30-minute kids' version of the film (Plastic Soup Foundation, 2018) This version is very suitable to show to children. It also contains powerful images that wake people up and explain why marine animals die from plastic.

The Dr. Binocs Show - What Is PLASTIC POLLUTION?

The clip is on YouTube and has a length of approx. 7.30 min. It is about a blue fuzzy animal that explains to children in cartoon style what plastic does to nature. It also shows what plastic is good for and what it is not good for. The video material is very colourful and child-friendly, and the messages are simple and informative. (Peekaboo Kidz, 2020)

2.3 Setting up a project working group with the environmental education degree program

Due to the scope of work and the lack of experience in developing educational material for children, I decided to set up a project working group with students from the Environmental Education course. These achievements will be credited to the students in their degree program as project work.

My tasks in the group are defined as follows:

1. Defining the boundary conditions such as target group, target location and content. This will be done through interaction with the TWS members on site, and the Siladen Spa & Resort.
2. Create a project working group
   - Establish contact with the environmental education programme of PH Weingarten.
   - Create a project description and a call for volunteers for the project
   - Introduce the project working group members to the project
     (What is to be done explicitly, what should the result look like)
3. Supporting the students in carrying out their work
   - Obtaining image and video material from TWS and other organisations

- Be the contact person for questions

4. Distribute the resulting material
   - Contact other organisations and share the material

     In order to create more added value for society, the material should be distributed. In this way, many people who want to do environmental education can benefit from the work and we benefit because environmental education is taking place.

2.4 Boundary conditions for Environmental Education Material

The following conditions are imposed on the educational material and apply as boundary conditions for the project Creating Environmental Education Material for Siladen.

- Create a learning unit for children between 6 and 12 years old.
- The unit will be in English and will be delivered by local contacts in Siladen.
- The level of education of the children in Siladen is very low, therefore messages should be conveyed in a very simple way.
- The attention span of the children is maximum 10 min. For this reason, when creating educational material such as a presentation, care should be taken that it does not last longer than 10 min.
- It is about plastic solids No chemicals, colours or food. The hidden pollutants or additives such as plasticisers and stabilisers should not be part of the learning unit as the children's educational level is too low.

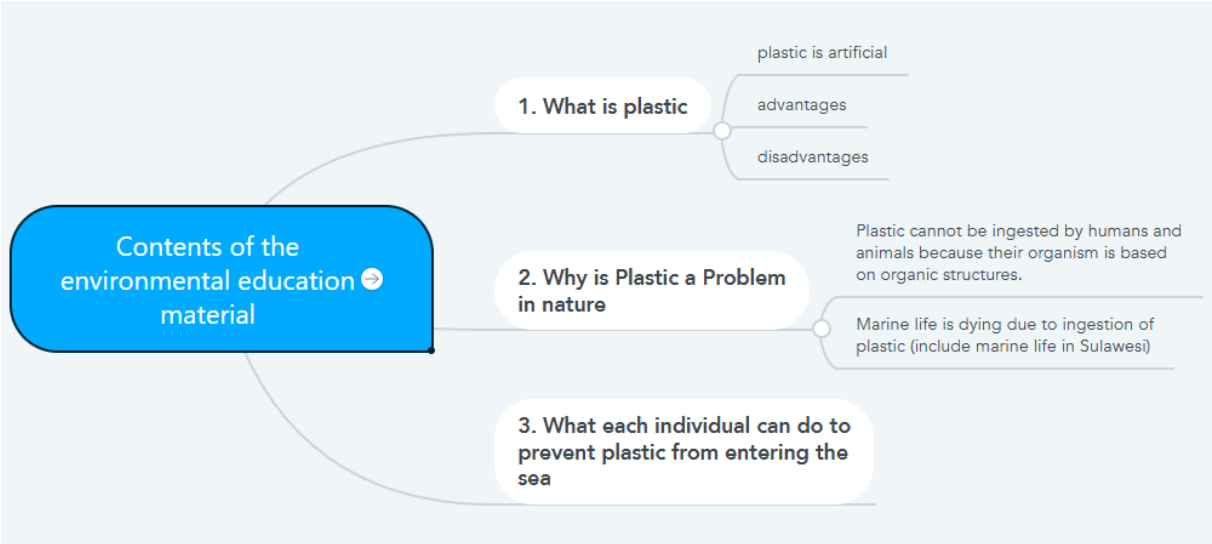


Figure 7 Contents of the environmental education material

2.5 Created environmental education material

The following section is quoted from the work of the project group.

“**Explanation of didactic methodological concept for raising awareness and educating children in North Sulawesi on the issue of plastic in the sea.”**

The newly designed educational material was created for the children on the island of Siladen near North Sulawesi in Indonesia. The concept is based on three modules, each of which was created at a very simple linguistic level so that children aged 6 to 12 can be addressed. Since the level of education there is rather low, the content is kept very simple and not dealt with in depth. In general, care was taken to include as little text as possible and instead many pictures for simple visualisation as well as examples from the children's everyday lives (→ relevance to the world in which they live). This ensures a better understanding and makes the relevance of the topic in their living environment clear without overtaxing them in terms of content and losing their attention.

The topics of the respective modules are: "What is plastic?", "What does plastic do to humans, animals and the environment?" and "Avoiding plastic waste in nature". The modules are designed in such a way that they can be carried out on different days and last a maximum of 15 minutes in order not to exceed the maximum attention span of the children. Each module is rounded off with a Beach Clean Up. In order to enable playful repetition and deepening of the contents, each child receives a small workbook with different didactic tasks and puzzles on the topics of the individual modules, which above all should also be fun. The different tasks have been created with different levels of difficulty so that children of different ages can be addressed. In this way, the children also have something to take home with them. The entire educational material is guided by a sea turtle named Yupi.

The high motivational content and exercises are intended to stimulate intrinsic motivation to improve the situation. The aim is that the children consciously stand up for a clean nature and pass on their learned knowledge. In an accompanying workbook, the children can independently repeat and deepen the contents. Here, too, the focus is strongly on a playful approach and appropriate tasks for different age groups. “ (Gerhart, Kober, Schmitteckert, & Speidel, 2021)

2.5.1 Day Structure, Beach Clean Up and Comic (Anita Gerhart)

“Daily structure:

A daily structure was developed, which, despite freely selectable modules, runs like a red thread through the action day. Care was taken to develop a structure that enables a creative introduction to the respective modules and thus encourages the children to think independently. In addition, repetitive rituals and games serve to structure the daily routine.

Welcome and organizational matters **[] Day , [] Month 2021**

Goals	Promote environmental awareness, basic knowledge about plastic, fun			
Time		**Duration**	**Person**	**Material**
[] pm	Arrival and welcome of the children	5 min		
[] pm	Short summary: What do you know about plastic?	10 min		Paper Pen
[] pm	Quick introduction of today´s programm	2 min		
[] pm	**The big knot** Everyone stands in a circle (or at least close together), then everyone closes their eyes. Now everyone should walk towards each other and grab another hand with each hand. So, no hand should be left over. To avoid simply taking the hand of the one next to them, the children can also turn in a circle or stretch their hands forward. Then the eyes can be opened again. The task is now to untie the big knot that has been created. And this without letting go of hands. It will always work! So, you need skill and patience until all are unknotted by climbing through, twisting and contorting.	20 min		Rope
[] pm	**Presentation:** What is plastic?	10 -15 min		Projector Screen Computer PowerPoint
[] pm	**Beach clean up** Choose games on the enclosed sheet.	60 min		Garbage bag Gloves
[] pm	**Five Finger Method**	10 min		

Figure 8 Excerpt from Day one - Structure

Beach clean-up:

The Beach clean-up serves to collectively remove plastic waste from the beach. The joint action concludes the day around the topic of plastic waste. The effects of plastic waste can be shown directly on site. In addition, the children of Sulawesi are shown what they can do themselves against plastic waste. Here, care was taken to make the beach clean-up interesting through playful methods. The interactive games support the repetition of the day's topics and at the same time are intended to consolidate the knowledge acquired. The focus is on an entertaining and fun Beach clean-up. For this purpose, the games were divided into two categories: Learning Games and Fun Games. Here, the children can decide whether they want to repeat previously learned knowledge in a playful way or whether they want to make the Beach

clean-up fun by playing funny games. The Beach clean-up should help to raise awareness of how much plastic is lying on the beach. In addition, the children should draw consequences from this and encourage them to collect plastic on their own. Furthermore, it should encourage them to rethink and consume less plastic in the future.

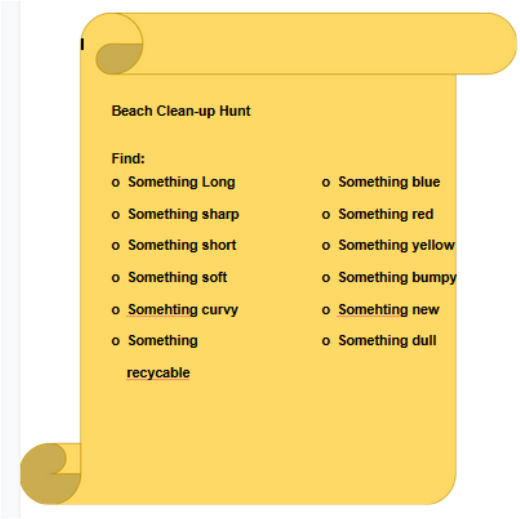


Figure 9 Beach Clean-up Hunt (Gerhart, Kober, Schmitteckert, & Speidel, 2021)

Comic:

The comic strip with sea turtle Yupi aims to repeat the content of the three modules on plastic in a simple and funny way. The children get an overview of the knowledge they have already learned in a short time. The comic should help to show the importance of the topic of plastic for humans, animals and the environment for the children in Sulawesi. For this purpose, the sea turtle Yupi is drawn in five different situations and meets friends in and outside the sea. The end of the comic is meant to encourage the children to pick up plastic themselves. The aim is to raise awareness of the issue of plastic in the children's minds in the long term." (Gerhart, Extract from: Explanation of didactic methodological concept for raising awareness and educating children in North Sulawesi on the issue of plastic in the sea, 2021)

2.5.2 Module 1: What is plastic? (Katharina Kober)

"We encounter plastic almost everywhere in everyday life, but what is plastic actually and which everyday objects are made of it? These are the central points of the first module.

The topic "What is plastic and where does it come from" was deliberately kept very simple and general, as this is a very complex topic and it would clearly be too abstract to go into

chemical processes and synthetic production methods in more detail. The aim of the module is rather to create a first, basic understanding and awareness of the topic and the material plastic. The children should first learn what plastic actually is, which everyday objects are made of plastic and what properties this material has. Through the properties of plastic, it should become clear to the children why we humans use so much plastic and that it can also have many positive properties. On the other hand, they should also be made aware of the problems associated with the properties of the material and the incorrect use of plastic.

The children should be actively involved through targeted activation, for example when deciding at the beginning "Is the object shown made of plastic or not" or during the search task (What in the room is made of plastic and what properties do the objects have?). This is to prevent them from taking on an exclusively passive listening role, which would cause their attention to be lost quickly. By thinking about and collecting together what properties plastic has, they are also specifically involved in the thinking process and encouraged to reflect without being presented with the answers to the question "What properties does plastic have? This joint elaboration ensures that the answers are anchored more deeply in their memory than would be the case if they were only told briefly.

The module thus serves as a general introduction and the children should get to know the material plastic and its properties. It is not yet primarily about the negative aspects and the consequences of plastic on the environment. This point is then taken up by the following module, which deals, among other things, with the effects of plastic on people, animals and the environment.” (Kober, 2021)

Figure 10 Targeted activation (Kober, 2021)

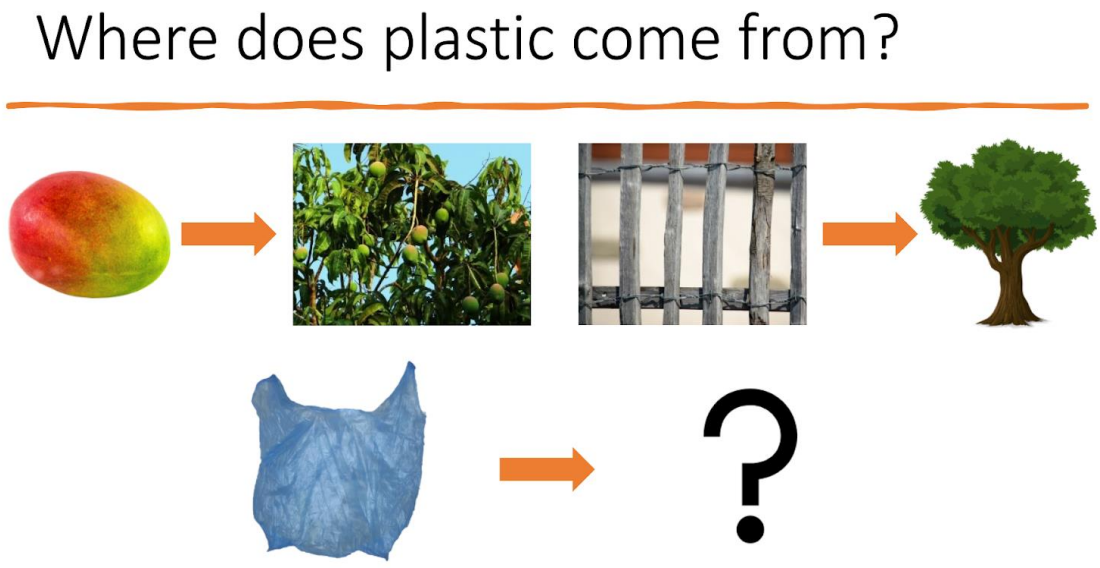


Figure 11 Where does plastic actually come from? (Kober, 2021)

2.5.3 Module 2: Effects of plastic on humans, animals and the entire environment (Ann-Katrin Speidel)

“After the participants have learned more about plastic and its properties in the first module, the second module will focus on the effects of plastic on humans, animals and the entire environment. The aim of the module is to get to know the local underwater world with its animals and plants. The aim is not for the participants to be able to identify animals at the end of the module, but for them to get to know and appreciate their local waters and to understand that the habitat is worth protecting. In addition to the goal of getting to know the underwater world, it is particularly important that the participants are sensitised to plastic waste in the sea. They should understand the consequences of plastic in the sea for animals, humans and plants.

The whole module is about presenting the consequences of pollution as simply as possible and without a lot of technical information. At the beginning, the participants get to know the local underwater world through some pictures of animals and corals. Selected animals, as well as the coral reef, are presented in the form of a fact sheet, so that the participants get a small overview of the local sea. In the second part of the presentation, the consequences are visually illustrated through pictures and drawings. The visual representation enables the participants to imagine the consequences more precisely and they can understand their significance for the animal and plant world. However, it is important that the children and young people are not overwhelmed or frightened by the content. That is why the explanations are kept very simple.

At the end, the participants put themselves in the situation of the sea turtle Yupi, who is caught in a so-called ghost net. The children get a rope/string or chain tied around their legs or hands and now have to free themselves from it without using any aids. It may also happen that it is not possible to free oneself independently. It is important that the leader takes over the tying of the string around the legs or arms and also unties it again if it is not possible to free oneself.

The game is supposed to represent the situation of an animal that has got caught in such a ghost net and has to free itself independently without any help. Animals often do not succeed in doing this, which is why it is not necessarily the aim that the child should be able to free itself. This method should show the participants that it is hardly possible for animals to

free themselves from a net without help. In this way, the children can better understand the situation and why plastic waste in the sea is dangerous for wildlife.” (Speidel, 2021)

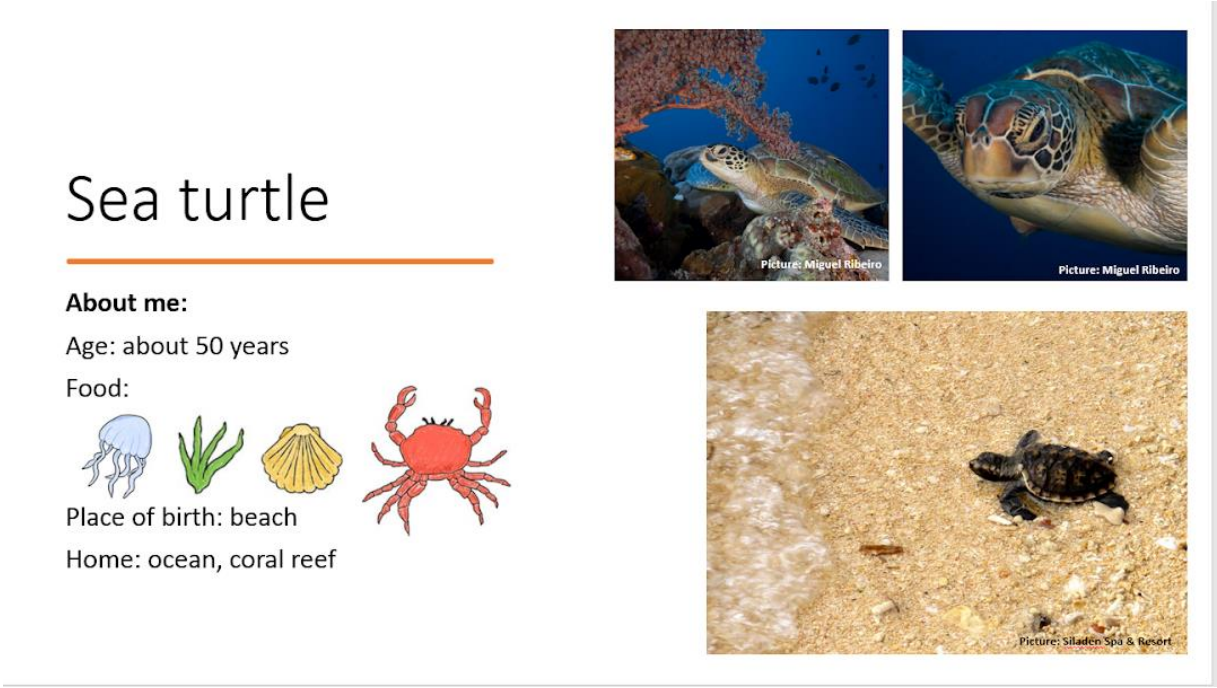


Figure 12 Sea turtle fact sheet (Speidel, 2021)

Figure 13 Consequences for marine life (Speidel, 2021)

2.5.4 Module 3: Avoiding plastic waste in nature (Franziska Schmitteckert)

“The aim of Module 3 is to provide concrete ideas for action and a sustainable improvement of the situation on site. To this end, the participants learn about the different types of waste, how to dispose of them correctly and what exactly happens to the disposed waste. Although a polluted nature is part of the children's everyday life, there is often a lack of awareness of the problems of the situation. With the prior knowledge from the first two modules, the aim here is to create motivation for independent action through playful incentives, without flooding the children with negative impressions or a feeling of hopelessness.

In order to achieve this goal, the learners are first made aware of which objects may remain in nature and which should be removed. For the concrete implementation, this means, for example, a hidden object picture in the workbook, in which objects foreign to nature have to be circled.

In order to get a feeling for the problem of litter, in addition to Module 2, the topic is which objects remain in nature for how long until they are naturally degraded. An estimation game actively involves the children. Objects such as cigarettes, apples, glass or plastic bags are to be put in the right order, and the instructor then gives more detailed information. The problem of toxic substances remaining behind should also be dealt with superficially at this point. In connection with this, the problem of illegal waste incineration, which is common on site, is addressed in order to emphasise the opportunities of correct disposal.

In addition to the correct disposal of one's own waste, the focus is placed on waste collection as an effective way to improve the situation. After completing the three modules, the children are aware of the enormous importance of this simple method, which creates a basis for thinking and acting in a more environmentally friendly way. The aim is to stimulate a change in the children's thinking and to internalise the collection of waste as an effective and simple method of improvement. The aim is for the participants to collect waste independently of the organised beach clean ups and thus actively contribute to improving the situation. On the example slide, the children should recognise objects that should not be disposed of in nature. The aim is to raise awareness that many of the items that the children have firmly associated with the surrounding nature should not be there.” (Schmittecker, 2021)

2.5.5 Workbook

The workbook contains small playful tasks for the individual learning units. After each learning unit, the corresponding page of the workbook is printed. After all learning units, the children have a coherent workbook that they can take home with them.

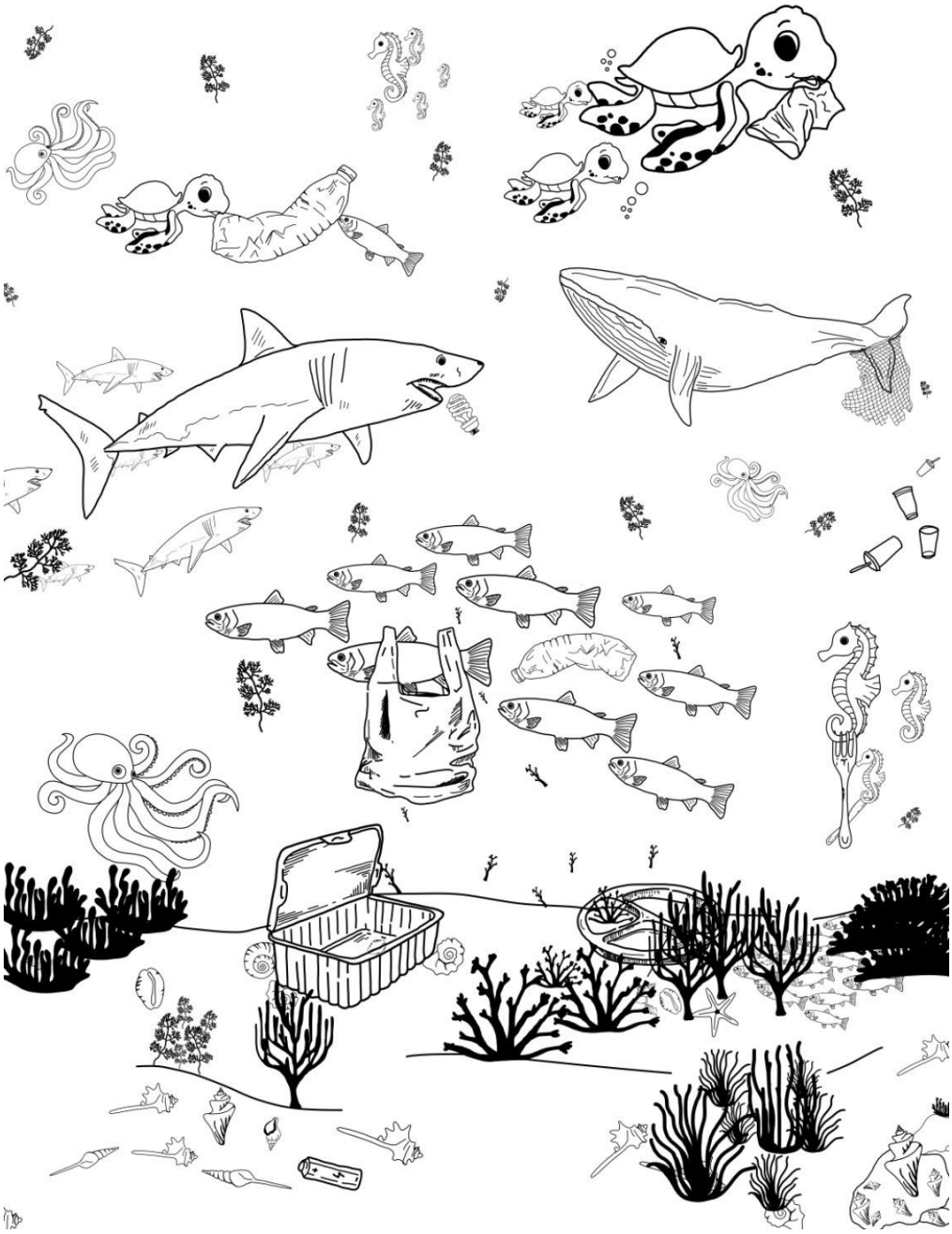


Figure 14 excerpt from the workbook: unnatural objects in a natural environment (Schmittecker, 2021)

2.5.6 Summary Environmental Education

The project group has successfully produced environmental education material. In my opinion, the material is well suited for the island of Siladen and its inhabitants. The material contains the most important points to understand what plastic does to nature in a very short and understandable way. The interrelated learning units lead the children to this realisation. The format of the presentations is appealing, and the comic and the workbook give the children something to touch, colour and take home. This gives the children the opportunity to engage more intensively with the problem and to learn through play with small tasks in the workbook.

The beach clean-up is interspersed with small games such as the Beach Clean-up Hunt, and if there are small meaningful prizes, the children are additionally motivated. In my opinion, such activities only make sense if the children enjoy them. Positive actions relate to positive emotions. If these are coupled with cleaning up, avoiding litter and a conscious approach to nature, this can have a lasting effect on litter prevention.

In August, the material will be discussed with Ana Fonseca and possibly adapted. Ana Fonseca's opinion is very important because she is the one who does the environmental education in Siladen.

The cooperation with the project group worked well. The deadlines were met, and the work put in by the students is reflected in the didactically demanding and creative educational material.

Furthermore, the material is to be distributed to other organisations that carry out environmental education.

3 Public opinion about the Brick

Identify and uncover local people's concerns about the Bricks is the core of this chapter. In order to strengthen the acceptance of the Bricks, it is first necessary to find out what the local population thinks of the Bricks. Only when their concerns are understood something can be actively done about them. For example, during a conversation between a TWS member and a local resident, it came out that the latter is afraid of microplastics in the air. He said that these could get into the air through the bricks. This fear is irrational and probably based on the current information spikes that spill over to the local population. Information is built like icebergs. The tip peeks out over water and can be easily picked up. However, to fully understand the information, the mass below the water must be understood. People need to be informed in a basic and all-encompassing way.

First, the points of who to ask and how to ask must be clarified. The Bricks are to be used all over the world and therefore it is important to generate a broad picture. The chapter is divided into two parts.

- Part 1 Generating a local public opinion through a survey in Siladen
- Part 2 Generating a global public opinion from the comments of a YouTube video.

3.1 Generating a local public opinion through a survey in Siladen and Region Manado

The opinions of the local population on Siladen Island and in the Manado region of Sulawesi are very decisive for the success of TWS's Precious Plastic Brick project. For this reason, a survey is being conducted. The data material of the interviews is considered with qualitative content analysis. A total of 16 people is interviewed.

- 8 on Siladen Island by Teddy Arther Bukunusa
- 8 in the Manado region by Rio Zee

The resulting picture of sentiment is not universally valid due to the number of interviewees. However, it gives a rough assessment of how the population reacts to the Brick. The interviews will be conducted by local contacts in their circle of acquaintances. Since the interviewees know the interviewers personally, it can be assumed that the reaction to the Brick is rather

positive. This results from the position of the interviewees. This assumption is based on personal experience with the local population. Teddy Arther Bukunusa works for the Siladen Spa & Resort and 7 out of 8 of his interviewees also work for tourism. This fact should be considered. Both interviewers were instructed to conduct the interview as neutrally as possible.

3.1.1 Research design

The data collection is carried out via a guideline-based interview, which is preceded by a fact-finding questioning of the person to be interviewed. The facts to be collected in advance concern the points: Name, age, job, children. The leading questions are:

- Would you live in a Precious Plastic house? Explain your reasons.
- What concerns do you have about recycled Plastic Bricks?

The interviews were collected between 03.05.2021 and 23.05.2021. Transcription and translation were carried out by the interviewers. The interviewers have already summarised the statements during transcription and translation. For this reason, there is no need to use a data analysis tool like MAXQDA. The data analysis is based on qualitative content analysis. The categories are formed inductively from the material.

Table 4 Summary Research Design public opinion Siladen, Region Manado

Research objective	Generating a local public opinion about the Precious Plastic Brick
Research question	Do the respondents want to use the Brick?
Data collection	- fact-finding questioning - guideline-based interview
Data material	- 8 Interviews conducted in Siladen by Teddy Arther Bukunusa - 8 Interviews conducted in Manado Region by Rio Zee
Data Analyse Tool	-
Categorisation	Inductive categorisation

Survey Design

Persons present at the interview: Date:

Table 5 Survey Design Fact Survey

Fact Survey of the person to be interviewed	
Name	
Age	
Job	
Children	

1. Collect plastic Waste at home

2. Sorting and cleaning the plastic waste in the Waste bank Manado

Marlon Kamagi in the Waste Bank Manado

3. Making Plastic Brick

4. Building walls, houses

Figure 15 1) 2) (Trash Waste Solution, 2021) 3& 4) (Precious Plastic, 2021)

Table 6 Survey Design Leading question

Leading question	Answer
Would you live in a Precious Plastic house? explain your reasons	
What concerns do you have about recycled Plastic Bricks?	

3.1.2 Survey Results conducted in Siladen

Table 7 Survey Results conducted in Siladen

	Siladen							
Age	28	28	33	38	33	29	44	33
Female / Male	M	F	M	F	F	F	M	M
Job	Security	Hotelier	Dive Guide	Dive Guide	Reservation	Housewife of a Dive Guide	Dive Guide	Dive Guide
Children	Yes	No	Yes	No	No	Yes	Yes	Yes
Live in a Plastic house?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Why?	Leer?	Reduce plastic waste (1)	Lightweight (2), Good properties in earthquakes (3)	Looks unique (4)	Reduce plastic waste (1)	Lightweight (2), Cheap to transport on island (5)	Strong Material (6), lasts very long (7)	Strong Material (6), lasts very long (7)
Concerns	Fire (a)	If material is combustible (a)	Health hazards due to plastic odour when heated by sun (b)	Fire (a)	Fire (a)	They can't be plastered (c)	They can't be plastered (c)	Fire (a)

3.1.3 Survey Results conducted in Manado

Table 8 Survey Results conducted in Manado

	Manado							
Age	40	54	45	47	43	46	48	38
Female/ Male	M	M	M	F	F	M	M	M
Job	Day labou-rer	Repair man	Day labou-rer	House-wife	House-wife	Repair man	Repair man	Day la-bourer
Children	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Live in a plastic house?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Why?	Good proper-ties in e-arthqua kes (3)	Good proper-ties in e-arthqua kes (3)	Reduce plastic waste (1)	Less costs (8), easy to build (9)	Good proper-ties in earth-quakes (3), less costs (8)	Easy to build (9), strong mate-rial (6) Good proper-ties in earth-quakes (3)	Less costs (8) and easy to build (9)	"If the item has been re-cycled it means that the item is suitable for use and ex-ploita-tion"
Concerns	No	No	No	No	No	No	No	No

3.1.4 Discussion of the survey

The average age of the respondents from Siladen is 33 years rounded off. The respondents were between 28 and 44. Among them were 5 men and 3 women. Three of the respondents do not have children. All respondents derive their income from tourism.

The average age of the respondents from Manado is 45 years rounded off. 6 men and 2 women were interviewed. Among the respondents there are 3 repairmen, 3-day labourers and 2 housewives.

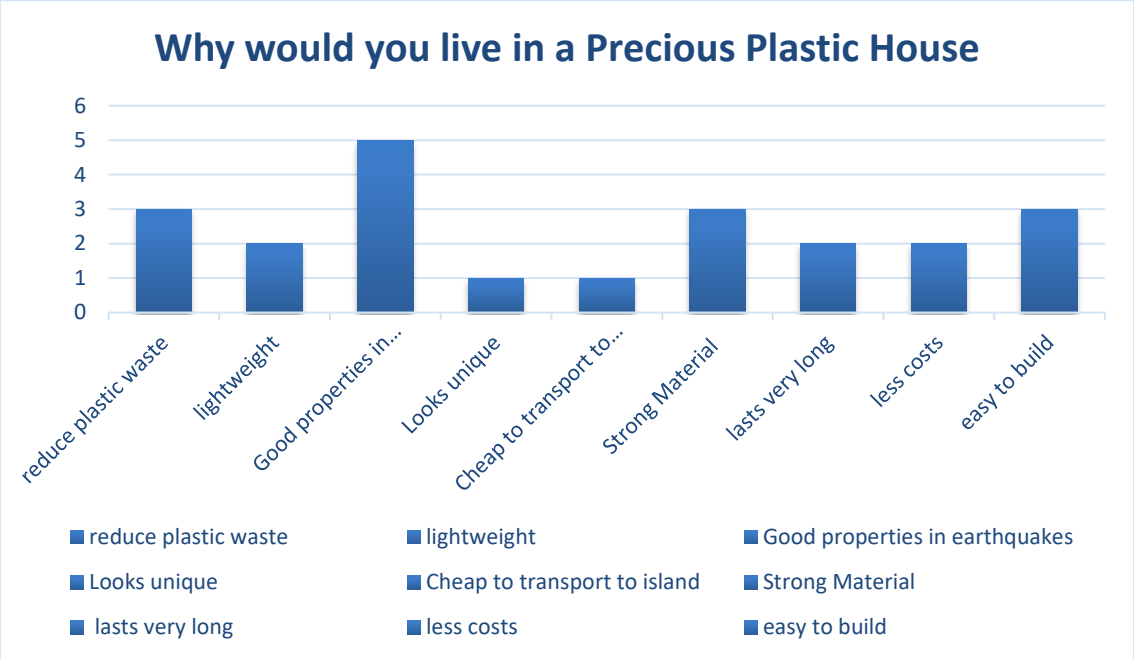


Figure 16 Why would you live in a Precious Plastic House?

All respondents would want to live in a Precious Plastic house and cite various advantages. The advantage of low costs is only partly true; the people in Sulawesi are provided with the bricks free of charge for the time being. Compared to a normal brick, it would definitely be cheaper than the Precious Plastic Brick.

The other advantages mentioned are relevant. It is pleasing to see that 3 of the respondents mention the reason of reducing plastic waste. It can be assumed that these respondents have understood the problem of too much waste.

Most of the respondents (5) appreciated the properties of the plastic brick during earthquakes. In Sulawesi, earthquakes are common and plastic bricks have excellent properties due to their high ductility.

The material properties of plastic are also perceived positively. 3 of the respondents think that the material of the Brick is very strong and 2 think that it lasts very long and that it is very light. The ease of building with the Bricks is also seen positively by 3 respondents.

The Brick is very well received by the respondents. Whether this is partly due to the proximity to the interviewees cannot be ruled out. However, the reasons given for wanting to live in a Precious Plastic house are understandable and, in my opinion, relevant for forming a proper opinion about the Brick.

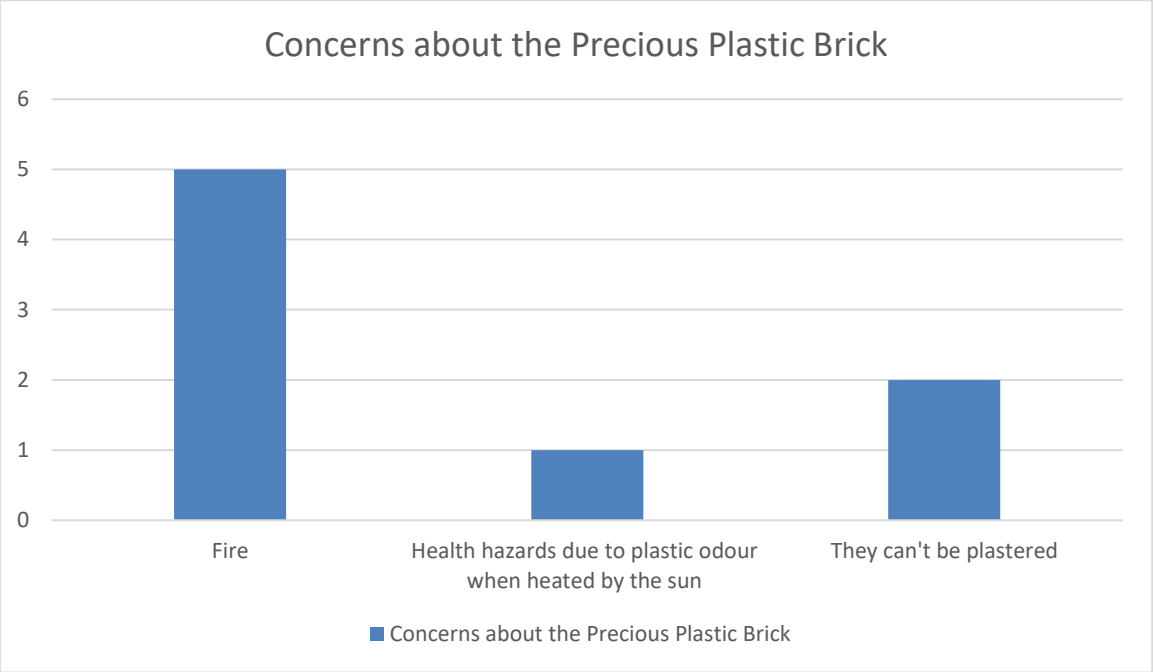


Figure 17 Concerns about the Precious Plastic Brick

The first thing that is striking about the surveys is that the test persons in the survey conducted by Teddy in Sulawesi expressed concerns and the persons interviewed by Rio in Manado did not. Teddy and Rio were encouraged to interview people as openly as possible, and that it was important to capture people's concerns in this survey. The wording of the interviews is not known, as only the text files are available as data. Therefore, it cannot be assumed that the people from Manado do not have any concerns.

Fire is the most commonly voiced concern. The primary concern here is the fire behaviour of the brick. The people in Sulawesi are used to burning plastic, so they are well aware that bricks made of plastic will also burn. One person expresses concern about off-gassing when heated by the sun "When exposed to the heat of the sun he will give off a very strong plastic smell.

Can make shortness of breath for children and adults". 2 people have concerns that the bricks cannot be plastered.

Fire can be a hazard brought by the plastic brick. Conventional bricks do not burn. This fact is indisputable. The aim of this work is to find out the fire behaviour of the brick by means of a fire test in order to assess whether the risk is too great.

The problem with plastering can be solved by plaster bases, which must be applied. More detailed solutions will not be discussed in this thesis.

3.2 Generating a global public opinion from the comments of a YouTube video

In today's society, a YouTube video has an immense reach that is difficult to compare with a real survey. Users voluntarily comment and share their opinions on the YouTube platform without even being asked. Most of the time, only a few users comment on a lot of videos and the majority are silent readers or leave a like or dislike. As with any qualitative study, the data should therefore be treated with caution. The great advantage of a qualitative content analysis of YouTube comments is, on the one hand, the large range (global) and, on the other hand, the availability of data without having to explicitly collect it.

> „The qualitative content analysis of user comments on YouTube videos thus enables a detailed picture of the mood both of the public as a communication space on YouTube and of the public that goes beyond the platform, since the users open up new contexts in the discourses conducted and themselves show what reach the video has outside YouTube, for example, when it is the subject of media reporting.“ (Cseke, 2018)

3.2.1 Research design

No data need be to be collected. The data is taken from the comment bar of the YouTube video from Recycle Rebuild “Why the world needs recycled plastic bricks “. The evaluation of the data is carried out via qualitative content analysis.

The following procedure is used: First, a research objective and a research question are defined. In the next step, the 897 comments are listed and coded. The categories are formed inductively, i.e., they are formed from the material itself. In the last step, the main categories created are processed, evaluated, and processed into a mood picture.

Table 9 Summary Research Design public opinion YouTube Video

Research objective	Generating a global public opinion about the Precious Plastic Brick. Identify YouTube users' concerns about the Precious Plastic Brick.
Research question	What concerns do you have about the Precious Plastic Brick?
Data collection	Data does not have to be collected

Data material	897 Comments under the YouTube Video “Why the world needs recycled plastic bricks (and how to make one yourself!)”
Data Analyse Tool	MAXQDA
Categorisation	Inductive categorisation

Data analysis tool

How the data is evaluated is determined by the options available. There is an evaluation software from Google YouTube Analytics, as well as other software such as Brandwatch Consumer Research; BuzzSumo; Social Blade; Tubular Intelligence and MAXQDA.

All except Maxqda are more interested in supporting the YouTube presence of the respective person/company in the area of marketing analysis. This is about content marketing, performance measurement and competitive analysis. “MAXQDA is one of the world's leading software programmes for qualitative and mixed methods research.” (MAXQDA, 2021) This software offers some very helpful tools especially for the qualitative data analysis of YouTube videos. For example, you can import YouTube comments directly into the software and have them coded automatically. For these reasons, the MAXQDA analysis tool was chosen.

Key data of the video

Table 10 key data of the video (measured on the 13.04.2021)

Name	Why the world needs recycled plastic bricks (and how to make one yourself!
Author/ Originator	Recycle Rebuild (8980 Follower)
Length	5:54 min
Uploaded	06.01.2020
Views	328.738 Views
Likes	13.214
Dislikes	327
Comments	892

Content of the Video

In the first section of the video, Rory explains why the Brick was designed and why it is needed. There is a great need for building materials and an even greater need to recycle plastics.

In the next section he describes the iterations that were necessary to get a high-quality brick design. "We judge ourselves on three criteria affordability, accessibility and quality." (Recycle Rebuild - Rory Dickens, 2020)

The iterations range from a solid brick with no voids to the Lego Brick, which has the advantage of creating straight walls and corners. Among other things, Rory explains that some tests have already been carried out, including pressure testing and "we even tested how different plastic types reacted to prolonged sun exposure and heat." (Recycle Rebuild - Rory Dickens, 2020)

- In the interview with Rory, he described these as very rudimentary and not reliable. For this reason, baseline testing needs to be done.

Finally, Rory shows where to find the blueprints, which are all available as open-source material.

3.2.2 Main categories

From the 896 Comments are 209 relevant in terms of the question: "What concerns do you have about the Precious Plastic Brick?" These are 23,36 % of all comments. Most of the rest around appreciates the idea or have some general questions. For this study only the relevant comments will be analysed. In the 209 relevant comments there are various statements for this reason the number of statements is higher than the number of relevant comments. In total there are 247 statements. All relevant comments summarised with their frequency can be found in Appendix 3. Those comments in Annex 3 have been grouped into main categories. This is only done for similar statements/concerns. YouTube users have been quoted for the categories. The citation reference can be found in Appendix 2

Table 11 Main categories

	Main categories	Included codes	Supplement and Explanation	Frequency
1.	Fire and toxic smoke	1; 2; 18	Concerns about consequences of too high temperature such as burning, toxic smoke and melting of bricks	83
2.	Bricks do not stand up to the demands of the environment	2; 6; 8; 11; 14	Cannot be used in extreme conditions such as high temperatures, wind or cold (problems with insulation).	54
3.	Harms the environment	5; 10; 12; 26; 28; 29	Concerns about the Brick harming the environment: • By ending up in the environment after its lifetime • By decomposing into microplastics during and after its lifetime. • Because the brick is toxic • by leaking oil and introducing hormones	32
4.	Outgassing/ off gassing	4; 17; 21	Consider that the brick outgasses: - during the manufacturing process; -by exposure to sunlight; -during its lifetime Concerns about VOC emissions	23
5.	Concern about aging due to environmental influence	2	Aging caused by UV irradiation and weathering	22
6.	Concerns about load-bearing capacity	9	Concern that the load-bearing capacity and mechanical properties of the brick do not allow for house construction.	9

7.	Bricks create an unhealthy indoor climate	15; 16	Problems with the accumulation of moisture, as the brick is not breathable with the smell	8

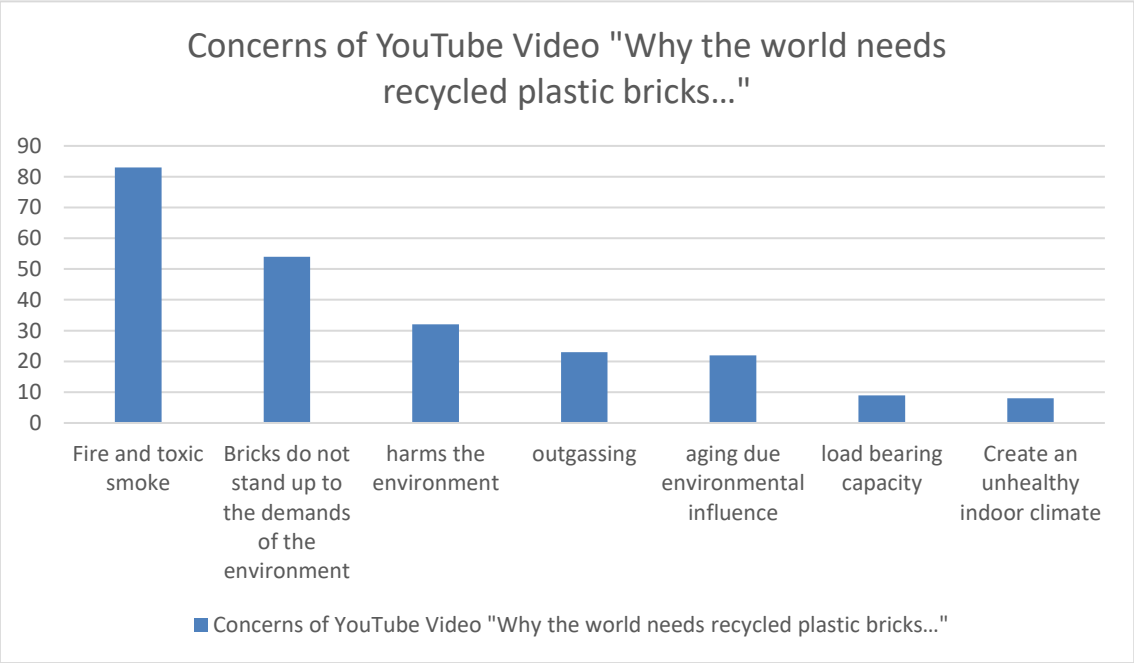


Figure 18 Main categories concerns of YouTube Video

Evaluation of the main categories

Fire and toxic smoke

Most of the YouTube users' concerns relate to the flammability of the plastic Brick. The burning of the Bricks is accompanied by toxic smoke and the melting of the Bricks. This is a very important aspect in terms of safety when building houses. For comparison, a normal red brick is not flammable. “Put it this way plastic brick melts at 300°C and is a source of fuel, standard red brick doesn't melt and isn't a fuel source. Let's just say I don't want to live in a candle that when lit reduce the structural integrity of that emidiat area rapidly, resulting to quick complete structural failure.” (McCausland, 2020)

This YouTube user puts the bricks in relation to other building materials that are also highly flammable. “@Andrew Cox As same as most insulating coats and materials, those bricks are

flamable, but I have a news for you: the paint of your walls is also flamable and highly toxic" (gosonegr, 2020);

In the context of this work, investigations with heat are to be carried out. It will be tested when the brick loses its mechanical properties. The aim is also to find out how easily the brick is flammable and how it develops smoke.

Bricks do not stand up the demands of the environment

The second most common concern is Bricks do not stand up to the demands of the environment. It says that the Brick cannot be used in extreme conditions such as high temperatures, wind or cold (problems with insulation). "How good would these work in climates that have harsh winters, high winds and hot summers? " (Eh!, 2021)These concerns are tested in the context of this work. It will be found out at what temperature the brick starts to lose its mechanical properties. It will also be tested whether the bricks can withstand the dynamic load of the wind through a simple experiment. Because the bricks are hollow, insulation material can be inserted. No cold tests are carried out as part of this work.

Harms the environment

32 statements in the comments concern that the bricks are harmful to the environment. 15 of these statements refer to the creation of microplastics through the use of Bricks." But what about micro-plastics, this will just introduce so many more to our environment as the bricks weather" (Pawar, 2020). Microplastics can be produced by decomposition through UV radiation and weathering. This point of decomposition is clarified by UV weathering, as the plastic can become brittle here. However, the introduction of microplastics through abrasion is unlikely due to the environmental influences. When bricks are used in house construction, the only significant component is rain, which can theoretically wash out microplastics. However, the pressure and quantity are too low to wash out a significant proportion of microplastics. "If I lick the brick how many millions of micro plastics come off of it ?" (Uppercut, 2020) Statements like these accumulate in the comments. Such deficits can arise from a lack of basic education on the topic of microplastics and plastics in general.

8 statements concern the aspect that the brick subsequently ends up back in the environment as waste. "This is a bad idea. The will end up in the nature anyways. The problem of plastic is not the lack of uses for recycled material." (Carbonell, 2020); "They are whitewashing the use

of plastics. In the end it will end up in the environment. By using those plastics you will make people and companies think it's okay to use plastic. So recycling may be good but it is not all good." (_____x, 2020)

Of the 32 statements, 6 include concerns that the Brick is toxic. "that's - so- f..... - toxic, better in a landfill than exposed to uv and washed by rain, this product is a massive danger" (Barocca, 2021) If it is established that the brick is only made of PP or HDPE, it is not toxic. In a comment the YouTube user says that he is worried about oil leaking out of the Brick. Another user writes that hormones can leak out. It is not possible for oil to leak from the brick. Likewise, when HDPE and PP are used as the base material, it is not likely that hormones can leak out.

Outgassing

23 YouTube users are concerned about outgassing "Is there a concern over VOCs (Volatile organic compounds) and vapor if the blocks are heated by the sun?" (Caskey, 2021); "Off gases with mystery chemicals because the plastic has been recycled." (DmD, 2021) The Recycled Plastic Brick may outgas. The aim of this work is to find out whether these outgassing's are hazardous to health or not.

Aging due environmental influence

"@Hyper Hektor Because of the chemical structure of polypropylene, it has a high degradation rate when exposed to UV light like the Sun. The light causes the bonds holding the polymer together to break which weakens the plastic. This makes polypropylene unsuitable for uses that require longterm exposure to sunlight." (Albert, 2020) "Sadly Plastic breaks down under UV so not a reliable building material!!"; "I'd be concerned about microplastics and degradation from rain and environmental impacts." (Saunders, 2020)

YouTube users are concerned that the brick will outgas, lose its polymer structure and become brittle due to sunlight and aging from weather. This is a very important point to clarify in this work. Aging caused by UV can make the plastic brick very brittle without additional measures. YouTube users have also shown many measures to protect the plastic against UV radiation. For example, adding additives such as carbon black or plastering the outside of the wall.

Load bearing capacity

9 Users are worried about the Load bearing capacity. They state, among other things, that in the video only one bicycle shed was built and that this shed was also reinforced with a wooden

structure. In the interview with Rory Dickens, it was revealed by him that the basic strength of the houses is to be produced by a conventional building structure. The bricks should not be used without a solid basic structure. This is not explained in the video, which is why another video of a house being built from Precious Plastic Bricks should be shown, in which the basic structure can be seen.

“The most important question of all is how much of a load can a single brick withstand? How much weight will a whole wall hold? Nobody will take these bricks seriously if you can't have a serious idea of how strong these bricks are. After all they are hollow and we are not talking about toys here. Over time plastic under load sags and breaks. And yes all plastics emit toxic chemicals when heated by mere sunlight.” (Perez, 2020); “I'm concerned that the biggest structure you showed is a bicycle shed that isn't even head-high, and is framed in. Is that the biggest structure you built? If so, how do you hope to use this technology to house millions when you didn't manage to build a single structure large enough to stand in?” (Allison, 2021)

Create and unhealthy indoor climate

In the 8 concerns expressed about this, 4 state that there can be problems with moisture and 4 that the bricks smell.” Moisture accumulation due to condensation as it has no where to go because of non Porosity” (Arun, 2020) The bricks are not breathable. The structure of the house must be built in such a way that there are still breathable parts that will absorb the moisture. In the interview with Rory Dickens, he said that houses should not be built entirely from plastic bricks, but that there should be a sensible mix of building materials. “Plastic recyclers are often faced with the problem that their input material and the regranulation produced from it have strong odours, especially when it comes to the reprocessing of PP and PE packaging. Recyclers of post-consumer plastic waste often have to deal with materials that contain migrated substances from food, cosmetics or cleaning agents. But also, residues of monomers, oxidation, hydrolysis and decomposition products (VOCs - volatile impurities) can be responsible for recycled granulates having an undesirable odour. Solid impurities and fibrous materials, such as paper or wood, cannot always be separated 100% even after an intensive washing process and can also cause odours in the extrusion process.” (Starling Group, 2021)

Starlinger recycling technology relies, among other things, on the outgassing during the production of the recycled product to reduce the odour of plastics. For example, the temperature

in the feeder of the extrusion screw is maintained until many volatile odours are separated. The smell is being investigated; the accumulation of moisture is a known problem that is being countered with sensible architectural arrangements. The brick cannot be made more breathable due to process limitations in the injection moulding system.

3.2.3 Discussion of the comments in the YouTube Video

When I first heard about the project and watched the video, I thought it was a great way to recycle plastic waste. Most YouTube users thought so too. This is shown by the fact that the video has more than 13,000 likes and only 327 dislikes. In the comments there are a lot of critical statements questioning the Brick. There are far more positive than negative comments towards the Brick. However, in this research the negative ones, the concerns of the users, are of interest. The users not only write about their concerns, but also suggest solutions, e.g., how to get a grip on the fire behaviour or the ageing caused by UV radiation. Many comments are backed up with good arguments. Others are rather unspecific and without solid facts in the background. Analysing the comments has helped me a lot in assessing the effects of living in a Precious Plastic House.

In my preliminary considerations of which areas to investigate, I came to similar points as the YouTube users. The biggest fear of YouTube users is the uncontrolled burning of the Bricks. I had not considered this concern to be so great and important before this investigation of the YouTube video. It was clear to me that the brick can burn, just as insulating material and wall cladding can also burn. In relation a house built of red bricks does not burn, so I find this an absolutely essential issue. The second most common concern, that bricks cannot withstand environmental conditions can be very well clarified. In addition, it is not planned to use the Brick in ice and snow for the time being, as such temperatures place increased demands on building materials, which the Brick cannot currently meet. However, the exposure to wind, UV radiation and water can be clarified. Personally, I find the concern that the Brick harms the environment very interesting. The concern that the Brick emits microplastics when used as a brick shows how irrational the fears of YouTube users can be. Unfortunately, many have not understood the purpose of using the recycled brick to replace a product that would otherwise have to be manufactured with new resources. The points Outgassing as well as aging due environmental influence, load bearing capacity and create an unhealthy indoor climate were also

on my list of investigations. None of the concerns mentioned except that of "harms the environment" were new to me before the study. However, the investigation of the comments revealed all the concerns that were also discussed in advance with the core team of TWS Natalie Blanc and Markus Kurath as well as with the university professor Thomas Schreier-Alt. This confirms me in the conduct of the investigations.

3.3 Comparison of local and global generated opinion about the Brick

The aim of this chapter is to generate an opinion of the population about the Precious Plastic Brick. The research carried out: Survey in Siladen and Manado in chapter 3.1 and the evaluation of the YouTube video in chapter 3.2 are related to each other. Both surveys aim at the same research objective, to generate an opinion (local or global) about the Precious Plastic Brick. In the case of the local opinion, the reasons for acceptance were also examined in more detail, whereas in the case of the global opinion, only the concerns were considered. The positive comments were only counted as a total and not examined in more detail.

Positive or negative opinion of the Precious Plastic Brick

Locally in the survey, if the Respondent wants to live in a Precious Plastic House or not, and globally as a like or dislike under the YouTube video.

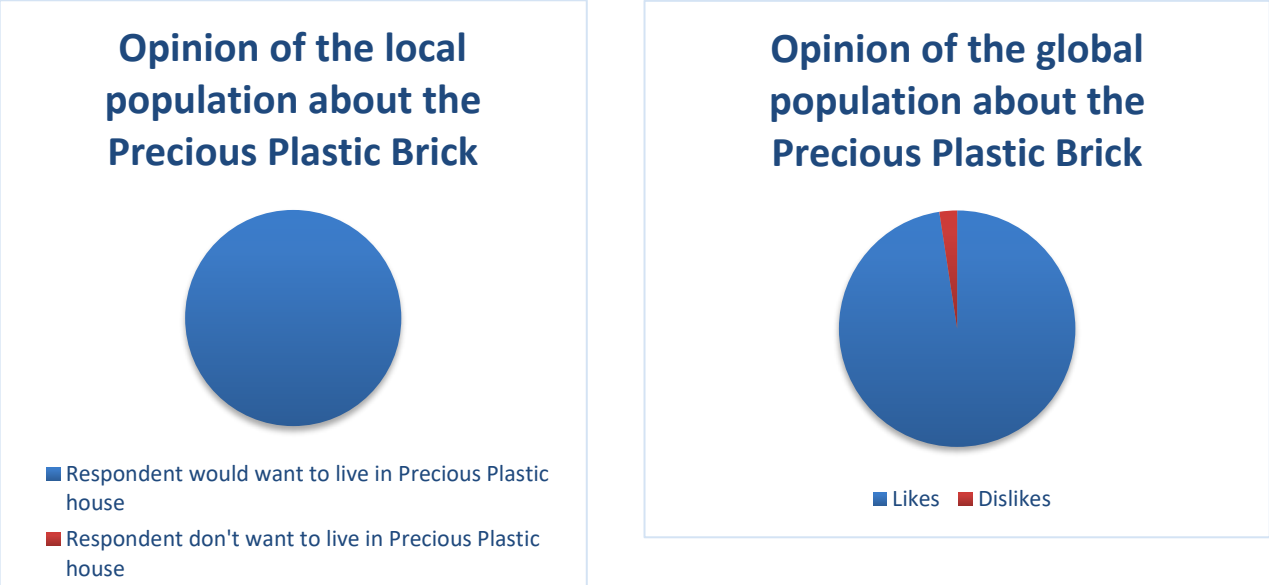


Figure 19 Positive/ negative opinion of the Brick local vs. global population

Figure 19 compares the two surveys in terms of positive and negative statement and shows a consistently positive picture of the population. Also, in the comments column of the video, 687 of the 897 comments were supportive statements or interested queries.

Concerns of the local and global population

Figure 20 Positive or negative opinion of the local population of the Brick vs global population

In both studies, the concern about fire is at the forefront of the concerns. In Indonesia, a lot of plastic waste is burnt, so everyone knows that it is flammable. The commentators on the YouTube video are also most concerned about the Brick in terms of fire and toxic smoke. Developer Rory Dickens intended the Brick to be a material that is complemented by other building materials and not to be used as a naked brick. He says that, like a normal house made of red bricks, they should still be clad with fire protection material. The ByBlock of ByFusion, which will be introduced in chapter 4.4, must also be clad with fire protection material in order to meet the safety requirements of a building material.

The respondents in Indonesia are concerned about the fact that the brick cannot be plastered. In addition, a local respondent expresses concern about the behaviour of outgassing due to

heating the brick in the sun. This concern is also represented in the global opinion under the main category outgassing. In addition, a local respondent is concerned about the composability of the Brick. Similar statements can be found in the YouTube comments. These were grouped under the item "Harms the Environment".

Different studies produce similar results. The fear of fire is one of the primal fears of humans. Especially in relation to their homes, dangers that can lead to fire should be excluded. In addition, many people know that plastics outgas, but which plastics outgas and which substances they outgas is unknown to most people. Every day we spend a large part of our time in the vicinity of plastic products. I suspect the public assumes that products that come onto the market are safe. One respondent made the following comment: "if the item has been recycled it means that the item is suitable for use and exploitation". I interpret this statement to mean that the respondent considers the recycling process to be a full product development process that has been tested and validated. This means that the resulting product is suitable for use, and he has no concerns about it.

4 Brick requirement and existing recycling Brick projects

This chapter deals with the requirements for the Brick and the raw material which is used for the Brick. It should be clarified which loads the brick is exposed to. In addition, it should be determined what it should be able to withstand in order to be used as a building material.

4.1 Define application area, brick load and which raw material to use

Application area

The bricks will eventually be used worldwide, but the target area for investigations in this master thesis is Sulawesi, Indonesia. The special challenge in Indonesia results from the high humidity, the tropical climate, and the enormous solar radiation.

Global horizontal irradiation:

“Global radiation is the solar radiation received at ground level from a horizontal plane and is composed of the direct radiation (the shadow casting radiation) and the scattered solar radiation (diffuse sky radiation) from the celestial hemisphere. At sun elevations of more than 50° and cloudless skies, about 3/4 of the global radiation consists of direct solar radiation, at low sun elevations (down to about 10°) only about 1/3.” (Deutscher Wetterdienst, 2021)

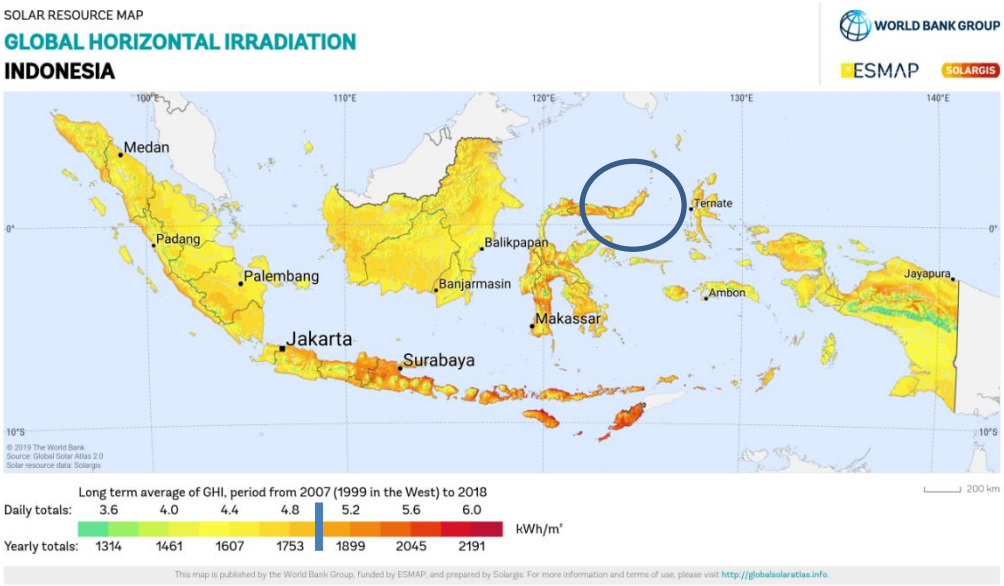


Figure 21 Global Horizontal Irradiation Indonesia (solargis, 2021)

The yearly Global horizontal Irradiation (GHI) in North Sulawesi is between 1753 and 1899 kWh/m² the mean value of 1825 kWh/m² is taken. Values from long term average of Global Horizontal Irradiation (GHI) for a period 1999 to 2016. (World Bank Group (ESMAP), 2017)

Temperature and Humidity in Manado, Sulawesi

The temperature is between High Temp: 33 °C and Low Temp: 22 °C and the average Humidity: 79%cf. (CustomWeather, 2021)

“Averages are for Menado / Dr. Sam Ratulangi, which is 10 kilometres from Manado. Based on weather reports collected during 2005–2015” (CustomWeather, 2021)

The maximum and minimum temperature is not within a critical range. Even the difference of 11 °C between the temperatures is no challenge for the material. The brick is to be fused to 40°C. The average humidity of 79% could lead to the absorption of water in the brick. The water absorption of the brick is investigated. The brick must not exceed a maximum water absorption of 2% in a water bath in which it lies for 30 days.

Load capacity of the brick

Rough estimate of the weight load on a brick:

Weight of a Brick 1.8 kg, height of a Brick: 160 mm

→ 19 Brick height of a single storey house (3040 mm)

→ 19x 1.8 kg = 34,2kg + Weight share from the roof (around 300 kg) = 334,2 kg

Based on the dimensions of the brick and the material, it can be assumed that it will withstand at least 10 tonnes. It will probably be much more. For use in building one-storey houses, 10 tonnes are more than enough. For this reason, the load-bearing capacity is considered sufficient if the brick can withstand 10 tonnes until it breaks.

Define permissible loss of Load capacity due to UV aging

The UV-irradiated brick must also withstand 10 tonnes of weight or 100 kN of weight under pressure. This is the only way to guarantee the required safety.

Deciding which raw material to use in Sulawesi

Rory Dickens, inventor of the Precious Plastic Bricks, recommends HDPE or PP.

TWS decided on PP as the base material because of Julia Giebel's master's thesis. The Waste Bank of Manado is taken as the source of the basic material. PP material is very common in the Waste Bank. For this reason, the PP material is used to produce Precious Plastic Bricks in the Sulawesi pilot plant. However, both base materials will be used for the investigation and for the data sheet to be prepared.

4.2 Product requirement document

Table 12 Product Requirement document

	Peak values
Minimum Load capacity of the brick until material failure corresponds to force of	10 t 100 kN
Minimum Load capacity of the UV irradiated Brick until material failure corresponds to force of	10 t 100 kN
Water absorption after 30 days in water bath	Maximum 2% of the Bricks weight
T_{max} [°C] for safeguarding	40°C
Burning behaviour	must have a non-critical fire behaviour. Can be verified, for example, with the UL 94 Vertical Burning Test.
Outgassing	Must not outgas any substances in an amount that are hazardous to health. Must be assessed and validated by experts

4.3 Existing recycling Brick projects

There are various projects to recycle plastic in the form of bricks. The 4 most popular ones besides the Precious Plastic Brick are listed here. There are many more like The Eco-Bricks produced by Nelplast Ghana in Ghana and the Plastic Bricks produced by Veolia in India.

ByBlock ®; ByFusion; California

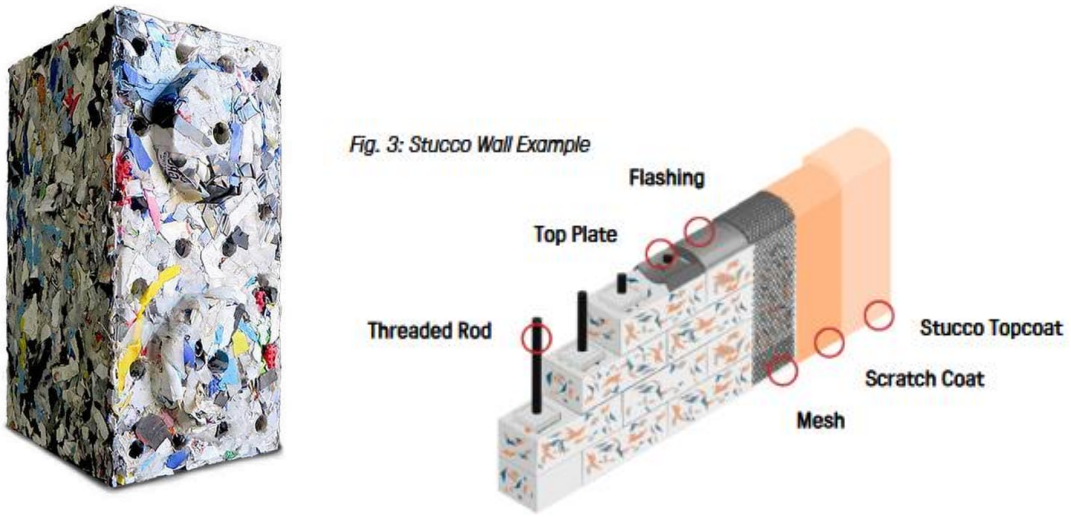


Figure 22 ByBlock ®-Brick and Stucco Wall Example (ByBlock®Product Data SheetByFusion Global, Inc., 2020)

Description: ByFusion, a company based in California, has developed a revolutionary process to recycle plastic into bricks. They operate in large quantities using a pre-process optimised profit-generating process. "Our unique, eco-friendly process uses steam and compression to convert all types of plastic waste into a revolutionary building material called ByBlock- No added chemicals. no fillers. no waste." (ByFusion Global Inc, 2020)

In their process, discarded plastic is collected, shredded, and then superheated and fused into ByBlocks. The collected plastic does not need to be laboriously separated

Specifications:

- "ByBlock is CA Section 01350 Compliant and meets GREENGUARD and GREENGUARD GOLD criteria for formaldehyde, total aldehydes, and CREL/TLV levels."

- Testing followed CDPH Standard Method v1.2 “Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers” and UL 2821, “GREENGUARD Certification Program Method for Measuring and Evaluating Chemical Emissions from Building Materials, Finishes and Furnishings Using Dynamic Environmental Chambers”
- Compression: 408 psi(unreinforced) corresponds to 28,13 bar
- Maximum Load 49.800 lbf (Pound-force) corresponds to 221,53 kN
- Temperature range: -20°C until 40°C
- Fire resistance: ByBlock are categorized as type 5 construction. Approved thermal barriers must be applied as part of finishing to conform with the building code for fire safety as required for the application. Secondary fire retardants (spray, wraps or panels) can be applied.”

(ByFusion Global Inc, 2020)

Conceptos Plásticos, Colombia

Figure 23 Conceptos Plásticos houses (CONCEPTOS PLÁSTICOS, 2019)

Description: “The production process from the recycling of building materials was developed in 2014 by architect and start-up founder Oscar Mendez. The process allows plastic waste, a material which is generally difficult to recycle, to be melted and

Like the Precious Plastics Bricks, they are made of plastic waste with a plug-in system. Which plastic waste is used is not disclosed. They use additive but it is not known which. In an email

interview with Markus Kurath, they wrote the following “We have a plastic made of 95% recycled plastics and 5% additives, with properties suitable for construction such as being fire retardant or not being a toxic material.” (Conceptos Plasticous, 2021)

The bricks are used without additional coatings.

Paving stones; Gjenge Makers; Kenia

Description: “Nairobi-based start-up company Gjenge Makers, founded by Nzambi Matee, has created a lightweight and low-cost building material that is made of recycled plastic with sand to make bricks that are stronger than con-

Figure 24 Paving stones (Gjenge Makers, 2020)

There are no product specifications listed. The requirements regarding outgassing and the material properties that are placed on paving stones are significantly lower than on bricks.

EcoBricks; Nestlé Philippines and Green Antz Builders, Inc., Philippines

Description: “Green Antz, which was established with Nestlé’s support, collaborates with corporations, LGUs and NGOs to establish Green Antz Hubs for the production of eco-bricks using waste plastic laminates which are cheaper to use and offer better insulation.” (Nestlé, 2018). “Eco-bricks are created using a mixture of wet cement and shredded plastic

Figure 25 Green Antz EcoBricks (Green Antz, 2021)

Compressive straight: 550 PSI (corresponds to 37,92 bar)

5 Examination of base material

After finding out the requirements in chapter 4, the target now is to examine the base material. The tests are carried out partly with PP and with HDPE or only with PP. This serves to safeguard the secondary material, since according to Rory Dickens both can be used, and additionally brings the possibility of comparison. However, the investigation in this chapter is limited to PP.

Definition of terms:

- Plastic varieties: PP or HDPE
- Raw material= purified PP household waste
- Base material= shredded raw material

Unlike production with PP granulate purchased from a plastic manufacturer, production from recycled plastic involves some difficulties. When purchasing granulate from a reliable manufacturer, quality assurance can ensure a consistent product. By adding specific additives, the properties can be changed as required. When recycling plastic, many different sources are used, and the material has already been stressed in its previous product life and may show damage. In the following chapter, PP is basically examined and then the waste material to be recycled (Base Material) is looked at.

To guarantee safety, it is very important that no critical plastics get into the raw material (which is shredded). Critical substances include PVC and PC, as these very often contain plasticisers such as PBA. PS and PU are critical in case of fire. The bulk plastic PE, which is also lighter than water, should be harmless just like PP. This chapter is among others about making sure that only PP material is used as a base material. In addition, the production of PP is considered and its properties in terms of health risks and resistance to UV. The output of this chapter is defined as a guidance document to ensure that only PP is used as the base material.

5.1 Examine Polypropylene

> “Polymers are very long repetitive molecules made up of monomers: poly meaning many, mers meaning parts, and mono meaning one. So, polymers are many parts of one […] long repetitive chains and the difference is not how they are formed, but where the polymers are derived from. “ (Precious Plastic, 2021)

> “Propylene is differentiated into:
> Isotactic polypropylene […] Atactic polypropylene […] Syndiotactic polypropylene […]
> The technically most important type of material at present is isotactic polypropylene, which is obtained by the initial process with stereospecific catalysts according to Ziegler/Natta. […] Polypropylene is produced by addition polymerisation (chain reaction) of propene. Monomers for addition polymerisation as a chain reaction therefore usually have a C= C double bond.” (Eyerer & Schüle, 2020)

Health risks that can emanate from PP

PP is a standard plastic with a wide range of applications. It can be found in vehicle interiors, in the food packaging industry, cosmetics industry or to produce pipes. As it is physiologically harmless, it is also used in medical technology. Theoretically, no health risks are to be expected from the professionally produced pure PP granulate, but additives can be added during the manufacture of products. The properties of polypropylene are given in the basic material of the granulate manufacturer without special additives such as softeners. Plastics in general can outgas Volatile organic compounds and residual monomers; Contain heavy metals and additives such as plasticisers.

UV resistance of PP

Basically, PP is only conditionally UV and weather resistant. Additives are needed for outdoor applications. The Precious Plastic Bricks are made from recycled material, so it cannot be 100% sure to what extent UV stabilisers are already present in the PP waste. From the point of view of Precious Plastics, no additives are currently planned to produce the bricks as of May 2021.

The behaviour of the bricks in relation to UV radiation is being investigated in this work.

„UV radiation leads to thermo-oxidative degradation of the plastic in a similar way to increased operating temperatures in the presence of oxygen. This means that, in principle, plastics with a high continuous service temperature are also more UV-resistant. The degradation accelerated by UV radiation is critical because it can take place at any temperature and exclusion of UV radiation is guaranteed in the rarest of applications. However, effective UV stabilisers are available on the market today for almost all plastics [...] Furthermore, even a stronger pigmentation (preferably with carbon black, or titanium dioxide/white) can bring significant improvements in UV stability.” C.f. (Bonnet, 2009)

Table 13 List of properties of PP and HDPE (Schröder, 2014)

	HDPE	PP
Designation	High Density Polyethylene	Polypropylene
the art of plastics	Thermoplastic	Thermoplastic
Density [kg/m³]	945-965	900-915
Bending strength [N/mm²]	20-30	40-45
Elongation at break [%]	250 between > 500	>450
Compressive strength [N/mm²]	22-32	-
modulus of elasticity [N/mm²]	700-1750	1250-2200
tensile strength [N/mm²]	25-34	30-40
softening point [°C]	120-130	90
Max (unloaded) [°C]	90	130
min (unloaded) [°C]	-90 / -140	-20
Water absorption at 20°C		
With relative humidity 50%	0.1	1.0
When submerged [%]	-	1.0

All values are from the book (Schröder, 2014) The values for HDPE and PP drift very far apart for different sources. For this Master thesis the values of the book by Bernd Schröder "Kunststoffe für Ingenieure- Ein Überblick" (Plastics for Engineers - An Overview) is chosen. The book was published by Springer Verlag in 2014. Nevertheless, these are only guideline values and depending on the manufacturing process, you will get different results.

5.2 Examine Process of Upcycling Polypropylene for Precious Plastic Brick

> "Upcycling is a process in which used materials are converted into something of higher value and/or quality in their second life." (Sung, 2015)

Because the recycling process of household waste creates a brick for building houses, it is called upcycling. To produce the Bricks the mechanical process of recycling is used which is described as follows:

> "In this process, only the thermoplastic polymers can be used, because they can be re-melted and reprocessed into end products.[…] This process is represented by a physical method, in which the plastic wastes will be formed by cutting, shredding or washing into granulates, flakes or pellets of appropriate quality for manufacturing, and then melted to make the new product by extrusion" (Grigore, 2017)

Two types are distinguished here. Pre-Consumer Recycling and Post-Consumer Recycling

Figure 26 Pre-Consumer Post-Consumer Recycling (BuildingGreen, Inc., 2021)

Pre-Consumer waste is produced during the manufacture of PP products. This can be regranulated and reused. New granulate is usually added to the regranulate to compensate for the physical degradation. Post-Consumer waste is generated after a consumer has used

the product. In the brick recycling process, post consumer waste is used to make the brick. This is contaminated by its previous use. Both types of waste have different properties. These are investigated and compared within the framework of this work with a tensile test.

5.3 Examine waste source for raw material

Plastic products made of PP are used in many ways. The resulting plastic waste is therefore very different. It makes a big difference to the PP Post-Consumer waste whether it was used to package food, for medical purposes or as a sewage pipe. Depending on the purpose, the waste can contain different additives. In addition, the material to be packaged can be absorbed in small quantities in the polymer structure. This can be released again in the form of odour escaping from the recycled product. The source from which the waste is obtained plays a decisive role here.

It is divided into reliable sources like Household; Medicine (hospital waste); Industry; Building materials and unreliable sources like Landfills and collected waste in nature

The quality of plastics from different sources varies greatly. The plastic waste from the landfill or the collected plastic from the beach cannot be used to produce the Brick. It became an unreliable source because of the following reasons:

- Partly already decomposed
- Absorption of water
- Damage to the polymer structure by UV rays
- It is no longer possible to determine the type of plastic without special equipment (no label).

For this reason, the Precious Plastic Brick is based on household waste. In order to be able to make far-reaching statements, PP household waste samples would have to be analysed over a longer period of time with regard to their ingredients.

Difference between PP waste from Indonesia and Europe

The production of plastics is carried out by the world's largest chemical companies such as BASF, DowDuPont, Sinopec, Sabic and INEOS. They sell their granulate to the companies that manufacture their products from it. It can be assumed that the granulate of the largest chem-

ical companies does not differ significantly from each other. Moreover, they operate worldwide, so the PP pellets bought by BASF in Europe do not differ from those bought in Indonesia. However, there may be differences in the processing of the granulate. Depending on the intended use, different additives can be added. How and to what extent these differences exist cannot be found out within the scope of this work. Whether Indonesian PP household waste contains more hazardous substances than European waste is not determined, but Indonesian PP household waste is examined. This should provide information on which hazardous substances it contains. It also serves as a rough guide. If the results show too many critical substances, it should generally be considered whether a different use would not be better. In the context of this master's thesis, household waste from Indonesia and from Europe will be analysed by during the Tensile tests. The household waste sample from Indonesia is analysed for heavy metals and for outgassing of emissions.

5.4 Waste Bank Manado

The Waste Bank Manado, headed by Marlon Kamagi, serves as the source for the PP to be recycled.

"The term waste bank consists of two words. Bank is an intermediary institution that has a function as a place to save and lend money and also financial transactions. Waste is defined as all unwanted or unusable material, which is usually discarded by its owner (Pinheiro, 2015) Waste bank is a campaign for handling waste by buying back waste in terms of a deposit like banking system. Waste bank operates like a bank which people in a community, subdistrict, and district can use to deposit their garbage or extract money from the value of the garbage they provide to the facility (Friedberg, 2017) Waste Bank began to develop in various cities in Indonesia such as in Bantul (2008), Malang (2010), Surabaya (2010), Gresik (2012), Cilacap (2012), Barat (2012) and growing to almost every city and regency in Indonesia. It was a good effort, especially in managing waste problems." (Wulandari, Utomo, & Narmaditya)

How does the Waste Bank in Manado work?

The material from the households is personally delivered by local people to the Waste Bank point.

1. The material is classified (28 subclasses), weighted and then recorded in a Smartphone App by assigning it to the user. Here, the person automatically receives the correspondent amount of money to his account, which can be claimed back in cash.
2. When the amount of material is enough to at least fill one 40feet container, it gets shipped to Jakarta for recycling. Then the recycling company pays the material back to the Waste Bank." (Kurath, 2021)
3. TWS can buy the PP Raw Material directly from the Waste Bank in Manado

Investigating Waste Bank Manado as a source for the base material

To guarantee safety, it is very important that no critical plastics (like PVC and PC because of plasticisers and PBA, PS and PU because of fire safety) get into the Base Material. For this reason, the preparation process of the base material is examined. The bulk plastic PE, which is also lighter than water, should be harmless just like PP.

An interview is conducted with Marlon, who is responsible for the Waste Bank in Manado. In the interview, the following questions are to be clarified: How is it ensured that only PP material is used? How does the classification of the individual plastics work? In addition, Waste Bank Manado sent a PP Base Material sample to me. This will also be looked at and will be used to assess Waste Bank as a waste source.

Interview and Survey Result with Marlon Kamagi about the Waste Bank Manado

Persons present at the interview: Marlon Kamagi; Natalie Blanc, Markus Kurath, Marina Seeger Date: 03.04.2021

Table 14 Guideline based Interview with Marlon Kamagi

Fact Survey of the person to be interviewed, Facts about the Waste Bank Manado	
Task at the Waste Bank Manado	Director of the Waste Bank
Education of Marlon Kamagi	Climate leader von Al Gore for Indonesia

	Engineer from Polytechnic Manado Master in Sustainable Tourism
How many people work at the Waste Bank in Manado?	10
How much money does a private person who brings their PE waste to the Waste Bank receive?	Depends on the waste. Plastic Paper or metal or any kind of waste has their price. For Example, 5 kg PET = 5000 Rupia
Which processed plastic waste is the best to sell?	PET and PE
Who do you sell your recycled plastic waste to?	They sell collected Plastic not recycled. They sell it to recycling Plants in Java / Bali / Makassar there it gets recycled to whom? They sell it to a Network which contents different buyers. For Example: PT Saam Jaya in Pasuruan Surabaya East Java. When one container of 20 ft² is full then they send it to Java. In Java they get more money for collected waste because no loss of money due to transport. The Precious Plastic Bricks are very good for them because no transport when it gets there recycled
How much waste do you separate (mass [kg]) per month?	500 kg -1000 kg. (Metal, Glass, Plastic) Because of COVID they closed → stopped in March 2020 and try to operate in the waste bank.
Leading question	Answer
Into which categories do you separate the waste? (PP; PE; PET…)	The materials metal, glass and plastic are accepted. For the plastic we separate PP, PET, HDPE, LDPE, PVC, ABS

Which method do you use to distinguish between the individual plastics?	1. Checking symbol on the plastics, separate by the kind of plastic 2. When there is no symbol: Doing a test with water or oil (certain plastics float on top, others do not) Burn the plastic (this should be the last option and should be done correctly → short time burning, at the lowest possible heat, outside because it can cause health dangerous fumes. Then compare the plastics with the table of the properties on the Precious Plastic Website (See appendix: Precious Plastic tables for determining the plastic). How often do you use other techniques than look at the symbol? – not often, most of the time we look at the symbol and use the precious Plastic table
For the brick we need very pure PP material. What do you think the purity of your separated PP material is?	The Team knows how to recognize PP. There is no problem about identifying PP. With which material do you make “Mistakes”? Which are too similar? “There is no problem with PP or HDPE. “ It gets sorted 2 times: 1. Sorting from consumer at home: before they bring the material to the waste bank, they sort the material at home 2. Sorting in Waste Bank: The material gets a second time sorted
PVC, PC, PS and PU should never get into the HDPE / PP material. Can you exclude this through your separation process?	“I learn about the plastic, and I know what the best plastic is for our project. Sometimes we get PVC bottles from the hospital or unlabelled PET Bottles. But we know how to distinguish them, so no other material can enter the process. “

The table for Visual Properties (Appendix 4) is most commonly used in Waste Bank Mando. It gives a very good overview of the identification and classification into plastic groups of articles of daily use. If the items cannot be classified according to their recycling symbol, the Precious Plastic Table Floating Properties (Appendix) is used.

Examination PP Base Material Sample of the Waste Bank Mando

The sample looks very homogeneous. The plastic is light and has the consistency of flakes.

Figure 27 PP Base material sample from Sulawesi (Marina Seeger)

During the production of the tension rods (described in chapter 6.3) there were three problems with the material. First the material does not trickle into the injection moulding machine on its own. Second the material contains magnetic metal dust. This arose during shredding. The shredder has not been in use for long and the distances between the shredder blades are too small. When the machine warmed up, the blades expanded and rubbed against each other. It has not been noticed by the Waste Bank staff. Thirdly, the material probably contained other plastics with a higher melting temperature.

Assessment about the process in the Waste Bank Mando

Communication with the staff works well. They are easy to contact if you have any questions. They carefully separate and clean the different plastic waste, even by colour. They use Precious Plastic's tables and their expertise to distinguish between the different types of plastic. They take their task very seriously and, in my opinion, it is safe to assume that they sort the waste correctly. However, they have very little expertise in the handling and use of machines. Training is needed to ensure the safety of the Waste Bank staff and the quality of the bricks. In addition, comprehensive checklists should be introduced to inspect the equipment. In this way, further introduction of metal dust into the base material can be prevented.

5.5 Guidance document for the production of PP Base Material

The figure 28 illustrates the production process of PP.

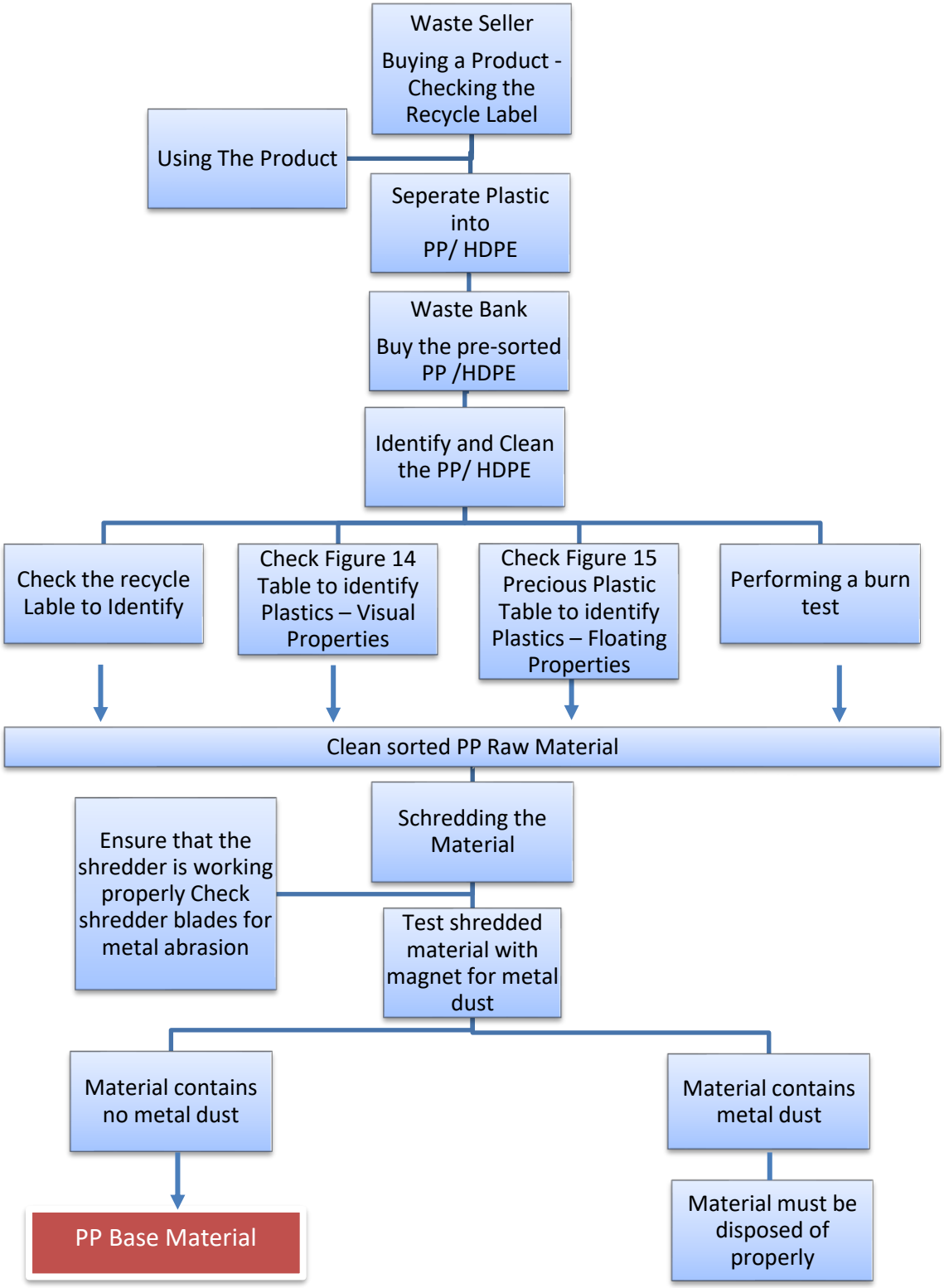


Figure 28 Procedure for separating PP and HDPE for the production of bricks

6 Preparation Examination Precious Plastic Brick

This chapter plans the examinations that will be carried out in chapter 7. First, it will be clarified which tests have already been carried out on the Precious Plastic Brick and its base material. This is done in an interview with Rory Dickens, one of the inventors and co-founders of Precious Plastic. This is followed by a definition of the tests that need to be carried out to analyse the risk posed by the Precious Plastic Brick and its base material. The risks are divided into health risks and risks of material failure. In this list it is clarified when and where the tests are carried out and what their output is. In the last section of this chapter, the production of the test specimens needed to perform the tests is outlined.

6.1 Existing research results, Interview and Survey Result with Rory Dickens

Summary of the interview (which can be found in Appendix 5)

No studies have been carried out so far on the mechanical properties of the bricks. Neither has the brick been investigated with regard to UV aging and weathering or fire safety. Whether the brick emits hazardous gases has also not been investigated. Other manufacturers of recycled plastic products that are subsequently used outdoors are provided with UV stabilisers. Adding these to the Brick would be too expensive. Conceptos Plásticos has been building houses with similar bricks for several years. Whether they use UV stabilisers remains to be seen.

A big problem that can occur is that the bricks smell too much. This is a common problem with recycled products. The brick should be used in combination with other building elements. Single storey "Lego" houses are possible, but residents should be made aware that the material is combustible.

6.2 Define the tests to be performed

In the following chapter, the experiments to be carried out are described and the exact experimental situation is clarified. This includes the decision which test specimen to use. There is a choice between Tensile Test specimen, UL94 vertical Flame specimen and the Precious Plastic Brick. The tensile tests are carried out with the basic test specimen 1A according to DIN EN ISO 3167. These are injection moulded at RWU.

Table 15 Overview of the tests that need to be carried out

	Analyse	Material	Facility	Location	Lessons learnt
	Health Hazard:				
	Outgassing Test				
A	Odour test according to VDA270 at different temperatures	PP Sulawesi	Emission test facility	FILK Labour Freiberg Bernd Matthes	Whether the bricks endanger the room climate through unpleasant odours
B	Emission Test B1: Thermal desorption (dynamics headspace) according to VDA278 B2: Static headspace according to VDA277 with individual evaluation B3: Flask method VDA 275 Formaldehyde	PP Sulawesi from Waste Bank Manado	Emission test facility	FILK Labour Freiberg Bernd Matthes	B1: Outgassing VOC B2: Outgassing Total Carbon B3: Outgassing Formaldehyde
C	Element analysis with AAS	PP Sulawesi	Atomic absorption spectroscopy AAS	Chemistry and environmental analysis RWU	Whether the manufacture of the bricks and the fumes from burning

				Saskia Brugger	them are hazardous to health.
	The hazard of material failure				
D	Tensile Test	PP, Konstanz PP, Indonesia	Universal testing machine (tension, compression and bending testing machine)	Multifunctional Laboratory Building D RWU	To generate general material properties (yield strength, tensile strength, elongation at break)
E	Pressure test with non-UV irradiated Brick with UV Irradiated Brick	1 HDPE Bricks from UK non-irradiated; 1 irradiated 1 PP Bricks from UK non-irradiated; 1 irradiated	Converted press with load cell	Multifunctional Laboratory Building D RWU	To obtain a rough guide value for the load-bearing capacity to compare the values: non-UV irradiated brick with UV irradiated brick
F	UL94 Vertical Flame Test	PP and HDPE Beams 127 mm long, 12.7 mm wide and maximum 12.7 mm thick	Bunsen burner, suction device, holding device, steel rule, stopwatch	Chemistry and environmental analysis RWU Saskia Brugger	Classification and assessment of the flammability of plastics

G	Weathering of the brick according to DIN 75220 Z-OUT - 480 hours	Brick from Rory Dickens UK HDPE, PP	Test conditions according to DIN 75220 Z-OUT	LABOR LEHMACHER | SCHNEIDER GmbH & Co. KG Albert-Einstein-Str. 32 49076 Osnabrück	Influence of UV radiation on brick
H	Water absorption	Brick from Rory Dickens UK HDPE, PP	Both bricks are placed in a water bath for 10 days and weighed before and afterwards	Office of Marina Seeger, Germany	How much water the bricks absorb

6.2.1 The health hazards

The points shown in figure 29 are clarified under the aspect of health hazards.

Figure 29 Overview of the health hazard

Outgassing

The Emission/ Outgassing tests that are carried out are standardised according to VDA guidelines. VDA guideline is a test procedure according to the German Association of the Automotive Industry. The VDA guidelines serve to compare the results internationally. The evaluation tests to be carried out were recommended by the specialist Dr. Bernd Matthes from the FILK Freiberg Institute and carried out under his guidance.

VOC's (VVOC; SVOC):

Plastics can outgas substances that are hazardous to health such as VOCs. Volatile organic compounds are called VOCs. "VOC describes gaseous and vaporous substances of organic origin in the air. These include, for example, hydrocarbons, alcohols, aldehydes, and organic acids. Many solvents, liquid fuels and synthetically produced substances can occur as VOCs, but also numerous organic compounds formed in biological processes." (Umweltbundesamt, 2016)

VOCs are to be distinguished into Very Volatile Organic Compounds (VVOC) and semi volatile Organic Compounds (SVOC)

Formation of VOCs:

- When e.g., solvents or liquid fuels evaporate
- via material emission: When different accompanying substances are not firmly integrated into the structure. These can be released slowly from the product surface into the air

cf. (Umweltbundesamt, 2016)

Health effects of VOCs: "Odour nuisance, irritation and symptoms that cannot be directly attributed to a disease have been described as acute effects on humans. These effects must be avoided, as well as possible chronic effects that scientists have derived from toxicological assessments; especially naturally carcinogenic, mutagenic and reprotoxic effects." (Umweltbundesamt, 2016)

Odour:

The smell is very decisive whether the brick is accepted as a building material by the population or not. Especially with recycled plastic products, there is often an increased development

of unpleasant odours. Polypropylene is used as a packaging material and is often used for food packaging. It is also used for toys, pipes, kitchen appliances and DVD cases. Due to its intended use, it should not contain any toxic substances or have a strong inherent odour. However, when used as a packaging material, for example, tiny molecules from the material to be packaged can diffuse into the polymer structure of the polymer and settle there between the polymer chains. These can permanently release odour. By introducing energy in the form of heat into the shredded PP material to be examined, this odour can be intensified.

Secreting microplastics into the environment

“Microplastics are scientifically defined as solid, insoluble particulate and non-biodegradable synthetic polymers smaller than 5 mm. Microplastics are divided into primary and secondary microplastics. Primary microplastics are particles that are already less than 5 mm in size when they enter the environment. Primary microplastic type A is produced in this small size. This includes, for example, particles used in the cosmetics and personal care industry, or plastic granulate on artificial turf fields. Primary microplastics type B are produced during the use phase. This includes, for example, the abrasion of car tyres, or fibres from synthetic textiles that get into the wastewater during washing. Secondary microplastics are produced by the decomposition of larger plastic particles in the weathering process caused by wave action and solar radiation.”((Fraunhofer-Institut UMSICHT, 2018) (Leslie, 2014) (UNEP, 2015))

Microplastic entry into the air through the Brick: The entry of microplastics into the air caused by conventional use of the bricks is physically impossible. In order to obtain such an entry, the brick must be strongly abraded, and this abrasion must then be swirled. Such a load case does not exist with the conventional use of the brick as a masonry unit.

Microplastics from bricks can theoretically enter groundwater in two ways:

- By heavy leaching from the rain of the undamaged brick, but this is very unlikely.
- If the brick becomes brittle due to aging, microplastics will form on its surface. This can be washed away by the rain and carried into the groundwater.

This point is clarified when weathering the brick in Test.

Can contain heavy metal

The material may contain heavy metals. These may be released during the manufacturing process of the Brick or when the Brick decomposes in a landfill after the life cycle of the Brick.

6.2.2 The hazards of material failure

The material failure of the brick can lead to the endangerment of humans and animals. Figure 30 shows what can lead to material failure in Indonesia when used as masonry bricks. It also shows which tests are necessary to investigate these points.

Figure 30 Overview of the hazard of material failure

Does not withstand environmental influences/ Does not withstand the pressure load

In order to clarify how the material reacts to UV irradiation, a brick is irradiated with UV and then subjected to a pressure test. This result is compared with an unirradiated brick. Here the brick is tested as a whole and therefore the maximum pressure load of the brick is also tested. Since the load case of the brick mainly consists of compressive load, it is also checked whether the brick meets the requirements of its load case.

In addition, the irradiated brick is examined for its changed properties. PP is not UV-resistant and decomposes under the influence of UV radiation. If the base material itself is not UV resistant, the material made from the base material will not be either. The question is how fast the brick decomposes and to what extent.

The water absorption of the brick can lead to swelling, which can have consequences e.g., for the joints and for the crumbling of plaster.

The wind exerts a force on a wall built from bricks. Due to the difference that this is not the case on the inside, a lever arm is created. The bricks are very light compared to red bricks, so

a wall has less weight force to resist this wind force. This risk must be taken into account but will not be examined further here.

Too risky burning behaviour

The concern about the Brick's properties in fire is the most common one that emerged from the surveys in Chapter 3. The fire performance of the bricks shall be rated using the UL 94 Vertical Flame test.

Tensile Tests

Tensile tests are carried out to compare general material behaviour and different sources of the basic material. Post-consumer waste from Sulawesi is compared with post-consumer waste from Germany and pre consumer waste.

> "Among the static or quasi-static testing and measuring methods, the tensile test is considered the basic test of mechanical materials testing. Despite the fact that a pure tensile stress is rather the exception in practice and experimental as well as interpretative problems exist, this test also has a priority position in plastics testing." (Grellmann & Seidler, 2015)

The tensile tests are carried out with the basic test specimen 1A according to DIN EN ISO 3167. This is also referred to as a multi-purpose test specimen. It is usually manufactured by injection moulding.

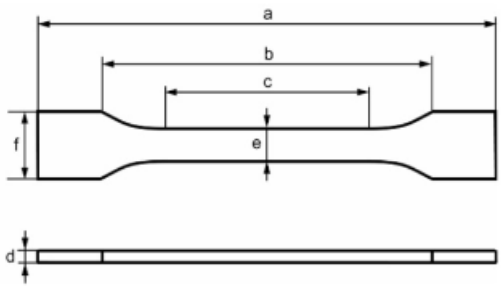


Table 16 Dimensions of test specimen, measured from Marina Seeger

a	b	c	d	e
74 mm	57 mm	35 mm	3 mm	5 mm

Figure 31 Test specimen for tensile test[mm] according to DIN EN ISO 527 (Meister, Vetter, Ehrenstein, & Drummer, 2013)

To test the aging caused by UV radiation, a pressure test is made with UV aged bricks and non-UV aged bricks. These values are then compared with each other.

6.3 Production and evaluation of the materials to be tested

Tensile Test specimen

The test specimens are manufactured by injection moulding in the materials laboratory at the RWU. An Arburg allrounder 320 C was used to produce the tension rods. Tension rods for the tensile tests were cast from the materials in Table 17 and compared with Tension Rod Material 1 which is not recycled PP granulate.

Table 17 Materials for the tension rods, properties during injection moulding, pictures taken by Marina Seeger

	Material 1	Material 2	Material 3	Material 4
Recycling level	New granulate	PP Pre-Consumer Waste Ravensburg	PP Post-Consumer Waste Constance	PP Post-Consumer Waste Indonesia (Sulawesi)
Origin	New granulate from supplier for Ravensburg University of Applied Sciences	Shredded sprues from the RWU laboratory which were produced with the PP granulate material 1	Constance, Precious Plastic Workspace HTWG Constance	Sulawesi Waste Bank Manado
Picture				
Visual and haptic inspection	New granules, solid small round pieces	Black coarse-grained material, very similar to granules in weight and feel	Light flakes, inhomogeneous in appearance (different colours)	Light homogeneous flakes

Problems with injection moulding	No	No	Material does not trickle into the injection unit on its own and has to be stuffed	Material does not trickle into the injection unit on its own and has to be stuffed The material contains Metal dust (magnetic) (at least 5% of its weight). Material The material probably contained other plastics with a higher melting temperature. A plug of unmelted plastic formed at the nozzle of the Arburg injection moulding machine.
Casting pressure	1200 bar	800 bar 1200 bar	800 bar	800 bar 1200 bar
Designation casted Rods	V1_1200bar_new_granulate Moulded with 1200 bar	V2_800bar_Rav_Pre_Consumer V3_1200bar_Rav_Pre_Consumer	V4_800bar_Con_Post_Consumer	V5_1200bar_Indo_Post_Consumer V6_800bar_Indo_Post_Consumer

Figure 32 Test specimen

Clarification of how the metal dust gets into the Material 4 from Indonesia:

After research at Waste Bank Mando, it turned out that the shredder generated the iron dust. It had not been used much (two months old at the time) and the tolerances of the blades to each other were not respected. When the shredder heats up, the blades expand and rub against each other.

Comparability of tensile test specimen and brick

The results obtained from the tensile tests with the test specimens cannot be transferred to the bricks without hesitation.

> "In plastics, processing has a significant influence on structure formation and thus on the resulting properties. This pronounced sensitivity to processing is a major cause of the limited informative value of parameters for plastics. Consequently, the internal structure of the polymer solid and the properties describing it are not solely dependent on the chemical composition. The problem of determining the characteristic values is that it is not the property of the material to be tested (moulding compound) that is recorded, but the property of a test specimen made of this material in a condition caused by the processing procedure. This means that the transferability of characteristic values determined on test specimens or components of a given geometry to components with a different geometry is not guaranteed from the outset due to different internal conditions." (Grellmann & Seidler, 2015)

The results cannot be transferred to the real brick without hesitation, but they can provide a good estimate, as long as one is aware of the difference between the test specimen and reality.

In addition, the values that result from the different materials that are tested can be compared with each other. In this way, statements can be made about the difference between post-consumer waste from Europe and Post-Consumer waste from Sulawesi. Statements can also be made about the difference between Pre-Consumer waste and post-Consumer waste.

PP Brick and HDPE Brick

Rory Dickens from England sent a total of 10 bricks for testing, 5 of which are made of PP and pink. The pink colour has not been added but is the result of recycling toiletries. 5 bricks are HDPE and green to purple, brown. These are made from recycled bottle lids. No colours or additives have been added. For the pressure test, the joints were sawn off at the top and then sanded. For UV weathering, the bricks were sent directly from Rory Dickens to the Lehmacher | Schneider laboratory in Osnabrück.

UL 94 Vertical Flame Test

For this test, 5 test specimens each were sawn from the HDPE and PP bricks with the following dimensions: 127 mm x12.7 mm x thickness maximum 12.7 mm.

Heavy metal analysis and emission analysis

The shredded base material from Marlon Kamagi's Waste Bank Manado, Sulawesi was used for this.

7 Examination and Evaluation of Precious Plastic Brick and Test Specimen

This chapter documents the examinations carried out. Each study is first described, then the results are presented and finally evaluated. In some cases, a conclusion is appended to the tests, such as the compression test and the tensile test, in order to put the results into perspective. The test results should fulfil the requirements of the Product Requirement Document from chapter 4.2, if this is not the case, consequences are derived in this work. These do not represent a concrete solution, but only a suggestion. A material data sheet is created from the examinations. This can be found in Summary, Abstract.

7.1 The health hazards

7.1.1 A Odour test according to VDA270 at different temperatures

Experimental Description

Heiko Schulz and Bernd Matthes describe the experiment as follows in their report: Odour testing is a standardised procedure according to VDA 270. Here, a sample is heated in a vessel (24 h at 40°C or 2 h at 80°C). The ratio of sample to vessel volume is defined. The sample is evaluated by 3 to 5 trained persons according to its odour in a grading system. The odour test belongs to the static procedures. The main feature of the static procedures is the closed space.

Grade 1	Not perceptible
Grade 2	Perceptible, not disturbing
Grade 3	Clearly perceptible, but not yet disturbing
Grade 4	Disturbing
Grade 5	Very disturbing
Grade 6	Unbearable

Cf. (Schulz & Matthes)

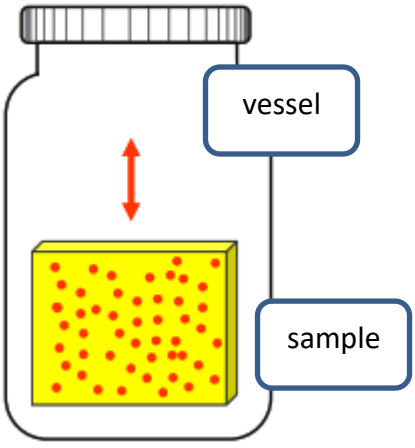


Figure 33 Experimental setup Odour test (Schulz & Matthes)

Table 18 Clarification of the experimental environment Outgassing-Odour Test A

A	
Examination	Odour test according to VDA270 at different temperatures
Clarification of	Whether the bricks endanger the room climate through unpleasant odours
Testing equipment	Special test chamber, trained examiners
Test site	FILK Labour Freiberg, Bernd Matthes
Test time	June
Test specimen	Shredded PP from Indonesia
Amount of Test specimen	5 gr
Output	Objective opinion of the experts in the form of a note on odour

Results

Table 19 Excerpt test report odour (Matthes, 2021)

Parameter Odour	Test Result	Normal Target Values Automotive Industry
VDA270 A2 (40°C, 24h) Rating	3,5 Single Values 3,5 3,5 3 Description old, musty	3
VDA270 A3 (80°C, 2h) Rating	4 Single Values 4 3,5 4 Description: musty, rotting, earthy	3

Evaluation

The sample was tested for odour according to VDA270 and is 0.5 to 1 point worse than the permissible value for the automotive industry for interior components. The values are OK for use as a masonry block with cladding.

> "It could be that odour problems occur at higher temperatures, but this should not be a fundamental problem." Dr Bernd Matthes comment on the test report (Matthes, 2021)

7.1.2 B Emission Tests according to VDA278, VDA277; VDA275

Experimental Description

The tests are carried out according to the VDA standardised procedures. The procedures can be roughly described as follows. The exact test set-up can be found in the VDA guidelines.

B1 Thermal desorption (dynamics headspace) according to VDA278

The sample is enriched in an open glass tube. The test method belongs to the dynamic methods. The gas flow of the enriched sample is passed on to the gas chromograph. This analyses the sample, and the deflections are compared with known deflections and thus determined.

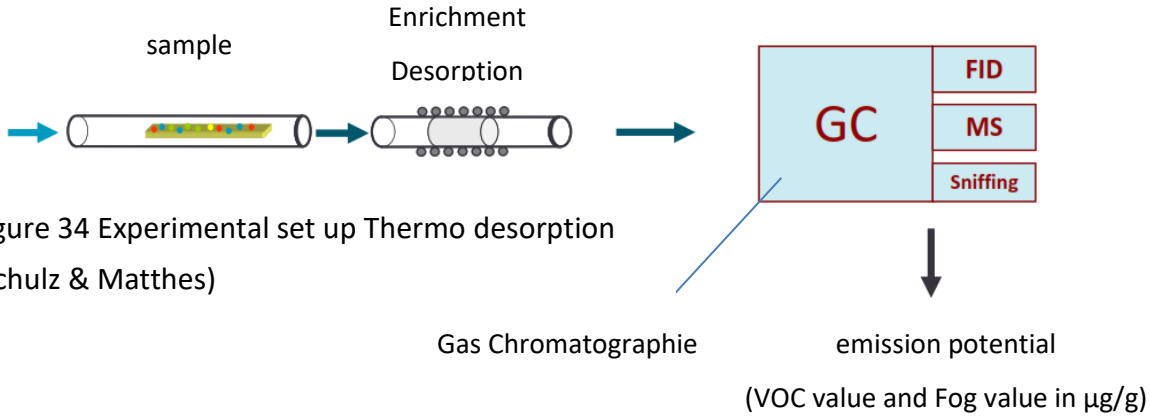


Figure 34 Experimental set up Thermo desorption (Schulz & Matthes)

B2: Static headspace according to VDA277

The sample is heated in a vessel. The resulting emissions are passed on to the gas chronograph. This determines the Carbon emission potential in µg/g. The static headspace belongs to the static procedures.

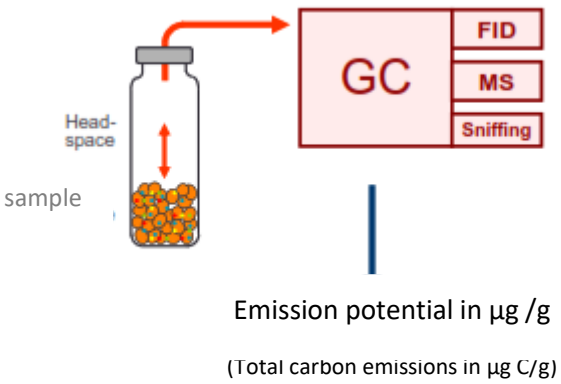


Figure 35 Experimental setup Static Headspace (Schulz & Matthes)

B3: Formaldehyde VDA275

The test specimen hangs on a hook in an airtight bottle. This is kept for 180 min at 40°C in a heating cabinet. There is an aqueous extrusion solution in the bottle, which is then cooled down to 20°C and examined. C.f. (German Institute for Standardization, 1996)

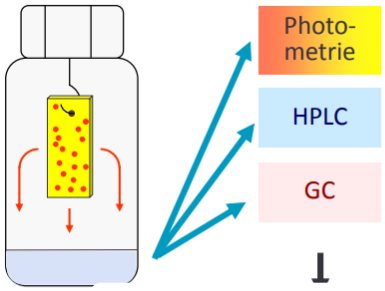


Figure 36 Experimental setup Formaldehyde DIN 275 (Schulz & Matthes)

Table 20 Clarification of the experimental environment B Emission Tests

B Emission Tests	
Examination	B1 Thermal desorption (dynamics headspace) according to VDA278 B2: Static headspace according to VDA277with individual evaluation B3: Flask method VDA275
Clarification of	If critical substances outgas
Test site	FILK Labour Freiberg, Bernd Matthes
Test time	June
Test specimen	Shredded PP from Indonesia
Amount of Test specimen	100gr
Output	B1: Outgassing VOC B2: Outgassing Total Carbon B3: Outgassing Formaldehyde

Results

Table 21 Excerpt test report (Matthes, 2021)

Parameter	Test Result	Normal Target Values Automotive Industry
Thermal desorption VDA278 VOC value in µg/g Fog value in µg/g Single evaluation	 215 491 See report sheets	 <250 <500 (PE; PP acc. DBL5430, Tab. 5)
Total Carbon VDA277 (µgC/g)	<10	<50
Formaldehyde VDA277 (mg/kg)	<2	<2

Results marked with „< “indicate value is below corresponding limit of quantification of the test procedure

Evaluation

All values are within the specifications of the VDA guidelines.

“The test results were better than expected. The material can be used. No harmful substances were found either” Dr. Bernd Matthes comment on the test report (Matthes, 2021)

The base material does not emit any hazardous substances. This means that the base material from the Waste Bank Manado can be used safely without the risk of hazardous outgassing. As long as the Waste Bank Manado maintains its purity and quality standards.

7.1.3 C Element analysis with AAS

Experimental Description

The material sample PP from Sulawesi (Named PP_Indo) was examined using AAS (atomic absorption spectroscopy). The sample was tested for Pb (lead), Sb (antimony), Mn (manganese) and Cd (cadmium). A measurement for one substance is very extensive, as the AAS must be calibrated with the respective element beforehand. Therefore, based on the experience of Dr. Professor Saskia Brugger, these elements were tested.

The sample was examined twice on the AAS with the same test procedure. The following test procedure was carried out:

1. Preparation of the sample

   Sample is weighed to 0.2g (1st attempt 0.199g, 2nd attempt 0.204g) and put into a glass tube for mixing. Add 65% nitric acid to the sample until it reaches the calibration mark, add a small magnet for stirring.
2. Sample is mixed in microwave pressure digestion unit and then the vapours produced are extracted.
3. Calibration of the AAS

   The elements that are measured must be calibrated on the machine beforehand, so the machine can compare the measurement with the calibration and output a difference value. For the calibration, a solution is prepared, e.g., for Pb. Here a solution of 10ppb Pb in pure water is prepared. The AAS dilutes this independently to half and a quarter with pure water and thus forms a calibration line.
4. Measurement

   In attempt 1 Pb (lead), Sb (antimony), Mn (manganese) and Cd (cadmium) are measured.

   In attempt 2, Pb and Sb were measured repeatedly, as these elements were above calibration in attempt 1.

Sample PP_Indo_1 was used for attempt 1 and sample PP_Indo_2 for attempt 2. Both samples were prepared in the same way as described in 1.

Table 22 Boundary Conditions Element analysis with AAS

C	Element analysis with AAS
Clarification of	Whether the recycled material contains heavy metals like lead, cadmium or semi-metal manganese and antimony
Testing equipment	AAS, Labour equipment
Test site	Chemistry and environmental analysis RWU Saskia Brugger
Test time	June
Test specimen	Shredded PP from Indonesia: Sample 1: 0,199 g; Sample 2: 0,204 g
Output	Whether the elements lead, cadmium, antimony and manganese are present

Results

All values below were measured at RWU Ravensburg in the Environmental Analysis Laboratory. The values have not been verified, they are only a rough guide as to what is present in the sample and in what order of magnitude.

Table 23 Test results Element analysis with AAS

Element	Attempt 1	Attempt 2	Comparative value drinking water all values from (Bundesgesundheitsministerium, 2020)
Pb	4,680 $\frac{\mu g}{l}$	9,797 $\frac{\mu g}{l}$	10 $\frac{\mu g}{l}$
Sb	35,74 $\frac{\mu g}{l}$	34,53 $\frac{\mu g}{l}$	10 $\frac{\mu g}{l}$
Mn	0,3764 $\frac{\mu g}{l}$		50$\frac{\mu g}{l}$
Cd	0,0120 $\frac{\mu g}{l}$		5 $\frac{\mu g}{l}$

Evaluation

Lead and cadmium are heavy metals that lead to heavy metal poisoning in case of overdose. The semi-metal manganese and antimony can also be toxic in case of overdose.

The test results are compared with the minimum requirements for parameter values for assessing the quality of water for human consumption of the German Federal Ministry of Health in 2020. Only the value of antimony with a factor of 3.5 is above the value specified by the Federal Environment Agency for water for human consumption.

The tested elements could be dissolved out by water, but their concentration is too low to cause a health hazard. A sample that was digested in acid is compared with drinking water. The increased value of antimony is therefore harmless. The bricks pose no threat to human health in terms of lead, cadmium, manganese, and antimony.

7.2 The hazards of Material failure

7.2.1 D Tensile Test

Experimental Description

Without aging; compression load at room temperature. The tensile test is the most common test in material testing. The wide range of tensile tests performed provides good comparability. The tensile tests were carried out according to the standard DIN EN ISO 527-1. Here, a tensile test specimen is clamped in a tensile testing machine, one side of the specimen in a fixed jaw, the other in a movable jaw. The moving jaw is pulled at a standardised speed. A displacement force diagram is recorded, the tensile force can be converted into tensile stress by means of the specimen diameter.

Table 24 Examine mechanical properties, without aging

D	Examine mechanical properties; without aging; compression load at room temperature
Clarification of	- mechanical properties (tensile) - to generate material comparison values raw material from Constance is compared with raw material from Indonesia
Testing equipment	Universal testing machine (tension, compression and bending testing machine)
Test site	RWU Ravensburg
Test time	May / June
Test specimen	PP Test specimen • V1_1200bar_new_granulate • V2_800bar_Rav_Pre_Consumer • V3_1200bar_Rav_Pre_Consumer • V4_800bar_Con_Post_Consumer • V5_800bar_Indo_Post_Consumer • V6_1200bar_Indo_Post_Consumer

	Test specimens with and without weld lines from the injection moulding process were used for the test evaluation. • The tests with a weld line have the abbreviation_1 • The tests without a weld line have the abbreviation_2. The repetitions are arranged alphabetically The diameter of the tensile specimens for calculating the tensile stress are 3x5 mm (15mm²)
Amount of Test specimen	2-3 per Examination
Output	Tensile strength Rm. Tensile stress R. Elongation e.

Influence of the weld line:

The weld line occurs in injection moulded parts when two mass flows meet. The outer layer of the flow front has already cooled down. This creates an inhomogeneity of the material within a component at the weld line. In the injection-moulded test specimens for this test, the weld line occurred due to the shape. The test specimens with the abbreviation 1 have two sprues, symmetrical and therefore two mass flows. Those with the abbreviation 1 have only one sprue. The weld line weakens the component because the mass flows are not homogeneously connected.

Influence of the injection pressure:

The injection pressure has a great influence on the strength in the test specimen. "The viscosity of the polymer melt is significantly influenced by the high pressure. A higher pressure reduces the free volume in the polymer melt on the one hand and intensifies the interactions between the molecular chains on the other. Both effects cause the viscosity to increase." (Sambale, 2015) With increasing viscosity and a high injection pressure, a higher density can

be achieved. As can be seen in the following tests, the test specimens sprayed with higher pressure also achieve higher values in their strength.

Explanation Tensile-Force/ Elongation Diagram:

The Y-axis shows the tensile force N with which the sample was pulled in the vertical direction. The X-axis shows the value in mm by which the clamped specimen has lengthened --> elongation. The value of the maximum tensile force the specimen can withstand is called F_m. This is then converted to stress using the specimen cross-section. The curve therefore does not change its nature and can therefore be compared with the typical tension/elongation curves of DIN EN ISO 527-1:2019-12.

Results

7.2.1.1 V1 injection-moulded with 1200 bar new granulate

This test serves as a basis for comparison with non-recycled injection moulding. Black colour pigments are mixed into the granulate to create similar basic conditions. In general, the injection moulded parts with lower injection moulding pressure achieve lower amplitudes of force.

Fracture behaviour:

The tensile tests carried out with the non-recycled material show the typical behaviour for PP and a typical Stress-Elongation curve. “They show a yield point […] with no increase in stress after the yield strain is reached.” (DIN German Institute for Standardization, 2019)The tests were stopped because the material stretched strongly before it broke. Fm is the maximum tensile force that the component can withstand. Then the force decreases, and it stretches until it breaks off.

Influence weld line

According to Schröder's book, the value for PP tensile strength is between 30 and 40 N/mm² (Schröder, 2014). The test specimens without a weld line are at the lower end of this range. Those with a weld line are clearly below this range. There is a notable difference of 17 % between the components with and without a weld line. This was to be expected and is usual for a component with a weld line. The elongation of the test specimens with a weld line is also significantly lower. 34,7 % less elongation for the test specimens with a weld line.

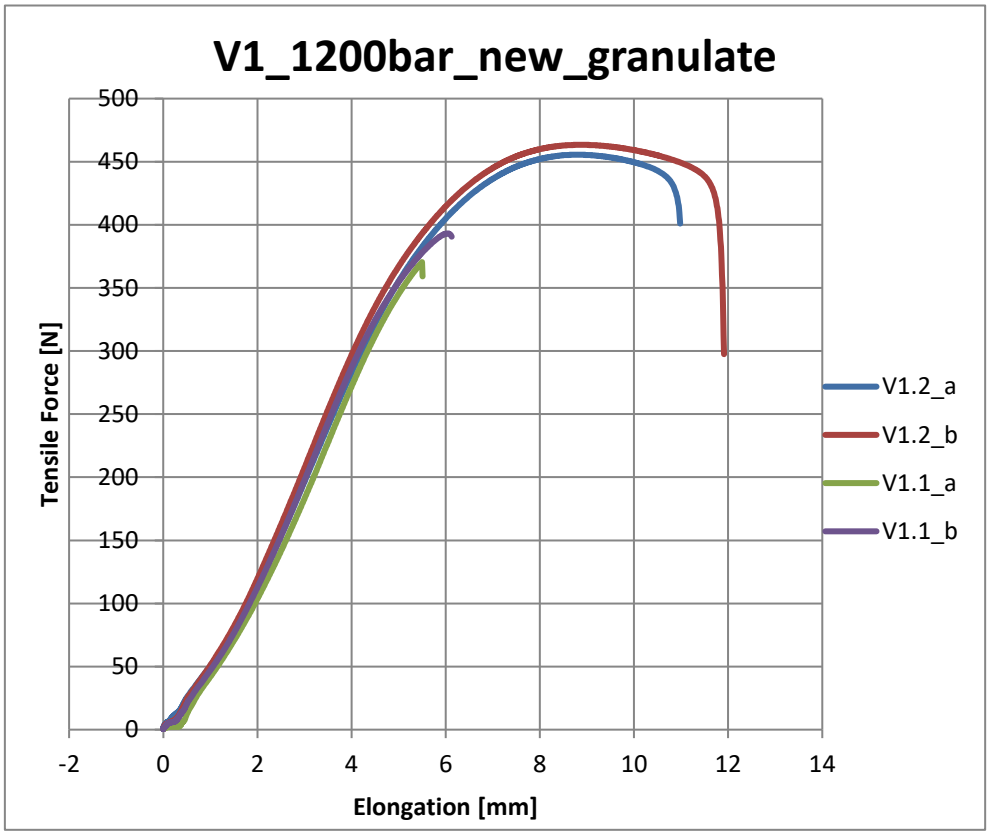


Figure 37 V1_1200bar_new_granulate_Tensile Force-Elongation Diagramm

7.2.1.2 V2 injection moulded with 800 bar, Pre-Consumer Recycling Material from Ravensburg

Fracture behaviour:

The stress-strain curve is comparable to that of the non-recycled material in V1.

Influence weld line

The weld line has no noticeable influence on the maximum tensile force Fm. The samples with a weld line withstand approx. 1.8 % more force than those without.

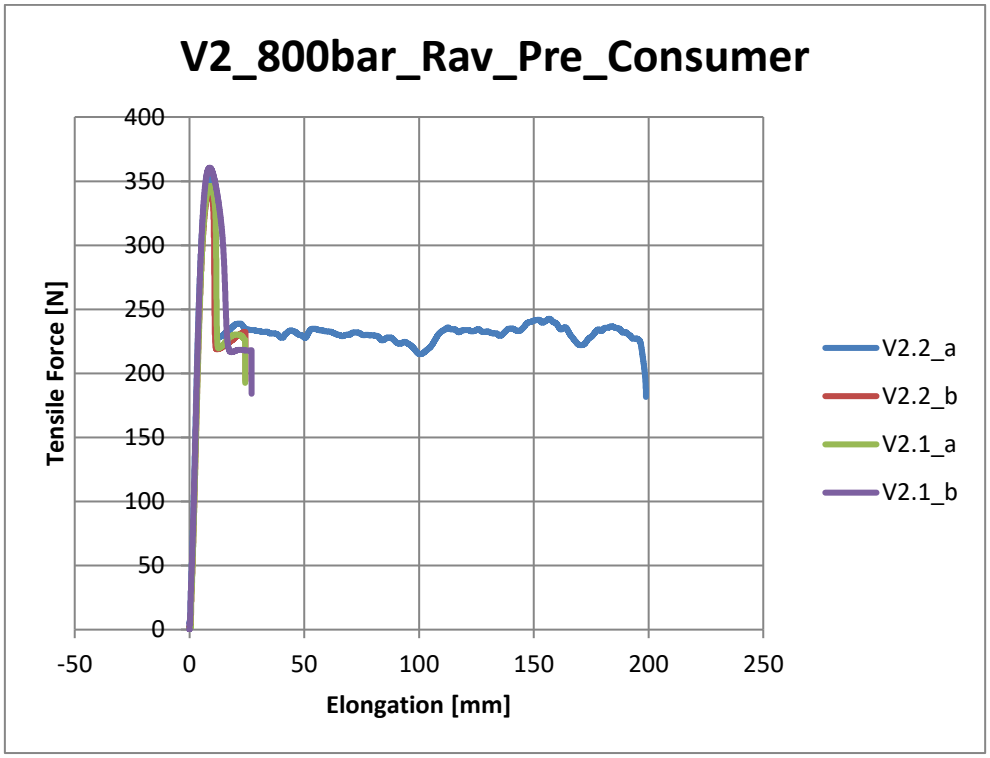


Figure 38 V2_800bar_Rav_Pre_Consumer Tensile Force-Elongation Diagramm

7.2.1.3 V3 injection-moulded at 1200 bar Pre-Consumer Recycling Material from Ravensburg

Fracture behaviour:

The fracture behaviour is similar to V1 and V2 and corresponds to the viscoplastic behaviour typical for PP. Here, too, the tests were aborted because the component stretched extremely before it broke. The time required and the associated larger quantity of measured values were thus limited. In V3, the highest elongation occurs at Fm (approx. 7,5%) in both tests with and without a weld line.

Influence weld line

The weld line has no noticeable influence on the maximum tensile force Fm. This is 2.2 % higher for the specimens with a weld line than for those without. Also, the Elongation is minimally higher by the test specimen with weld line.

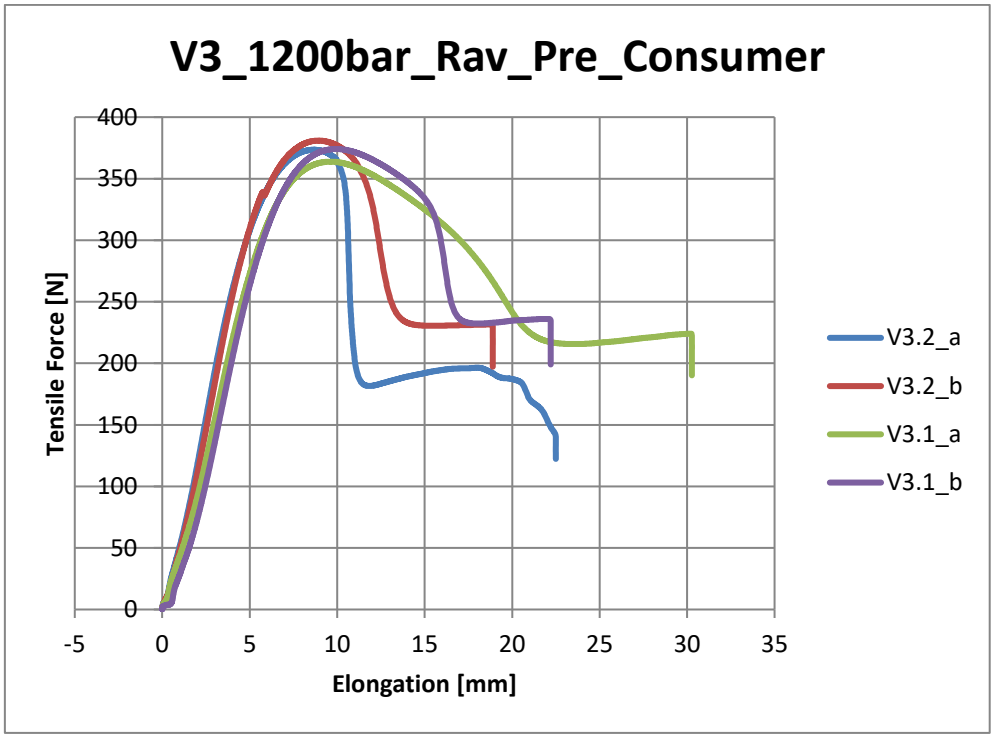


Figure 39 V3_1200bar_Rav_Pre_Consumer Tensile Force-Elongation Diagramm

7.2.1.4 V4 Injection-moulded with 800 bar Post-Consumer Recycling Material from Constance

Fracture behaviour:

The course of the curve corresponds to that of V1 and V2 until after the maximum Fm. The test specimen elongates by approx. 5% at Fm, which is approx. 2% less than at V1 and V2 (without weld line). After that, the test piece breaks without stretching any further. There is a large blowhole at the breaking point in the material. All tested test specimens made of the Constance material have this blowhole (diameter approx. 2 mm²).

Influence weld line

Not much influence of the weld. Fm of the test specimens without weld line is approx. 2.1% higher than Fm of the test specimens without.

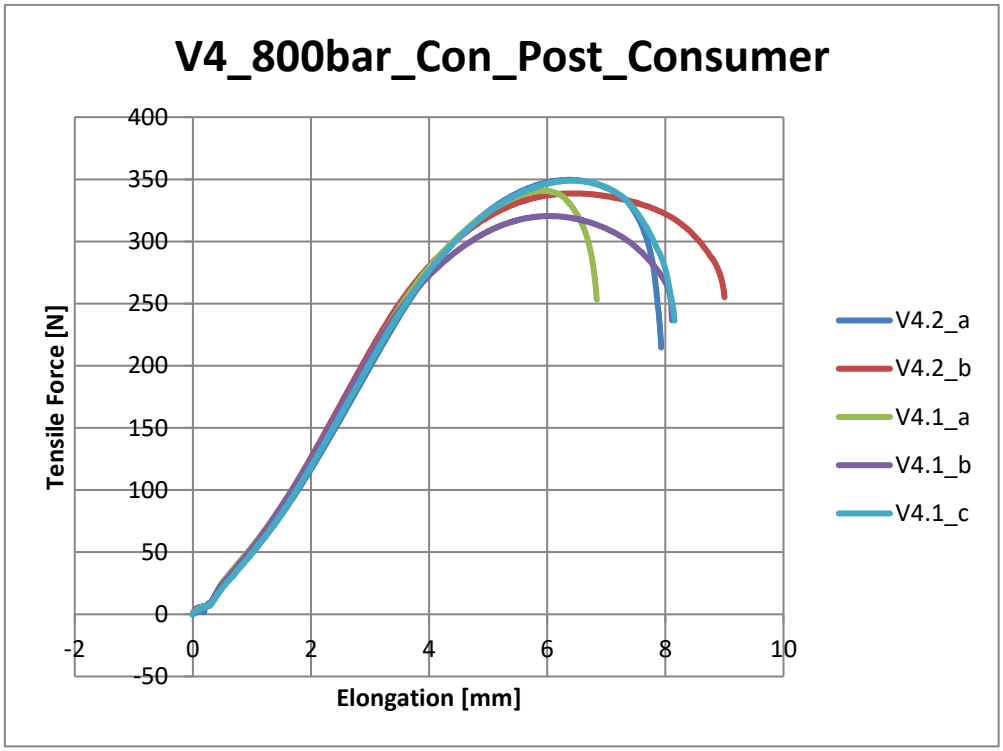


Figure 40 V4_800bar_Con_post_Consumer_Tensile Force-Elongation Diagramm

7.2.1.5 V5 Injection-moulded with 800 bar Post-Consumer Recycling Material from Indonesia (Sulawesi, Waste Bank Manado)

Fracture behaviour:

The fracture behaviour and the curve in the tensile force-elongation diagram correspond to that of V4. Both recycled materials break after a small elongation after the Fm maximum. The test specimens do not have any blowholes at the fracture point.

The values for Fm at V5.1 have a large dispersion between the 3 trials performed.

- V5.1_a: 421.82
- V5.1_b: 241.07
- V5.1_c 362.03

The dispersion at V5.2 is not significant.

Influence weld line

Due to the wide dispersion, it cannot be excluded that the weld line has an influence, but the results are not reproducible. The test specimens from Indonesia contain iron dust, which further distorts the results.

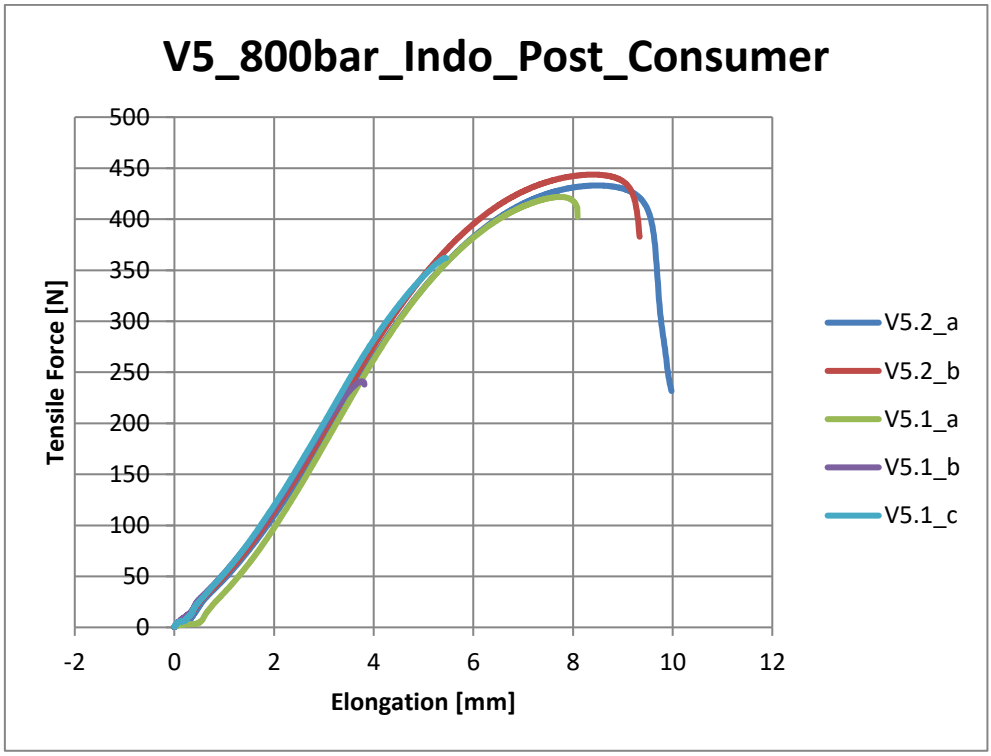


Figure 41 V5_800bar_Indo_Post_Consumer Tensile Force-Elongation Diagramm

7.2.1.6 V6 Injection-moulded with 1200 bar Post-Consumer Recycling Material from Indonesia (Sulawesi, Waste Bank Manado)

Fracture behaviour:

The tensile force of the elongation curve corresponds to that of V5. As with V5, there is a large dispersion of the values of F_m.

Influence weld line

There is a clear difference between the values with and without the weld line. The values of the test specimens with a weld line in test 6.1 also have a wide dispersion but are at least approx. 150 N lower in tensile force than those without a weld line.

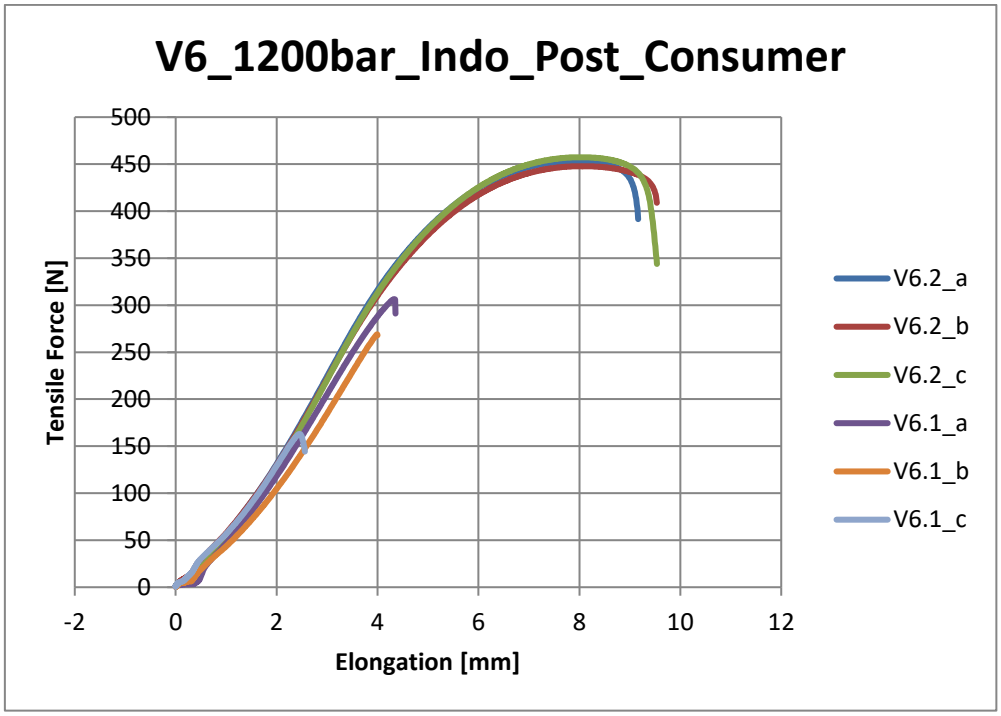


Figure 42 V6_1200bar_Indo_Post_Consumer Tensile Force-Elongation Diagramm

7.2.1.7 Summary of all results of the tensile tests

Table 25 Evaluation all Values Tensile Test

	F_m[N]	Average [N]	σ_m[N/mm²]	Aver-age[N/mm²]	ε_m [%]	Average [%]
V1.1_a	370,46	381,78	24,67	25,44	4,42	4,64
V1.1_b	393,17		26,21		4,85	
V1.2_a	455,54	459,46	30,37	30,63	7,08	7,11
V1.2_b	463,37		30,89		7,13	
V2.1_a	346,34	353,47	23,09	23,17	7,19	7,13
V2.1_b	360,59		23,24		7,06	
V2.2_a	352,23	347,15	23,48	23,14	6,84	6,94
V2.2_b	342,07		22,80		7,04	

V3.1_a	363,79	368,95	24,25	24,6	7,76	7,88
V3.1_b	374,11		24,94		8,00	
V3.2_a	373,49	377,2	25,9	25,65	6,99	7,09
V3.2_b	380,91		25,39		7,19	
V4.1_a	340,71	336,66	22,71	22,44	4,78	4,94
V4.1_b	320,42		21,36		4,85	
V4.1_c	348,86		23,26		5,18	
V4.2_a	349,50	344,07	23,3	22,93	5,13	5,16
V4.2_b	338,63		22,56		5,18	
V5.1_a	421,82	341,64	28,12	22,78	6,23	4,54
V5.1_b	241,07		16,07		3,03	
V5.1_c	362,03		24,14		4,37	
V5.2_a	433,04	438,36	28,89	29,24	6,83	6,79
V5.2_b	443,68		29,59		6,75	
V6.1_a	306,40	246,15	20,43	16,41	3,48	2,9
V6.1_b	269,04		17,94		3,21	
V6.1_c	163,01		10,87		2,00	
V6.2_a	453,09	452,77	30,21	30,19	6,57	6,64
V6.2_b	447,85		29,86		6,68	
V6.2_c	457,36		30,49		6,658	

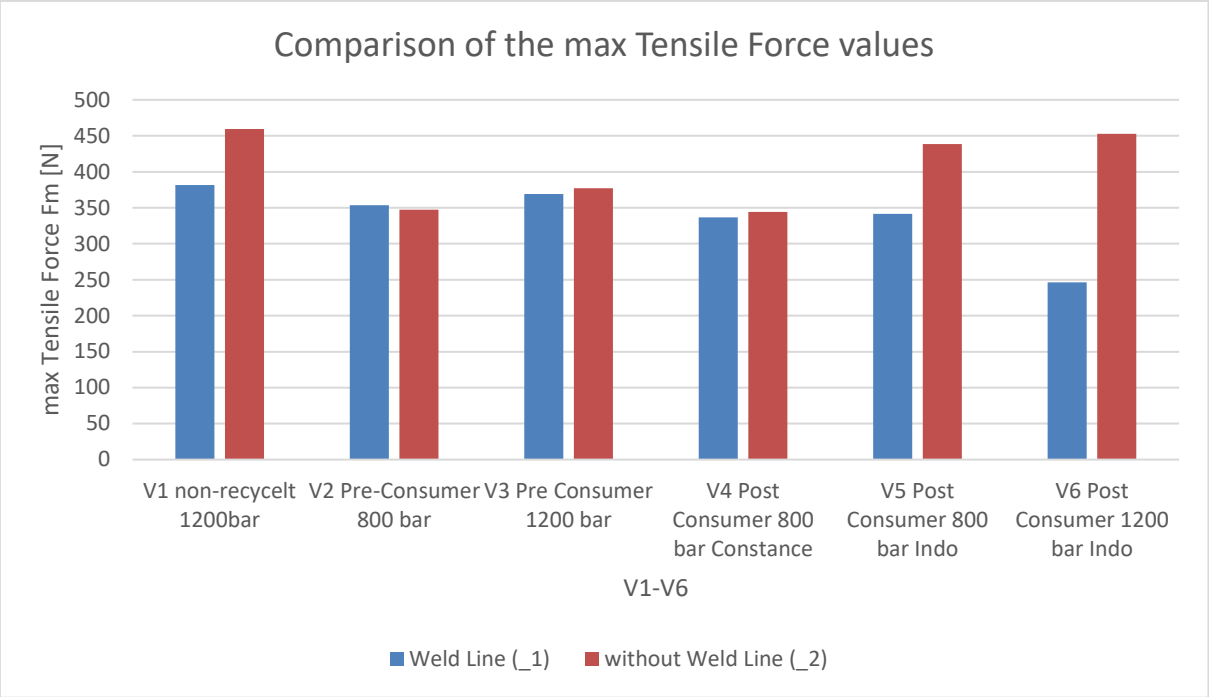


Figure 43 Comparison of the max Tensile Force values

Evaluation

The non-recycled material from V1 gives the base value for PP. The weld line acts like a pre-determined breaking point. It causes the material to break earlier. PP consists of polymer chains. These are not connected to each other at the weld line because two flow fronts/mass flows meet here.

Recycling damages the polymer chain structure. In her work, chemist Grigore cites the following reason for the deterioration of the material during recycling: “The disadvantages of this method refer to […] the deterioration of product’s properties in each cycle which occurs due to the low molecular weight of the recycled resin. It happens because of chain-scission reactions caused by the presence of water and traces acidic impurities” (Grigore, 2017)

The polymer chains are shortened by processing. The Pre-Consumer recycled material from V2 has significantly lower Fm values compared to V1, but the same viscoelastic fracture behaviour.

The influence of increased pressure during injection is clearly visible in the difference between the Fm values of V2 and V3. The test specimens were injected directly one after the other. The values of the test specimens with and without weld lines, which were injected at 1200 bar, are at least 15 N higher.

Test V4 was carried out with post-Consumer recycled material from Constance. The base material from which the tension rods were injected did not have any recognisable foreign bodies. Therefore, this tensile test and the value from it are considered authoritative for the tensile properties of post-Consumer recycled material. The weld line has no noticeable influence on the tensile properties. The test specimens with a weld line were minimally worse than those without.

The tensile tests from the Indonesian material from V5 and V6 cannot be used for comparison because they were contaminated with metal dust. The influence of the weld line is much stronger than in the previous materials and the maximum tensile forces are similar to the non-recycled material from V1. It can be assumed that the metal dust restores the original tensile strength. However, the fracture behaviour is a brittle fracture, and the material no longer exhibits the viscoplastic properties of the original PP.

Conclusion:

Non-recycled material (V1_2) - Pre-consumer material (V2_2) - Post consumer recycled material (V4_2).

The Post-Consumer recycled material from V4 (injected at 800 bar, without weld line) withstands 25% less tensile force compared to the non-recycled material from V1(injected at 1200 bar, without weld line). Because the pressures used for injection are not the same, the value should be viewed with caution.

It was to be expected that post-Consumer recycled material is less tensile stable than non-recycled material. The value of 25% gives a good indication of the order of magnitude.

Surprisingly, the Post-Consumer material is not significantly worse than the Pre-Consumer material in terms of tensile strength. Only 3 N difference separates the two values (mean values of V2_2 to V4_2, both injected at 800 bar).

In conclusion, simply recycling without using the product (Pre-Consumer) decreases the tensile strength, but the viscoplastic behaviour of the material is maintained. By recycling after using the product (post-Consumer), the tensile strength remains at the level of Pre-Consumer, but the viscoplastic behaviour is no longer present. The material breaks brittle, without much elongation. The weld line has no significant influence on the recycled material.

7.2.2 E Pressure test with non-UV irradiated Brick and UV irradiated Brick

Experimental Description

The compression test was carried out on a converted hydraulic press with load cell.

The joints of the brick were sawn off and ground flat to simulate the stress on the real brick. This allows the force of the pressure plate to act on the surface of the brick. The brick is placed between the plates and subjected to weight. The weight is increased until the brick breaks

Figure 44 prepared Brick for Pressure Test (Marina Seeger)

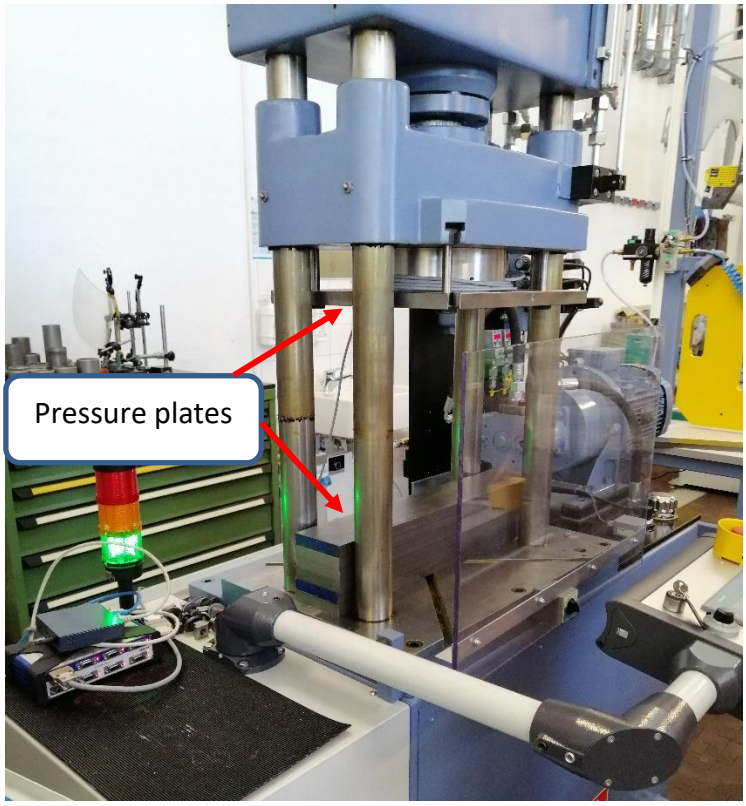


Figure 45 Converted Press for Test (Marina Seeger)

Table 26 boundary conditions pressure Test

E	Pressure test with non-UV irradiated Brick and UV irradiated Brick
Clarification of	To get a guideline of the maximum force the brick can withstand For comparison value to determine behaviour towards UV radiation
Testing equipment	Converted Press
Test site	Multifunctional Laboratory Building D RWU
Test time	June
Test specimen	1 HDPE Bricks from UK non-irradiated; 1 irradiated; 1 PP Bricks from UK non-irradiated; 1 irradiated

Results

Table 27 Test results Pressure Test

Sample	Maximum Force until Brick breaks [kN] $F_{ultimate}$	Maximum distance until brick breaks [mm] Value at maximum force	Break Fracture
PP non-irradiated attempt 1	274,06	7,86	Brittle fracture
PP non-irradiated attempt 2	252,53	8,95	Brittle fracture
PP irradiated	287,25	8,19	Brittle fracture
Arithmetic mean	271,28	8,33	
HDPE non-irradiated	109,99	6,52	Crack expansion
HDPE irradiated	116,8	5,51	Crack expansion
Arithmetic mean	113,4	6,02	

The PP non-irradiated brick was not loaded to breaking point in attempt 1. It was stopped at the first loud crack. When no crack was visible afterwards, the PP Brick was loaded to the point of material failure in the second attempt. The maximum distance is determined by the maximum force value because after the break the measuring plates have moved further together.

Figure 46 Break Fracture taken by Marina Seeger (left PP irradiated, right HDPE irradiated)

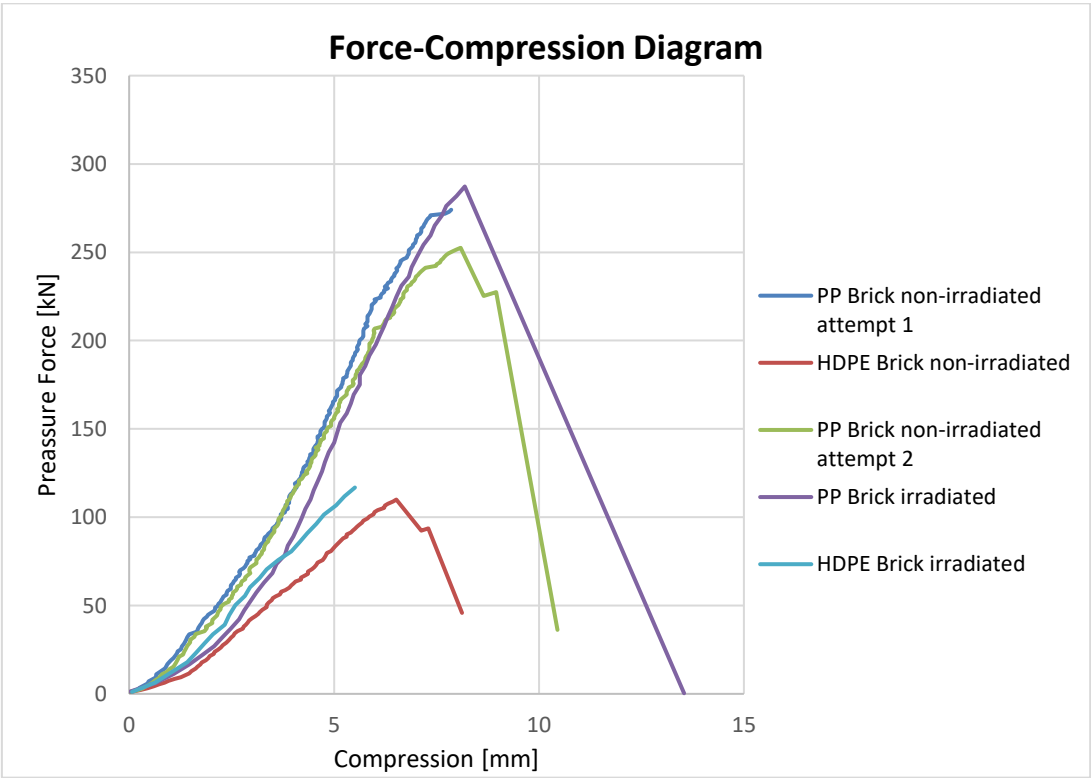
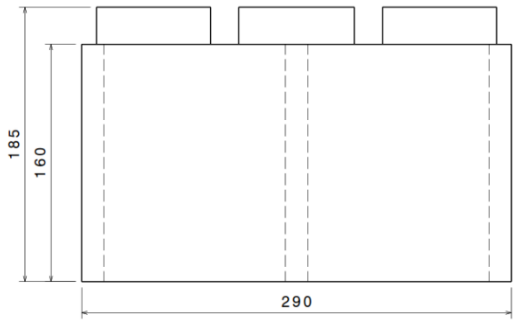
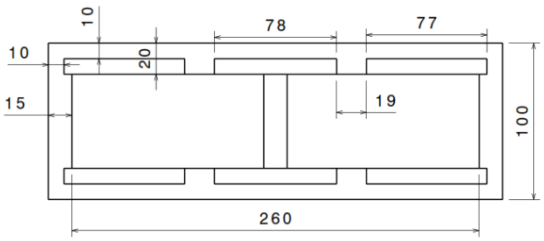


Figure 47 Force- Compression Diagram PP and HDPE Bricks

Evaluation

Comparison compressive strength of red brick according to DIN EN 1996 with Precious Plastic Brick non-irradiated





Surface on which the force acts: 1340mm²

Figure 48 Sketch Brick (Marina Seeger)

Table 28 Comparison red Brick with Precious Plastic Brick non-irradiated

	Value for masonry units of category I according to DIN EN 771-1 (DIN German Institute for Standardization, 2015)	Precious Plastic Brick PP (Calculated Arith-metic Mean)	Precious Plastic Brick HDPE (Calculated Arith-metic Mean)
Compres-sive strength	18,0 N/mm2 (Medium compressive strength)	202,45 N/mm²	84,62 N/mm²

Safety in relation to weight force

The PP Brick can withstand 271 kN until it breaks, the HDPE 113,4 kN Both values are above the required 100 kN This means that both bricks have met the requirements. When comparing with a red brick, the force the brick can withstand is related to the area on which the force is applied. Then this value is extrapolated to 1m². Compared to a red brick, the pressure that both Precious Plastic Bricks can withstand is much higher.

Safety regarding to fracture behaviour

The PP brick breaks abruptly and shatters into many small pieces (fracture seen in Figure 47). This brittle fracture behaviour is not advantageous for building materials. The PP material absorbs the force and distributes it evenly, but once the permissible force is exceeded, it breaks abruptly. There is no advance notice of when the material will break. This makes it unpredictable and therefore not suitable as a building material.

The HDPE brick breaks after cracking. The crack forms when the force is applied and the brick breaks into large pieces when the force exceeds an allowable value. By inspecting the brick, a fracture can be predicted, which is better suited to the fracture behaviour of a building material.

Conclusion

Both bricks can withstand an enormous amount of force and more than the required 100 kN The PP brick was compressed approx. 8 mm, the HDPE approx. 6 mm. The breakage behaviour of the HDPE brick is better suited for use as a building material.

7.2.3 F UL94 Vertical Flame Test

Experimental Description

The test specimen is hung vertically on a mounting device at a distance of 9.5 mm from the burner surface. Then the sample is flamed with a defined flame (20 mm high Tiril burner flame) for 10 s. Then the afterburning time is measured (the time it takes for the flame to go out). Immediately afterwards, the sample is flamed again for 10 s and the afterburning time is measured. For both afterburn times, it is checked whether the test specimen emits burning drops.

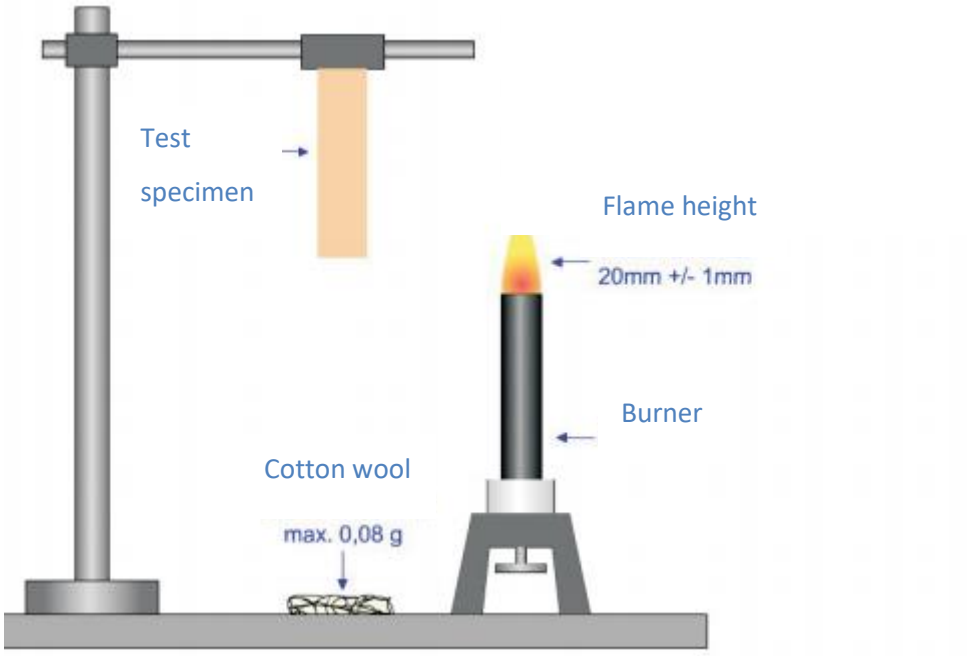


Figure 49 Test setup UL 94 Vertical Flame Test (apra plast, 2017)

Table 29 boundary conditions UL94 Vertical Flame Test

F	UL94 Vertical Flame Test
Clarification of	Determine the flammability classes UL 94 V-0, V-1, V-2
Testing equipment	Holding device, steel scale, Bunsen burner, cotton pads, stop-watch, Extraction unit
Test site	Natural science Labour RWU Ravensburg -Saskia Brugger
Test time	June
Test specimen	127x12,7x(max)12,7

Amount of Test specimen	5 PP 5 HDPE

Results

Table 30 Test results UL94 Vertical Flame Test

Test Specimen	First afterburning time	Second afterburning time	Burning dripping Yes/ No	Smoking behaviour
PP_1	18	1	Yes	Hardly noticeable smoke development no odour is perceived after the test
PP_2	Completely burnt down	-	Yes	Low smoke emission no odour is perceived after the test
PP_3	Completely burnt down	-	Yes	Little to medium smoke development no odour is perceived after the test
HDPE_1	Completely burnt down	-	Yes	Hardly noticeable smoke development Smells slightly like candle
HDPE_2	Completely burnt down	-	Yes	Hardly noticeable smoke development Smells slightly like candle

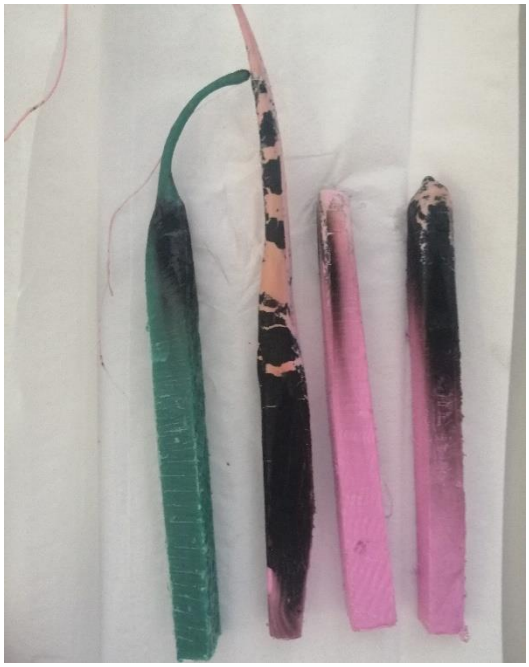


Figure 50 Test specimen after Test (from left to right HDPE_1; PP_3; PP_1; PP_2)

Evaluation

Neither the samples made of PP nor those made of HDPE passed the UL94 Vertical Flame Test. Surprisingly, the smoke development was very low. So, this should not be a problem with the Brick.

There are various tests to ensure fire safety. In the following, the German fire protection classification is shown and then that of the NFPA, which acts as an international organisation. This is done to show the UL 94 Vertical Flame test in relation to other tests.

Comparison to DIN 4102 -1 Test (German Institute for Standardization) Category B2 normal flammability.

In order to be allowed to be used as a building material in Germany, at least the category normal flammability B2 according to DIN 4102 -1 must be achieved. Otherwise, the material falls into category B3. “According to the specifications of the respective state building regulations, they may not be used in construction without further measures leading to a higher classification, such as flame retardants or in combination with other building materials.” (Baunetzwissen, 2021). The test set-up for the classification in B2 according to DIN ISO 4102-1 shows parallels to the UL 94 Vertical Flame Test. 5 samples each are needed for edge ignition, which are 90 mm wide and 190 mm long.

> "The thickness of the specimen depends on the use [...] For the specimens for edge ignition, a measuring mark is placed at a distance of 150 mm[...] from the lower edge of the specimens in the full width of the specimen. The test is passed if in none of 5 samples [...] the flame tip reaches the measuring mark before the end of the 20 seconds." The burner shall be placed at an angle of 45° to the edge. The flame is set in the vertical position of the burner and has a height of 20 mm. (DIN German Institute for Standardization, 1998)

International comparison to NFPA 220

> “The National Fire Protection Association (NFPA) is a global self-funded non-profit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards” (National Fire Protection Association, 2021). The ByBlock (presented in chapter 4.5.1) is classified in the category "Type 5 -Wood framed" according to NFPA 220. NFPA stands for National Fire Protection Association which has developed standards to classify buildings into categories. Type 5 is the least favourable category; the buildings burn quickly. "This standard promotes protection from fire and its associated hazards by defining types of building construction based on the combustibility and the fire resistance rating of their structural elements. It is an extract document of Section 7.2 NFPA 5000®: Building Construction and Safety Code®." (National Fire Protection Association, 2021)

Consequences for the Precious Plastic Brick

In order to be approved as a building material in Germany, a minimum fire rating of B2 according to DIN 4102-1 must be achieved. For this purpose, the test according to DIN 4102-1 must be carried out and certified. Since the area of application of the Precious Plastic Brick in the case study of this paper is Indonesia, the NFPA 220 Type 5 Wood Frame should be targeted. → To meet the requirements of NFPA 220 "Type 5 -Wood framed " the Precious Plastic Brick needs an attached fire protection.

The fire performance of the brick is not uncritical. In 4 out of 5 tests, the sample burned down completely and had to be extinguished. In addition, there were burning drops and smoke development in all 5 samples. Additional fire protection for the interior is therefore strongly advised.

7.2.4 G Weathering of the brick according to DIN 75220 Z-OUT - 480 hours

Experimental Description

„DIN 75220-Z-Out is a standard for the ageing of automotive components in solar simulators. "Designation of a cycle test (Z) [...] under outdoor conditions (OUT). [...] "A cycle test consists of 15 successive dry-climate cycles and [...] -10 successive wet-climate cycles. “ (DIN German Institute for Standardization, 1992)

The Bricks have been irradiated for 480h with 1000 ± 100 W/m2. Compared to the global horizontal irradiation of Mando, this would correspond to 3.16 months.

Equivalent to solar radiation in Indonesia:

The value of the irradiation energy of 480 kWh/m² (From Table 31) is compared with the value of the global horizontal Irradiation for one year for the Manado region in Sulawesi. This value is 1825 kWh/m² (Figure 21 Global Horizontal Irradiation Indonesia)

The global horizontal radiation is the solar radiation received on the ground from a horizontal plane. The brick surface is not horizontally exposed to global radiation when used as a masonry block. The energy introduced by the simulation corresponds to approx. 3.16 months of horizontal global radiation. Due to the difference in surface orientation, it can be assumed that the introduced energy is present for a longer period than 3.16 months in reality. To calculate the exact time simulated, the position of the sun and the orientation of the Brick must be taken into account. This investigation serves to obtain an estimate of the behaviour of the brick in relation to weathering. This estimate is also possible without more precise calculations of the actual energy input over a year.

Table 31 Boundary conditions weathering of the brick according to DIN 75220 Z-OUT - 480 hours

G	Weathering of the brick according to DIN 75220 Z-OUT - 480 hours
Clarification of	Reaction to weathering due to climate change and UV irradiation
Testing equipment	Equipment according to DIN 75220 Z-OUT

Test site	LABOR LEHMACHER | SCHNEIDER GmbH & Co. KG Albert-Einstein-Str. 32 49076 Osnabrück
Test time	May/June
Test specimen	1 PP Brick and 1 HDPE Brick
Irradiance	1000 ± 100 W/m2 with specified spectral distribution according to DIN 75220 Z-OUT
Irradiated hours	480 h
irradiation energy	480 kWh/m²
Black panel temperature	70°C
Test chamber temperature	40 ± 3 °C
Relative humidity	80 ± 3 %
Test instrument	Atlas SC3 1000 MHG
Water for the production of humidity	Distilled water according to VDE 0510 or DIN 43530

Results

according to DIN EN 20105 A2 from LABOR LEHMACHER | SCHNEIDER GmbH & Co. KG

Table 32 Test results determination of colour fastness by means of grey scale according to DIN EN 20105 A2

Test specimen	Grey scale level	Examination according to
PP Brick (pink)	2/3	DIN EN 20105 A2
HDPE Brick (green)	3	DIN EN 20105 A2

Rating scale for assessing the colour change with the aid of the grey scale

- Grey scale level 5 no discernible colour changes
- Grey scale level 4,5 very slight colour changes
- grey scale 4 slight colour changes
- Grey scale 3.5 noticeable colour changes
- Grey scale level 3 clearly discernible colour changes
- Grey scale level 2.5 very clearly discernible colour changes
- Grey scale level 2 strong colour changes
- Grey scale level 1 very strong colour changes

(Schneider, 2021)

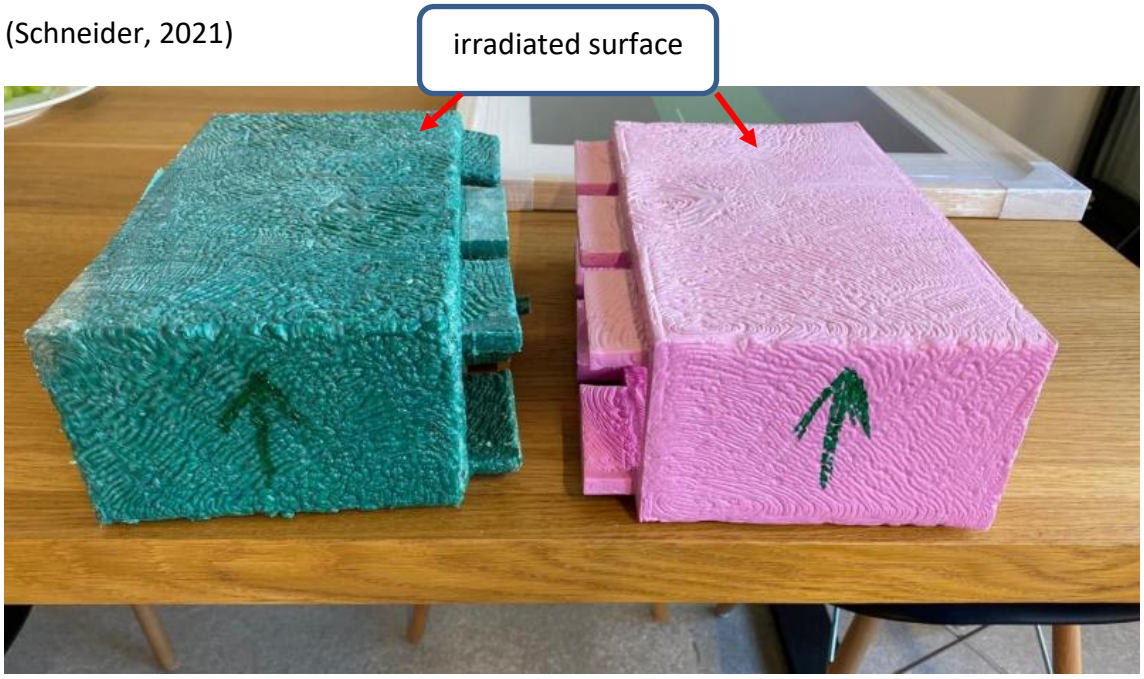


Figure 51 Test specimen after weathering of the brick (left HDPE Brick; Right PP Brick) (Schneider, 2021)

Surface of the brick after the test

“After the UV simulation, the bricks on the surface (see picture), which was directed towards the UV source, are very faded. If you rub your finger over them, you will see plastic abrasion on your fingers. This indicates that the surface has become very brittle (microplastic is formed) after UV simulation.” (Schneider, 2021)

Evaluation

The HDPE and PP bricks are not UV resistant. The penetration depth of the UV rays is approx. 0.2 mm for PP material and approx. 0.1 mm for HDPE material. Compared to the global horizontal radiation of Indonesia, the bricks would decompose on the surface after only 3 months. The decomposition creates microplastics on the surface. This can be washed away by the rain and enter the groundwater. For this reason, the bricks need additional UV protection.

Comparison PP Brick with HDPE Brick

In the graphics below, the pink bricks are made of PP and the green ones of HDPE. In figure 52 and figure 53, the bricks are compared with a non-irradiated brick to see the fading of the bricks more clearly. The PP Brick is much more faded than the HDPE Brick. In figure 54, a finger was rubbed over the surface of the brick for approx. 60 mm with similar pressure. There was significantly more abrasion on the PP brick than on the HDPE brick.

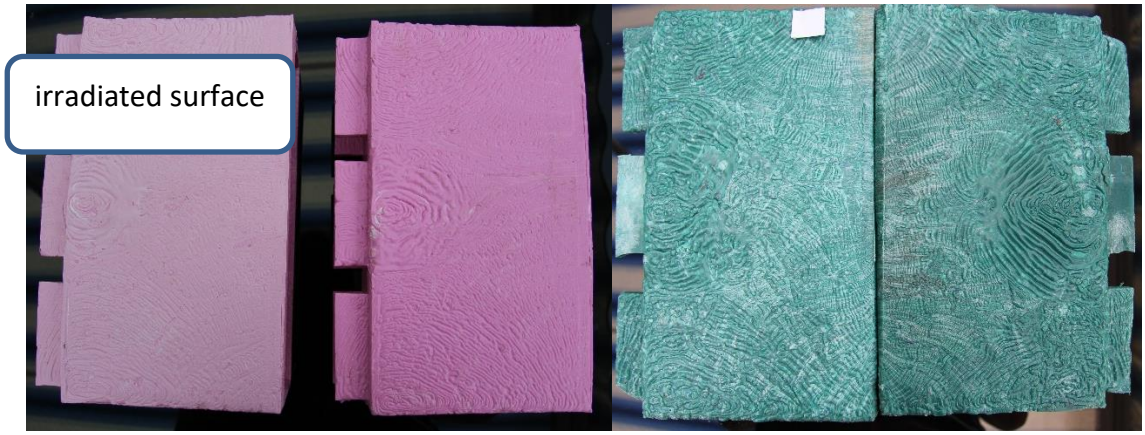


Figure 52 Comparison of the faded surface of the irradiated brick to an unirradiated brick (each right) (Marina Seeger)

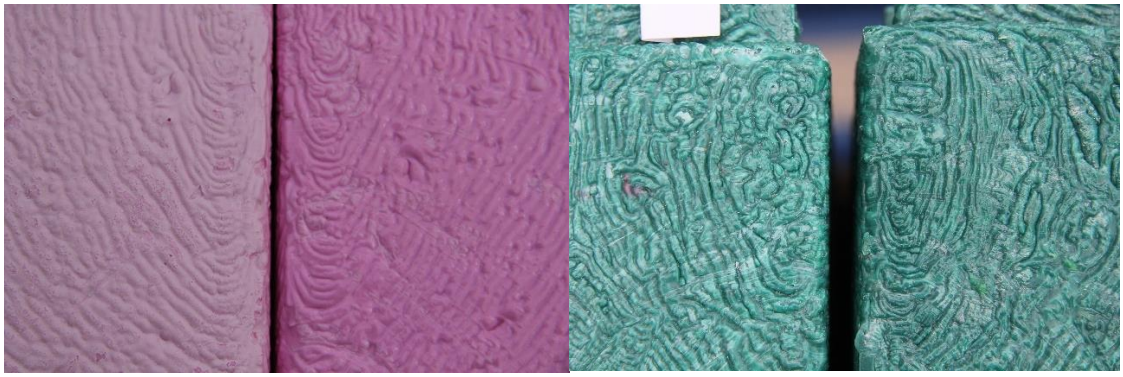


Figure 53 Closer comparison (Marina Seeger)

Figure 54 Microplastics on fingers; abrasion test (Marina Seeger)

The surface of the PP Brick has been more damaged by weathering than that of the HDPE Brick. The PP Brick is more faded and the surface has decomposed into microplastics more. As you can see in the Figure 54.

Possible reasons for the difference between PP and HDPE Brick:

- PP is more sensitive to UV radiation than HDPE.
- HDPE brick is more protected by dark colouring.

  "The colouring of a plastic component in outdoor use can also have a considerable influence on the quantities of antioxidants and UV stabilisers required, as the component heats up to different degrees depending on the colouring." (Bonnet, 2009) The darker the colour, the warmer the surface. In addition, "all other coloured pigments absorb UV radiation to varying degrees." (Bonnet, 2009)

In order to make a statement on whether HDPE is more resistant to UV radiation than PP, further bricks with the same colours would have to be tested.

7.2.5 H Water absorption

Experimental Description

An HDPE and a PP brick are placed in a water bath at constant ambient temperature for 10 days. They are pressed down with the help of a weight so that they are surrounded by water. They are weighed 3 times with the same scale. Before the water bath, after one day in the water bath and after 10 days in the water bath. It is always measured at 3 p.m.

Table 33 Boundary Conditions Water Absorption

H	Water absorption
Clarification of	How much water the HDPE and PP Brick absorb
Testing equipment	Water bath, scale
Test site	Office of Marina Seeger, Germany

Results

Table 34 Test results Water absorption

	Start weight [g] 22.06.2021	After 1 day	After 10 days
PP	1805	1807	1810
HDPE	1745	1755	1754

Evaluation

The tolerance of the scale is ±2g. The weight of the PP brick has increased by 0.28% due to water absorption, the weight of the HDPE brick by 0.57%. Surprisingly, the HDPE brick reached its final weight after only one day in the water bath (with tolerance), whereas the PP brick absorbed water slowly. Both values of water absorption are harmless and can therefore be excluded as a risk.

8 Summary and Outlook

I am very grateful for the work of the project group to produce the environmental education material and the provisional result is, in my opinion, a successful didactic concept. The implementation is also feasible and, according to discussions with Ana from Siladen Spa and Resort, usable for use in Siladen. The environmental education material produced must be distributed. Contact has been made with Greenpeace, aqueis.org, Gili Shark Conservation, GreenBooks.org and the local hotels and partners of TWS in Siladen: Siladen Spa Resort and Celebes Divers. Once the project is fully completed by the project group in August 2021, it will be distributed.

The survey brought to light the public's attitude towards the Brick. To begin with, it can be said that the majority of the population has a positive attitude towards the Brick. Nevertheless, concerns are expressed which shows what measures are needed to gain the acceptance of the population. The Brick has to be secured with regard to

1. Fire and toxic smoke
2. Bricks do not stand up to the demands of the environment (wind, sun, rain, heat)
3. Harms the environment (Use of the Brick harms the environment through e.g., microplastic)
4. Outgassing/ off gassing
5. Concerns about aging due to environmental influence
6. Concerns about load-bearing capacity
7. Practical use (plastering, drilling ...)
8. Bricks create an unhealthy indoor climate

The list is sorted in descending order. The most expressed concern is at the top These test results must be communicated transparently.

The above concerns reflected my own views on what needs to be investigated in order to secure the Brick. For this reason, tests were carried out. The following results, briefly summarised according to the above concerns, were obtained. Concerns were partially summarised

Table 35 Investigations carried out in relation to concerns raised

	Concern	Investigation performed	Result	Measure
1.	Fire and toxic smoke	F: UL 94 Vertical Flame Test	Failed	Building a wall from bricks, plastering it. Carrying out a second fire test.
2.	Bricks do not stand up to the demands of the environment (Sun, Heat, Wind) Concerns about aging due to environmental influence	G: Weathering of the brick according to DIN 75220 Z-OUT - 480 hours E: Pressure Test H: Water Absorption Test The environmental influence of the wind was not clarified.	passed conditionally The brick decomposes under UV and breaks down into microplastics. However, this does not affect its load-bearing capacity. (Clarified in Pressure Test) It was secured for heat of 40°C and water absorption.	Apply UV protection, e.g., by plastering the wall.
3.	Harms the environment	G: Weathering of the brick according to DIN 75220 Z-OUT - 480 hours C: Element analysis with AAS The subsequent recycling of the brick was not investigated.	passed conditionally If the brick is used without UV protection, it can decompose into microplastics and thus harm the environment. the elemental analysis did not reveal any	Apply UV protection, e.g., by plastering the wall.

			quantities of Pb (lead), Sb (antimony), Mn (manganese) and Cd (cadmium) that might be of concern.	
4.	Outgassing/ off gassing	B: Emission Tests according to VDA278, VDA277; VDA275	Passed	No measures necessary
5.	Concerns about load-bearing capacity	E: Pressure Test	Passed	No measures necessary
6.	Practical use (plastering, drilling ...)	No tests been carried out		Build a wall from bricks and see how it performs in terms of practical use.
7.	Bricks create an unhealthy indoor climate	An Odour test according to VDA270 at different temperatures Dampness and mould growth inside was not investigated	Passed	Carry out an examination for moisture and mould growth

In conclusion, the Brick has a lot of potential to be one of many solutions to recycle plastic waste in a meaningful way. To ensure the safety of people living in a Precious Plastic house, final fire behaviour tests are necessary. This includes investigating whether and in what form a fire barrier such as plastering can be installed.

Recycling in small communities like Waste Bank Manado in Indonesia and especially with local people working there sends an important message. Plastic waste can be recycled and has

value. It is also very important to educate people that plastic waste should not end up in nature because it damages it.

What I like about the Precious Plastic concept is that there are many small communities that can make a difference. That the bricks are made by locals and the whole production chain is in their hands. It takes some support and education to get the process going, but the chance is that communities will support each other and promote recycling.

The other brick recycling concepts are also relevant. The ByBlock concept is particularly exciting from my point of view. It offers the possibility to recycle large quantities and the fact that it can be economical makes it a successful measure. The aspect of education and integration into the communities is missing.

The ingenuity of people nowadays to solve the environmental pollution of waste with recycling brings forth great ideas. One of these is the idea and implementation of the young African woman Nzambi Matee who produces paving stones from plastic waste. We need to be open to all ideas and attempts to reduce, reuse and recycle plastic waste. It is about solving problems and not discarding ideas because of difficulties.

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Appendix

Appendix 1 Description of machines needed to produce a Precious Plastic Brick

Table 36 Shredder Pro

<table>
<tr><th>Shredder Pro</th><th colspan="2">Technical Data</th></tr>
<tr><td rowspan="11"> 
Figure 55 Shredder Pro (Precious Plastic, 2021)

The Shredder Pro shreds plastic waste into smaller flakes ready to be recycled. This double axis machine is able to shred up to 50 kg of plastic every hour depending on the desired flake size.</td><td>Type</td><td>Double Shaft</td></tr>
<tr><td>throughput</td><td>up to 40 kg/hr</td></tr>
<tr><td>materials</td><td>thermoplastics, thermo-sets, wood, cardboard etc., not suitable for met-als, minerals, glass and similar materials</td></tr>
<tr><td>Weight</td><td>350 KG</td></tr>
<tr><td>Dimensions</td><td>1205 x 550 x 1512 MM</td></tr>
<tr><td>Blade’s width</td><td>6 MM</td></tr>
<tr><td>Power (W)</td><td>2,2 to 4 KW</td></tr>
<tr><td>Voltage (V)</td><td>400 V</td></tr>
<tr><td>Amperage (AMP)</td><td>16 A</td></tr>
<tr><td>Material Cost (in the Netherlands)

Price Precious Plas-tic Bazar fully built</td><td>2.200 € + Motor

2.900 €

(TWS bought their Shred-der from Precisi)</td></tr>
<tr><td colspan="2">Values from (Precious Plastic, 2021)</td></tr>
</table>

Table 37 Extruder Pro

<table>
<tr><th>Extruder Pro</th><th colspan="2">Technical Data</th></tr>
<tr><td rowspan="10"> 
Figure 56 Extrusion (Precious Plastic, 2021)

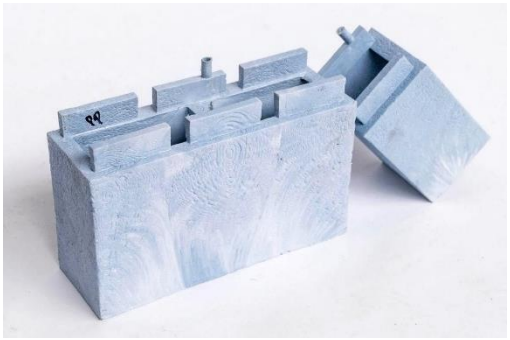
Extrusion is a continuous process where plastic flakes are inserted into the hopper and extruded into a line of plastic.
These lines can be used to make new raw material, granulated plastic, spun around a mould, or used in your own creative ways.
The Extrusion Pro extrudes recycled plastic into a mould.
This machine is able to recycle up to 15 kg of plastic every hour and make productions of beams or bricks.</td><td>Type</td><td>Single screw</td></tr>
<tr><td>Flow rate:</td><td>5 – 15 kg/hr</td></tr>
<tr><td>Materials:</td><td>all thermoplastics</td></tr>
<tr><td>Weight</td><td>160 KG</td></tr>
<tr><td>Dimensions</td><td>1500x600x1550 MM</td></tr>
<tr><td>Power (W)</td><td>4 KW</td></tr>
<tr><td>Voltage (V)</td><td>400 V</td></tr>
<tr><td>Amperage (AMP)</td><td>16 A</td></tr>
<tr><td>Material Cost (in the Netherlands)

Price Precious Plastic Bazar fully built</td><td>2.000 €

2.700 €</td></tr>
<tr><td colspan="2">Values from (Precious Plastic, 2021)</td></tr>
</table>

Table 38 V4 Brick Mould

<table>
<tr><th>V4 Brick Mould and V4 Brick</th><th colspan="2">Data and Description</th></tr>
<tr><td rowspan="8"> 
Figure 57 V4 Brick Mould 1 (Precious Plastic, 2021)

 
Figure 58 V4 Brick (Precious Plastic, 2021)

Generates a Brick through an Injection mould. The plastic flakes from the shredder are heated up by the extruder and injected into the mould. After cooling, the finished brick can be removed.

V4 Brick Mould in 3 different types because of the Plug Connection which are therefore to generate a straight wall.</td><td>Mould Types</td><td>Single Brick
Double Brick
Triple Brick</td></tr>
<tr><td>Dimensions of the Brick [mm]</td><td>Width 290
Depth 100
Height 160 (without plugs)</td></tr>
<tr><td>Weight [kg]</td><td>1,8</td></tr>
<tr><td>Material</td><td>Polypropylene</td></tr>
<tr><td>Cost for Shredder Pro, Extrusion Pro and 4V Brick Mould</td><td>7500€</td></tr>
<tr><td colspan="2">“The brick was designed over 4 months and was designed as a replacement to conventional masonry building [..]. The brick aims to act as an affordable, accessible, and durable alternative for low-income nations and countries affected by natural disasters. Each brick sequesters 1.5kg of plastic waste and is made using Precious Plastic's open-source recycling machines.” (Dickens, Linked In, 2021)</td></tr>
<tr><td colspan="2">Values from (Precious Plastic, 2021)</td></tr>
</table>

Appendix 2: List of YouTube commentators cited

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Appendix 3 Summary of all relevant concerns

From the 896 Comments are 209 relevant in terms of the question: “What concerns do you have about the Precious Plastic Brick?” These are 23,36 % of all comments. Most of the rest around appreciates the idea or have some general questions. For this study only the relevant comments will be analysed. In the 209 relevant comments there are various statements for this reason the number of statements is higher than the number of relevant comments. In total there are 247 statements.

Table 39 Summary of all relevant concerns

	Concern	Supplement and Explanation	Fre-quency
1.	concerns about fire		61
2.	concern about aging due to environmental influences	Aging caused by UV irradiation and weathering	22
3.	concerns about toxic fumes while burning		19
4.	concerns about off-gassing		18
5.	causes microplastic	The Brick dissolves into Microplastic due to rain	15
6.	concerns about using Brick in high temperature area	Concerns that the Brick loses its stability at higher ambient temperatures or outgasses strongly	12
7.	project is not profitable, and Bricks are too expensive		12
8.	concerns about wind	concerns that the Brick will not withstand the wind	9

9.	Concerns about load-bearing capacity	Concern that the load-bearing capacity and mechanical properties of the brick do not allow for house construction.	9
10.	afterwards it ends up in the environment again	The people are concerned that the Brick will end up in the environment again and that the effort of recycling is no longer necessary	8
11.	Problems with insolation	The Bricks do not insulate	7
12.	Bricks are toxic?	General statement that the Bricks are toxic because plastic is toxic	6
13.	material is not suitable for this purpose	Plastic is flammable; therefore, it is not suitable as a building material	5
14.	damage due to too light brick	Red Bricks are heavy and thus give strength and stability to the wall built from them. Precious Plastic Bricks do not have this property	4
15.	Bricks will smell	Recycled materials usually have a strong inherent odour	4
16.	problems with moistre	Because the material is not breathable like red bricks, moisture forms on the inside walls which can lead to the formation of mould inside	4
17.	off-gassing of Greenhouse gases	The Brick emits Greenhouse gases during production and over its lifetime	3
18.	bricks melt under heat	When the house built from bricks catches fire the bricks melt	3
19.	house will look ugly		2
20.	not water resitant	Concerns about the Bricks being not water resistant	2

21.	concerns about VOCs	That are emitted during outgassing/ off gassing	2
22.	The Bricks lack safety	General concern that the bricks are not secure	2
23	concerns about too slippery surface	Paint and coatings do not hold due too slippery surface	2
24.	Bricks can not be drilled	Concerns about not being able to attach items to the brick wall	1
25.	looks too childish and is therefore not taken seriously		1
26.	concerns about hormons		1
27.	insects will live inside the Brick	The Brick is hollow inside, which is why insects can live inside it and cause problems	1
28.	oil leaching out	Oil can leak from the bricks and enter the environment	1
29.	Emissions during metling		1
30.	Problems with thermal expansion	Thermal expansion could cause problems with other building materials	1
31.	Bricks create an unhealthy indoor environment		1
32.	Bricks can not be easily replaced		1

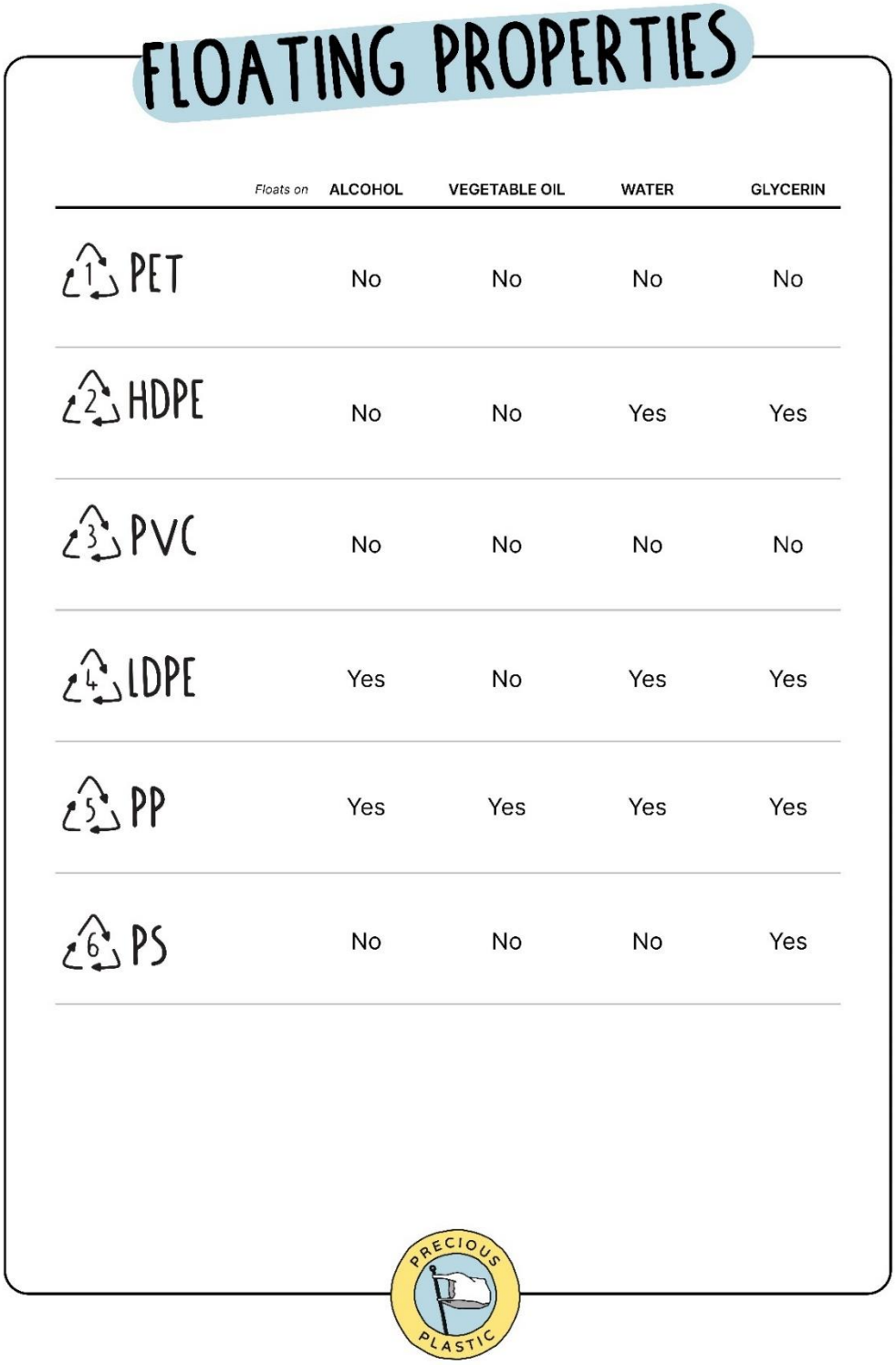
Appendix 4: Precious Plastic tables for determining the plastic

VISUALS PROPERTIES

Type & Name	Properties	Common use	Burning
1 PET POLYETHYLENE TEREPHTHALATE	Clear, Tough, Solvent Resistant, Barrier To Gas And Moisture, Softens At 80°	Soft Drink, Water Bottles, Salad Domes, Bisquit Trays, Food Containers.	Yellow Flame Little Smoke
2 HDPE HIGH-DENSITY POLYETHYLENE	Hard To Semi-Flexible, Resistant To Chemicals And Moisture, Waxy Surface, Softens At 75°	Shopping Bags, Freezer Bags, Milk Bottles, Juice Bottles, Iceacream Containers, Shampoo, Crates.	Difficult To ignite smells like candle
3 PVC POLYVINYL CHLORIDE	Strong, Tough, Can Be Clear And Solvent, Softens At 60°	Cosmetic Containers, Electrical Condult, Plumbing Pipes, Blister Packs, Roof Sheeting, Garden Hose.	Yellow Flame Green Spurts
4 LDPE LOW-DENSITY POLYETHYLENE	Soft, Flexible, Waxy Surface, Scratches Easily, Softens At 70°	Cling Wrap, Garbage Bags, Squeeze Bottles, Refuse Bags, Mulch Film.	Difficult To Ignite Smells Like Candle
5 PP POLYPROPYLENE	Hard But Still Flexible, Waxy Surface, Translucent, Withstands Solvents, Softens At 140°	Bottles, Icecream Tubes, Straws, Flower- Pots, Dishes, Garden Furniture, Food Containers.	Blue Yellow Tipped Flame
6 PS POLYSTYRENE	Clear, Glassy, Opaque, Semi Tough, Softens At 95°	CD Cases, Plastic Cutlery, Imitation Glass, Foamed Meat Trays, Brittle Toys.	Dense Smoke
7 OTHER ALL OTHER PLASTICS	Properties Depend On The Type Of Plastic	Automotive, Electronics, Packaging	All Other Plastics

PRECIOUS PLASTIC

(Precious Plastic, 2021)



(Precious Plastic, 2021)

Appendix 5: Interview with Rory Dickens

Persons present at the interview: Rory Dickens, Natalie Blanc, Markus Kurath, Marina Seeger

Date: 18.03.2021

Table 40 Fact Survey and guideline-based Interview with Rory Dickens

About Rory Dickens	
Name	Rory Dickens
Profession	"Consultant at The Circular Designer, UK" (Dickens, Linkedin.com, 2021)
Study history and degrees	"Robert Gordon University Aberden, Scotland, UK Master of Architecture (M. Arch.) Bachelor of Architecture (B.Arch.)" (Dickens, Linkedin.com, 2021)
Intersections with the Precious Plastic Brick	"Lead Project Manager Company Name: Precious Plastic Freelance Dates Employed: Jun 2019 – Present Employment Duration1 yr. 10 months Location: Eindhoven Area, Netherlands Co-Founder Company Name: Recycle Rebuild Dates Employed: Mar 2018 – Present Employment Duration3 yrs. 1 month Location Edinburgh, United Kingdom" (Dickens, Linkedin.com, 2021)
Leading question	Answer
In my master's thesis, I would like to examine the Bricks for their	No studies have been carried out, nor are their many studies of recycled plastic as a whole.

compatibility with regard to human and animal health. Have such studies already been carried out?	
Are you aware of any health risks related to the Brick?	None other than in the production due to fumes which is standard in the recycling industry.
what would be the best basic material for making the bricks?	PP; HDPE
Have the bricks been tested in terms of:	
dimension and shape retention	No
Long-term deformations	In the Netherlands, a wall was built from the bricks because of an exhibition. It is not deformed; the bricks are not compressed. The wall has been standing for 6 months and has not changed. Conceptos Plásticos has already built several houses in Colombia almost exclusively from recycled plastic bricks. Presumably, they also use a UV stabiliser to protect the recycled plastic from the massive sunlight. There are no known problems with these houses.
Stiffness and breaking strength	Slightly, we did compression tests and got a result of 10 tonnes: The compression test was stopped after 10 tonnes of weight. When PP breaks, it breaks suddenly. The brick was subjected to the weight under a hydraulic press.
UV resistance	No there is no real Research in UV resistance.

	The Brick is very thick its about 1 cm at its thinnest point and about 2 cm at its thickets point. The UV rays do not go as deep into the material. Usually, UV beams do not go deeper than 1 mm into the material. There are manufacturers of park benches in Europe who have been using recycled plastic for years. UV stabilisers are added to their base material. The products are still recyclable afterwards. (https://www.rk-shop.de/informationen/material/) The additives are relatively expensive.
Heat resistance	No true experience with heat resistance. Plastic is made from oil, so it contains a lot of energy. It might make sense to cover the interior walls with mortar, for example. When tests are carried out, it is useful to compare the results with conventional building materials. e.g., insulation material burns very well. In architecture, it is about hiding flammable material. For example, the example of Notre-Dame in Paris 2019 serves this purpose. The cathedral has been severely damaged by fire because a fire was started during construction work. In Colombia Conceptos Plásticos build a whole village out of plastic houses. It's about understanding the risks and managing it. Conceptos Plásticos don´t add additive because of price.
Brick manufacturing process: Do you think unskilled workers can handle the brick-making process?	Yes, and that is our target audience, though basic training is required. Moreover, the employees have no training in the processing of plastic. They must be trained beforehand and wear sufficient protective clothing such as respirators.

Is there a high risk of injury when making the bricks?	Yes. Workers need to be aware of the risk. There is a risk of burns when extruding. High pressure and temperature are used. The shredder poses the greatest risk because people tend to pull out jammed objects by themselves. Toxic fumes can be produced when heating plastic. This is partly because the wrong plastic may have entered the extruder as raw material, or because the materials being recycled have absorbed liquid.
house built from Precious Plastic Brick:	
Do you think there could be problems with mould?	Has not been investigated yet. If it is studied, it should be compared with conventional building materials.
Do you think there could be problems with the statics of houses built from Precious Plastic Bricks?	If we are referring to the use of plastic bricks to build houses. I think often the problem is the assumption that a house is made only from plastic, and nothing else. The bricks are not intended to be used with bare plastic, but instead the basic structure to add additional rendering or plaster to turn the house into a standard house. Think Earth Ship houses or Eco Brick. A simple one-storey house made of the bricks should not be a problem in terms of statics
Are there any studies on the fire safety of Precious Plastic houses?	No. Maybe Conceptos Plásticos did some.
Are there any studies on the earthquake resistance of Precious Plastic houses?	There are no explicit studies with the Precious Plastic Brick, but this is the fundamental reason why the Brick was designed. It has very good properties in terms of earthquakes. The Eco Brick did some studies in terms of earthquakes https://www.eco-bricks.org/?lang=de

Is there any feedback from existing projects with Precious Plastic Bricks regarding the acceptance of the Bricks by the population?	No, but there is from Precious Plastic as a whole or Eco Bricks. There are interviews with people who live in Conceptos Plásticos houses. They describe life in the houses very positively. However, these houses were given to them as a gift, so they cannot view the matter objectively. (https://www.youtube.com/watch?v=wtJwViFD7uo=)
Are there any reports on what it is like to live in such a house?	No, but there are for eco brick and Earth Ship houses. Also, in Indian exists a project where they build a complete house out of recycled Plastic sheets. https://www.youtube.com/watch?v=icg-zeSWo7C4
How would you use the Brick?	Provide key elements of architecture and upgrade it with Bricks to make it them own. By European architectural standards, bricks are a building material that can be used in combination with other materials. A completely plastic house would not be as pleasant as a house made of plastic, wood, glass, concrete, for example, because of the indoor climate and feeling. The bricks are very suitable as design elements. For example, the Adidas flagship store in Avenue des Champs Elysée uses the bricks. A “Lego House” build out of Precious Plastic and some other Material for the roof can work as well, if it was built on one level. There is not a problem with the strength of the Bricks. Residents should be made aware that the material is flammable. Compared to conventional building materials in Indonesia, it is not necessarily more dangerous. People in different countries have a different perception of comfort. Perhaps a house made entirely of plastic is not comfortable. However, a simple plastic house in Indonesia should be compared to a simple house built to traditional Indonesian standards.

Appendix 6: FILK Test Report 212593 (Emission and Odour Test)

Akkreditiertes Prüflaboratorium

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-17362-01-00

Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren

FILK Freiberg Institute

FILK Freiberg Institute gGmbH
Meißner Ring 1–5
09599 Freiberg | Germany
Telefon +49(0)3731 366-0
Telefax +49(0)3731 366-130
prueflabor@filkfreiberg.de
www.filkfreiberg.de

Test report	**212593**	29.06.2021
Customer	Verein Trash Waste Solution Mrs. Marina Seeger Villmergenstr. 6 5619 Büttikon Switzerland	
Order	Emission Tests	
Date of order / delivery	May 2021	
Test sample / amount	100 g Recycling Flakes	
Sampling	by customer, test pieces from material by FILK gGmbH	
Test methods	VDA 270, VDA 275, VDA 277, VDA 278	

Test report No.: 212593 page 2 of 2

Test Results

Parameter	Test Result	Normal Target Values Automotive Industry
Odour		
VDA270 A2 (40°C, 24h) Rating	3,5 Single Values 3,5 3,5 3 Description. old, musty	3
VDA270 A3 (80°C, 2h) Rating	4 Single Values 4 3,5 4 Description: musty, rotting, earthy	3
Thermal desorption VDA 278 [A]		
VOC value in µg/g	215	< 250
Fog value in µg/g	491	< 500
single evaluation	see report sheets	(PE; PP acc. DBL5430, Tab. 5)
Total carbon VDA 277 (µgC/g)	< 10	< 50
Formaldehyde VDA 275 (mg/kg)	< 2	< 2

Results marked with "<" indicate: value is below corresponding limit of quantitation of the test procedure

FILK gGmbH

Dr. Bernd Matthes
Deputy Head of Test Laboratory

Annex: Data Sheets, Chromatograms

Emission test results - VDA 278

Test Laboratory: FILK - Research Institute for Leather and Plastic Sheeting - Germany

File :	FILK-A-07870.D		
Path:	C:\MSDChem\Zwischenablage\	Test Report:	**212593**
Operator:	FILK/Matthes/Gerät A	Date of Order:	
Date:	14.06.2021 11:56	Sampling:	
GC-Method:	11-VOC.M	Date of Production	

Sample :	**Recycling Flakes E=15,86mg**	
Info:	**Seeger**	

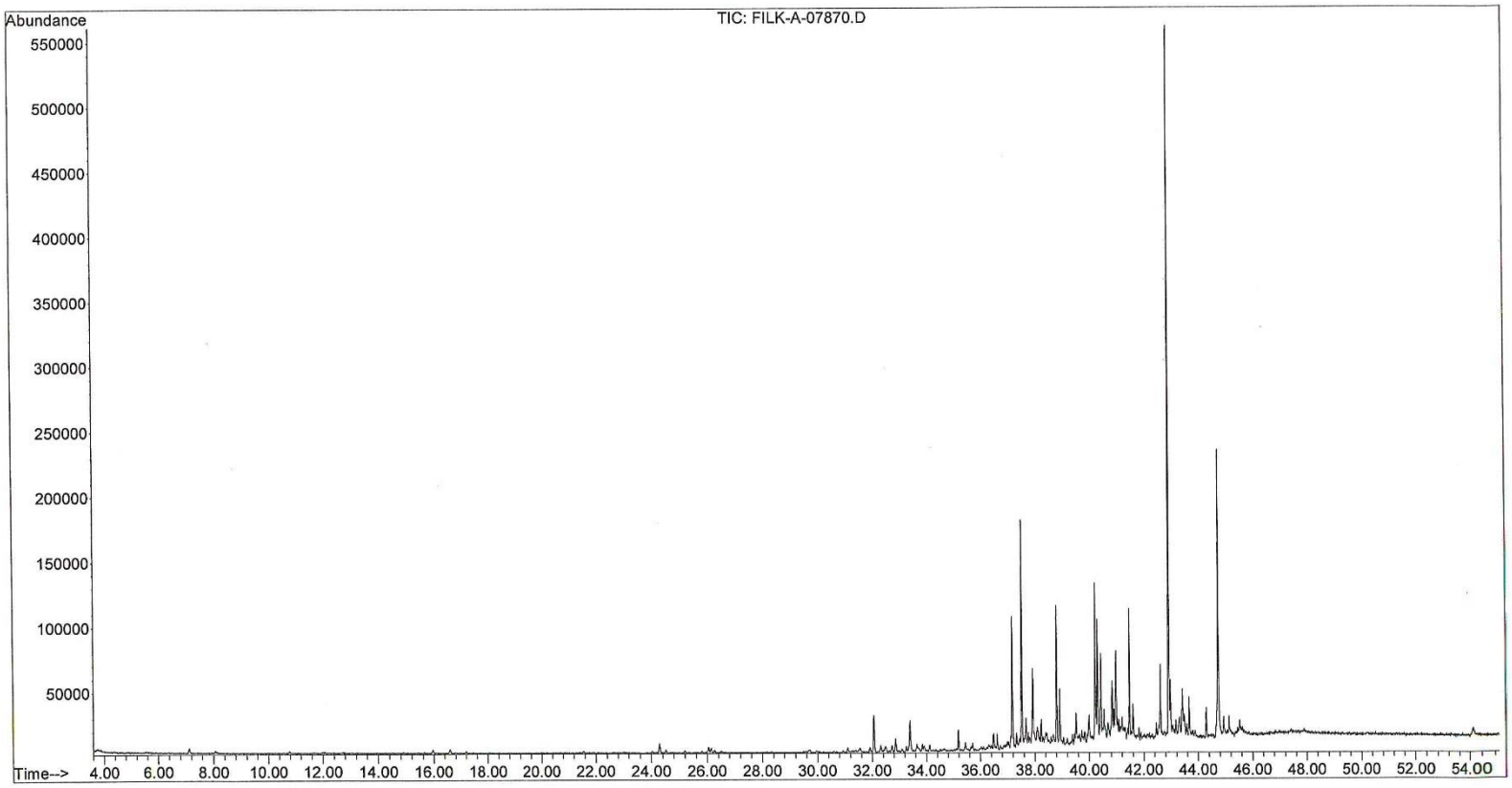
Rohr-Nr. : 12

VOC - Value in µg/g

215

Retention time in min	Substance	CAS-Nr.	Area (%)	µg/g	Remarks
32,06	Branched Alkane		1,9	**2**	
33,39	Branched Alkane		1,3	**1**	
37,17	Pentadecane	000629-62-9	6,5	**6**	
37,51	Phenol, 2,4-bis(1,1-dimethylethyl)-	000096-76-4	8,2	**7**	
37,93	Branched Alkane		3,7	**3**	
38,81	Hexadecane	000544-76-3	5,2	**5**	
38,92	Diethyl Phthalate	000084-66-2	2,4	**2**	
40,22	Heptadecane	000629-78-7	6,1	**5**	
40,31	Pentadecane, 2,6,10,14-tetramethyl-	001921-70-6	5,5	**5**	
40,43	Branched Alkane		3,1	**3**	
40,84	2,6-Diisopropylnaphthalene	024157-81-1	2,4	**2**	
40,97	Branched Alkane		3,4	**3**	
41,47	Octadecane	000593-45-3	4,8	**4**	
41,60	Branched Alkane		1,0	**1**	
42,61	Nonadecane	000629-92-5	3,4	**3**	
42,91	Hexadecanoic acid, methyl ester	000112-39-0	23,4	**21**	
43,41	Branched Alkane		1,7	**2**	
43,66	Eicosane	000112-95-8	1,5	**1**	
44,30	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-d	082304-66-3	1,4	**1**	
44,74	9-Octadecenoic acid (Z)-, methyl ester	000112-62-9	13,2	**12**	
41,00	Hydrocarbons (30,00-48,00)			**126**	
	Sum of identified Substances		100,0	215	

File :C:\MSDChem\Zwischenablage\FILK-A-07870.D
Operator : FILK/Matthes/Gerät A
Acquired : 14 Jun 2021 11:56 using AcqMethod 11-VOC.M
Instrument : Instrument #1
Sample Name: 212593 Recycling Flakes E=15,86mg
Misc Info :
Vial Number: 12



Emission test results - VDA 278

Test Laboratory: FILK - Research Institute for Leather and Plastic Sheeting - Germany

File : FILK-A-07871.D
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Operator: FILK/Matthes/Gerät A
Date: 14.06.2021 14:03
GC-Method: 11-FOG.M

Test Report: **212593**
Date of Order:
Sampling:
Date of Production

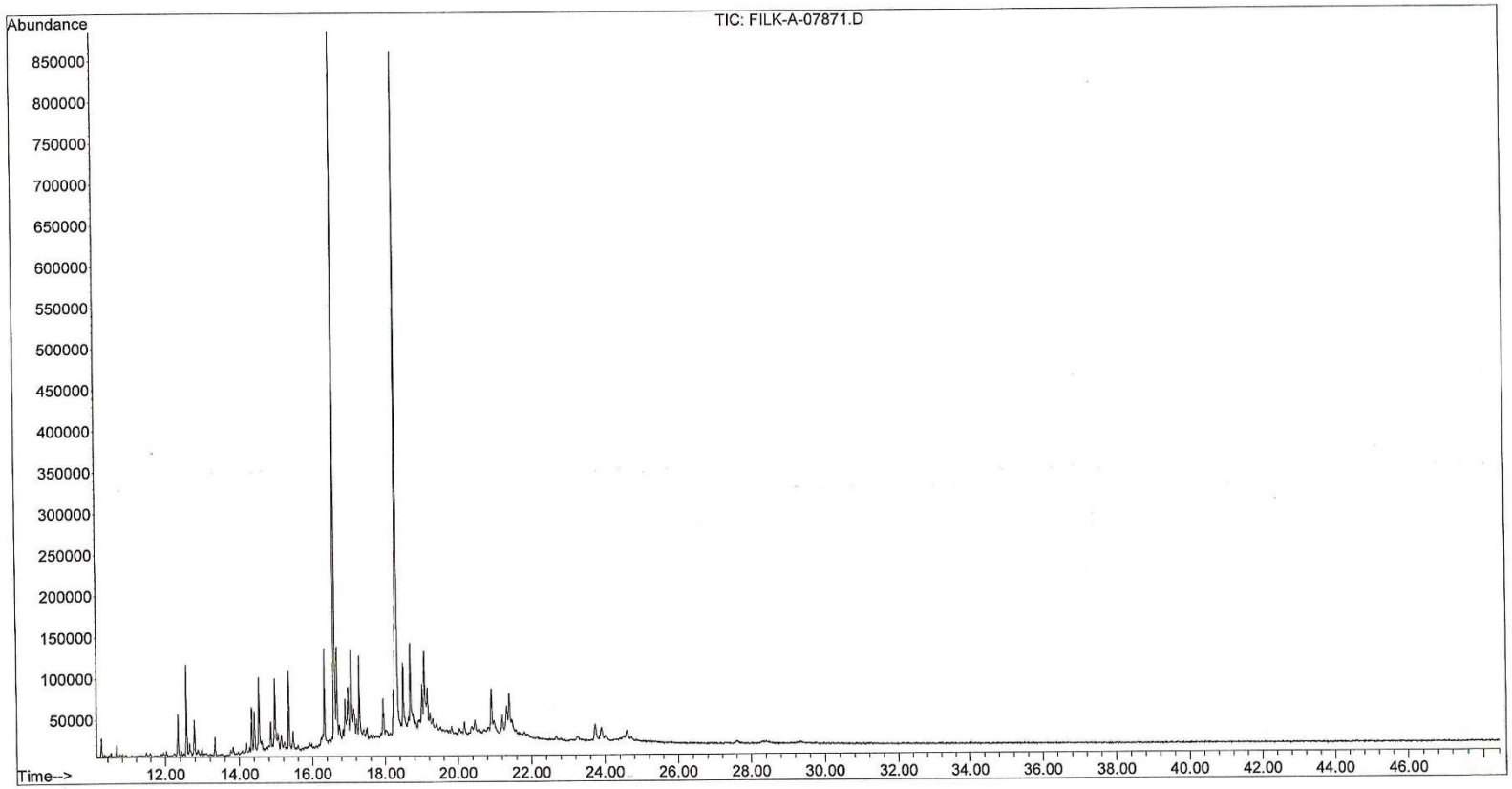
Sample :	**Recycling Flakes E=15,86mg**
Info:	**Seeger**

Rohr-Nr. : 12

fog - Value in µg/g **491**

Retention time in min	Substance	CAS-Nr.	Area (%)	µg/g	Remarks
12,35	Pentadecane	000629-62-9	1,5	**2**	
12,57	Phenol, 2,4-bis(1,1-dimethylethyl)-	000096-76-4	2,7	**4**	
12,78	Branched Alkane		1,2	**2**	
13,33	Hexadecane	000544-76-3	0,5	**1**	
14,34	Heptadecane	000629-78-7	1,4	**2**	
14,54	Pentadecane, 2,6,10,14-tetramethyl-	001921-70-6	2,8	**5**	
14,96	Branched Alkane		2,4	**4**	
15,35	Octadecane	000593-45-3	2,6	**4**	
16,33	Nonadecane	000629-92-5	3,1	**5**	
16,60	Hexadecanoic acid, methyl ester	000112-39-0	22,9	**37**	
16,68	Branched Alkane		3,8	**6**	
16,98	Branched Alkane		2,4	**4**	
17,07	Eicosane	000112-95-8	4,4	**7**	
17,30	Branched Alkane		2,7	**4**	
17,95	2,5-di-tert-Butyl-1,4-benzoquinone	002460-77-7	1,5	**2**	
18,23	Branched Alkane		1,4	**2**	
18,30	9-Octadecenoic acid (Z)-, methyl ester	000112-62-9	28,9	**46**	
18,49	Methyl stearate	000112-61-8	2,7	**4**	
18,69	Docosane	000629-97-0	3,3	**5**	
19,01	Branched Alkane		1,2	**2**	
19,07	Branched Alkane		2,1	**3**	
20,92	Branched Alkane		1,6	**3**	
21,33	Branched Alkane		0,7	**1**	
21,40	Tetracosane	000646-31-1	1,0	**2**	
23,74	Bis-2-ethylhexyl phthalate	000117-81-7	1,0	**1**	Re1B, Rf1B
17,00	Hydrocarbons (11,0-30,00)			**331**	
	Sum of identified Substances		100,0	491	

File :C:\MSDChem\Zwischenablage\FILK-A-07871.D
Operator : FILK/Matthes/Gerät A
Acquired : 14 Jun 2021 14:03 using AcqMethod 11-FOG.M
Instrument : Instrument #1
Sample Name: 212593 Recycling Flakes E=15,86mg
Misc Info :
Vial Number: 12



Pädagogische Hochschule Weingarten

Digitale Version meiner Bachelor-/Masterarbeit

Studiengang: Master Höheres Lehramt an beruflichen Schulen für Fahrzeug & Fertigungstechnik

Matrikelnummer: 7153626

Name: Marina Seeger

Thema: Plastic upcycling holistic study of a sustainable plastic brick

Gutachter*in: Prof. Dr.-Ing. Thomas Schreier-Alt; Prof. Dr. Andreas Schwab

Abgabetermin: 26.07.2021

Bitte kleben Sie hier die CD in einer Papier/Plastikhülle auf (keine Hartplastikhülle)

und geben dies zusammen mit der/den gedruckte/n Version/en

Ihrer Bachelor-/Masterarbeit im Prüfungsamt ab.

Hiermit bestätige ich, dass der Inhalt der CD mit dem gedruckten Exemplar übereinstimmt.

Datum: Unterschrift