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RUHR-UNIVERSITÄT BOCHUM

MechEng
Mechanical Engineering



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A CONCEPT OF A MOBILE SYSTEM FOR BEACH CLEANING WITH APPLICATION IN VIETNAM

BACHELOR THESIS

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Vietnamese-German University

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Abstract

The activities carried out under this bachelor thesis include a conceptual approach to design a mobile system for plastic beach cleaning with an application in Vietnam.

Plastic pollution is rapidly becoming a serious problem threatening the marine environment. One of the biggest sources of plastic waste is from the beaches, with the litter from the people living nearby. This is especially true for Asia region and in particular for Vietnam, as the country has one of the highest amounts of plastic waste released. After the bigger plastic pieces are discarded, the plastic debris will break down into smaller pieces of plastic, called microplastic. These microplastic particles are hard to perceive and therefore often overlooked when the plastic pollution situation is discussed. With gradually more researches on microplastic and subsequently more awareness on the topics, the microplastic pollution will be shown to be a serious problem and needed a solution. Thus, a way to reliably clean microplastic will be increasingly needed.

On the current market, there are not many beach cleaning machines that can clean microplastic very well. Therefore, a beach cleaning machine that can collect both macroplastic and microplastic is desired. This work will attempt to find a conceptual design using a systematic approach for the machine. The potential structure of the machine is realized by a CAD drawing. Identifiable weakness and potential for improvement are determined for future development of the topic and the conceptual design can be a base for further development of macro- and microplastic cleaning.

Declaration of Academic Integrity

I hereby declare that I have written the present work myself and did not use any sources or tools other than the ones indicated.

Datum:

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Table of Contents

Acknowledgement.....	I
Abstract	II
Declaration of Academic Integrity	III
Table of Contents	IV
List of figures and tables	VI
1. Introduction.....	1
1.1. Explanation of the task	1
1.2. Motivation	2
1.3. Method.....	4
1.4. Objective of the work	5
2. Engineering plastic: structure, origin, and technical requirements for extraction	6
2.1. Macroplastic	10
2.1.1. Origin of the macroplastic.....	10
2.1.2. Source and routing of the macroplastics to the marine environments	11
2.2. Microplastic	12
2.2.1. Origin of the microplastic	12
2.2.2. Source and routing of the microplastic into the marine environment	14
3. Potential beaches focusing in Vietnam	16
3.1. Phan Ri beach	17
3.2. Do Son beach.....	18
3.3. Ca Na beach.....	19
3.4. Con Son island.....	20
4. State of science and technology	21
4.1. Type of system of beach cleaners.....	21

4.1.1. Macro	21
4.1.2. Micro	29
4.2. Patents research on the topic of plastic beach cleaner.....	36
5. Derivation of a Conceptual Approach for an Innovative Mobile Beach Cleaning System ...	41
5.1. Design process	41
5.1.1. Requirements list.....	42
5.1.2. Abstracting to identify the essential problems	43
5.1.3. Establishing function structures	44
5.1.4. Developing working structures	46
5.1.5. Developing concept.....	50
5.2. Description of the concept of plastic beach cleaner	54
5.2.1. Transferring section.....	55
5.2.2. Filtering and storage section.....	57
6. Conclusion.....	61
Literature references.....	IX
Picture references	XIV
Program used.....	XVI

List of figures and tables

Figure 1.1: A plastic polluted beach in Phan Ri, Vietnam

Figure 1.2: The primary method to clean the beaches in Vietnam

Table 2.2: Plastic classification

Figure 2.1: World plastic materials demand by resin types 2006

Figure 2.3: Global production, use, and fate of polymer resins, synthetic fibers, and additives (1950 to 2015; in million metric tons).

Figure 2.4: Potential harm of microplastic to wildlife and huma

Figure 2.5: Macroplastic waste

Figure 2.6: Microplastic waste

Figure 2.7: Microbeads waste



Figure 2.8: Microplastic flow

Vietnamese-German University

Figure 3.1: Vietnam's map

Figure 3.2: Map of Phan Ri beach

Figure 3.3: Sight of Phan Ri beach

Figure 3.4: Sight of Do Son beach

Figure 3.5: Sight of Ca Na beach

Figure 3.6: Sight of Con Son beach

Figure 4.1: Barber Surf Rake: a) Working mechanic, b) Real image

Figure 4.2: SCAM RAKE

Figure 4.3: Barracuda

Figure 4.4: Simex beach cleaner

Figure 4.5: Sand Man

Figure 4.6: Cherrington beach cleaner

Figure 4.7: Density of plastic materials

Figure 4.8: Sediment -Microplastic Isolation Unit

Figure 4.9: SMI unit results

Figure 4.10: Microplastic Separation device

Figure 4.11: Electroseparation device results

Table 4.12: Patent search result

Figure 5.1: Conceptual design process

Table 5.2: Requirement list

Figure 5.3: Overall function

Figure 5.4: Function structure



Vietnamese-German University

Table 5.5: Classification scheme

Table 5.6: Working principles and their combinations

Table 5.7: Selection chart

Figure 5.8: Draft of Variant 1

Figure 5.9: Draft of Variant 3

Table 5.10: Assessment table

Figure 5.11: An overview of the full machine

Figure 5.12: Transferring section

Figure 5.13: Rotating blade

Figure 5.14: Conveyor belt

Figure 5.15: Vibrating screen

Figure 5.16: Macroplastic storage

Figure 5.17: Microplastic filtering system



1. Introduction

1.1. Explanation of the task

The network CleanRiverSolutions is committed to the ecological upgrading of rivers, inland and marine waters. Not only the regional market, with a focus on Central Germany, but also a global capacity for action is in the focus. Here, both active and passive systems and methods for water purification are developed, manufactured and tested. The basis for this is the expertise and specialist know-how of the growth core Fluss-Strom Plus. These resources will be bundled with those of the network partners and used for the innovative development of systems for the reduction of waste in water bodies. In the long term, this will create energy-producing turbomachines with an ecological cleaning effect.

Within the framework of this bachelor thesis, a mobile system for sand beach cleaning will be conceptualized. The focus is on the extraction of plastic both on the scale of macroplastic and microplastic.

In the beginning, the motivation and goals of the bachelor thesis are explained.



The following chapter contains information on structure, the origin of plastic and the technical requirements of its extraction. The regional focus is set with Vietnam. A large and complex river system and a long coastline with beautiful beaches and a heavy plastic load is the decisive criteria. An overview of the potentially to-be-cleaned beaches with the existing pollution structure is defined.

Following are the comprehensive researches on the current state of the art and the patents research regarding beach cleaners. Through a qualitative comparison of the currently available systems, they should be systematically analyzed and subsequently evaluated. Identified weaknesses and determined potentials for improvement is the basis for a conceptual solution approach. Possible constructive explanations and solutions are discussed.

Finally, alternatives of the solutions are evaluated and the summary of the work is presented.

1.2. Motivation

Nowadays, plastic is one of the most widely used materials around the world. Since mass production in the 1940s, plastic has been rapidly manufactured, with about 381 million tons being produced in 2015. [1] However, the characteristics of plastic that make them into such a popular material, namely durability that takes a very long time to break down, is the reason why they accumulate and contaminate the environment, especially the ocean. It has been estimated that the amount of plastic generated in land that enters the ocean is 4 – 12 million tons annually [2]. However, the general awareness of the population about the plastic littering is lacking, especially in Asia, despite reports dating back to 1972 [3]. Ingestion of plastic by seabirds [4] and sea turtles [5] are heavily documented, and the seas are heavily polluted and the ecosystem is endangered.

Recently the matter started to gain more attention from the people, but it is not too much, especially in Vietnam. That is evident in the state of many rivers and beaches in Vietnam.



Figure 1.1: A plastic polluted beach in Phan Ri, Vietnam /1/

Annually, Vietnam releases about 0.28 to 0.73 million ton of plastic wastes to the beach (6% of the world, rank 4th worldwide) [2]. A lot of the amount of plastic waste comes from the trashes that the tourists at the beaches left behind and from the civilians living near the beaches. While there is some effort to change this situation, it is not very sufficient. The answers are usually using manpower, which is not very efficient, or using machines, which is still at a very small scale due to the high price and inefficient.



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Figure 1.2: The primary method to clean the beaches in Vietnam /2/

The matter is even more serious with many types of research into microplastic pollution and its effects on human and the ecosystem [6], [7], [8]. There are as many as 51 trillion microplastic particles are in the oceans [9]. Some researches show that the most likely places for microplastic to generate from the larger plastic pieces are the beaches [7].

Therefore, beach cleanup can not only have a benefit far beyond the aesthetic improvements of the beaches, but also contributes towards the health of the marine and human life.

Therefore, the development of an accessible, efficient and microplastic-compatible beach cleaning machine is highly needed and should contribute tremendously in the polluting situation in Vietnam.

1.3. Method

As a preliminary, the scope of the bachelor thesis has to be defined. Thus, the investigations should be limited to the choice of location and to a conceptual solution with regard to a beach cleaner. Dimensioning, load, and performance calculation are not carried out in this bachelor thesis.

Firstly, an insight into the information about plastic and the current situation of plastic pollution are presented, to provide an overall understanding of plastic waste and how to collect and treat them. Focusing on macroplastic and microplastic, the study will research about how to effectively collect macroplastic and finding a way to filter the microplastic from sands.

Following chapter presents about the beaches and coasts in Vietnam and their geography and pollution situation. The appraisal of the potential locations serves to delineate the range of applications. Thus, the conceptual solution is to be derived from the comprehensive documentation of the location-specific characteristic.

Follow is the research on the current state of the art, first the conventional and modern beach cleaners' models are presented, and then a subsequent patent search is carried out. To effectively design and develop a concept for a beach cleaner, the properties of the models and variants are then compared in order to put together the requirements for the beach cleaner and to derive a proposal regarding the systemic and constructive properties. In additions, statements are made about possible innovations. These are then subjected to a critical evaluation to determine the possibility regarding their implementation.

Finally, after each individual component are designed, they are merged together to form the overall system of the beach cleaner. The CAD drawing should contribute to the visual and provide a better look at the final product.

1.4. Objective of the work

The aim of the bachelor thesis is the development of a concept for a mobile beach cleaning machine with the application in Vietnam. With the pollution situation in Vietnam, an effective beach cleaning machine can help clean up a large part of plastic waste before they are carried to the oceans. Technically, this machine is able to not only clean the macroplastic debris in the beach but also the microplastic mixed in with the sand. Methods for gathering macroplastic waste debris from current beach cleaners should be reviewed and studied. Because there is not really a microplastic cleaner for beaches currently, the technology for collecting microplastic should be explored. Afterward, how the solutions can be combined to form an overall concept for the whole machine is considered. Therefore, the main objectives of the work are:

- _ To research about plastic waste, the situation of plastic pollution in the beaches around the world and in particular the situation in Vietnam's beaches
- _ To review and study the current possible options for the mechanic of macroplastic collecting in beach cleaners.
- _ To research about the technologies for collecting microplastic from the beach's sands, and how to utilize them in a beach cleaning machine.
- _ To examine how to combine the technologies into a concept for a machine that is effective in cleaning the beaches of serious plastic pollution situation



2. Engineering plastic: structure, origin, and technical requirements for extraction

People had been using polymers since ancient time, processing natural rubber into items. They started to engineer plastic in the 1900s, with development of polyvinyl chloride (PVC) with applications in building and construction, electronics; polystyrene (PS) with applications in food packaging, containers; etc. Plastic has proven to be versatile for use in many types and forms, including natural polymers, modified natural polymers, thermosetting plastics, thermoplastics and more recently biodegradable plastics [10]. The success and popularity of plastic can be attributed to its range of properties: can be used in a wide range of temperatures, are chemical and light-resistant, strong and durable, but can easily be worked by hot melting at high temperatures. Combined with its low cost, plastics has risen to become a widely utilized material, with increasing worldwide demand, with 348 million tons of plastic produced in 2017 [11]. Below is the graph about different types of plastics produced in 2006.

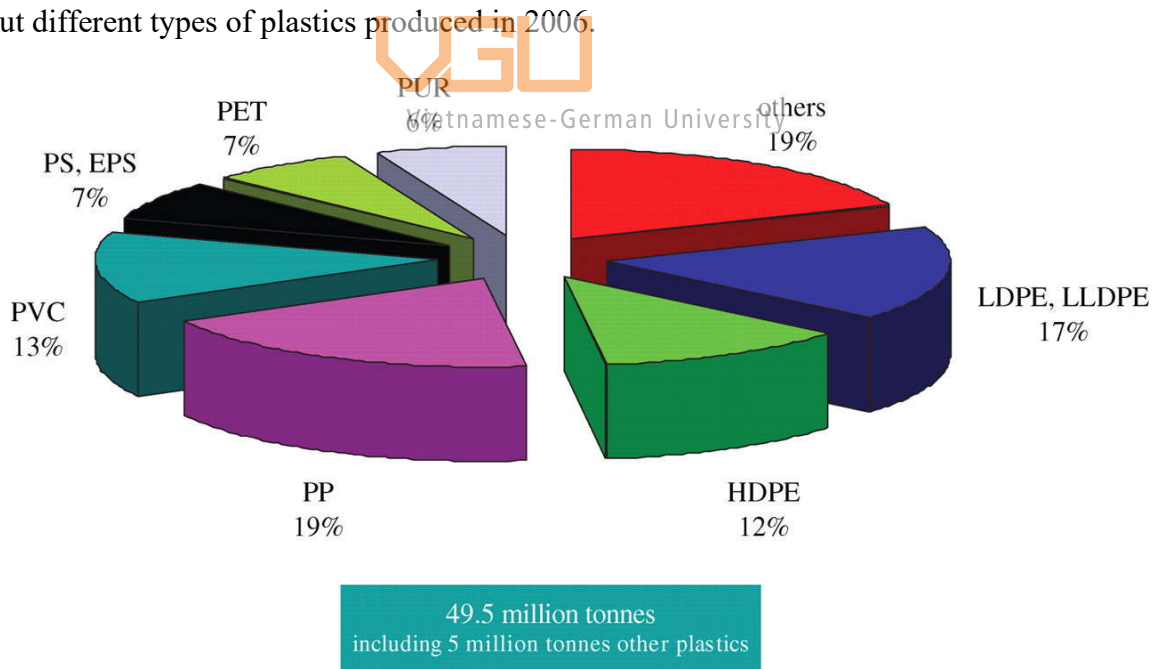


Figure 2.1: World plastic materials demand by resin types 2006 /3/

Plastic can usually be divided into classification based on sizes. There are megaplastic, macroplastic, mesoplastic, microplastic and nanoplastic [12]. Their classification based on size can be found in the table 2.2 below:

Classification	Size
Mega	>1m
Macro	2.5cm – 1m
Meso	5.0mm – 2.5cm
Micro	1 μ m – 5.0mm
Nano	<1 μ m

Table 2.2: Plastic classification /4/

In the scope of this beach cleaner, we consider macro- and mesoplastic into only one category which is macroplastic because they are the majority of plastic waste visible and can be collected using the same method. Mega- and nanoplastic are not considered, because the former is too big to reliably collect using the beach cleaner, and the latter, as of the time of writing, there is still not much research into the way to retrieve it. Microplastic will be discussed later, with the collection method and the way to filter it from the sand being the main discussing point.

The vast majority of monomers used to make plastics, such as ethylene and propylene, are derived from fossil hydrocarbons. After polymerization and adding additives, the polymers are made into everyday objects, with primary being packaging items, like bags, boxes, bottles, ... After being used, plastic waste has three endings: discarded (either going to landfill or littering), incinerated and recycled. With recycling, plastic materials are retrieved and reused to make new ones, which will reduce the amount of plastic wastes that goes into the environment. By incinerating, plastic wastes can be converted into fuel and energy in form of heat and steam to turn turbine blades and generate electricity. For plastic wastes that go into the environment, they are subjected to degradation, with mechanical, chemical or biodegradation. Plastic objects will break down into smaller parts (microplastics) and then the microplastics will be carried and dispersed throughout the world's ocean; at shorelines, beaches, on the surface waters from Arctic to Antarctic where they concentrate at different location in different density. The buoyant and persistent natures of microplastics allow them to become easily and widely dispersed via hydrodynamic processes and ocean currents.

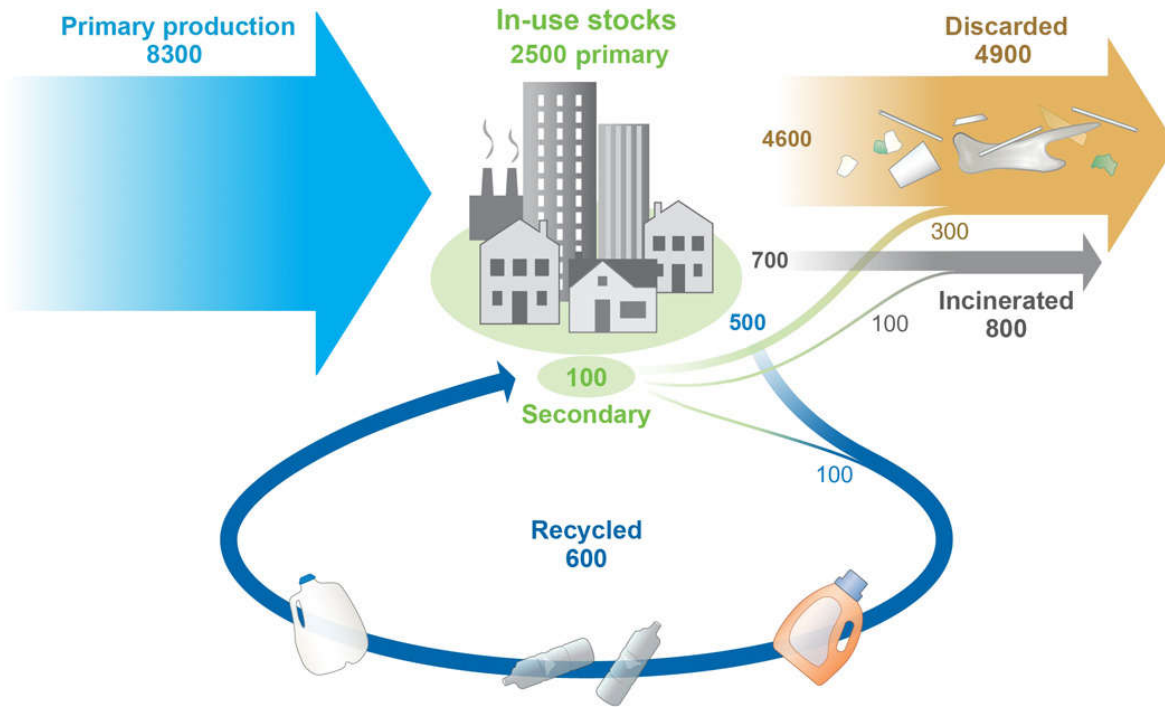


Figure 2.3: Global production, use, and fate of polymer resins, synthetic fibers, and additives (1950 to 2015; in million metric tons). /5/

As the plastic continue to accumulate in the ocean, they are affecting the marine life. Not only do the plastics end up in animals' stomach or around their neck, but there is also growing concern that plastics are acting as a medium for invasive species. The hard surfaces of plastics are now an alternate material for invasive species such as barnacles, mollusks, and algae to attach, compared to the natural material which previously carried invasive species for centuries. [13] Oftentimes, the wildlife is injured because of entanglement or ingestion of the plastics found in the environment. For Procellariiformes such as the albatrosses, shearwaters, or petrels, the appearance of eroded plastic pieces is similar to many types of food they consume [14]. Fish and cetaceans also mistakenly eat the microplastic due to the resemblance with phytoplankton. Ingested plastic debris has been found to reduce stomach capacity, hinder growth, cause internal injuries, and create intestinal blockage [15]. Marine life can become entangle with plastic fishing nets or other ring-shaped materials and this can result in strangulation, reduction of feeding efficiency, and in some cases drowning. Pinnipeds can often become entangled in marine debris at a young age because of natural curiosity, which can constrict their body as they grow thus reducing quality of life [16].

Globally, at least 23 % of marine mammal species, 36 % of seabird species, and 86 % of sea turtle species are known to be affected by plastic debris [17].

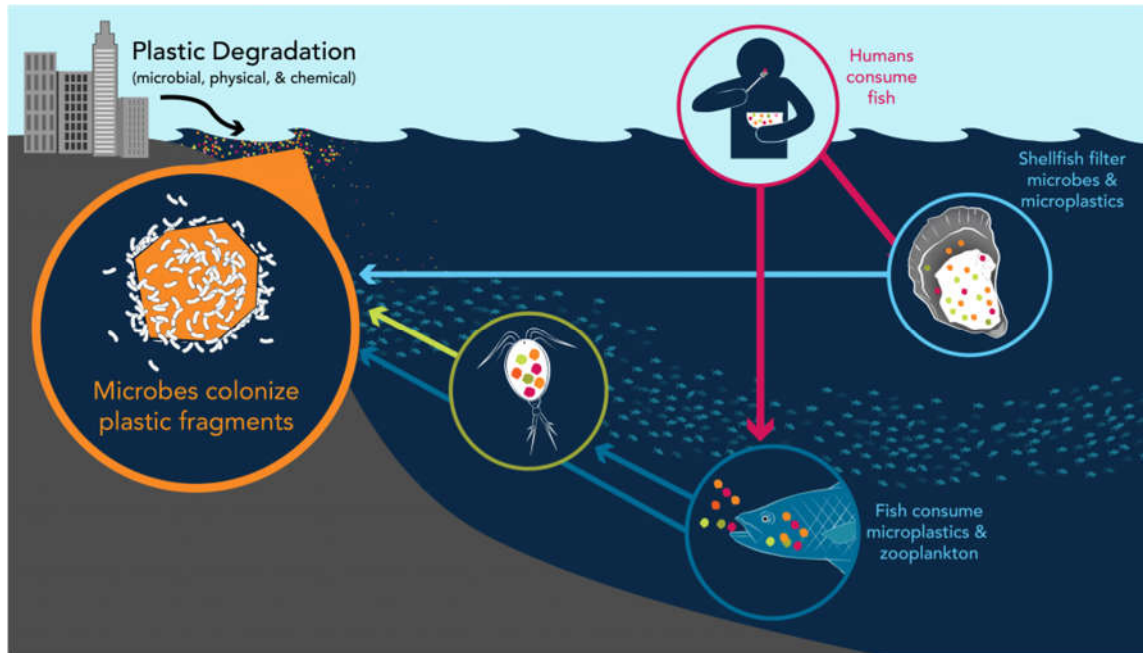


Figure 2.4: Potential harm of microplastic to wildlife and human /6/

The organisms that have ingested microplastics and have microplastics inside them may subsequently be fed upon by other higher animals in the food web thereby, transferring the microplastics to other animals in the trophic level. Therefore, the consumption of marine wildlife of microplastic can lead to the consumption of human. There have not been many studies about the effect of the microplastic consumption in human; nonetheless, the microplastics can contain many additives that are incorporated into plastics during manufacturing and many harmful pollutants such as metals, chemicals that can be absorbed by the microplastics. This can potentially lead to wide scale health problem to the people frequently consume marine food.

2.1. Macroplastic

Large visible plastic debris (> 2.5 cm) is defined as **macroplastic** [12]. In this case, we can also include mesoplastic, whose size is from 5.0mm to 2.5cm, to become a group of easily visible plastic object. This group of plastic is the most common to be collected and the majority of plastic waste cleaning is to clean this group of plastic waste.

2.1.1. Origin of the macroplastic

Most widely available macroplastic debris are divided into 24 categories. They are bags (shopping bags and garbage bags), food wrappers, beverage bottles, bottle caps, bottle label, cleaning product containers, personal care product containers, paint pots, disposable cigarette lighters, pens, disposable tableware products, disposable hard food containers, disposable foam food containers (cups, etc), straws and stirrers, toys, strapping bands, personal care products (toothbrush and hair brush, etc), medical products, household appliance pieces, plastic cards, rope pieces, fish line and hose pieces. [18]



Figure 2.5: Macroplastic waste //

According to researches [18], the dominant macroitems are food wrappers, bags and disposable foam food containers. The beverage bottles are both the heaviest and the highest volume group. Food wrappers are made using mainly polypropylene (PP) and polystyrene (PS), while both high-density polyethylene (HDPE) and low-density polyethylene (LDPE) are the main resin used in

plastic bags. Expanded polystyrene (EPS) is the resin of numerous macroitems, in which the dominant items are the styrofoam containers. Heavy plastic like polyethylene terephthalate (PET) is the materials for beverage bottles, cosmetic product containers and hard food containers. Other resins are identified at low densities, such as polyvinyl chloride (PVC), nylon, acrylic glass.

2.1.2. Source and routing of the macroplastics to the marine environments

Being a versatile, light weight, strong and potentially transparent material, plastics are ideally suited for a variety of applications. The low cost, excellent properties and light weight make plastic excellent packaging materials. Conventional materials such as glass, metal and paper are being replaced by cost effective plastic packaging of equivalent or superior design. Therefore, nearly a third of plastic resin production is converted into packaging material that become disposable single-use items that are commonly encountered in the beaches [19]. It has not been reliably estimated of how much of the 75–80 million tons of packaging plastics used globally each year that ends up in the oceans.



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There are many ways for macroplastic to enter the oceans. First is the fishing industry, with extensive fishing and the globally widespread use of plastic gear. This means that inevitably some gears will become lost or even discarded carelessly at sea during use. About 18% of the plastic debris in the oceans can be attributed to the fishing industry. The rest is largely from land-based source including littering. It is estimated that land-based sources including beach litter contributes about 80% of the plastic waste [19]. In 1988, an international agreement (MARPOL 73/78 Annex V) was implemented to ban marine vessels from disposing of plastic waste at sea; however, a lack of enforcement and education has resulted in shipping remaining a dominant source of plastic in the marine environment [20], in the early 1990s contributing an estimated 6.5 million tons of plastic to the oceans [20].

2.2. Microplastic

Whilst macroplastic debris has been the focus of environmental concern for some time, it is only since the turn of the century that tiny plastic fragments, fibres and granules, collectively termed “microplastics”, have been considered as a pollutant in their own right [7]. Plastic debris which is smaller than 5mm is defined as **microplastic** [12].



Figure 2.6: Microplastic waste /8/

2.2.1. Origin of the microplastic

Primary microplastics:

Plastics that are manufactured to be in microscopic size are called primary microplastic. These plastics are typically used in facial cosmetic, as air-blasting media or increasingly as vector in drugs medically. The cosmetic industry had begun to produce microplastic “scrubbers”, used in exfoliating hand cleansers and facial scrubs, and the traditionally used natural ingredients, including ground almonds, oatmeal and pumice have been replaced. The use of exfoliating cleansers containing plastics has risen dramatically since the patenting of microplastic scrubbers within cosmetics in the 1980s. Typically marketed as “micro-beads” or “micro-exfoliates”, these

plastics can vary in shape, size and composition depending upon the product [21]. For example, polyethylene and polypropylene granules (<5 mm) and polystyrene spheres (<2 mm) were reportedly presented in one cosmetic product. More recently, an abundance of irregular shaped microplastic were reported in another cosmetic product [21].



Figure 2.7: Microbeads waste /9/

Primary microplastic are also produced for use in air-blasting technology. This process involves blasting acrylic, melamine or polyester microplastic scrubbers at machinery, engines and boat hulls to remove rust and paint. When these scrubbers are used repeatedly, they become diminishing in size and lost their cutting power, and after that they will often become contaminated with heavy metals (such as Cadmium, Chromium, Lead) and then discarded into the environment. [20]

Secondary microplastics:

Secondary plastic describes small plastic fragment that break down from larger debris, both in land and in the ocean. Over time the combination of mechanical, chemical and biological processes reduces the structure of the bigger plastic debris into small microplastic fragments.

Over prolonged periods, large plastic debris under the exposure of sunlight can result in the photodegradation of plastics; ultraviolet (UV) radiation in sunlight causes oxidation of the polymer matrix, leading to bond cleavage [7]. While under the ocean surface the cooler temperature, the lack of sunlight and oxygen might make the process slowing down, on the beach the situation is different. With the direct UV sunlight, the abundance of oxygen and the physical abrasion of the

wave, the large plastic debris can easily break down into smaller size. This process can continue for many times, until the debris break down into microplastic, leading into the profusion of microplastic in the beach and marine environment, potentially harming the wildlife.

2.2.2. Source and routing of the microplastic into the marine environment

The microplastic that are in the ocean results from the disposal of plastic waste, either directly or indirectly. ~80% of the plastics found in marine litter are plastic litter with a terrestrial source [6]. With over one-third of the world's population, nearly 2.4 billion people, residing within sixty miles of an oceanic coast [9], these kinds of plastic have a high chance to enter the marine environment through rivers and wastewater-systems, or by being blown away to the shore. Microplastics can enter waterways via domestic or industrial drainage systems [20]; whilst waste-water treatment plants will trap macroplastics and some small plastic debris within oxidation ponds or sewage sludge [21]. Plastics that enter river systems will then be transported out to sea, either directly or within waste-water influence. Extreme weather, such as flash flooding or hurricanes, can affect and intensify the transfer of terrestrial debris to sea.

Coastal tourism, recreational and commercial fishing, marine vessels and marine-industries (e.g. aquaculture, oil-rigs) are all sources of plastic that can directly enter the marine environment, posing a risk both as macroplastics, and as secondary microplastics after degradation. An array of plastics being discarded along beaches and coastal resorts comes from tourism and recreational activities [20]. Fishing gear is one of the most commonly noted plastic debris items in the marine [6]. Another notable source of microplastic stems from the products that use granules and small pellets. These raw materials can enter the marine system through accidental spillage or direct outflow from plants.

Microplastics everywhere

High amounts of microplastics have been found not just in the sea and on beaches, but also in rivers and soils around the world, demonstrating how pervasive this modern pollution is. Sources include leakage from landfills, plasticulture, littering, and sewage sludge. Data from (1).

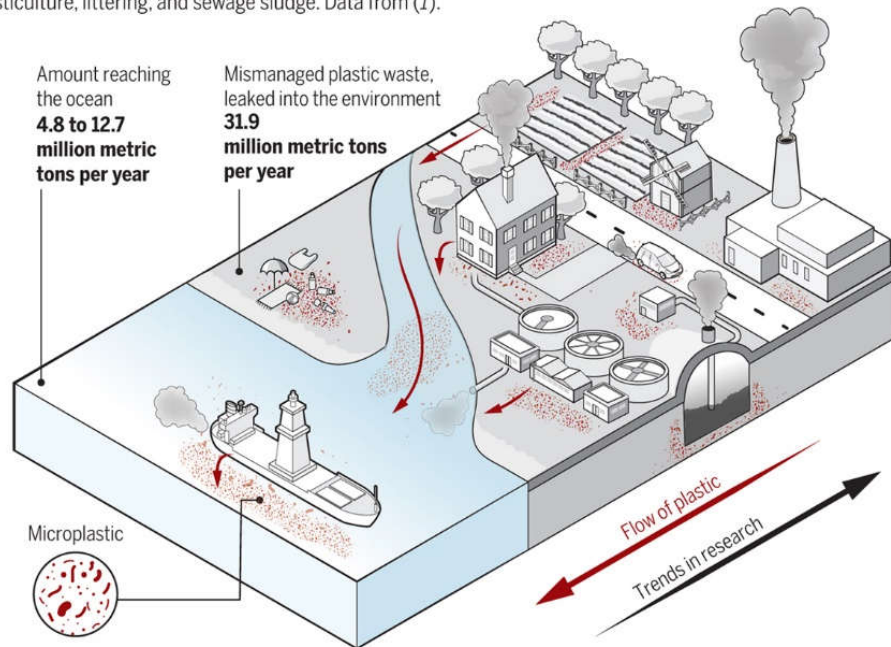


Figure 2.8: Microplastic flow /10/

While plastic debris in the ocean are subjected to degradation, the plastics that are floating in water are less affected because of low water temperature, lack of UV and lower oxygen concentration [7]. Thus, the most likely site for generation of microplastic is the beach. Recognition that microparticles (and also nanoplastics) are most likely generated on beaches underlines the importance of beach cleaning as an effective strategy. The removal of larger pieces of plastic from beaches can have sizable value in reducing the microplastic ending up in the ocean.

3. Potential beaches focusing in Vietnam

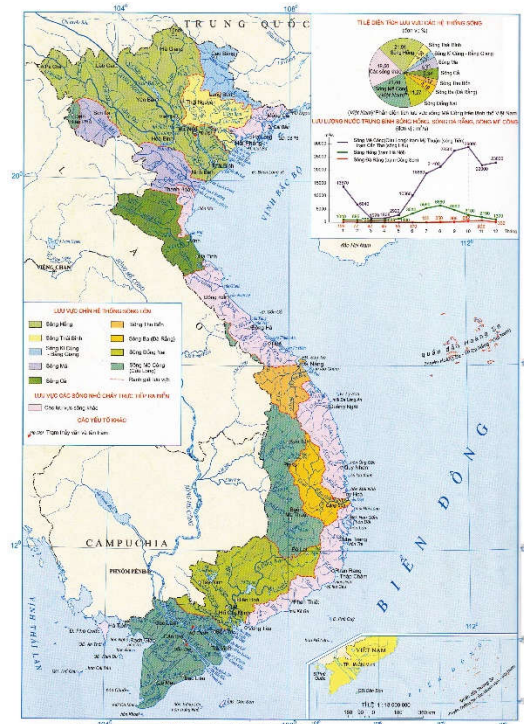


Figure 3.1: Vietnam's map /11/
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Vietnam is a South – East Asia country, located on the eastern margin of the Indochinese peninsula, bordering the Gulf of Thailand, Gulf of Tonkin and the Pacific Ocean. With an extensive coastline of 3260 km (excluding islands), Vietnam has a long history of capitalizing on the rich and resourceful sea and Vietnam's marine activities is very strong and dynamic. The South China Sea carries tremendous strategic importance; one-third of the world's shipping passes through it, carrying over \$3 trillion in trade each year [22]; it contains lucrative fisheries, which are crucial for the food security of millions in Southeast Asia. In addition, with a long coastline and many beautiful beaches, seaside tourism in Vietnam has the standpoint to develop quickly and strongly: according to Vietnam National Administration of Tourism (VNAT), in 2018 there are 15.5 million foreign tourists visiting Vietnam and 80 thousand domestic tourists, of which the proportion of visitors who travel in the region bordering the sea is 75% and 50% respectively [23].

However, because of the strong activities near the coast and also because of the poor awareness of Vietnamese about environmental issues, the majority of beaches in Vietnam are polluted, especially with plastic. Annually, about 0.28 to 0.73 million ton of plastic wastes are released to the beaches

in Vietnam [2]. This comes from both inland through the rivers and winds and from residences near the beaches. While in large and famous tourist spots, the beaches are cleaned frequently, in smaller there are not enough manpower for it. Therefore, the situation there is very bad.

3.1. Phan Ri beach

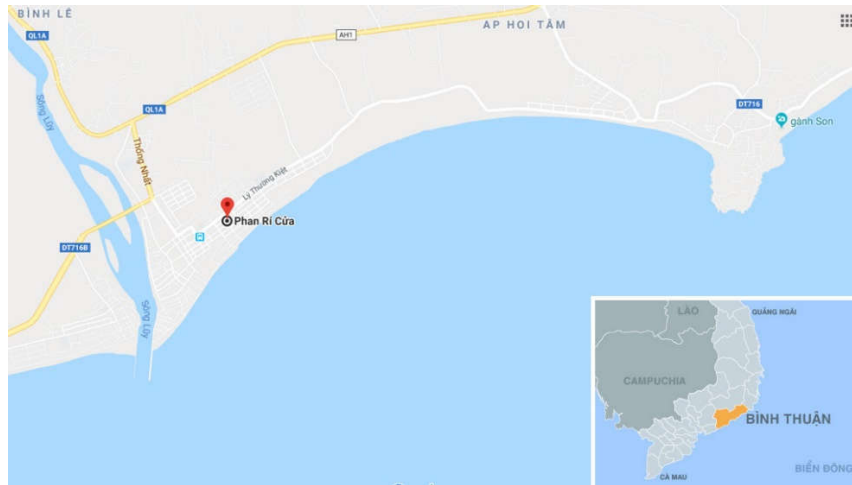


Figure 3.2: Map of Phan Ri beach /12/



Figure 3.3: Sight of Phan Ri beach /12/

For many years, the littering from the people living near the beach has changed the beautiful beach into a place filled with waste and trashes. Near 2km length of sandy beach has been polluted by many types of waste, primarily plastic waste. The city officials have arranged cleaning events to help clean up the beaches but to little effect. This situation is affecting the environment, making the beach dirtier and more polluted, and also pose a potential threat to the safety of people and children living near the beach.

3.2. Do Son beach



Figure 3.4: Sight of Do Son beach /13/

Once a beautiful beach with little popularity and exposure to tourism, the Do Son beach was a pure and pretty beach that only some people knew about. However, by words the beach increasingly became more popular, and in turn became more polluted. This situation shows that tourism and business, while brings more money and prosperous to the province, it also has a huge drawback to the environment. It shows that if the preparation is not enough and there is little effort in cleaning and maintain the beach, the pollution will become worse.

3.3. Ca Na beach



Figure 3.5: Sight of Ca Na beach /14/

Located in the middle of Vietnam, people in the middle region are very vulnerable to the natural disaster, and beaches are no different. High waves with high frequency clap constantly into the shore, carrying many plastic debris and waste with it. The people live there are also guilty: because of their focusing on living and working, their knowledge of the matter is also lacking. Therefore, the pollution situation is very serious, with the littering occurs daily by the local people. The plastic debris is mostly everyday items, such as plastic bags, food containers, etc. Fishing gears from the local fishermen are also usually carelessly discarded, of which mostly are made from plastic.

3.4. Con Son island



Figure 3.6: Sight of Con Son beach /15/
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Islands are the most susceptible to plastic pollution as the plastic waste that is drifting in the ocean is easily carried through waves to the sandy beaches of islands. Being far from land also means that less effort is poured into cleaning and maintaining the sanitary of the beach environments. In addition, because of little effort in cleaning the plastic debris that are lying in the sand makes them extremely susceptible to degradation by high temperature and UV light. Thus, in the beaches mixed between the sand are an immense amount of microplastic that is hard to collect and very harmful to the marine wildlife and environment. Therefore, the groups of islands in Vietnam is very in need of cleaning and the development of a beach cleaning machine that is mobile and can clean microplastic efficiently.

4. State of science and technology

4.1. Type of system of beach cleaners

Beach cleaners are machines that remove unwanted materials from beaches and make them comfortable and visually pleasing for beach-goers. Various beach cleaners can be used to effectively remove litter, sharp shells, glass, rock, and excessive seaweed from the beaches.

Beach cleaners come in all shapes and sizes. The most popular kinds are tractor-towed and powered by a tractor's hydraulic shaft. Smaller walk-behind models are also manufactured for private beaches and sandy areas.

4.1.1. Macro

There are three common technologies to apply in the beach cleaners:

Mechanical raking:

Raking technology can be used on dry or wet sand. When using this method, a rotating conveyor belt containing hundreds of tines combs through the sand and removes surface and buried debris while leaving the sand on the beach. Raking machines can remove materials ranging in size from small pebbles, shards of glass, and cigarette butts to larger debris, like seaweed and driftwood. By keeping the sand on the beach and only lifting the debris, raking machines can travel at high speeds.

Raking examples:

Barber Surf Rake

The SURF RAKE line of sand cleaners is the one of the most versatile beach cleaning machinery on the market. The SURF RAKE excels at removing all kinds of unwanted material from the sand by utilizing a 'top-down' cleaning method of tine raking and leveraging perforated conveyor system.

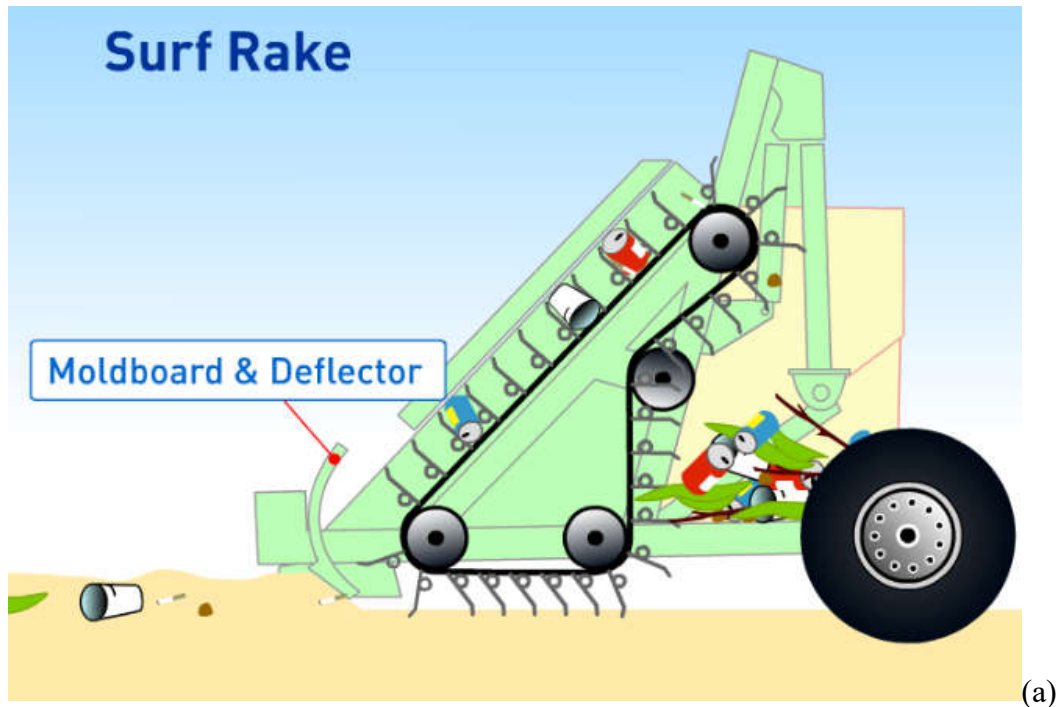


Figure 4.1: Barber Surf Rake: a) Working mechanic, b) Real image /16/

At the end of the cleaner there is a moldboard to level uneven area for an even surface and for controlling the cleaning depth. Surface and submerged debris are removed with ease using a rake system consisted of stainless-steel tines mounted a belt-covered bar flight conveyor.

The refuse is then bounced off the beach cleaner's deflector moldboard and is deposited on the elevating portion of the conveyor, which transports the refuse to the hopper, while the remaining

sand falls through the perforations in the conveyor. After cleaning, the bucket can be raised and tripped to dispose of the waste into a truck or container.

[24]

SCAM RAKE machine



Figure 4.2: SCAM RAKE /17/

At the beginning of the summer season it is very common that the beach is covered with big waste washed ashore by winter storms. Remove manually is exhausting and requires many efforts with few results, while using beach cleaning machine may cause damage or breakage to the machine due to large obstacles.

The RAKE is therefore one effective tool to remove large debris, move the sand and prepare it to be easily sifted by a beach cleaning machine. The RAKE consists of a support frame on which there are special springs for turning over the soil, collecting waste and levelling the sand when pulled by a tractor.

[25]

Sifting (screening):

Beach cleaners that employ sifting technology use a cutting edge to lift all the sand from the beach on to a vibrating screen. The screen then sifts the unwanted materials from the sand, while the sand returns to the beach, and the remaining debris is deposited in the bucket.

Sifting technology is practiced on dry sand and soft surfaces. The sand and waste are collected via the pick-up blade of the vehicle onto a vibrating screening belt, which leaves the sand behind. The waste is gathered in a collecting tray which is often situated at the back of the vehicle. Because sand and waste are lifted onto the screening belt, sifters must allow time for the sand to sift through the screen and back onto the beach. The size of the materials removed is governed by the size of the holes in the installed screen.

Sifting (screening) example:

Barracuda walk-behind beach cleaner

Figure 4.3: Barracuda /18/

The Barracuda beach cleaner is an excellent choice for working on the sensitive beach environment and is designed for sand areas in the small to medium size range and is well suited for soft sand. Because of its size, it will produce less disruption to sand areas.

The Barracuda walk-behind can remove broken glass, cigarette filters, syringes, stones, seashells, weeds, wood, pop-tops, etc. The sand is well aerated due to the intensive sifting action of the screen, allowing the ultraviolet rays of the sun to dry and sanitize the sand. This cleaning process helps eliminate harmful bacteria buildup and makes the beach a healthier place.

Because of low footprint created by the rubber tracks, the Barracuda has very little sand compaction. The sifting screening action is also behind the drive tracks, combine both of which results in very few tracks and less compaction on the finished area.

[26]

Simex beach cleaner



Figure 4.4: Simex beach cleaner /19/

The cleaner can be controlled by an electro-hydraulic valve to start and stop sifting, control working depth, and activate hopper opening from the cabin. This means easier and more controlled operation for the operator. The debris can be quickly sifted and collected in the 350-liter hopper and afterward easily dumped thanks to the Cleaner's high discharge capability and hydraulic hopper gate. The machine is ideal for both wet and dry sand or soil.

[27]

Combined raking and sifting technology:

Differs from pure sifters in that it uses rotating tines to scoop sand and debris onto a vibrating screen instead of relying simply on the pick-up blade. The tines' position can be adjusted to more effectively guide different-sized materials onto the screen. Once on the screen, combined raking and sifting machines use the same technology as normal sifters to remove unwanted debris from the sand.

Combined example:



Barber Sand Man



Figure 4.5: Sand Man /20/

The sieving unit is compact and lightweight for one person to use, adding to the usability and ease of operation. There are independent brakes on each wheel and a differential lock, which assist in soft sand condition and aid maneuverability. The walk-behind sand sifter is propelled by high

flotation rubber tires, which provide excellent traction in the sand but will not harm grass or paved surfaces.

The sifter elevates the sand and sieve the debris using a screen. The debris afterward is then deposited into the basket. Different size of screens is available and can be easily change to suit the need of the user. Therefore, the machine can clean from ultra-fine sand to deeper cleaning and rapid speed in wet sand. The cleaning depth can also be easily adjusted while in use, add to the ease of operation of the user.

[28]

Cherrington Beach Cleaners



Figure 4.6: Cherrington beach cleaner /21/

Cherrington lifts and screens the sand to screen-clean and sanitize your beach. The machine works efficiently and economically by lifting the sand from the beach using a rotating rake, screening it

through a powered oscillating screen, and then retaining all objects larger than the chosen screen size and finally returning the sand to the beach.

[29]



4.1.2. Micro

Microplastic has been accumulating in the oceans for at least the last four decade [30]. A large amount of the microplastic currently in the environment is created from the processes of degradation of large plastic waste, under the influence of the environment. While there are many factors affecting the degradation processes, including environmental factors such as sunlight, temperature and oxygen, and the properties of the polymer (size, density), arguably the primary element is the UV radiation in sunlight that initiates the photo-oxidative degradation. This process is not very effective when affecting the plastic debris floating in the oceans because of the lower temperature, lower oxygen concentration and reduced UV radiation; however, with the plastic debris that is lying on the beaches the direct exposure to the UV radiation and higher temperature and exposure to more oxygen, the degradation becomes very effective, leading to the high amount of microplastic lying in the beaches, especially in addition to the amount that the wave carried into the beaches. Therefore, collecting microplastic in the beaches is a task should be studied and researched to develop a way to efficiently gather them.

Currently there are not many methods to collect microplastic from the beaches. This is due to their small size which is difficult to capture. Their relatively invisibility from people's eyes makes them hard for people to notice and collect them from the sandy beach. In addition, the similarity in size of microplastic and sand results in the difficulty in using filters and screens to filter them from the sand. Due to these reasons the practice of microplastic cleaning is still new and not very widespread. People are still researching for ways to reliably collect microplastic in an efficient and mechanical manner and applying them in machines for commercial and widespread use.

For researching purpose, there are a few ways to collecting microplastic from sand which are used in a small scale and are in development for widespread use. They have reportedly high success, with high percentage of filtering microplastic from other sediments, and therefore should be in more development to utilize them in practical use. In the section below two methods will be analyzed for how they work and for their capability for application in the beach cleaning machine. The two methods are floatation (or buoyant) and electrostatic.

Floatation

The idea here is to use the difference between the density of microplastic and other sediments to separate them from each other using buoyancy. The density of plastic ranges from 0.92 g/cm^3 to 1.39 g/cm^3 , with polypropylene (PP) at 0.92 g/cm^3 , polyethylene (PE) at 0.95 g/cm^3 , polystyrene (PS) at 1.01 g/cm^3 , which are the ones that will float in seawater, with seawater average density at 1.027 g/cm^3 . Nylon at 1.15 g/cm^3 , polyvinyl chloride (PVC) at 1.3 g/cm^3 , and polyethylene terephthalate (PET) at 1.39 g/cm^3 are the ones sinking in seawater. [31]

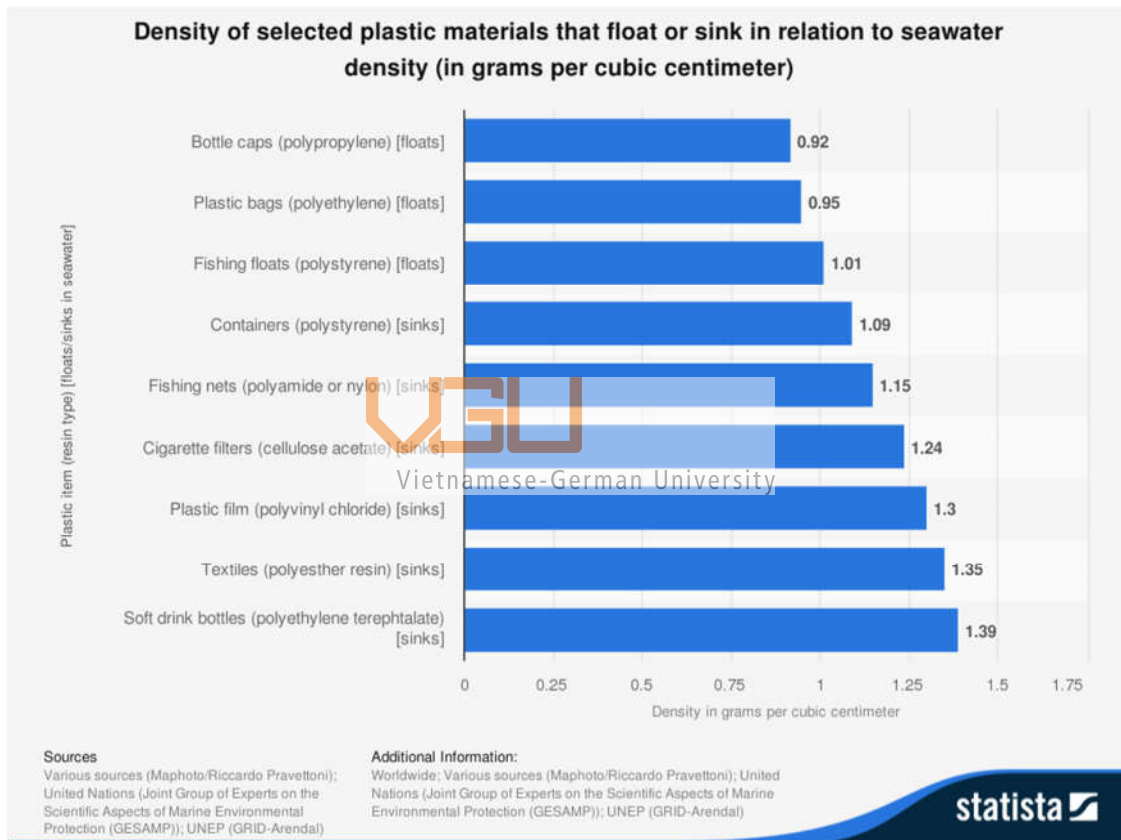


Figure 4.7: Density of plastic materials /22/

Due to the characteristic of the plastic, seawater is not a very useful solvent to use to collect microplastic, with a sizable amount of plastic sink in seawater and other sediments also sink, in particular sands with average density of 1.6 g/cm^3 . Coppock et al. [32] therefore experimented with many other floatation medias, with solution of sodium chloride (NaCl), sodium iodide (NaI), and zinc chloride (ZnCl_2), with density ranging from 1.2 g/cm^3 to 1.8 g/cm^3 . They also designed a

method for rapid, simple and efficient extraction of microplastics from other sediments, which they called the Sediment – Microplastic Isolation (SMI) unit.

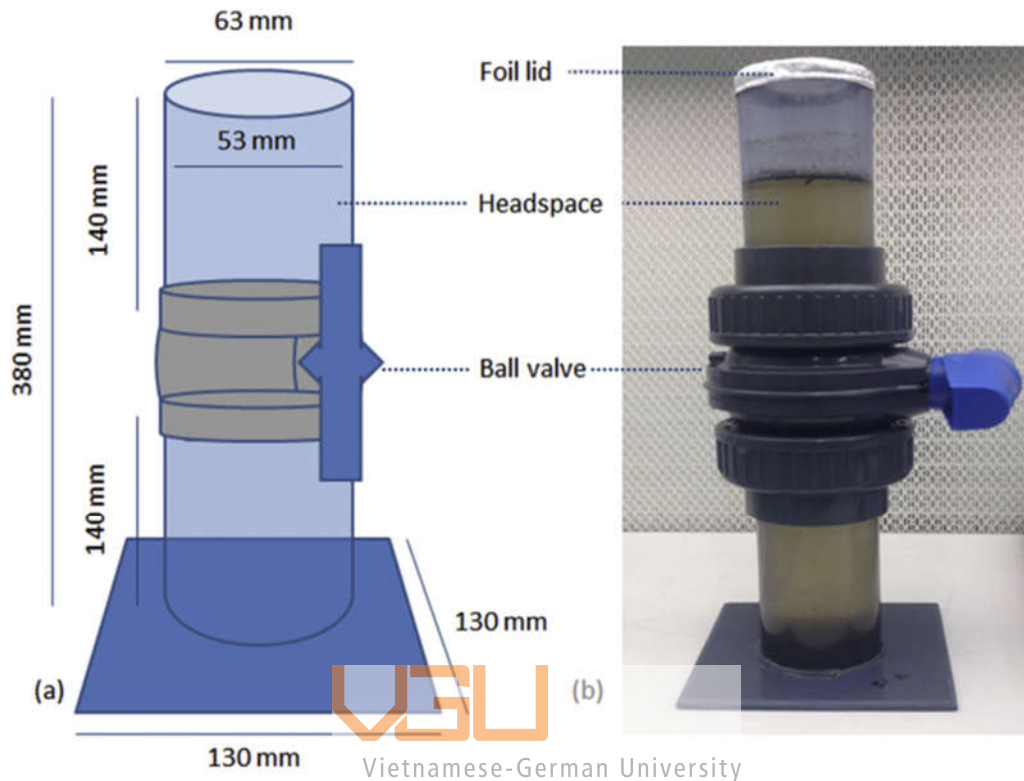


Figure 4.8: Sediment -Microplastic Isolation Unit /23/

The SMI unit is constructed using a PVC pipe and a ball valve. The inside surface is smoothed out to avoid restriction on the movement of microplastic and the sediments and allow free movement of all the particles. The testing was carried with samples contain microplastics and many types of sediments in different types of solvents. Microplastics included PE, PVC, and nylon, and the sediments collected from different places including clay, silt, coarse sand. A range of densities of different solvents were tested to determine the most optimal floatation media. Coppock et al. concluded that NaCl, being the cheapest option, is not very suitable due to the maximum density achieved is only 1.2 g/cm^3 . This means that NaCl can only separate low-density plastic, and other denser plastic such as PVC ($1.3 - 1.45 \text{ g/cm}^3$), and PET (1.38 g/cm^3). NaI can be prepared to higher densities than NaCl, however the high cost made NaI not very desirable for further use. ZnCl₂ on the other hand is a relatively inexpensive option, and also can be made to attain density up to higher than 2 g/cm^3 . The density of ZnCl₂ at 1.5 g/cm^3 is very useful for separating denser plastic and also

light enough for denser sediments like sands to sink to the bottom. At $1.6 - 1.8 \text{ g/cm}^3$, the fine sediments remain in suspension making the solution impractical for plastic extraction. In conclusion, the most optimal solvent is ZnCl_2 at density of 1.5 g/cm^3 , balancing the requirement for a media dense enough to allow different plastic floating while allowing sediments to sink and achieve the desirable separation.

Microplastic were extracted using the SMI unit with ZnCl_2 at the density of 1.5 g/cm^3 and the mean extraction rate for different type of plastic can be seen in the graph below, ranged from 92% to 98% for a mean of 95.5%. [32]

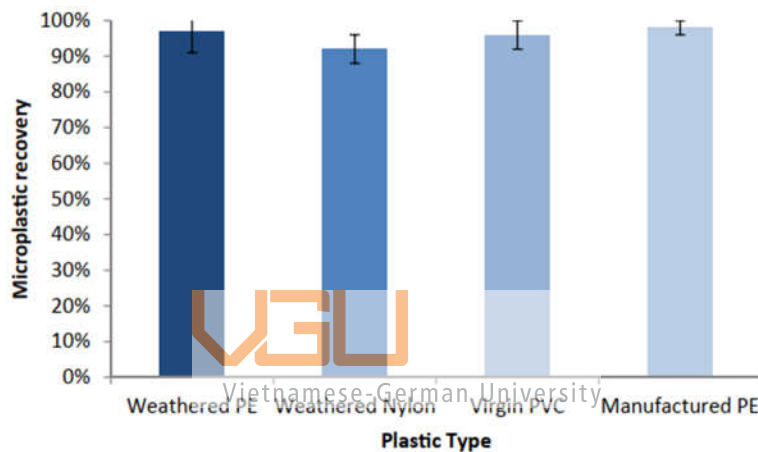


Figure 4.9: SMI unit results /23/

The result is good, with high efficiency of plastic extraction. This method can be very useful for collecting samples of microplastic for researching and studying of the microplastic pollution situation. However, the method can be difficult to apply in a beach cleaning machine, with long time to wait for the separation and difficulty of using the floatation media in the machine.

Electrostatic

The second method is to use electrostatic to attract the microplastic and do not fall down, separating them from the other sediments. Currently, the floatation method using chemical solvents is mostly the popular method in separation of plastic particles. However, there are some disadvantages: the method cannot separate the higher density plastic like polytetrafluoroethylene (2.2 g/cm^3). The plastic may prone to degradation due to exposure to chemical treatment. A promising physical method is the electrostatic method, which are currently utilized in recycle sector. The devices that make use of electrostatic for recycling or separation process are manufactured by hamos GmbH [33]. Felsing et al. [34] utilized the devices to apply and test the electrostatic method for plastic extraction purpose.

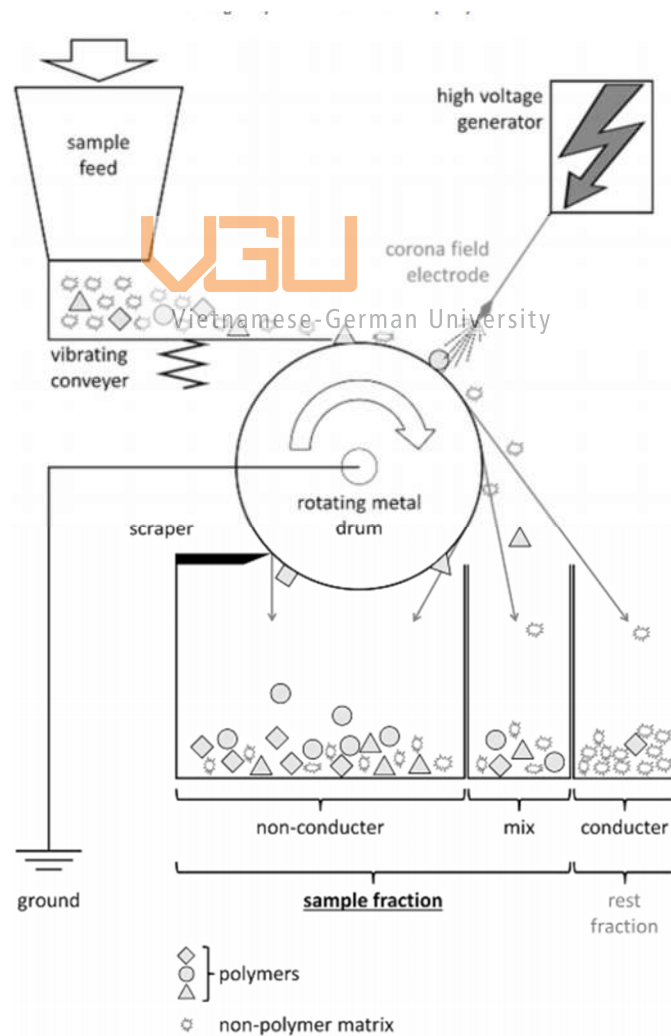


Figure 4.10: Microplastic Separation device /24/

The device makes use of the vibrating conveyor to transfer the mixture of microplastic and other sediments into the system. The mixture is then slowly scattered into the rotating metal drum. Here the mixture is exposed to an electrical field caused by a corona electrode, and then electrostatically charged based on the substance's properties. Because the drum is grounded, the particles discharge as soon as they leave the field, with the discharging speed differs depend on the material. The more highly conductive materials will discharge faster, and the less conductive ones will be slower. This combines with the rotational movement of the metal drum results in the separation of the particles as they are discarded into different collectors based on the speed of discharging. Therefore, the non-conductive material, such as common plastic, will be divided from other more conductive sediments. [34]

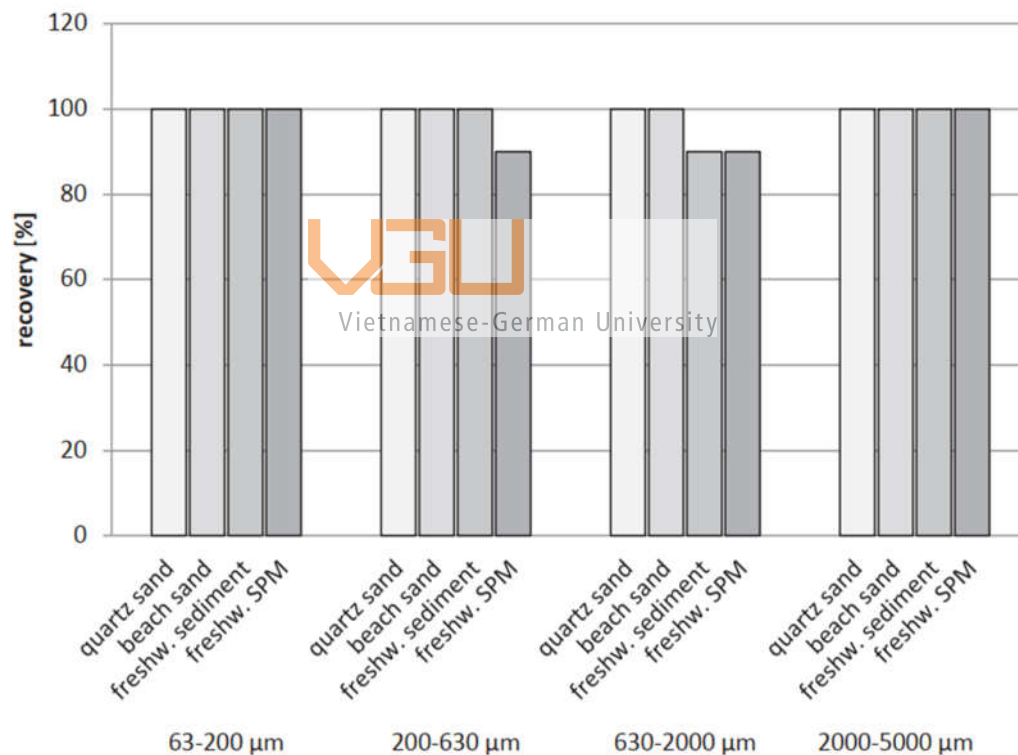


Figure 4.11: Electroseparation device results /24/

The results show that electroseparation is a promising method to extract microplastic from a large amount of other sediments. For sediments material, the mass reduction of almost 99% is reached. After the experiments, only 2.34 g of quartz sand remained in the sample, with 98.4% filtered out. For freshwater sediments, the final mass of 2.33 g was recovered, corresponding to a 98.4% reduction. The beach sand was reduced to 2g, with a reduction of 98.7%. The microplastic recovery

rate is also remarkable, with almost 100% of the microplastic sample was recovered. [34] While this result was from a relatively small sample size of microplastic, it is very impressive and therefore should be researched and experimented more for application in microplastic extraction. The results also show that the performance of this method is greatest in the case of quartz sand and beach sand, making it a notable choice for extracting microplastic from the beach.



4.2. Patents research on the topic of plastic beach cleaner

After the overview with the most important beach cleaners, the specifications of the beach cleaner will be compared with the current state of the art with the help from patent research.

The patent research carried out by the bachelor thesis will serve to fulfill several tasks. Firstly, it shows and examines to what extends the components and the methods in the products, are protected by the respective existing patents. In addition, it also provides both the qualitative and quantitative information about the subsequent patents' application. The patent research was carried out with the help of Google Patent, German Patent and Trademark Office (DPMA) and the World Intellectual Property Organization (WIPO).

The keywords using as the search terms are the following:

Beach

Cleaner

Plastic

Microplastic

Separation

Rake

Sifter

Screen

Vibrating

Electrostatic



Furthermore, the combinations of these keywords are used. Here is a short excerpt of the search results for different combinations of keywords:

Keywords	Results
Plastic/Cleaner	175
Beach/Cleaner	115
Rake/Cleaner	108
Plastic/Electrostatic/Separation	29
Plastic/Vibrating/Screen	19
Plastic/Sifter	10
Microplastic/Separation	6

Table 4.12: Patent search result

In total, more than 400 patent applications were reviewed. In the following, a small selection of entries was examined for relevance in more detail.



Patent application: Golftek LLC, Publication date: 28.02.2019

The patent US 020190060955 A1 relates to a system and device for cleaning impurities, garbage, rocks and etc. from sand. The device includes a spinning brush head that pushes garbage, rocks and sand through, which then the sand will drop through the screen. The system includes a remote power unit and a basket to contain the impurities. [35]

Patent application: Herman A. Lindau, Publication date: 29.09.2016

Patent US 020160281313 A1 describes a tool that cleans debris from sand when pulled on the sand by a user. The tool includes a sieve and a handle. Using manual force to collect debris and filter out the sand. There are two position: working position which cleans the debris when pulling on the sand and non-working position which contains the debris is in the basket when pulling on the sand. [36]

Patent application: WD Thompson Inc., Publication date: 28.05.2015

The present invention US 020150144362 A1 is directed toward a sea turtle friendly beach cleaning assembly designed for removal of seaweed and other debris from a sand beach. The device includes a number of S-shaped tines, combined with a drag bar and a wire basket. The S-shaped tines are pulled across the sand surface when the device functions, collecting unwanted substances and debris from the surface. The drag bar helps leave behind a smooth and clean surface free of ruts. The movement of the tines is substantially non-invasive for turtle nests, thereby eliminating possible damage. This combines with the clean sand surface helps the turtles and hatchlings hatch and move freely and healthily. [37]

Patent application: H. Barbers and Sons, Inc., Publication date: 24.03.2009

Patent US 20070119606 A1 shows a tine raking device includes a frame and a conveyor assembly supported on the frame. The conveyor belt has a define size of perforations to allow granules of sands to fall through and prevent passage therethrough of larger sized debris such as plastic waste. Extending outward from the conveyor belt is many rows of flexible tines. These tines are arranged across the width of the conveyor and each row are longitudinally spaced from adjacent rows along the conveyor belt such that a generally unimpeded path is defined along an outer surface of the conveyor belt for debris to flow between adjacent tines along an associated row. Also included in the assembly is the lower section which is a part of the conveyor and system of tines. The tines there contact and remove debris on the ground surface and in the sand being cleaned, before lifting debris away on the belt. [38]

Patent application: Kässbohrer Geländefahrzeug AG, Publication date: 26.01.2016

The patent DE 10 2016 203 381 B3 describes a screen belt system for a beach cleaning vehicle, including a flexible, sheet-type screen belt arrangement which is connected to at least two deflection shafts, with at least one being driven by a drive unit. On opposite longitudinal sides of the screen belt arrangement there are outer straps extending lengthwise. Extending over a working width of one screen belt fabric and being connected to the one screen belt fabric and attached to the outer straps on the face end side is a transversely extending reinforcing profiles. [39]

Patent application: Kohn Heiko, Publication date: 09.07.2015

Patent DE 10 2014 119 668 A1 relates to a tractor for collecting flotsam from the beach, is designed with 3 walls and a screen at the bottom to screen the sand from the debris. At the gate where there

is a front blade to enter into the sand and a rotating sweeping brush hydraulically driven to sweep the flotsam into the tractor. [40]

Patent application: Wuhan Polytechnic University, Publication date: 19.12.2017

The utility model of patent CN 206768722U provides the sandy beach cleaning cart belongs to the field of environment protection. The device includes frame, running gear, founding device, screening and dustbin. The founding device includes a digging and transfer mechanism for debris and sands. These will be sent to the screen where debris and sands will be filtered and the waste falls into the dustbin connected to the screen while sands go back to the ground. [41]

Patent application: Beijing Inst Technology, Publication date: 20.04.2016

The patent CN 105507202A discloses an unmanned electric amphibious cleaning vehicle. The vehicle comprises a frame, a rotary drum, brushes, a conveying belt, a controller, a lithium ion power battery, a garbage recycling device and a propeller. The frame is connected with the rotary drum through a spring, and the brushes are arranged on the upper portion of the rotary drum and connected with the conveying belt to collect debris. The conveying belt is then connected with the garbage recycling device to recycle plastic waste at the end. A monitoring camera is arranged on the frame for people from afar to control wirelessly with a remoted control device. The frame is connected with the propeller, a motor and the monitoring camera, and the frame is provided with the lithium ion power battery which provides power for the unmanned electric amphibious cleaning vehicle. The device has low manufacturing cost, is simple to use and environmentally friendly. The efficiency is high and the cleaning of both garbage on surface and buried in the beach is fast and thorough. [42]

Patent application: Research Center for Eco-Environmental Sciences, Publication date: 17.08.2018

The invention of the patent CN 108407145A relates to a device for separating microplastic through a static electricity technology. The device consists of a tank and a feeder arranged in the tank. A trough is placed below an outlet of the feeder, and the end of the trough is connected with the left side of a drive roller electrode. On the right side of the roller is a high voltage power supply, while the roller is grounded. A static field is thereafter formed between the drive roller electrode and the high-voltage compound electrode, and air is subjected to ionization to generate a large number of electrons. Below the drive roller electrode is a V-shaped hopper, with the lower portion of the V-

shaped hopper is connected with a separation electric field device for generating electric field force in the horizontal direction. Four tanks are sequentially arranged on one side wall of the separation electric field device from top to bottom to collect the plastic which is charged. [43]

Patent application: Marc Ward, Publication date: 03.02.2015

Patent US 8944253B2 describes a microplastic particle removal tool comprises an elongated mesh screen supported by a pair of poles. The mesh screen comprises a polymer coated, fine mesh that when sifts microplastic affected sand the microplastic is charged and stick to the screen while the sands fall down, therefore remove the microplastic particles during cleanup activities. The poles support the mesh screen while sifting and can be utilized to fold the mesh screen when not in use. During use, the screen is placed horizontally and mixture of microplastic and sand is deposited onto. Users pick up the handles and start sifting the sands and the sands fall down. Afterward remove the microplastic that is attracted to the screen. [44]



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5. Derivation of a Conceptual Approach for an Innovative Mobile Beach Cleaning System

5.1. Design process

The objective of this thesis is to design a concept for a beach cleaning system that is mobile and can efficiently clean both macroplastic and microplastic from the sandy beaches. This conceptual design is carried out in many steps, from abstracting the essential problem, establishing the function structure, searching for working mechanisms, combining them into working structure and evaluating. The result is the specification of a principal solution or the concept. [45]

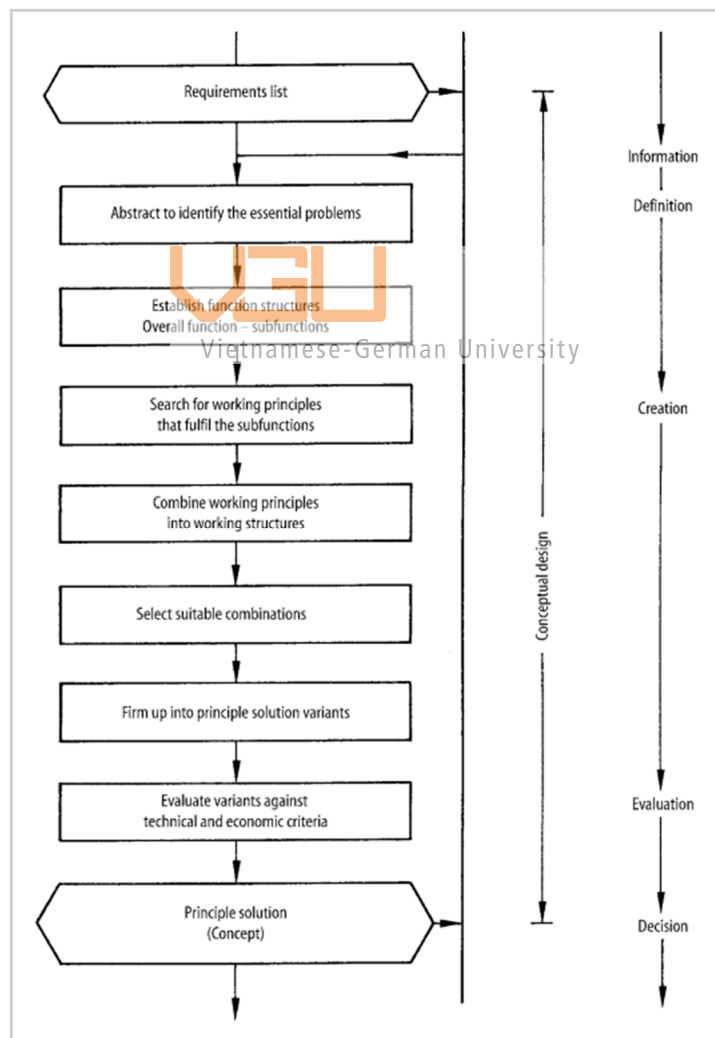


Figure 5.1: Conceptual design process /25/

5.1.1. Requirements list

The first step of developing a conceptual design is to setting up a requirements list (design specifications). The document is the result of task clarification, whose purpose is to collect information about the requirements that has to be fulfilled, and about the existing constraints and their importance. This document will serve as the basis for subsequent conceptual design phase. [45]

		Requirement list for mobile plastic beach cleaner	Page: 1
Changes	D W	Requirement	Responsible
		<ol style="list-style-type: none"> 1. Size: no larger than 3m x 2m x 2m 2. Moving using tractor 3. Reliable transferring of mixture 4. Weight of the whole machine 5. Using gasoline 6. Collect macroplastic 7. Collect microplastic 8. Return sands to the beach easily 9. Low fuel consumption 10. Simple operation 11. Easy to extract trashes 12. Low noise operation 13. High service life 14. Detachable and easy dismantle of parts for simple maintenance 15. Safety for nearby people 	

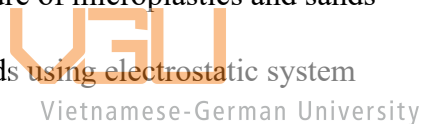
Table 5.2: Requirement list

5.1.2. Abstracting to identify the essential problems

The next step is the abstraction, which is used to ignore what is particular and incidental and emphasizing what is general and essential. This will lead straight into the heart of the problem, without prejudicing the choice of any existing or conventional solution. [45] Applying abstraction and systematic extension into the problem, which is to design a beach cleaning machine, the following problem formulations are possible, each representing each level of abstraction:

Step 1 & 2:

- _ Move using tractor
- _ Collect plastic and sands
- _ Control conveyor belt using hydraulic system
- _ Transfer them using conveyor belt
- _ Filter macroplastic from mixture of microplastics and sands
- _ Extract microplastic from sands using electrostatic system
- _ Return sands to the beach



Step 3:

- _ Mobile machine
- _ Collect mixture of microplastic and microplastic and sands
- _ Controllable transfer system
- _ Filter sands and return them to the beach

Step 4:

- _ Mobile system
- _ Collect plastic ranging from micro to macro
- _ Transfer mixture
- _ Filter mixture

Step 5:

_ A mobile system that collect various size of plastic from the beach and filter them from other sediments

5.1.3. Establishing function structures

Overall function

Because requirements determine the function that represents the overall relationship between inputs and outputs, after the heart of the problem has been put together, an overall function based on the flow of energy, materials and signal can be expressed. By the overall function we can have a clear and general at the whole system and at the crux of the problem. [45]

Here in the designing of the beach cleaner, we have a relatively simple overall function (figure 5.3) with the aim to gather mixture of various size of plastic and sands and filter them out into microplastic, microplastic and other sediments as output, using energy supplied by the tractor and the gasoline.

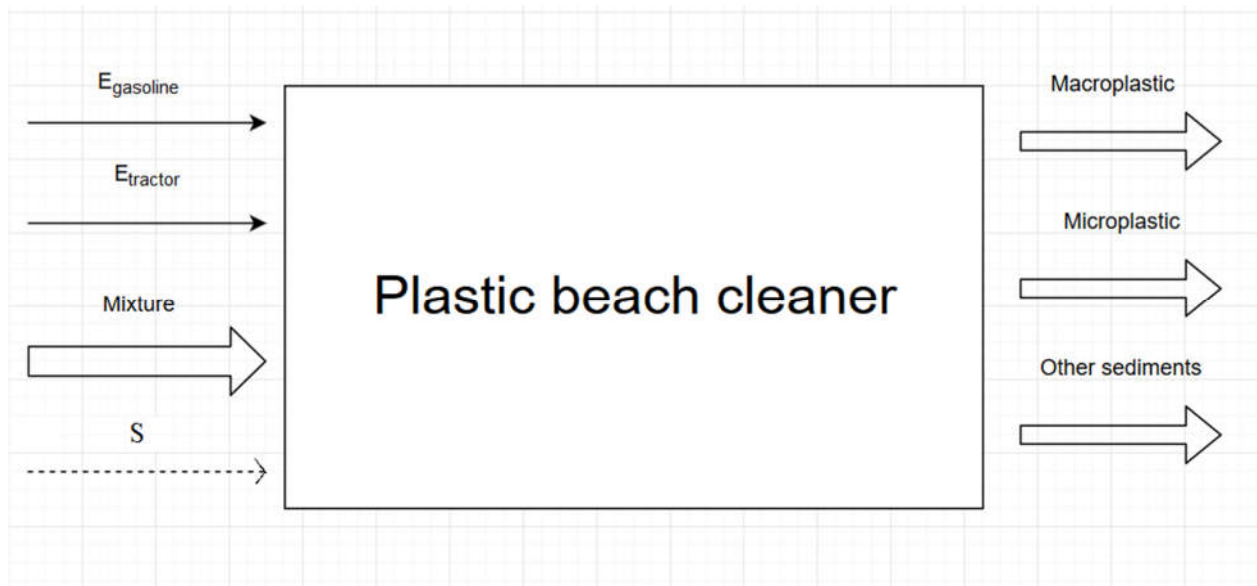


Figure 5.3: Overall function

Subfunctions and function structure

Overall function can be broken down into subfunctions for clearer look at the relationship between inputs and outputs. In doing this we can determine which subfunctions that can be subsequently studied for more solutions and also combine the subfunctions into a function structure, which gives a simple look at the working of the whole system. [45]

Figure 5.4 shows the subfunctions and the function structure of the beach cleaning machine. With inputs of both energy from gasoline and the signal to start the machine, the energy is converted into mechanical energy and booting the machine into working. The mechanical energy is then converted into force and motion that combines with the force from the tractor applying on the machine results in the collecting and transferring of the mixture of plastic and sands. The mixture is then filtered out the macroplastic by mechanical energy, and then filtered using electrical energy resulted in outputs of microplastic and other sediments, the latter of which is released into the beach.

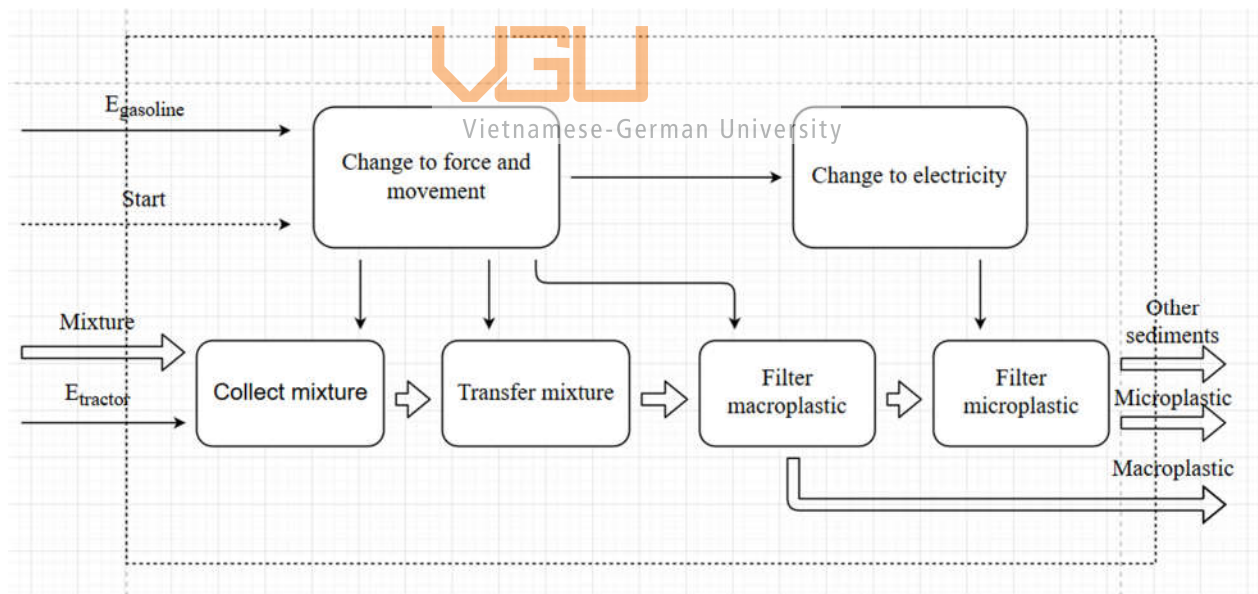


Figure 5.4: Function structure

5.1.4. Developing working structures

Searching for working principles

After developing the subfunctions, working principles will need to be found for the subfunctions. The working principles must reflect the physical effect for a given function and also the geometric and material characteristic. After that, these principles will combine to become the working structure and the working structure will eventually lead to the principle solution.

Firstly, we must search the working principle for each subfunction. This can be done by literature researches, analyzing the existing technical systems and intuitive methods. One other important tool is the classification scheme where the potential working principles are listed for various subfunctions. Some guidelines should be noted for the searching of working principles:

- _ The main subfunctions that determine principle of the overall solution would be the preference should no other principle have yet been discovered.
- _ Classifying criteria and associated parameters should be derived from the relationships between energy, material and signal flow.
- _ Working principles should be attained from firstly the physical effect, in particular from the type of energy. If physical effect has been determined, form design such as geometry, motions and materials is chosen next.
- _ Solutions that are found intuitively should be analyzed for key classifying criteria
- _ Important properties of the working principle should be noted.

[45]

For the subfunctions of the beach cleaner, table 5.5 shows the possible working principles of each subfunctions. For collecting the mixture of plastic and other sediments, often used is a scoop, when combined with the forward movement of the machine can collect the plastics and sands on the surface reliably. Other options are the rotating blade or the rake, and also the combination of all of them. Two possible selections for transferring the mixture are the conveyor belt and the vibrating sifter. For the conveyor belt the filter function can happen after the transferring while for the vibrating sifter the filter function occurs simultaneously with the transfer function.

	1	2	3	4
A Generate force/ motion	Hydraulic engine	Petrol engine		
B Collect mixture	Scoop	Rotating blade	Rake	
C Transfer mixture	Conveyor belt	Vibrating sifter		
D Generate electricity	Generator	Accumulator / Battery		
E Filter macroplastic	Rake	Vibrating sifter	Screen	
F Filter microplastic	Floatation	Electrostatic screening	Electrostatic separator	



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Table 5.5: Classification scheme

Combining working principles

After searching for the principles, it is necessary to combine them into a working structure to generate a solution that fulfills the overall function. The combination is based on the established function structure, which reflects the physical or logical possible connection between subfunctions. [45]

For the beach cleaner, three possible combinations are showed in table 5.6. The first variant employs a scoop combined with a vibrating sifter to collect and transfer the mixture. The vibration sifter also acts as the filter for macroplastic, which is then transferred from the mixture into the storage right after that. The remaining mixture comprised of microplastic and other sediments meet an electrostatic screener, at which the microplastic is stuck behind while the sands fall back into the ground. The second variant utilizes the rake to collect both macroplastic and microplastic, with

the priority being the macroplastic. After the macroplastic has been filtered out, the microplastic is then filtered using a floatation and pump system. The third variant uses both the scoop and rotating blade to collect mixture, and a conveyor belt to carry them. At the end there is a screen to filter out the microplastic, and the remaining mixture is fallen to an electrostatic system which will separate the microplastic and sands.

	1	2	3	
A Generate force/ motion	Hydraulic engine	Petrol engine		Variant 1
B Collect mixture	Scoop	Rotating blade	Rake	Variant 2
C Transfer mixture	Conveyor belt	Vibrating sifter		Variant 3
D Generate electricity	Generator	Accumulator / Battery		
E Filter <u>macroplastic</u>	Rake	Vibrating sifter	Screen	
F Filter microplastic	Floatation	Electrostatic screening	Electrostatic separator	

Table 5.6: Working principles and their combinations

Subsequently, a selection chart is constructed to illustrate the main criteria and to assess the variants for selection. The criteria are compatibility assured, fulfills demands of the requirement list, realizable in principle. Remarks on the variants are made to comment and explain on the idea. ()

	Compatibility assured	Fulfills demands of the requirement list	Realizable in principle	Remarks	Decision
V1	+	+	+	Simple and low fuel consumption Not very good microplastic filter	+
V2	+	-	-	Poor microplastic collection Floatation is not ideal for microplastic filter	-
V3	+	+	+	Bulky and complex High energy consumption	+

Table 5.7: Selection chart

A closer look at the first variant will show that this variant is a very simple and uncomplex concept. The main mechanism for collecting, transferring and filtering both macroplastic and microplastic is the vibrating screen, with two layers for macroplastic and microplastic. The vibrating motion serves as the main force to pick up mixture of plastic and sands and to transfer them to the basket. The vibrating motion also plays an important role in filtering the plastic from the sands. The first layer will filter the macroplastic, with the small particles falling down. The next layer is an electrostatic screen, which will attract the less conductive microplastic particles and other sediments will fall back to the sand. While the concept is simple and have low energy consumption, the reliability of collecting microplastic is not very high. However, it still fulfills the demands and therefore should be looked at for further development.

The second variant will use rake to pick up the mixture and transfer them to a system for filtering. The system utilizes the buoyancy method, because when using the right media, the plastic and other sediments can be separated into two parts: one floats and one sinks. However, rake is not a good method for microplastic collecting and the floatation system also has many flaws. Firstly, it will need a long time for two parts to separate, making it not good for a cleaner. In addition, using liquid

is hard and tricky, and it makes the collecting process of the separated plastic after cleaning the beach difficult.

The last variant uses both rotating blade and scoop to pick up the mixture and a conveyor belt to transfer them. This is a reliable method for collecting both macroplastic and microplastic. The electrostatic system is also quick and accurate in separating the microplastic and other sediments. However, this machine is hence more complex and energy-consuming. The size is also bigger and bulkier due to many parts and spaces needed.

5.1.5. Developing concept

Firming up into principle solution variants

Before the concept variants can be evaluated, they should be firmed up, for the principles are usually not concrete enough for a definitive concept. The most important properties should first be given a more concrete qualitative and also a rough quantitative definition. [45]

The draft of the two possible variants above for the beach cleaner is showed below for a more concrete look at the design of the concepts.

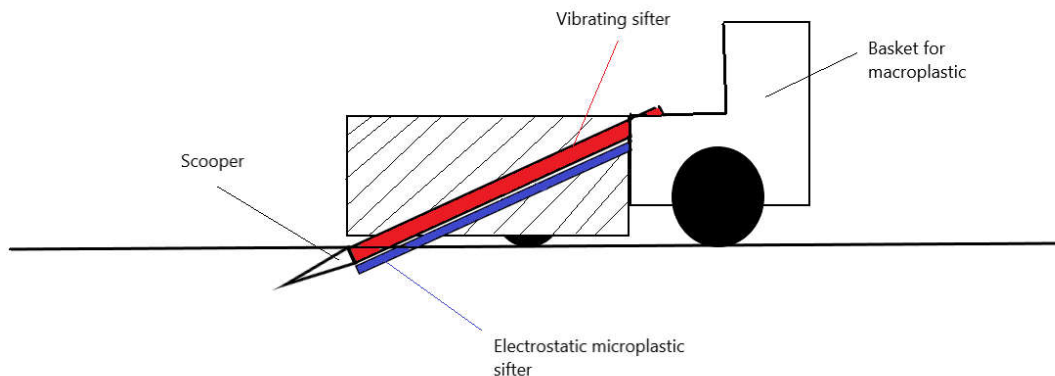


Figure 5.8: Draft of Variant 1

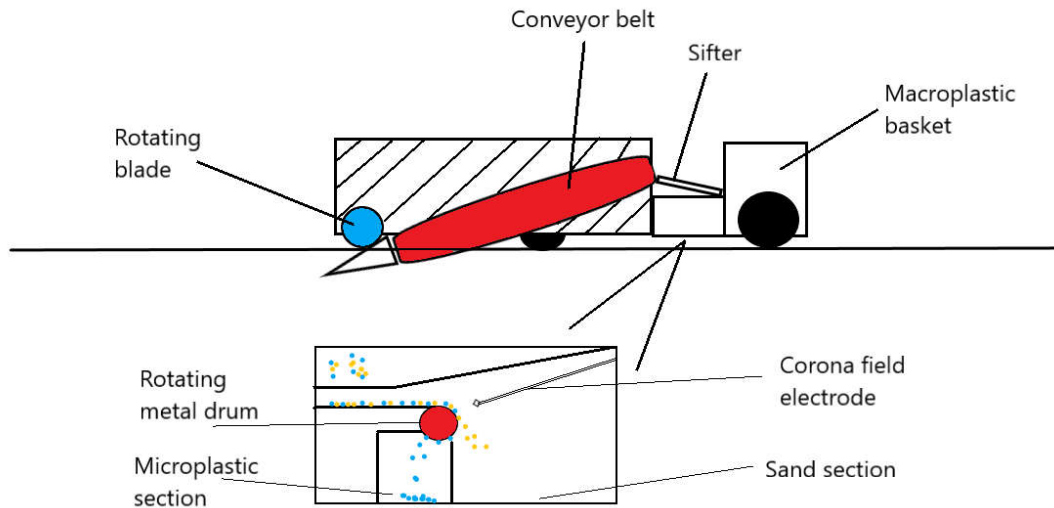


Figure 5.9: Draft of Variant 3

Evaluating Principle Solution Variants

After determining the principle solution variants, they must be evaluated for a clear look at their characteristic and for comparison and selection between the variants. The first step should be to identify the criteria for evaluation. Secondly, these criteria are weighted according to their importance to the system. Following is the addition of the parameters for clearer and easier grading and comparison. [45]

Based on the requirement list, the assessment of the variants in regard to their technical aspect is recorded and compared in the assessment table 5.10 below.

Evaluation Criteria			Parameters		Variant 1		Variant 3	
No.		Weight		Unit	Value	Weight	Value	Weight
1	Not too large	3	Size	m	4	12	3	9
2	Not too heavy	3	Weight	kg	4	12	3	9
3	Run slowly	2	Machine speed	m/s	3	6	4	8
4	Collect macroplastic	5	Macroplastic collecting efficiency	%	4	20	4	20
5	Collect microplastic	5	Microplastic collecting efficiency	%	2	10	4	20

6	Return sands to the beach easily	4	Sand returning ratio	-	4	16	3	12
7	Low fuel consumption	3	Fuel consumption	1	4	12	3	9
8	Simple operation	3	Complexity of usage	-	4	12	3	9
9	Easy to extract trashes	2	Easiness of extract	-	2	4	4	8
10	Low noise operation	1	Noise of operation	dB	4	4	3	3
11	High service life	1	Service life	year	2	2	3	3
12	Simple maintenance	1	Time and cost of maintenance	-	3	3	4	4
13	Safety for nearby people	4	Safety	-	4	16	4	16
						129		130

Table 5.10: Assessment table

Not too large: the machine is working where there may be many people, larger size will be more inconvenient and can potentially cause more damage when accident happens. Variant 3 with larger size will have lower score in this category.

Not too heavy: the machine is working on the sand. Heavy system can be harder to move and in addition become more dangerous for creatures living under the sand.

Run slowly: because the machine will work in a crowded environment, fast speed can lead to accidents for the people. Slow speed can also benefit the plastic collecting efficiency, as many methods cannot handle very fast speed. However, too slow is also a problem for efficiency and energy.

Collecting macroplastic: both machines are, in essence, using screen for macroplastic filtering. Therefore, the score will be the same for this category.

Collecting microplastic: efficiency of collecting microplastic. Variant 1 has low efficiency for collecting microplastic due to using of the electrostatic screen while variant 3 has better efficiency for separating microplastic and sands.

Return sands to the beach easily: the rate of sands returning to the beach.

Low fuel consumption: variant 1 with simpler structure consume less energy than variant 3 with many functions.

Simple operation: both are simple to use with only a few buttons. However, variant 3 with more functions is naturally more complex to use.

Easy to extract trashes: plastic waste for variant 3 are sorted into many compartments and therefore are easily to extract from the machine.

Low noise operation: loud noise will affect nearby people, especially at a crowded place like the beaches. Because of more machines comprised, variant 3 will have louder noise than variant 1, but not so much to potentially annoy people surround.

High service life: strong vibrating from variant 1 may cause it to have lower service life.

Simple maintenance: most of the components in variant 3 can be disjointed, making maintenance for broken parts more easily.

Safety for nearby people: both are relatively safe, but variant 3 with slower speed of transferring and also most of the vibrating are inside making it a bit safer.



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5.2. Description of the concept of plastic beach cleaner

The basic idea of the plastic beach cleaning machine is to combine both macroplastic collection technique with microplastic to make a convenient beach cleaner that can clean both macro- and microplastic simultaneously. This can be achieved by sequentially filter out macro- and microplastic. Hence, this means the application of another filter after macroplastic has been separated from the mixture of microplastic and other sediments.

The whole machine can be moved by using a tractor to pull. This makes the device easier for developing and constructing as the whole part about moving and controlling. In addition, it will lower the cost and make it easier to apply for many places.

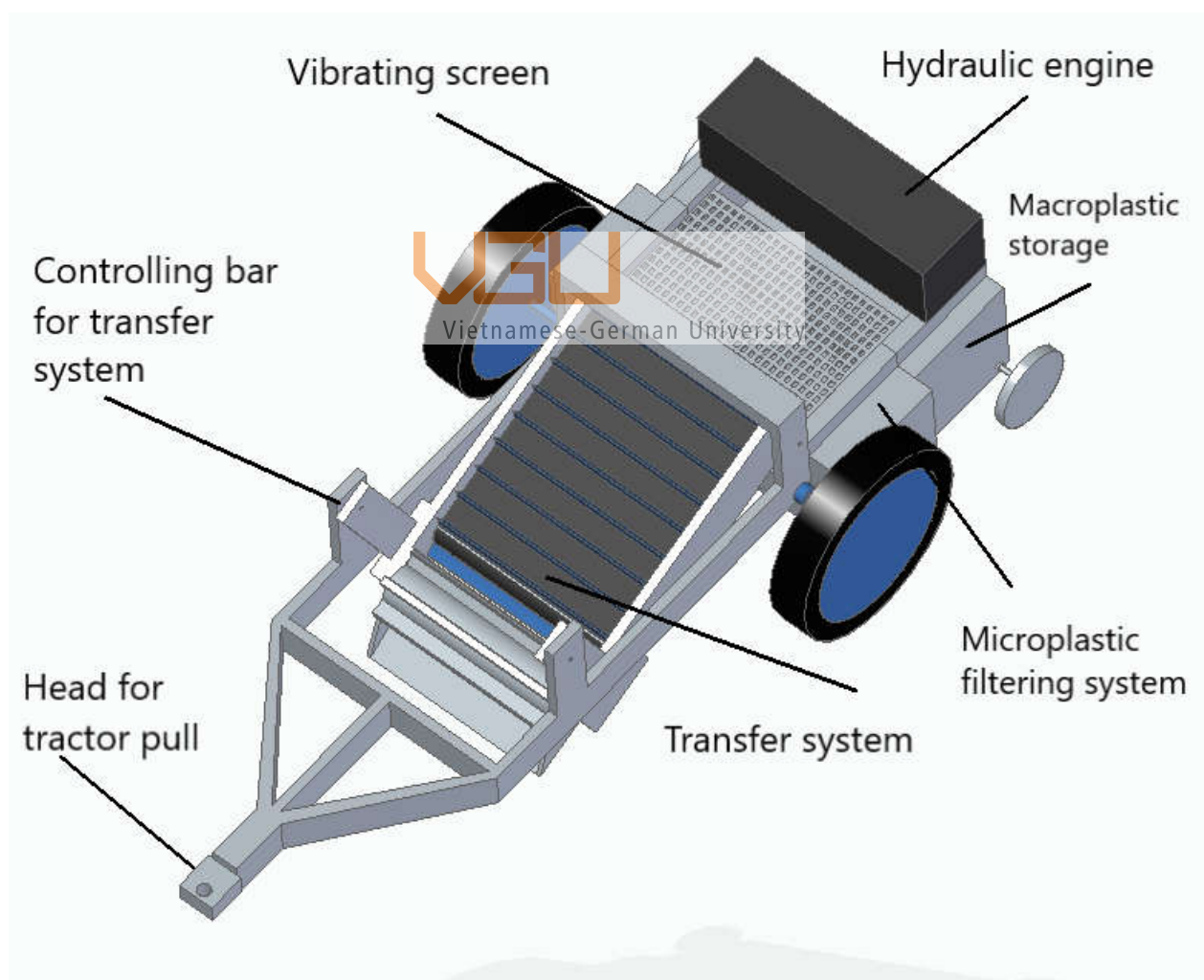


Figure 5.11: An overview of the full machine

5.2.1. Transferring section

The transferring section consists of the three parts: a scoop for digging into the sand, a rotating blade for picking up the mixture and a conveyor belt for transferring to the filter and storage section. The main functions of this section are to collect and transfer the mixture of plastic and sands to the next section.

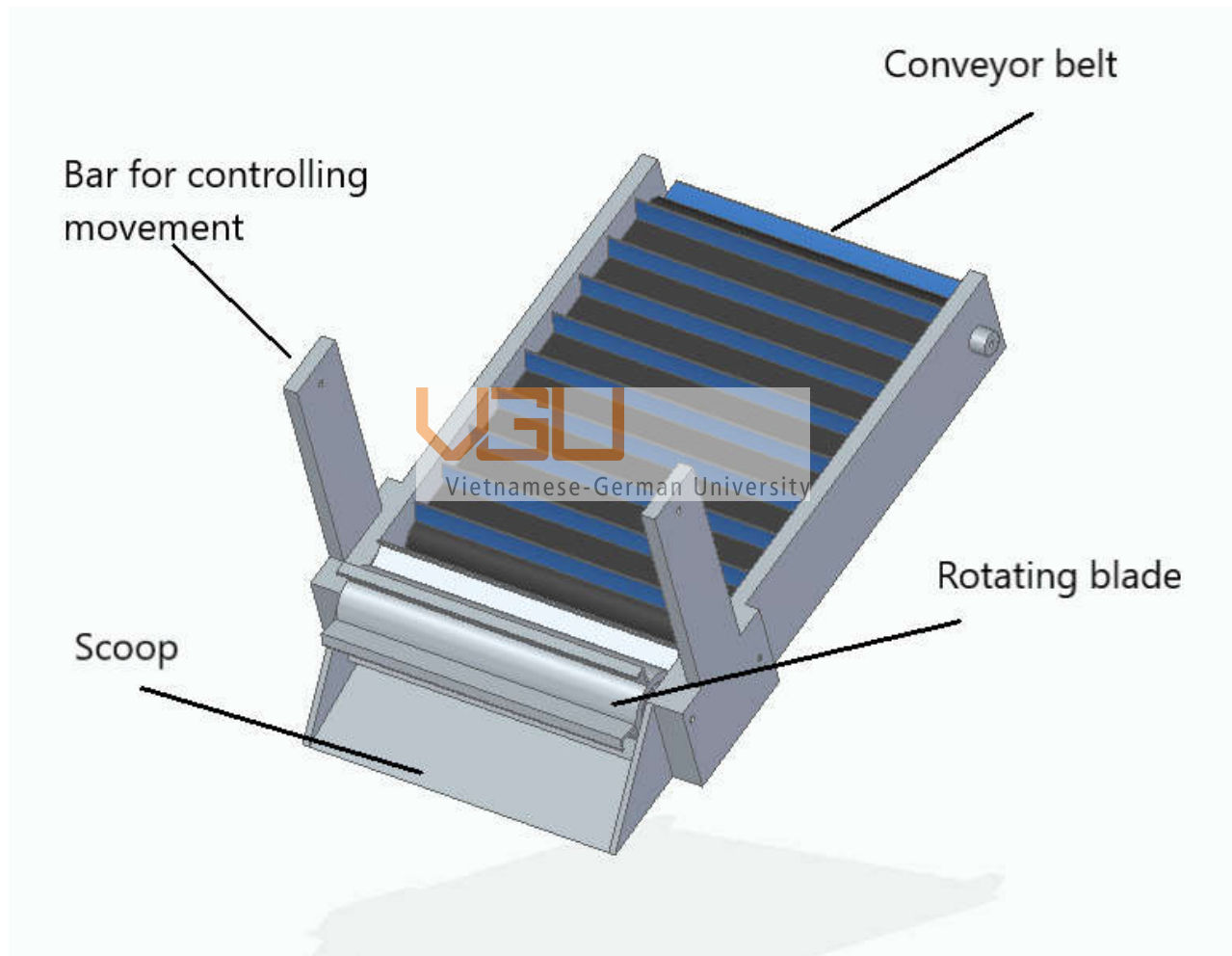


Figure 5.12: Transferring section

This section, including the blade and the conveyor belt, will be supplied energy from the hydraulic engine. The section can be controlled to move up and down corresponding to not working and working status. This can be done using a bar that connects to the main body of the machine and is

powered by the hydraulic engine. The rotating blade and conveyor belt can also be controlled, only work when the section is in working state.

When in working status, the scoop will sink into the sand, prepare for pick up mixture of plastic and sands. Combined with the forward movement of the whole machine, the mixture will be picked up by the rotating blade and carried to the conveyor belt.

The rotating blade is positioned near the scoop, and can collect mixture using rotating movement. Unlike other reels of blade or rake, the rotating blade is designed to have no space in the blade, to reliably pick up all macro-, microplastic and other sediments.

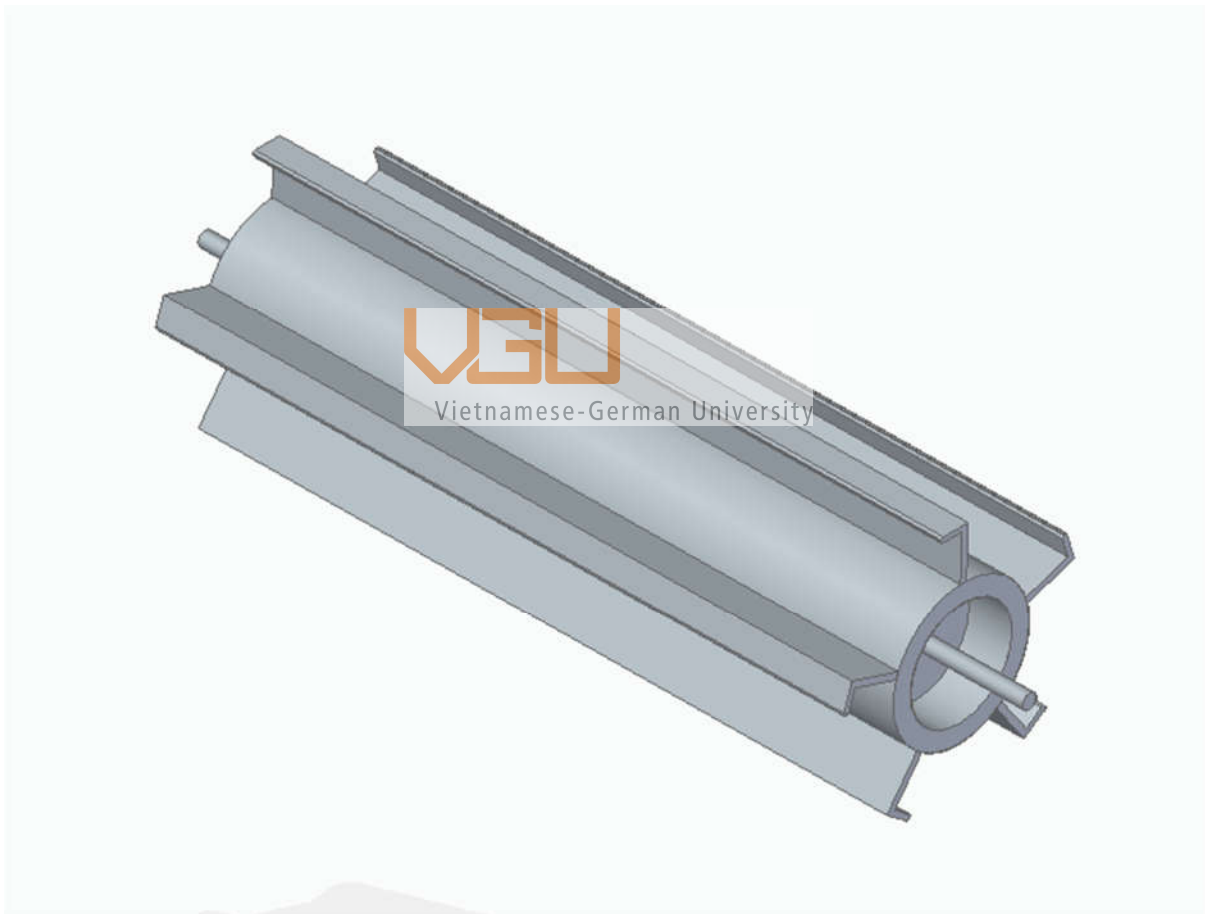


Figure 5.13: Rotating blade

The speed of the rotating blade should not be too fast, as too rapid speed cannot collect fully and cause damage to the sandy beach. However, the blade still causes some damage to the structure of

the sand as it picks up a lot of sand from the beaches. Future improvement should focus on the shape of the blades to collect more efficient and also cause less damage to the sandy ground.

The conveyor belt will then pick up the mixture from the blade and carry them to the next section. Similar to the rotating blade, the blades on the conveyor belt do not have space, for carrying both sand and microplastics. Here both macro- and microplastic are still mixed with other sediments to the next section. The speed should also not too fast as it can make the mixture fall off, decreasing the efficiency and amount of plastic collected.

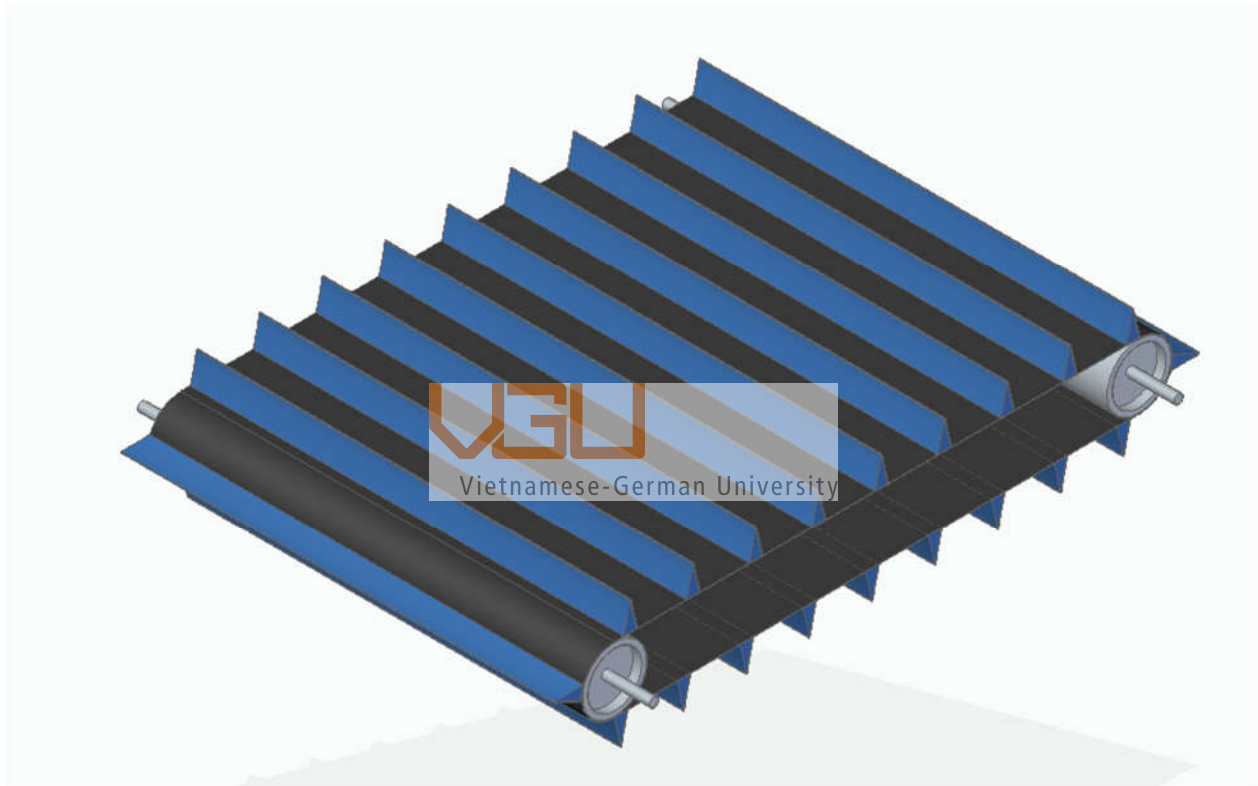


Figure 5.14: Conveyor belt

5.2.2. Filtering and storage section

After picking up and transferring the mixture, it is carried to the filter section, where macro- and microplastic will be separated from the sands. This section is structured as two boxes positioned next to each other, each box is the storage of macro- and microplastic. Firstly, the mixture will come to the microplastic box. Here there is a vibrating screen for filter and transfer macroplastic

to the next box, while microplastic and sands will fall into the former box. The screen should have mesh of above 5 mm for microplastic and sands to fall consistently. The vibration will help the mixture to fall consistently while carry the macroplastic to the next basket.

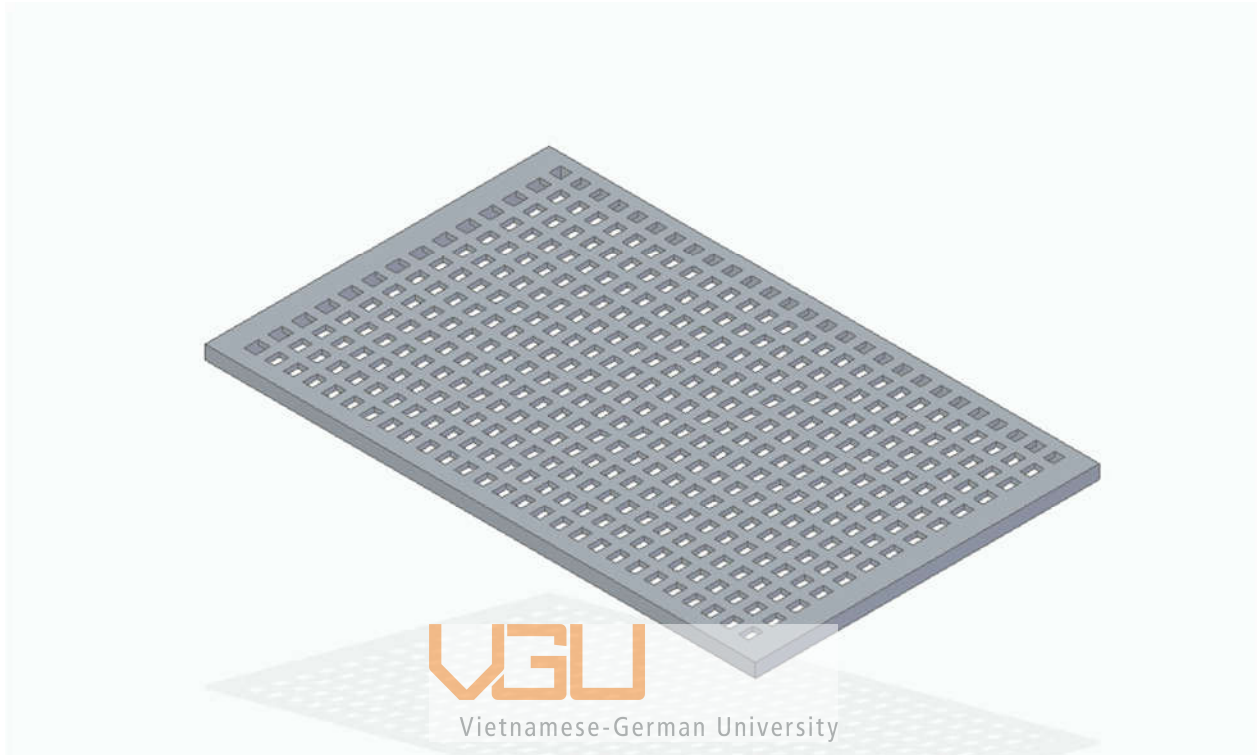


Figure 5.15: Vibrating screen

The macroplastic box is a simple basket that have large space for storing macroplastic waste. While it cannot raise to pour out the waste, a door can be installed to help retrieval of macroplastic waste easier from the machine. A moldboard should also be developed and attached to the end of the box for levelling the sand surface and leaving behind a smooth and cleaned beach surface. The whole box can also be detached out from the machine for possible repair or maintenance.

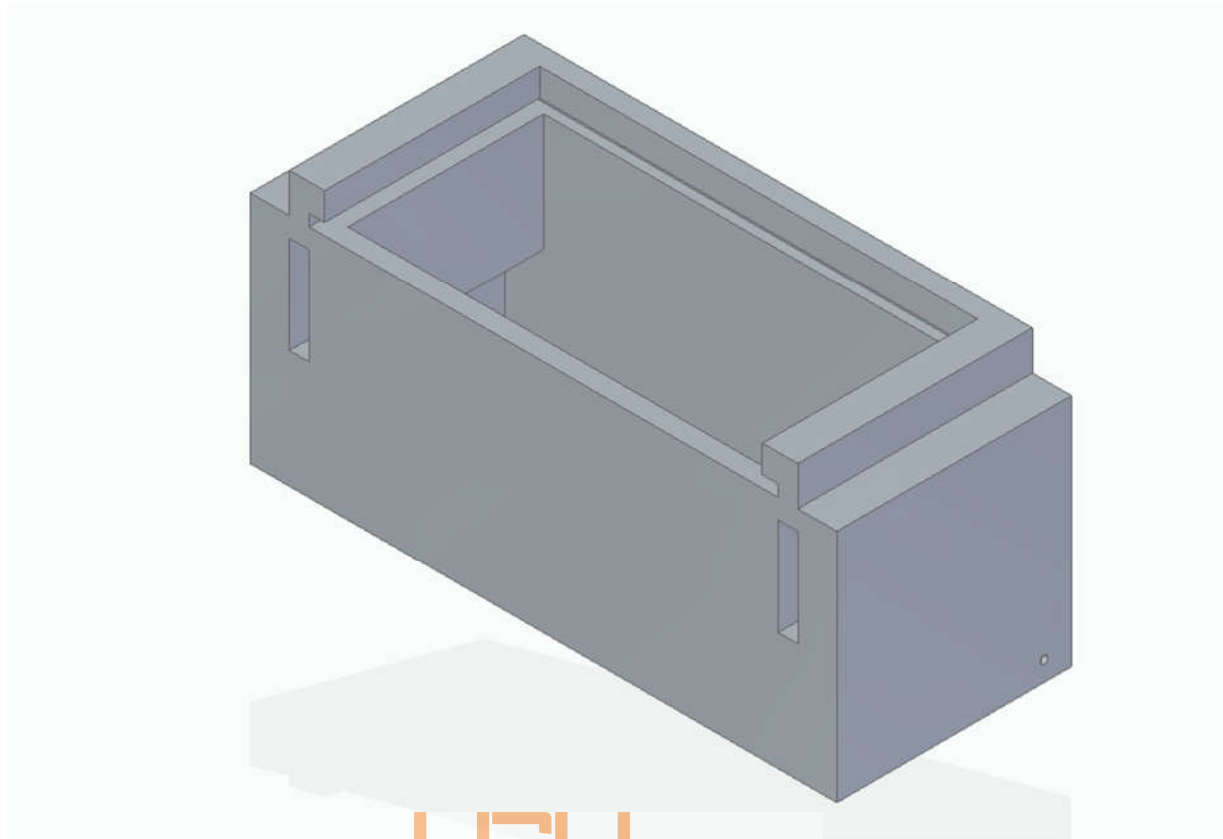


Figure 5.16: Macroplastic storage
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Meanwhile, the mixture of microplastic and sands is falling into the microplastic filter box. At the beginning there is a hopper for concentrate the mixture into one place and prevent any from falling out. The mixture will then fall and scatter into a vibrating conveyor, where it will be carried into the filtering section.

Firstly, the mixture will be carried to a rotating drum. Here there will be a voltage supplied electrode, while the roller is grounded. This will create an electrical field, which the particles will be exposed to and be electrostatically charged. This will attract the particles to the roller, keeping it from falling down to the ground. However, due to different electrostatic properties of plastic and sands particles, the statics will be discharged at different rate after they leave the field. Highly conductive material will discharge faster than low conductive material, making them fall out faster. This combines with the rotational movement of the drum makes the more conductive sand particles fall down first back into the ground, while the microplastic particles keep going and fall directly into the storage section or meet the scrapper and fall down. Hence, the mixture is separated into sands that fall back to the ground and microplastic particles in the storage.

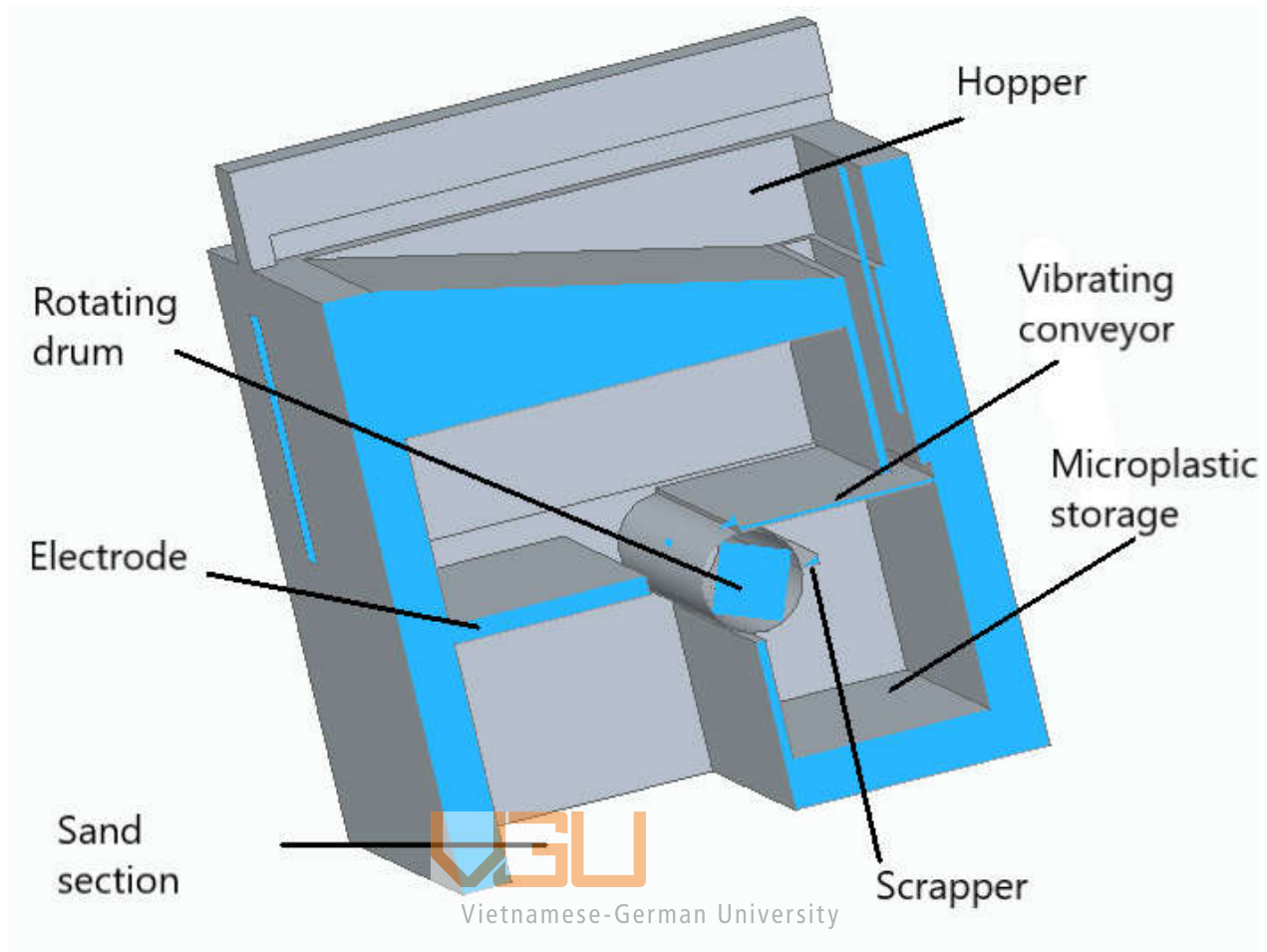


Figure 5.17: Microplastic filtering system

For future improvement, a door can be developed and attached into the storage section of microplastic for easier retrieval of microplastic waste. The speed of conveyor and rotating drum and the voltage should be calculated for accurate separation.

Powered all of the parts in the machine is the hydraulic engine, running using gasoline. The power and size of the engine should be calculated for optimized performance.

6. Conclusion

The plastic beach cleaner is a mobile system that can simultaneously clean both macroplastic and microplastic from the sandy beaches. It can be easily maneuvered by using a tractor, and has simple operation and is easy to maintenance. The main selling point is the inclusion of electrostatic technique to separate microplastic from other sediments from the beaches and collect them. As the beaches are one of the main sources of the generation of microplastics due to degradation from larger plastic pieces lying on the beaches, a way to retrieve them without large amount of effort is important for cleaning up the plastic waste in the marine environment and preventing more to enter.

With the rotating blade and conveyor, the machine can reliably collect both macroplastic and microplastic from the beaches. A vibrating screen will sort the mixture into the respective section for easy retrieval. The microplastic and other sediments will be separated, with the microplastics falls into the collector and the sands fall back to the beach. While the speed of operating is slow, the machine has the potential of cleaning both macroplastic and microplastic as once, saving a lot of efforts and manpower.



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In the future more development is need to optimize and increase the speed and efficiency of the machine. More adjustments can be made for improving the performance of the machine, lower energy-consumption and easier plastic retrieval.

Dimension, performance and strength calculation not performed in the context of this bachelor thesis is to be carried out in advance of the production of a prototype. Programs for modern finite element method can be included.

In conclusion, it should be said that the development of a beach cleaning machine that can collect both macroplastic and microplastic from the beaches is advisable due to the serious situation of plastic pollution in beaches around the world, especially in Vietnam and the potential in saving efforts and manpower for the activity. Whether the concept should also be implemented must be examined with further calculation and the construction of a prototype.

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Program used

- MS-Word 2016
- MS-Excel 2016
- Paint 3D
- Solid Edge ST9

