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RUHR-UNIVERSITÄT BOCHUM

**MechEng**  
Mechanical Engineering  
INTEGRATION



Vietnamese-German University

“Conceptualization of a mobile system for river water purification with a focus for application in Vietnam.”

BACHELOR THESIS

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Vietnamese-German University

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## **Task for Bachelor Thesis**

For Mr. An Phuoc Lam

Department of Engineering and Industrial Design

Matriculation number: 108018205502

**Topic:**       ” Conceptualization of a mobile system for river water purification with a focus for application in Vietnam.”

### **Explanation of the task:**

The CleanRiverSolutions Network is committed to the ecological improvement of terrestrial, fresh and ocean waters. The focus is not only on the regional market, which is Central Germany, but also on a global scale. Here in the network, both active and passive systems and methods for water purification are developed, manufactured and tested. The foundation for this project is the expertise and specialists from the “growth core Fluss-StromPlus”. These resources, with the addition of the network partners will be used for the innovative development of systems for the reduction of waste in water bodies. In the long term, the network aims to produce energy-producing turbo-machines with an ecological cleaning effect.

Within the framework of this bachelor thesis, a mobile and buoyant system for the river water purification is to be conceptualized. The focus is on the extraction of plastics in both the macroscopic and the microscopic range. These definitions should first be described and defined.

Of particular interest are the specific requirements for the corresponding technical process for the extraction of the different particulate orders of magnitude. The regional focus is set in Vietnam.

A far-reaching river system that flows through both urban and rural areas, with a heavy plastic load are the decisive criteria. An overview of the potentially to-be-cleaned rivers with their current pollution forms the entry. The subsequent comprehensive research on the current state-of-the-art in the field of mobile watercourse purification forms the basis of the conceptual

design. Through a qualitative comparison of the currently available plants / systems, they should be systematically analysed and subsequently evaluated. Identifiable weaknesses and determined potential for improvement serve as the basis for the conceptual solution approach. A summary of the results obtained, the assessment of possible sources of error and the potential connection options will complete the work.

**Task breakdown:**

1. Problem definition and development of a strategy to come to desired solution.
2. Research on typical types of debris to encounter.
3. Analysis and evaluation of potential application sites with regard to their specific characteristics and the working requirements of CleanRiverSolution.
4. Research on the state-of-the-art and related systems.
5. Comparison of application characteristics, between existing models the desired one.
6. A systematic approach to the design of CleanRiverSolution.
7. Summary and Conclusion.



## **Abstract**

This bachelor thesis aims to conceptualize a working boat that serves the sanitation of fresh water bodies in Vietnam. First, types of common found water debris are listed and defined, mainly plastics and vegetation.

Second, some common methods used to collect water debris are examined, including equipment used in Vietnam. In addition, some patents found with similar purpose are presented as ideas to improve functionality.

Third, a systematic approach to the conceptual design of the boat is adopted in order to find a solution. This includes setting up a requirement list, a function-structure and its sub-functions. Mechanisms to fulfil sub-functions are listed and discussed. After that, logical combinations are formed and evaluated to choose the concept that satisfies most requirements. The result is a model of catamaran with more attention paid to the arrangement on the deck of the device. These small changes are made to ensure a safe working environment for both the full-time workers as well as the occasionally working volunteers. The latter target is a popular case in Vietnam, since the country does not have enough sanitation workers and often organises clean-up events to both raise awareness and help reduce the workload. The goal is a concept of a small, inexpensive, safe and easy-to-use device for cleaning water bodies. Possible improvements are discussed.

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# 1 Introduction

Never before had environmental issues caught more attention than nowadays. We are in a position where cautious actions are needed to revert the damage done on our living space. Though climate changes are most obvious to see, it is pollution that is the real threat to many lives. Of particular interest is water pollution. Numerous reports have been made on a large amount of litter accumulating in the ocean. There are several so-called “ocean garbage patches” known to exist. They are large areas of the ocean where marine debris (litter, fishing gear and other types of debris) collects [1]. The question is: what types of debris are there? And what effects do they have? The answer for that is, at a global level, 83–87% of all marine litter are plastics [2]. Recently, research has been done on the effect of those on marine life. One of the most common problems found is that marine species often mistake litter for food. Besides any hygienic problems, plastic debris simply will not disappear. It takes a long time for plastics to decompose into inorganic matters known as microplastics, not something digestible unfortunately. The animals end up starving while feeling full. Animals are also easily entangled by plastics [2] [3]. If one were curious about the origin of all those vicious traps, then an indirect answer would be that “land-based sources are reported to be responsible for approximately 80% of marine litter” [2]. In fact, there are 5 countries that dump more plastics in the ocean than the rest of the planet, one of which is Vietnam. The main reason stated for plastic leakage was waste that has not been collected [4].

Above are the rationale of this work. To make it clearer, let us consider the route that plastics enter the environment. Plastic products all start from land-based factories. Failure of collection after use leads them to system of rivers before ends up at the ocean. Damages are done along the way, not merely at their destination, I believe. Not only the ecosystem for wildlife, but also the place we live in are under the effects. Vietnam with exemplary images will serve as a good study place for this work.

## 1.1 Motivation of the task

This section gives information on Vietnam, the country chosen as the field of study, and the reason why it is believe to be suitable. Officially named the Socialist Republic of Vietnam, it locates on the easternmost of the Indochina Peninsula. With an estimated 97 million (2018) and total area of

331 210 km<sup>2</sup> [5], the country can be considered one of the most populous country in the world. Vietnam shares its land borders with China to the north, with Laos and Cambodia to the west. It shares its maritime boundary with Thailand through the Gulf of Thailand, and the Philippines, Indonesia and Malaysia through the South China Sea. Its capital city, Hanoi, lies in the north, while Ho Chi Minh City in the south is the most crowded city of the country.

The most important characteristic that makes the country an ideal study target is its dense network of rivers and canals.

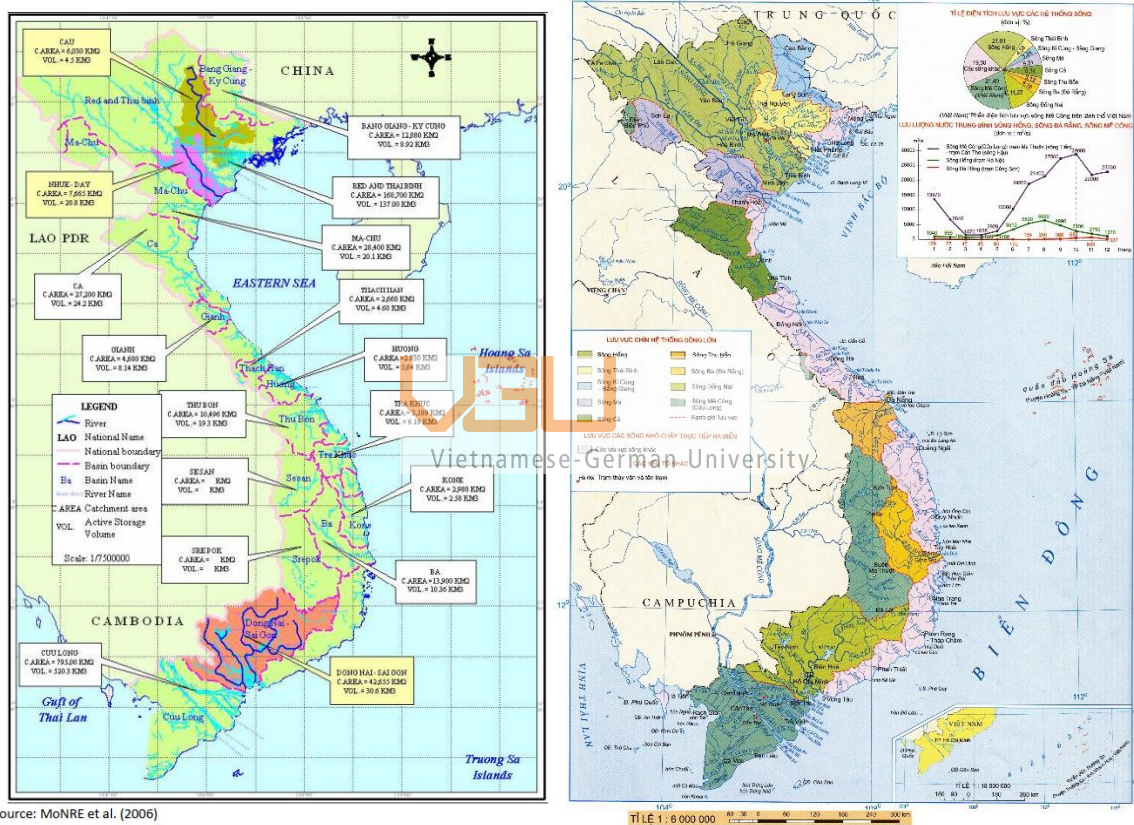


Figure 1: Major river basins in Vietnam (left); dense system of rivers and canals (right) [6]

In total, there are approximately 2360 perennial rivers longer than 10 km, and 14 basins larger than 2,500 km<sup>2</sup> (see Figure 1 - left). These account for 80 percent of the country area. Many of them are international water bodies. Major rivers have their headwaters located in other countries. For example, the Cuu Long (including the Tien and Hau rivers in Cuu Long Delta) originates from the Mekong River, Red (“sông Hồng” in Vietnamese) and Ca Rivers (in the north) starts from Chinese territory. Locally found are only middle and small-scale rivers, connecting cities together. [6]

The country climate is typically tropical and seasonal, which means high temperature is expected all year, but distinctive phenomena occur for each season. There usually are two, one prolonged dry season, and the other when it rains a lot. Furthermore, a combination of different terrains, such as lowland areas, vast deltas, tropical forests and mountainous regions, helps the variation depend not only on time but also on place. A related important consequence is an uneven distribution of annual precipitation. Nguyen Phuoc Ngoc Ha et al. (2013) reported that the national average precipitation fluctuates, between a high number of 4,000-5,000 mm and 500-600 mm in some places (which means it could be 10 times different depending on places). Except for these areas of particularly high or low precipitation, the average rainfall ranges from 1,400 mm to 2,400 mm per year. [6]

The challenge with the climate is that it poses different questions to solve. To be more specific, in dry season, the level of the water would be low, without significant flows, while during rainy seasons there might be flood.

This network of waterways allows better transportations between regions, provides water for domestic use to residential areas, for agricultural, fishing and other activities. However, it also associates with the urgency to control and maintain the quality of the sources, in case pollution occurs, a domino effect could take place and spread the problem at a speed faster than any measure can catch up with.

In this context, it is worth worrying. During recent years, an alarming increase of water pollution warnings emerge over the country. The deterioration of water quality has become an important issue in national and local water management. Waibel (2010) suggested that most of the water usage also lead to water pollution, either by uncontrolled discharge of wastewater and / or the utilisation of pesticides and other substances applied in agriculture, fishery and aquaculture production. Another contributor of pollution might be the water transport sector (navigation, construction and maintenance of ports, etc). Considering the fact that some major rivers of Vietnam are international, a number of sources of water pollution are presumably located across the borders. [7]

A news published by the Vietnamese Department of Water Resources Management stated that more than 2000 rivers were on the verge of becoming dead rivers due to the above mentioned

reasons [8]. However, least to be mentioned is floating debris (including plastics, vegetation, wood and all other types) although it is visibly damaging both urban landscape and the living environment. And it is to this critical yet not so well noted issue that I would like to dedicate my effort.

## **1.2 Objectives of the thesis**

The objectives of the thesis is: (1) Give a brief overview of Vietnam water bodies situations. (2) Give a brief overview of plastics and their existence in water bodies (3) Give an overview, analysis of products that currently exist on the market, their pros and cons. (4) Conceptualize a product that better suits working conditions in Vietnam.

I hope my work will serve firstly as a reference on the situation in Vietnam for people who feel the need and see the potentials for something to be done, and secondly as a proposal for some improvement concepts.



## **1.3 Organization of the thesis**

After this first part of introduction (Chapter 1), which gives an overview of water system in Vietnam, the next chapters reveal further aspects of the problem and form the main idea of the thesis.

Chapter 2 focuses on giving the background of plastics, their existence in environment, their impact on aquatic life and other types of floating debris could be encountered in the country.

Chapter 3 will give some examples of rivers in Vietnam that are polluted with waste and can serve as testing fields. Those will lead to some parameters for the design of the CleanRiverSolution.

Chapter 4 discusses state-of-the-art products and technologies. An analysis of the products/designs is given.

Chapter 5 compares the characteristics of existing products/design (including methods currently used in Vietnam) with the desired model, which supposed to fulfil the requirement of working conditions in Vietnam.

Chapter 6 gives the conceptual design process of the CleanRiverSolution.

Chapter 7 discussed the concept, its pros and cons, room for improvement as well as further projects that could continue from here.

Finally, references that were used for the writing of this bachelor thesis are to be listed.

## **2. Overview of debris types found in river**

Floating debris in freshwater bodies can be encountered in various types and ranging sizes. With a focus in Vietnam region, this chapter aims to identify types of debris that are often found in the country. These are input targets of the desired working model to be developed later. The initial goal of the CleanRiverSolution Project is to clean up plastic debris in water bodies, hence a lengthy section is dedicated to plastics – explaining definitions of macro- and micro-plastics, their life-cycle and how they get into the environment.

During my research for the topic, it came up to me that plastics are not the only type of debris that sanitation workers have to deal with. I did try to find exact compositions of freshwater debris across Vietnam, but little was found, at least according to my knowledge. One research carried out by Kieu Le et al. (2016), suggested that in the canals of Ho Chi Minh City, floating debris includes mainly vegetal, plastic and a small percent of others. Gasperi et al. (2014), with their study field though not in Vietnam but on the Seine River in France, indicate the same types of floating debris be found there. The report also suggested the reason why research had been done on the submerged debris, but not considered floating plastic debris, claiming it is mainly due to “methodological choice, sampling difficulties and/or the plastic size category being targeted”. Low abundance and random spatial distribution due to flows are reasons for inherent sampling difficulties. It is in fact difficult to perform any floating debris assessment. [9] [10]

I therefore assume it would be more practical to consider possibly encountered types of debris instead of just focusing on plastics as my initial intention. This chapter is then divided into plastic, vegetal and other types of debris accordingly.



## 2.1 Overview of plastics

Plastics was first introduced back in the 1800s, when there was a breakthrough in the rubber technology – the discovery by Charles Goodyear that the rubber elasticity and strength could be improved using a process called vulcanization. Throughout the 1800s, numerous attempts were made to produce synthetic polymers, yet the results were usually not desirable. It was until the 20<sup>th</sup> century that synthetic polymers saw its strong development with many types enjoyed mass production and use. [11] From then, plastic materials have become more and more involved in everyday life. Application of them can be seen in packaging, sports, clothing, engineering and other industries. They appear in almost every area, everywhere on this planet. The reason for that is simple: they possess undeniable advantages over other materials, even though they do come with certain drawbacks.

The aim of this chapter is to give an overview of plastics as a material, by describing and defining plastics, types, their characteristics, leading to their advantages and disadvantages. Subsequent section in the chapter discusses the environmental effect of plastics.



### 2.1.1 Definition

In order to understand plastics, we must first introduce the definition of polymeric materials, or **polymers**, which are macromolecules synthesized from monomers by a “polymerization” process. The process explains why monomers are also called “repeated units” - the unit that makes up the long molecules.

Our target subject, **plastics**, is one in many types of polymeric materials, often classified according to their end use. Other types that belong in the group of polymeric materials include elastomers (or rubbers), coatings, fibers, adhesives, foams and films. But none of them can be compared with the plastic classification in terms of popularity. Plastics are defined as “materials that have some structural rigidity under load and are used in general-purpose applications”. They cover any degree of crystallinity, all molecular structures and configurations (linear, branched, isotactic, etc.). Nevertheless, to be considered plastics, linear or branched polymers must be used below their glass transition temperatures (if amorphous) or below their melting temperatures (if semi-crystalline), or must be cross-linked enough to maintain their shape.

Plastic materials are usually subclassified into either **thermoplastic** or **thermosetting**, with regard to their behaviour at high temperatures. Thermoplastic polymers have linear and branched structures; they soften when heated and harden when cooled. This process is reversible and repeatable. But when the temperature gets too high, then degradation occurs. The consequence is that thermoplastics can be melted for reuse, which makes them really widely used. Some familiar examples of thermoplastics are: polyethylene, polystyrene, poly (ethylene terephthalate), and poly(vinyl chloride). In contrast, thermosetting polymers, with cross-linked and network structures, once hardened, they will not soften upon heating. Raising temperature further will only lead to degradation of the materials. These polymers are generally harder and stronger than thermoplastics and are less sensitive to changes in temperature and humidity. Some examples include: vulcanized rubbers, epoxies, and phenolics and some polyester resins. [12]

In addition, to have desired properties, they are often processed with different chemical additives. This means that the structure and performance of plastic materials depends on the type and quantity of additives they are compounded. As a consequence, they have a wide variety of combinations of properties [11]. Each plastic has very distinct characteristics, but most have some general attributes. Plastics can be very resistant to chemicals. They can be both thermal and electrical insulators, generally very light in weight with varying degrees of strength and can be processed in various ways to serve different purposes.

All types of plastic products are classified within the plastic industry as being either a **durable** or **non-durable** plastic good. These classifications are used to refer to a product's expected life. Products with a useful life of three years or more are referred to as durables. They include appliances, furniture, consumer electronics, automobiles, and building and construction materials. Products with a useful life of less than three years are generally referred to as non-durables. Common applications include packaging, trash bags, cups, eating utensils, sporting and recreational equipment, toys, medical devices and disposable diapers. [13]

The tables below include some familiar plastics, their repeated units, trade names, characteristics and typical applications.

Table 1: Familiar plastics and their repeated units [12].

Polymers	Monomers
polyethylene terephthalate (PET) $(C_{10}H_8O_4)_n$	Ethylene terephthalate $C_{10}H_8O_4$
Poly Ethylene $(C_2H_4)_n$	Ethylene $C_2H_4$
Poly Vinyl Chloride (PVC) $(C_2H_3Cl)_n$	Vinyl chloride $C_2H_3Cl$
Poly Propylene (PP) $(C_3H_6)_n$	Propylene $C_3H_6$
Polystyrene (PS) $(C_8H_8)_n$	Styrene $C_8H_8$

Table 2: Trade Names, Characteristics, and Typical Applications for a Number of Plastic Materials (only some). [12]

Material type	Trade name	Major application/Characteristics	Typical applications
polyethylene terephthalate (PET) or PETE)	Celanar Dacron Eastapak Hylar ...	One of the toughest of plastic films; excellent fatigue and tear strength, resistance to acids, humidity, greases, oil, solvents	Magnetic recording tapes, clothing, automotive tire cords, beverage containers
polyethylene (PE)	Alathon Alkathene Fortiflex ...	Chemically resistant, electrically insulating; tough, relatively low coefficient of friction; low strength, poor resistance to weathering	Flexible bottles, toys, tumblers, battery parts, ice trays, film wrapping materials
polyvinylchloride (PVC)	Darvic Exon Geon Pliovic ...	Good low-cost, general-purpose materials; ordinarily rigid, but may be made flexible with plasticizers; often copolymerized; susceptible to heat distortion	Floor coverings, pipe, electrical wire insulation, garden hose, phonograph records

Polypropylene (PP)	Herculon Meraklon Moplen ...	Resistant to heat distortion; excellent electrical properties, fatigue strength; chemically inert; relatively inexpensive; poor resistance to UV light	Sterilizable bottles, packaging film, TV cabinets, luggage
Polystyrene (PS)	Carinex Dylene Hostyren	Excellent electrical properties, optical clarity; good thermal and dimensional stability; relatively inexpensive	Wall tile, battery cases, toys, indoor lightning panels, appliance housings

Table 3: A selective list of additive compounds used to make plastics fit for purpose. [11]

Additive compounds	Function
Plasticisers	Renders the material pliable
Flame retardants	Reduces flammability
Cross-linking additives	Links together polymer chains
Antioxidants and other stabilisers	Increases the durability of plastics by slowing down the rate at which oxygen, heat, and light degrade the material
Sensitisers (e.g. pro-oxidant transition metal complexes)	Used to give accelerated degradation properties
Surfactants	Used to modify surface properties to allow emulsion of normally incompatible substances
Inorganic fillers	Used to reinforce the material to improve impact resistance
Pigments	For colour

Plastics can also be subclassified according to their size. The term ‘**macroplastic**’ is used unanimously to imply that the diameter of the particles is >5 mm. The term ‘**microplastics**’ commonly refers to plastic particles whose longest diameter is <5 mm and is the definition used by most authors. The **nanoplastics** (NPs) are usually defined as plastic particles which measure less than 100 nm [14]. However, it has been suggested that the term ‘microplastics’ be redefined as items <1 mm to include only particles in the micrometer size range, and the term ‘mesoplastic’ introduced to account for items between 1 and 2,500 mm. Lambert et al. described:

Categories	Size
Macroplastics	> 5mm

Mesoplastics	1mm << 5mm
Microplastics	0.1 $\mu\text{m}$ << 1mm
Nanoplastics	< 0.1 $\mu\text{m}$

Up to now, the upper limit of 5 mm is generally accepted because this size is able to include a range of small particles that can be readily ingested by organisms.

Microplastics (MP) can be distinguished between **primary** and **secondary** MPs based on their origins. Primary MPs are manufactured as such and are used either as resin pellets to produce larger items or directly in cosmetic products such as facial scrubs and toothpastes or in abrasive blasting (e.g. to remove lacquers). On the other hand, secondary MPs are formed from the disintegration of larger plastic debris. [11]

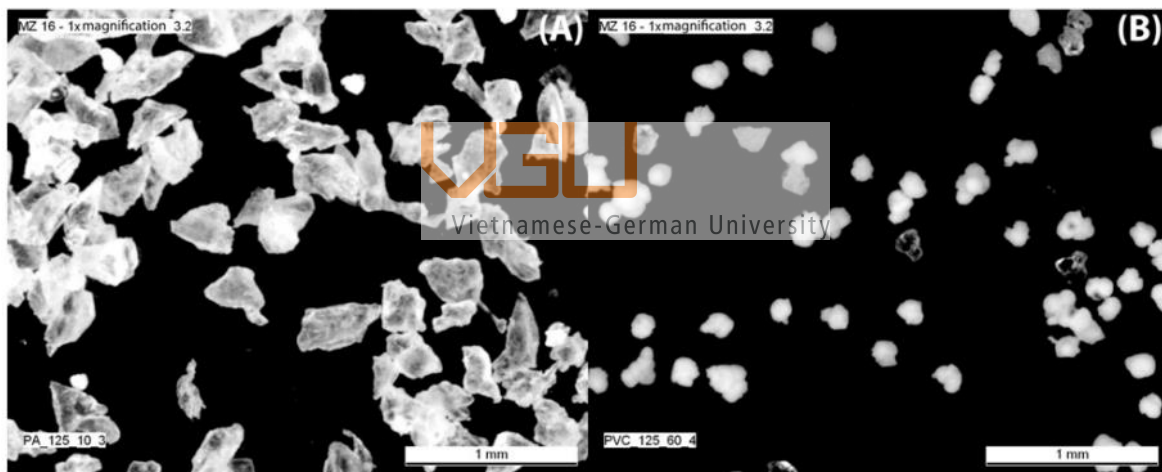


Figure 2: Particles of polyamide (A) and polyvinyl chloride (B) used for the experiments. The PA grains have very angular shapes, whereas the PVC grains are more rounded. Observation: Leica M216 binocular magnifier,  $\times 3.2$ ; IM500 software. [15]

Several studies have reported the presence of MP in freshwater systems, including river beaches, surface waters and sediments of rivers, lakes and reservoirs all over the world [11].

### 2.1.3 Plastics life cycle

It is necessary to understand the route which plastics enter the environment in order to have better ideas on when intervention needs to be made. This section therefore aims to clarify the life-cycle of a plastic product, from raw materials, to products and then disposal or recycling.

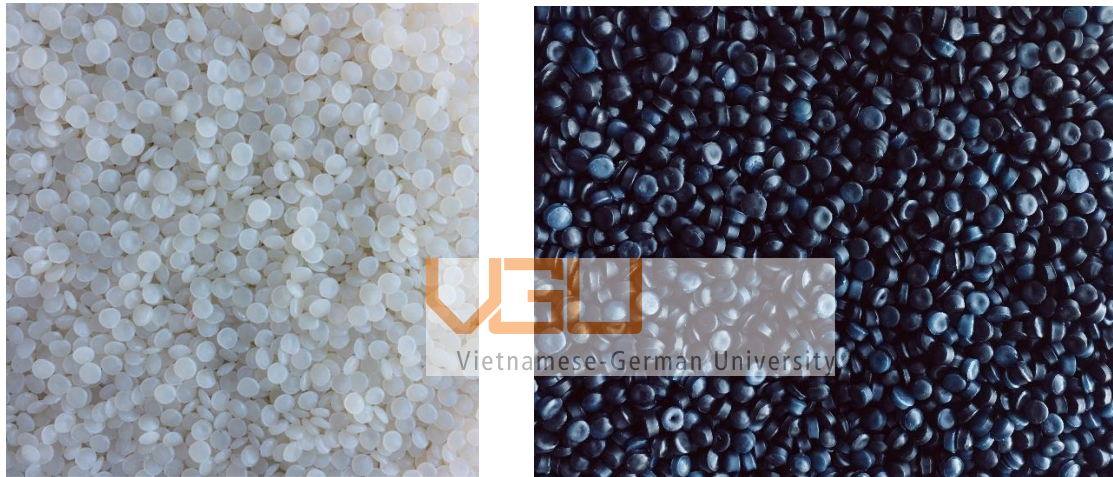
First, raw materials used to manufacture plastics are mainly oil and natural gas (or crude oil, a form of unrefined petroleum product). They are treated in a "cracking process" in order to convert their components into hydrocarbon monomers such as ethylene and propylene. Further processing leads to a diversity of monomers, such as styrene, vinyl chloride, ethylene glycol, terephthalic acid and many others.

The next step in the life-cycle is called "polymerization". In this process, monomers are chemically bonded into long chains to form a polymer backbone. A wide range of properties and characteristics can be achieved using different combinations of monomers and/or by adding more components. Polymers/plastics when first synthesized are often in the form of pellets. This allows the ease of transportation and later production of plastics products. These pellets are packed and transferred to factories where they will be melted and further treated with different additives and formed into shapes. Some pellets may be of the size of microplastics. During transportation, spills may happen, leading to microplastics entered the environment (primary microplastics).

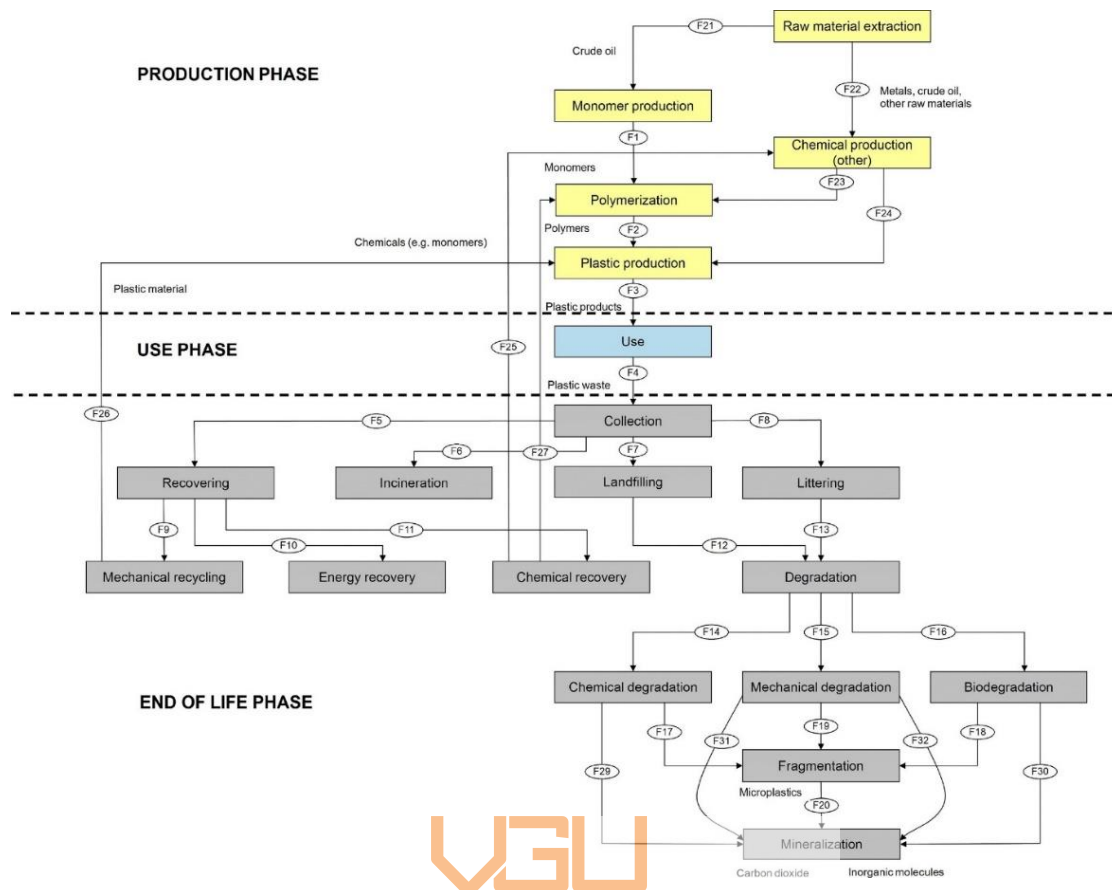
Plastic products are then introduced into the market, entering their use phase. The length of this phase depends on types of plastics, their usage and performing conditions. Once these products reach their end, signs of quality deterioration occur – losing colours, plastic properties or breakage. This is when they are dumped and must be collected before experiencing their not-so-well-known phase of their life – recovery/disposal.

The 4 main routes in this final phase are recovering, incineration, landfilling and littering. **Recovering**, or recycling, involves process to re-use the products, thus making full use of the materials and saving energy in comparison with producing new products. However, in some cases, when recycling is not that cost-effective, then the products will be **incinerated** to create energy. These are so-called waste-to-energy process. Debates are still on-going whether incineration is good to perform. **Landfills** have been the most common means of waste disposal due to their simplicity and cost efficiency. In the old days, waste is simply dumped into piles or thrown into

pits. But lately, landfills must satisfy certain conditions. They often contains technology to ensure that waste decompositions are dealt with thoroughly and thus will have little effect on the environment. The problems with landfilling have always been its effect on neighboring areas and land consumption, especially nowadays land becomes constantly in high demand. **Littering** is the choice that cost least. Waste is dumped directly into the environment, on land, in rivers or ocean. This economical advantage yet comes hand-in-hand with environmental damage, since the plastics will undergo degradation into harmful components for wildlife. These will be discussed in next section.



*Figure 3: Plastic pellets [16]*



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Figure 4: The life cycle of plastic products (excluding energy input and emissions) created in STAN (subSTANCE flow ANalysis) Software. [17]. “F” stands for Flow and the number shown next to corresponds to the particular flow series (an automatic procedure incorporated in STAN))

## 2.1.4 Impact on aquatic life

Up to now, a large number of research have been done to clarify the effect of plastics on the ecosystem. An increasing number of studies in the last years focussing primarily on marine biota. Meanwhile, the effects of MPs on freshwater organisms are catching less attention.

Overall, we know that a large number of organisms are exposed to these particles. This exposure may cause a variety of effects and threaten individuals of many different species, the ecosystems they live in and, ultimately, humans. But what exact effects, under what circumstances, are still uncertain. To be specific, results suggest a knowledge gap on the effects that different types of plastics have on different types of species. Often, the studies were carried out using one particular type of MPs, with high concentration, to test on a particular object, in quite a short amount of time. Besides, there are restrictions in the done work. It is not known how the mixture between different



size groups and material types will interact with biota. The synergy of chronic exposure at different levels of the biological communities has also not been studied.

For example, PE MPs were used on other organisms beyond fish; PS MPs are used on all groups of organisms except fish and small crustaceans. Polyethylene and PS MPs are clearly the most studied type of polymers, although others, namely PP, PES and PA, may pose the same threat to aquatic life. And while spherical particles are most commonly used in laboratory studies, fibres and fragments are the most common types of shapes detected in organisms collected from field samples and the common size of these particles varies between 800 and 1600  $\mu\text{m}$ . [18]

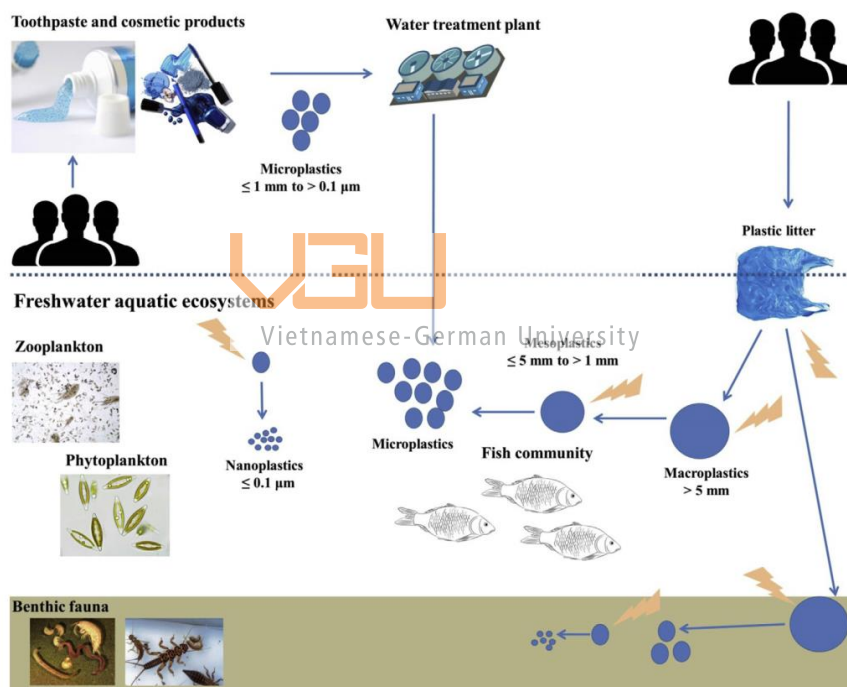


Figure 5: Some of the major ways of the contamination with micro and nanoplastics of the freshwater ecosystems. [14]

Figure 5 demonstrates major routes from which plastics enter the ecosystem. MPs are fragmented eventually to NPs. Based on the published results, plastic particles present in environmental matrices, such as surface and column water and/or sediments, can originate from primary and secondary sources, been either directly introduced through sewage discharge/storm outlets/tributaries (e.g. PE and PP microbeads from cosmetic products and airblast cleaning and/or

artificial fibers from washing of synthetic textiles) or derived from the breakdown of larger plastics which may originate from numerous and varied sources (Fig. 2). In fact, numerous studies assume that the plastic debris found in the fresh water systems originate from land-based sources, and the rivers and urban tributaries are the major transport pathways of MP. In addition, the wind and currents have an important role in the distribution of plastic debris in the freshwater environment. In contrast to non-buoyant materials that are transported along the tributary riverbed, the buoyant plastics are transported on surface waters. MP in the water samples mainly were in sheet and fiber shapes, while in sediment samples the plastic debris were more diverse. A large number of published works have shown an increase of MP concentration in the vicinity of cities, tourism sites, industrial areas and sewage treatment plants, PE, PP and PS being the most abundant MP types. Although far less data is available compared to marine system, several studies of river sediments have shown that the MP concentration is broadly comparable to that reported in marine sediments studies.

Zooplankton organisms drifting in oceans, seas, and bodies of fresh water. Phytoplankton are microscopic marine algae. Benthic fauna organisms that live on, in, or near the seabed, river, lake, or stream bottom. They are the base of several aquatic food webs.

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In their work, Strungaru et al. (2018) mentioned numerous interactions and effects of MP and NP on freshwater biota. Both MP and NP may have direct and indirect toxicological effects through their uptake by various species, as well vector effects through the adsorption of organic contaminants, such as hydrophobic persistent organic pollutants (POPs) and of pathogens from the surrounding media. Besides, the degradation process monomers and additives. Various adverse effects, including early mortality, inflammatory responses, inhibited growth and development, reducing energy, low feeding activity, oxidative damage, immunity and neurotransmission dysfunction and even behavioural abnormality. Furthermore, the toxicological harm toward a given species is dependent on the duration of exposure, particles concentration, shape, chemical composition and size, with stronger effects for smaller particles. A strong relationship between size of particles and their toxicological effects and interaction with hydrophobic pollutants from the surrounding environment

PE and PS micro- (nano) spheres previously characterized at high concentrations after short-exposure, purchased from different companies. It must be taken into account that in the freshwater

ecosystems, the plastic particles have irregular shape and are often found in the form of fragments, fibers, foams and films. Thus, compared with microbeads, plastic fragments may have sharp edge, increasing the possibility to physical damage of gastro-intestinal wall, gills and skin. [14]

## 2.2 Vegetation

Surprisingly, besides plastics, a large amount of invasive vegetation is reported. Water hyacinth and water lettuce are two most encountered species in the region. Those vegetation are often in the form of floating plants, which means they absorb nutrition directly in the water column, and do not require soils. They often reproduce quickly, thus are able to cover the water surface in quite a short amount of time.

Water hyacinth has broad, thick, smooth, ovate leaves. The leaves are 10–20 cm across on a stem which is floating by means of buoyant bulb like nodules at its base above the water surface. They have long, spongy and bulbous stalks. The feathery, freely hanging roots are purple-black. An erect stalk supports a single spike of 8–15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. One of the fastest growing plants known, water hyacinth reproduces primarily by way of stolons (connection between organisms), which eventually form daughter plants. Each plant additionally can produce thousands of seeds each year, and these seeds can remain viable for a long time. Water lettuce is similar to water hyacinth, though smaller in size and are often found in lakes, channels, still water bodies.

Within in control, they serve as a great filter to the water bodies, soaking up harmful chemicals, providing shade, hiding place for fish and other aquatic wild life. They can also be used for certain pharmacological purposes. However, if left unchecked, they will grow into thick mats and become a quite dreadful thread. As plants, they do photosynthesis and respiration. Too much vegetation can choke aquatic life at night, due to low oxygen supply. Reports on serial deaths of fish have been reported in places where invasive vegetation are active. In some cases, they carry diseases within their dense root system, an ideal place/microhabitat suitable for the breeding of many vectors of human diseases and for hosting poisonous snakes.

The thick mats of vegetation can cause a great amount of water loss since they use up water to transpire. They impede the water flow, which means waterway transport is obstructed, canals and

drainage systems are blocked. They also make it more difficult for the fishermen to catch fish. These are the reasons why the government has to dedicate time and resources to deal with the vegetation.



Figure 6: Pictures of the water hyacinth (the colon is circled in red) on the left and water lettuce on the right. [19] [20]

In Ha Tinh, Vietnam, it was reported that the fast growth of water hyacinth caused concern for the people living there. They flowed and stuck under fish net, then floated up, raising the fish net above water level, causing fish dead. Dead water hyacinth decayed and gave horrible smell to the neighbourhood, polluted the water. People reported that they felt itchy after getting in the water to feed the fish. [21]

### 2.3 Other types in the environment

One problem we have to consider is that those mentioned above in this chapter often do not come alone in Vietnam. Most of the time, a big chunk of a mixture of everything can be found in water bodies. These chunks may include organic materials wood, leather, glass, metals (such as aluminum cans, machine parts).

Here I discuss visible impacts of debris on wildlife and human life. In the process, I came across the work of Sheavly and Register (2007) which lists different impacts of marine debris [22]. I notice there are similarities that freshwater debris also has.



Figure 7: Red River in flooding season [22]. A mixture of everything: a sofa, plastic bags and bottles, tree branches, styrofoam boxes, wooden boards.

Firstly, solid inorganic debris - such as broken glass, medical waste, fishing line and discarded syringes - can harm residents and visitors; they can entangle, inflict cuts and wounds to both human and wildlife. Ingestion of debris by animals is another serious problem. Many animals confuse debris for food and cannot regurgitate an item once it has been swallowed; it often becomes lodged in their throats and digestive tracts. Debris that will not pass out of the stomach gives a false sense of cessation, causing some animals to stop eating and slowly starve to death.

Medical and personal hygiene waste (including condoms and tampon applicators) that enters water bodies directly or without adequate sewage treatment will bring bacterial contamination and viruses. Consumption or contact with contaminated water can result in infectious diseases, namely hepatitis, diarrhoea, bacillary dysentery, skin rashes, and even typhoid and cholera.

Secondly, debris ruins the landscapes and make them potentially hazardous (the sites may be toxic, or smelly). This forces communities and governments to spend funds for beach and waterway maintenance. Old fishing gear has been found to be lethal to ocean life for years after being disposed of. An abandoned fishing net will continue to catch and kill ocean life, which is called “ghost fishing”. It can also cause serious damage to vessels by entangling propellers and rudders. Organic waste can be pulled in the propellers, thus cut into pieces, turned into a mess, releasing unpleasant smell. Plastic bags containing waste from domestic uses thrown into the water, dead fish/animals and vegetation are all the usual suspects.

While research has been done on the harm marine debris can cause to humans, wildlife, habitat and vessels, there are many environmental impacts that are less well understood. These include

what other impacts beach cleaning have on the environment, how exactly the debris and pollutants we extracted into water bodies affect the food chains, how broad these effects are. Those are the questions we cannot know for sure. Especially in Vietnam, a country that is growing, the focus is thus placed more upon economical objectives. So not enough studies are made to grant us an adequate insight on what really happen to the biota. Or maybe it is the absence of an open, public, unified system that prevents everyone to contribute a part of their observation, their work to the community.

### **3 Potential application sites in Vietnam**

As mentioned earlier in the motivation section, a large number of water bodies are under the threat of becoming dead, especially in big cities. The increasingly growing number of people coming to big cities with hope of finding a well-paid job leads to inevitable problems, one of which is environmental. Ho Chi Minh City is the biggest city of the country and therefore can serve as a great (if not extreme) example of what happens. I added one site in Dong Nai as it is where I live and so I can have a familiar case, which serves as a personal motivation.

In Vietnam, domestic wastewater usually goes into a septic tank before arrives at the collection system of the city and is then discharged into the city's canal network. The problem is that wastewater treatment complexes usually possess ineffective systems, which means the quality of the water is still really poor. Small cities or suburban areas usually lack any means of treating used water, and are more likely to let untreated wastewater discharged directly from households and industrial activities into waterway network. Therefore, environmental pollution of waterway network is unavoidable. The width of some canals often gets narrower with time due to the invasion from both sides of the canals. In many cases, in order to make space for new buildings, waterways are buried partly or even completely. Those facts add to the problem: as the flow is now hindered, garbage improperly discarded into the canals easily gets jammed up, giving off disgusting smell in the whole area.

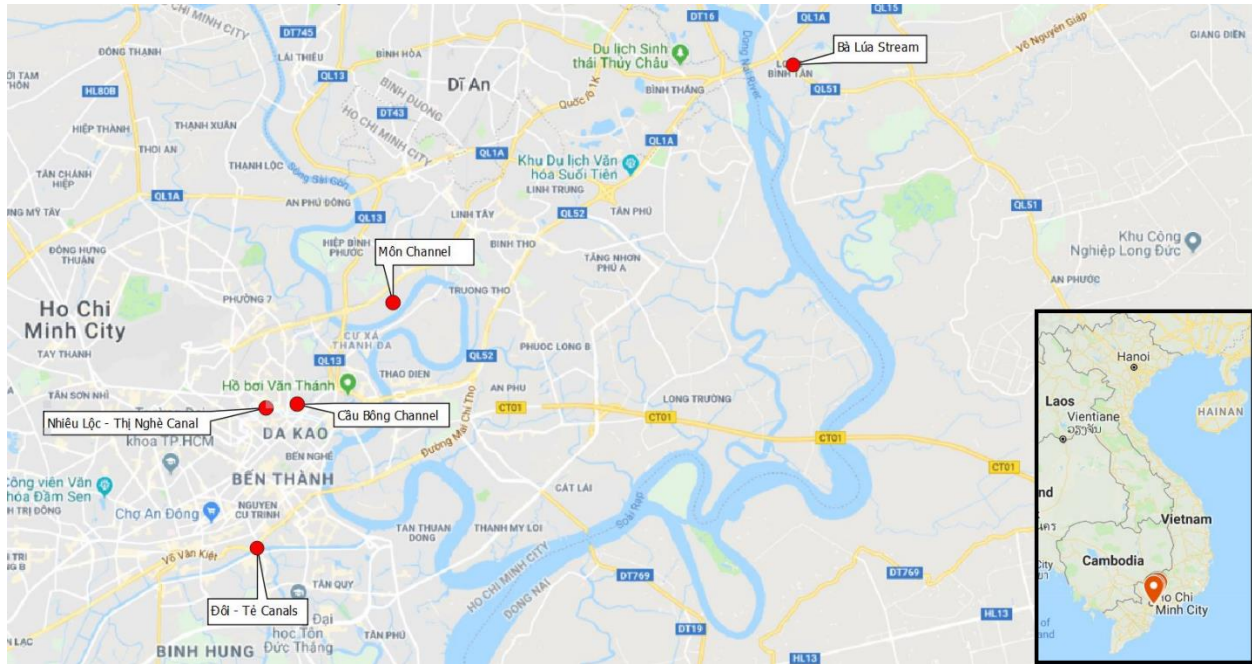


Figure 8: The map shows positions of 5 sites that could be used for the device application. Four of them are in Ho Chi Minh City. Only Ba Lua Stream (upper top) is in Dong Nai Province.



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### 3.1 Nhiều Lọc – Thị Nghè Canal

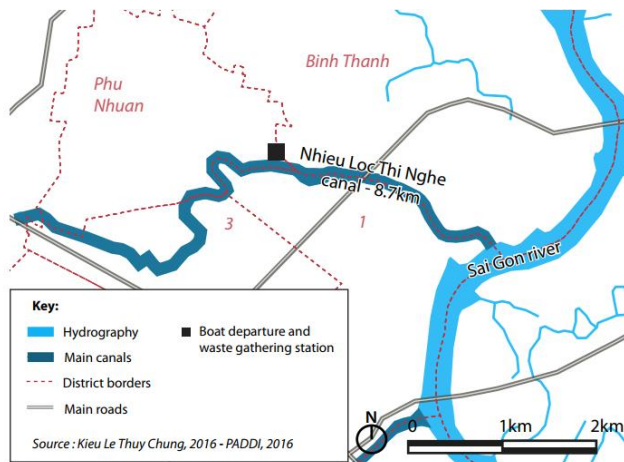


Figure 9: The map of Nhiều Lọc- Thị Nghè Canal [9]

One of the most contaminated canals known in Vietnam, the Nhiều Lọc - Thị Nghè Canal has received a great deal of public attention in the last few years. It is the main canal of a canal system of the same name, which has a basin of about 3,000 hectares. The main canal is 9,470 meters long, and the total length of its sub-canals reaches 8,716 meters. It flows through many urban districts of HCMC, namely Phu Nhuan, Go Vap, Binh Thanh, Tan Binh, 10, 3 and 1 in a path full of turns and bends; starting from the box culvert near the No.1 Bridge (in Tan Binh District) and pouring to the Sai Gon River at Ba Son Gate. Historically, the natural canal played an important role in the establishment and development of the city. At the beginning of the reclamation of the South of Vietnam, together with Ben Nghe

arroyo, the Nhieu Loc - Thi Nghe canal was well-known as Sai Gon's most beautiful canal where cultural, commercial and transportation activities used to be really busy. However, the city's urbanization and industrialization starting in the 1970s brought the consequences: residents migrated from other places in search of jobs and lived in the slums along the canals. An increasingly amount of solid waste and waste water started to be discharge directly into the canal. During this time, the establishment of a series of factories without any care to the environment brought the canal to a dying state.

In 1993, The World Bank and the City funded the first HCMC Environmental Sanitation Project to resurrect the Nhieu Loc – Thi Nghe canal (120 and 256 Million USD, respectively) from its moribund state. In 2012, after a decade of rehabilitation of the drainage system, wastewater collection and riverbank urban masterplan, the benefits of the project are significant not only for the residents' quality of life but for the tourism activity and the increase in property values. Collecting debris starts from 2012. Before 2014, everything is done absolutely manually.

Currently, a second HCMC Environmental Sanitation Project funded by the World Bank aims to build a wastewater treatment plant for the wastewater collected around the Nhieu Loc – Thi Nghe canal and the rapidly growing District 2 area (World Bank, 2014).

The Nhieu Loc – Thi Nghe canal has many sub-canals such as the Bong Bridge Canal, Van Thanh Canal, Bung Binh Canal and Phan Van Han Canal. However, most of the sub-canals are terribly polluted and nearly clogged by the invasion of the slums along both sides of the sub-canals.

[9]

### **3.2 Doi – Te, Ben Nghe – Tau Hu Canals**

The Ben Nghe – Tau Hu and Doi – Te canal systems locating in the South of the urban area of HCMC flow through the districts 1, 4, 7 and 8 and are the waterway connecting the city with Mekong River Delta. Commercial activities used to be really dense on the whole canals. Currently, there are some bustling places on Doi, Te and T Hu canals, where agricultural products such as coconuts, bananas and flowers transported from the Mekong River Delta are sold. The canals have been rehabilitated by the HCMC Water Environment Improvement Project for Tau Hu - Ben Nghe – Doi – Te Canal Basin funded JICA. The canal environment has been significantly improved too.



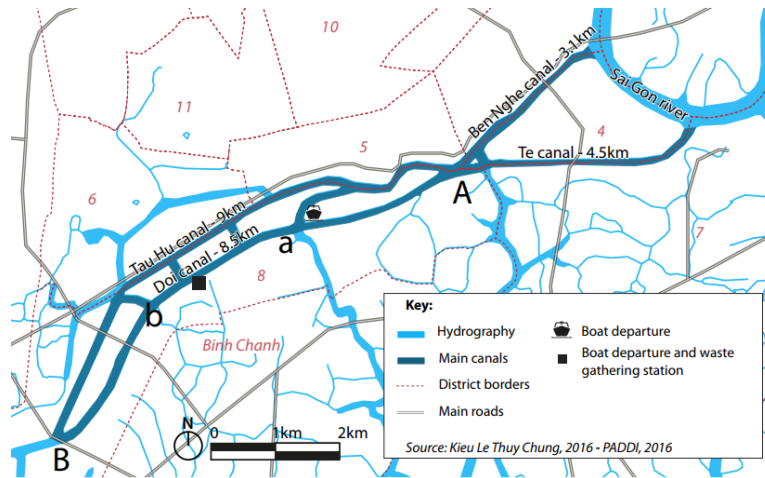


Figure 10: Doi-Te and Ben Nghe-Tau Hu Canals [9]

Beside the visual aspect, the banks were reinforced by concrete embankments in Ben Nghe, Tau Hu and Te canals, the densely stilt house areas were removed around the “Y confluence” and Nguyen Van Cu bridges and the inhabitants relocated. The relocation is still in progress along the Doi – Te canal.

Collecting debris here is a recent activity, which started in 1999 in the Doi–Te and Ben Nghe–Tau Hu canals. Before 2014, everything is done absolutely manually.

[9]

### 3.3 Cau Bong Channel (Ho Chi Minh City)

Xuyen Xuyen Canal, located in Ward 15, Binh Thanh District, 6.2 km long, has three branch routes 1.94 km long (including the branches of Son Bridge, Binh Trieu, Binh Loi) [1], originating from Nhieu Nhieu Loc - Thi Nghe, Binh Thanh district flows to Vam Thuat river Go Vap district, is the home of thousands of people in the city. Ho Chi Minh. They have had to eat and sleep for many years on the stinky canal, which is covered with rubbish and disease. This area is reported by Tuoi Tre daily newspaper as the most polluted place in Ho Chi Minh City. [23]

Cau Bong canal is part of the Xuyen Tam canal system. Bong bridge canal starts from Moi Bridge (Bach Dang) to Bui Huu Nghia Bridge (belonging to Nhieu Loc - Thi Nghe canal) with a length of about 1,500m. Cau Bong canal mainly receives domestic wastewater from people in Ward 2, 15, Binh Thanh District and wastewater from Long Van Tu Canal, which eventually flows into Nhieu Loc - Thi Nghe Canal. In addition, the Bong bridge canal is also a place to transport fruits (coconut, bananas ...) for traders of Ba Chieu Market. [24]



*Figure 11: A picture of Xuyen Tam Channel. Trash floats on the water surface, especially under the houses along side the banks of the channel.*

### **3.4 Mon Channel (Ho Chi Minh City)**



Connected to Saigon River, a system of small canals behind houses flows into the channel. Receiving domestic wastewater from nearby residential areas, the water gives up frequent bad smell and sometimes turns black. Water hyacinth grows excessively due to the water column. Litter often gets stuck in the vegetation. The length of the channel is approximately 900m.

*Figure 12: A picture of Mon Channel*

### **3.5 Ba Lua Stream (Dong Nai Province)**

About 2-3 meters wide, the long stream flows through an industrial area and several residential areas in Long Binh Tan Ward, Dong Nai Province before reaching Dong Nai River. It receives the outflows of wastewaters from these places, thus always gives off a bad smell. Normally the flow rate is not fast (actual statistics is not known), but can peak dangerous speed during raining seasons.



*Figure 13: A picture of Ba Lua Stream near Nguyen Huu Canh High School*

Trash of different types is conveniently dumped into the water by passers-by and washed away by the flow. However, a large amount still get stuck on both banks frequently and required sanitation workers to clean up.

## **4 Products on markets and patents**

This part aims to provide a general overview of equipment, technologies, methods that are currently used to clean up the rivers. Explanations and remarks are made based on my own observations and deduction. These include products that are already on the market, especially what are being used in Vietnam.

There are some patents that are related to the topics, which were results of one of my tasks during my time at ZPVP. The task was instructed by my supervisor and colleagues.

A brief explanation of state-of-the-art technologies used to deal with the microplastic problem is to be given, since it is one of the priorities of the project. Due to subjective and objective limitations, I refrain from including the function into the design. However, I feel the need to give reasons and plan to fulfil this by explaining in this section.

Finally, reasons why a new model of sanitation boat is desirable in Vietnam are given.

### **4.1. Products on market:**

This section mainly focuses on products that have been produced and used on the market for a period of time. First, equipment that is used in Vietnam is listed with their use. It is noted that these means of water sanitation are not applied on a national scale unanimously but more locally

dependent. The report aims to provide an outlook based on my observations as well as other sources like newspapers and reports by organisations. Following are a number of products serving water cleaning work that I found online. This is also the limitation of this work: it do not include products that are sold and used but are not available online. Furthermore, I found little on specifications of these products, such as the efficiency of the product, their tonnage, materials, exact sizes, what type of energy they use, how long the product lifetime is. I suggest that field trips or industrial connections could prove useful in improving the practical aspects of this bachelor thesis.

### Equipment in Vietnam



Figure 14: a. Workers collected debris on Te Channel [25];  
b. Workers in Ho Chi Minh City cleaned up the Nhieu Loc Canal [26];  
c. Sanitation workers from Urban Environment One Member Co.Ltd. [27];  
d. Hanwha Q CELLS' Q.PEAK [24];

In Vietnam, the main method is using workforce. Boats available are of different sizes and equipment. A typical example is shown in Figure 15a, a worker uses a small boat and collects floating debris on the water surface, using rakes or nets. Small boats are used for collection under

stilt houses or any other areas that cannot be accessed by big boats. The debris may be stored directly on board, or in standard green garbage bins for ease of transport later.

The bins are often 60, 120, 240 and 660 litre in capacity. Once full, the sanitation workers will move the boat to some collecting points to unload the debris. This method is the most common, especially in small cities or rural areas, where there are little attention or limited budget available. It is of low efficiency since debris is manually salvaged in small amount each time (limited by size of the nets/rakes, strength of workers), small storage and do not provide safe working conditions for the workers, they have to stand on the boat and lean out to pull the waste, and are in contact with the waste all the time.

On each small boat, two workers on small boats without engine use handhold nets and manually pick up the debris. Once the containers are full, the workers cover the containers with a big mat so that the debris cannot fly, and other people cannot see nor feel bad smell. The containers on the boats are lifted up on land at the gathering and then transported to a transfer station.

In Ho Chi Minh City, the largest city of the country, bigger boats equipped with cranes (Figure 15c) are used in order to remove a large volume of floating debris. As reported in 2017, everyday on average 9000 tons of waste are produced in the city [25]. Not all of it is collected though. Every day, workers of Urban Environment Company salvage about 7-8 tons of waste on Nhieu Loc - Thi Nghe canal (with water hyacinth up to 16 tons/day). In the basin of Đôi and Tê channels, each day, 42-43 tons of rubbish are collected (with water hyacinth up to 60 tons/day) [26]. Due to the fact that the city is the symbol of the country, it is requisite that the water bodies here be cleaned everyday so that the city looks and smells clean. Boats with crane can definitely carry more waste, although the exact number is not known. The crane can be used to pull up large chunk of debris (including vegetation) or used together with a net to cover a wider size range of debris in an area. Again, debris can be stored directly on boat, which allows more tonnage. But for the ease of later transportation, bins are usually installed on board for storage.

There is no evidence, but I believe that these vehicles use diesel or gasoline engines.

After full, the boats get to a loading point where there are crane trucks pulling up the debris to a transfer station (Figure 15b, 16). Then garbage trucks come and move the debris to landfills.

There were 2 boats, sponsored by Hanwha (Korea), that were tested on the Mekong River. They use solar energy via big solar panels on roof. Report claimed that their operations are smooth, quiet and without discharging any exhaust fumes [27]. It is not certain how their collecting mechanism works, but I suggest they requires an operator driving the boat. As the boat moves, it will eat the debris, store it into the space between 2 hulls. Their tonnage is unknown, as well as whether they have some kind of energy storage or alternative power source and hence could work in raining season.



Figure 15: Collected floating debris at transfer station in Truong Sa Street [9]

### Skip barges

Barges are low boats with flat bottom, used to carry goods or bulk materials in canals and rivers.



Figure 16: A picture of skip barges [38]

They allow recovered debris and waste to be stored and transported using transfer skips employed by waste removal contractors world-wide.

Figure 16 is a Modular Skip Barges by a company named Water Witch, who specialises in providing waterway clean-up. The design has some advantages in comparison with the original barges.

Loading and discharging fully laden skips

is reported to be fast, and without any manual handling, helping operators to immediately resume work. Each barge also features quick-connect couplings to allow additional units to be connected to suit capacity requirements. Further adjustments can be made to match the design to the needs of customers. Range of deck configurations and equipment options including heavy duty fendering, access ladders, handrails, storage lockers and bilge pump. Built from highest quality 6mm all welded Grade A shipyard steel for strength and durability - scantlings exceed Lloyds Register requirements.

## Floating debris boom

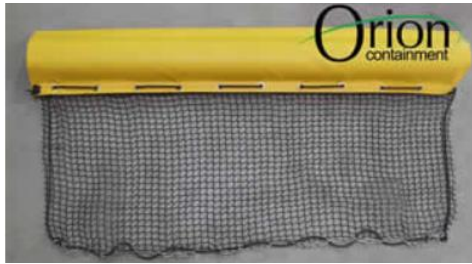


Figure 17: Floating Trash Net Boom [34]  
[35]

Containment booms are a solution widely used for keeping hold of debris, trash, leaves, wood until it is properly cleaned up. These booms consist of floatation units, ballasts (to provide stability), tow cords to connect the units together and a net/curtain to block debris from flowing through. The curtain's upper sleeve is connected with the floatation units while lower sleeve is attached to the ballast. Certain types of materials of the curtain allow it to contain oil spill. These products vary in design and properties, serving different purposes as well as conditions of water.

## Mr. Trash wheel

Mr.Trash Wheel is a product designed and constructed by Clearwater Mills, LLC based in Baltimore, Maryland. It is a trash interceptor which operates semi-autonomously when placed at the end of an outfall. The product consists of containment booms, rakes, conveyor belt, dumpster, water wheel and solar panels. Trash flowing down the river is trapped by the containment booms, thus directed into the product's gaping mouth. The rakes pull trash that is trapped in the boom out of the water, onto the conveyor belt. Here, it is moved slowly to the dumpster. The whole process is powered by means of solar panels and a giant, 14-foot, water wheel.



Figure 15: Mr.Trash Wheel in Baltimore, Maryland [28]

It is claimed that though the process is slow, the machine is able to lift everything out of the water, including tires, mattress, or trees. The device is remotely controlled, so once a dumpster is full, it will give a signal to a phone of the operators. The full dumpster will then be towed away by a boat and replaced with an empty one. The collected trash is pulled on shore, then moved to waste

treatment complex and incinerated to create electricity. The machine is told to be able to withstand severe conditions of weather, even storms.

The idea of a device sitting on its own, requiring minimal effort to operate and yet working passively 24/7 is really attractive. Its eye-catching design is obviously a plus, since it draws the residents and visitors' attention, thus plays a role in raising people's awareness. Mr. Trash Wheel has also become an icon of the city, more of a tourist attraction, with souvenirs sold near the place for funding development costs. This means that mass production of the product is not favoured, as it can have counter-effect – reducing the product's popularity. Instead, similar working principles with rich variety of designs could be a hit.

The drawbacks of the design are the fact that, up to now, there is no sound solution to sort out the trash, so incineration is the only viable option. Furthermore, the set-up of the design hinders waterway transport activities. If we want to consider application in Vietnam, where a dense network of rivers (with a lot of small-sized branches) encourages the importance of waterway transport, a careful choice of placement and adaptive solutions are surely needed. Also note-worthy is the risk of unintentional mischievous and intentional destructive actions. And let us not forget the fact that this interesting device may encourage some people to try throwing garbage in the water to see just how well the machine works. Why would this machine be installed if there was no trash anyway?

### Weed tow boats



Figure 19: On the left, a weed tow boat, named “Pollution Hunter” by Water Witch, is unloading the bucket. On the right is a photo of using truck to unload a full barge.

The weed tow boat is another solution, in the picture are boats made by Aquarius Systems. They look like flat-bottomed boats, working like loader tractors (in some models, it is similar to a forklift truck) in water.



The boat is equipped with a large volume bucket and hydraulic arms which can raise and lower the bucket. When the boat is moving, by keeping the bucket half-way deep in the water, trash will be lured in and get trapped in the bucket. Once full, the operator can move the boat to the shore to unload the bucket. Or if a barge is towed alongside the device, the operator can store collected debris there, allowing the process to continue undisturbedly. This requires a crane truck to pull up the barge and transfer the trash to waste treatment sites. Similar products can be found from Water Witch, under the name “Pollution Hunter”. This mechanism is simple to operate, but requires working space and good steering associated.

### Trash hunters/ Aquatic weed harvesters



Figure 16: Trash skimmer [30]. Weed harvesting machine [31] Vietnamese German University

Two products with similar working principles are present on the market by Aquarius Systems. They are big heavy boats using a ramp with conveyor belts to pull debris out of the water and put in storage area. The ramp can be lifted up or lowered down below water surface to collect trash/vegetation. Once the storage area is full, another conveyor belt at the end of the boat is used to unload debris stored. Trash Hunters have an adjustable collection device that is attached on its ramp. This device can open wide, or close down to control the input of debris.

The weed harvesting machine, on the other hand, has one horizontal and two vertical cutter bars attached to the ramp, in order to sever the vegetation as the machine moves forward through the water. Products of same functionality can be found in Vietnam. Many groups of engineers have tried to manufacture such a product with local materials and resources.

## Trashbot



Figure 21: A picture of Trashbot [36]

Trashbot is a product created by Urban River with the aim of cleaning the Chicago River. It is a small catamaran with its length and width not over 1 meter. I guess it uses electric motor to create propulsion. The boat is equipped with a blade in front, so when it moves through the water, it pulls the trash along (like a bulldozer). This boat is controlled remotely via a website where everyone can access and use basic arrows

on their keyboard to control the product. GPS and tracking system is installed to prevent vandalism. A small waterproof box is attached between 2 hulls, containing all components performing the functions of the design (electronics, motors, steering system and camera). The aim of it is to enable anyone, at anywhere, any time, to help with cleaning the river. At the time, the makers are raising funds for further development of the project.

This device has certain advantages: it is of small size, thus mobile and portable. Remote control can be an enjoyable experience, especially for children, whose access to the water is limited due to safety reasons. It is also easy to operate, judging on the fact that it could be manoeuvre by arrow buttons on a computer keyboard.

The disadvantages are there, some of which I would call trade-offs. Its size does not allow for any great volume of debris to be cleared. Electric motor using solar energy/batteries restricts operating time. Its unloading mechanism is unknown. My best guess is that someone (not the operator, as he is controlling the device at somewhere in front of his computer) would use a net to collect what is in the front blade. And then just how will it be recharged? I suppose someone needs to do the maintenance, despite its ability to be remotely controlled.

Small device of similar size (some with similar working principle, some using conveyor belts) can be found in Vietnam. Usually it is the students who try to adapt the design to the country, using available materials (PVC tubes are favourite choice). They may try to reduce the cost, or maybe improve some functions. Most of them serve study purposes and do not offer practical results or compete on the market.

## Omni Catamaran.



Figure 17: A picture of an Elastec Omni Catamaran [32]

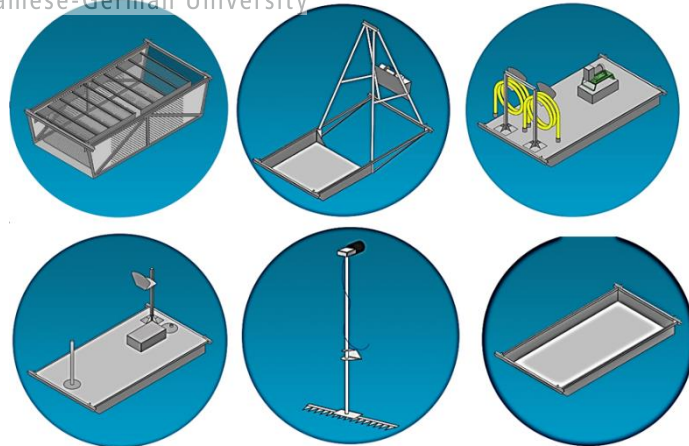
The Omni Catamaran is a product for waterway maintenance from a company named Elastec. It is a catamaran design (2 parallel hulls) made of aluminium. The special things about the product is that its deck can be replaced by different pods to perform different tasks, which they call “unique drop-in pod” feature. Some of the tasks listed are: collecting floating debris, transporting cargo, pumping out boat sewage, cutting invasive aquatic weeds, supporting diving operations, lifting buoys and responding to oil spills.

Figure 18a shows a picture where they use a crane truck (or an excavator) to pull up the *Litter Basket pod* (Figure 18b top-left), which has a capacity of around 2,800 litres. The corner points are strengthened to allow for crane hoisting. The device works in harbours, marinas and protected waterways using this, drifting toward floating trash and debris to collect them.



a)

Vietnamese-German University



b)

Figure 18: a) Exchanging an Omni Catamaran pod; b) Options for pod slot. Top row: Litter basket - A-frame lifting pod - Pump out pod; Bottom row: Wash down pod - Weed cutter and Cargo pod.

The *A-frame lifting system* (Figure 18b, the middle of first row) with a 680 kg mid-ship pull for added stability is ideal for hoisting and inspecting navigational buoy moorings and a multitude of applications that cannot be accomplished with standard craft. The *Pump out pod* (Figure 18b, the

third of first row) is design for servicing sewage holding tanks on boats allowing the Omni Catamaran to serve as a “valet” pump out boat. The pod’s holding tank is located below deck, adding to the stability of the design. The pump system may also be used in emergency situations where pumping of a bilge or other location is needed. Pump out grants may be available for vessels equipped with these systems. *The wash-down pod* (Figure 18b, the first of second row) features a gasoline power washer to spray river walks and docks. *The weed cutter* (Figure 18b, the middle of second row) is designed to cut invasive aquatic plants. The 4ft wide cycle cutter is used in conjunction with the collection basket to trim and collect marine vegetation. *The cargo pod* (Figure 18b, the third of second row) is a recessed compartment for transporting equipment. It features strengthened corner points for crane lifting and has a maximum load capacity of 1000kg.

Versi-Cat Trash Skimmer Boat is an alternative introduced by Water Witch, a company specialises in providing waterway clean-up. It is broadly similar to the Omni Catamaran, except for the pod exchange feature.

Outboards are often the choice of propulsion for these work boats. They provide the ease of manoeuvrability, minimal effort of installation and maintenance. If the outboard broke down, it would be easy to replace it with another, which keeps the boat on duty as long as possible. The device’s modular design also serve this purpose, while it gives the flexibility of usage. The producer says it can be moved easily by trucks to different sites, which means it is of low weight.

Considering its water cleaning function, there are drawbacks which may be further improved in the future. First, the device must move to “eat” the floating debris, which can be difficult if we take into account the catamaran design is not the best for speed. Second, there is no sorting mechanism, a common problem at this time for any device. Third, as the basket is half-way submerged in the water, coupled with the fact that our target is floating debris, I doubt that the whole 2,800 litres of the basket could be used. The operators have a great chance to find themselves in a situation where they need to unload the basket when it is only half-full. All have been said, it is still a product claimed to have receive success on the market and I find that it is worth considering.

## 4.2. Patent

This section lists ideas that have been registered but may or may not be produced and used on the market. After a brief overview of the most important river cleaning products has been given in terms of subject and task, a comparison with the specifics of the CleanRiverSolution will now be carried out with the help of a patent search.

The patent research carried out as part of the bachelor thesis should fulfil several tasks. First, it is to examine to what extent the components of a product to be developed, and also mechanisms used within the product, are protected by respective existing patents. In addition, the search should provide both qualitative and quantitative information about any subsequent patent application. The patent search was carried out with the help of the German Patent and Trade Mark Office (DPMA) and World Intellectual Property Organization (WIPO).

The search terms used the following keywords and combinations of them. Below is a table showing search results for different word combinations:



<b>Keywords</b>	<b>Results</b>
Cleaning boat	2089
River cleaning device	967
Microplastics	143
Floating plastic collection	151
Floating debris collection	181

In total, there were 3531 patents related to the product. I also tried the categories related to a product I found interesting.

### **[CN101475047A] Small-sized water surface floater automatic cleaning ship**

Patent applicant: Guilin University of Electronic Technology

Date of application: 16.10.2008

The invention relates to a water surface cleaning device, in particular to a small catamaran for automatically cleaning surface floating objects. The boat works automatically, moving back and forth. There are 5 sub-functional groups. Power used for the boat is from 2 sources, solar panels and battery (for less sunny days). Hull power mechanism includes 2 motors, powering 2 propellers via 2 connecting shafts. Hull steering mechanism is included. Floating debris collecting mechanism is of interest: using battery-powered motor connected to a rotating shaft, a turning blade under water is turned to lure trash into the boat. A bag opening lifting device is installed to prevent trash from flowing out: using another motor which rotates to close the mouth after taking in the trash. A garbage bin is placed at the stern to store the debris. The boat also have a remote control device of 2 tasks - image acquisition (camera, image receiving) and image transmission (transmission modules and transmission antenna). The invention can work automatically without any labour required, which is a plus point. However, it comes with a short working time due to small garbage bin as well as the use of battery and solar panels for quite a number of motors. [28]



Vietnamese-German University

**[CN102020004B] Water surface garbage cleaning ship**

Patent applicant: South China University of Technology

Date of application: 09.07.2010

The patent claimed that there are 2 main types of collecting mechanisms – bucket and conveyor. The invention is a combination of 2 mechanisms. It will use bucket/conveyor alternatively depends on the current situation with the help of a detection system. Interesting components include a water surface adaptive device allowing the boat to work at different water depths. Satellite ships are used to unload the full bin. Cutting device and compression device are means of reducing volume of debris. A collecting system uses 2 working modes depending on the operator's decision or the process system. Also included is a garbage disposal system with hydraulically automatic steering water jet device to wash the rubbish bucket. The invention works as the navigation detection system identifies garbage and get to position. The collection system is put under water surface. In case large amount of garbage is detected, conveyor is turned on. If only a small amount of garbage

is detected, the conveyor is turned off, and the system is used as a bucket. Once the bucket is full, the hydraulic motor is activated, transferring the garbage to storage bin. Compressive unit is enabled to deal with the collected garbage. Once the pressure inside the storage bin reaches a certain level, the boat will return to shore to unload, or there will be auxiliary ships to help unload the bin. [29]

**[CN103287549A] Intelligent water quality monitoring and surface cleaning ship**

Patent applicant: Jinan University

Date of application: 10.04.2013

The invention relates to the field of water quality monitoring and water surface cleaning, and discloses an intelligent water quality monitoring and water surface cleaning ship, comprising a solar power supply module, a water surface cleaning module a power control module a water quality data acquisition module, a main processor, a wireless transmission module, a GPS, Positioning module, automatic navigation module, intelligent obstacle avoidance module remote control terminal. The invention integrates new energy technology, embedded platform development technology, long-distance transmission and control technology, sensing technology and mechanical power technology into one field - water quality monitoring and protection, and is made into an automated and integrated monitoring ship and cleaning ferry. [30]

**[CN106969941A] Device and method for acquiring microplastic in surface layer water.**

Applicant: NINGBO UNIVERSITY

Date of application: 14.04.2017

The invention discloses a device and method for acquiring microplastic in surface layer water. The device is characterized by comprising an upper wood frame and a lower wood frame which are identical in frame surface shape and size, wherein the upper wood frame and the lower wood frame are fixedly connected, a steel wire mesh is arranged between the upper wood frame and the lower

wood frame, the upper wood frame is formed by four cross rods, balance weight grooves for placing balance weight objects are formed in the centers of at least one pair of symmetrical cross rods, the sum of the overall gravity of the microplastic acquiring device and the gravities of the balance weight objects is rightly equal to the buoyancy produced by the lower wood frame in liquid, and the steel wire mesh is a quadrangle having the hole diameter of 1-2 mm. The device has the advantage that a surface layer water sample of a water body can be rapidly and effectively acquired.

**[CN108344600A] System for synchronously collecting multi-particle size microplastic samples in water bodies of different depths**

Applicant: CHINESE RESEARCH ACADEMY OF ENVIRONMENTAL SCIENCES

Date of application: 20.03.2018

The invention provides a system for synchronously collecting multi-particle size microplastic samples in water bodies of different depths. The system comprises a floater, a sinker and a vertical fracture surface connecting rope. The floater is installed at an upper end of the vertical fracture surface connecting rope. The sinker is installed at a lower end of the vertical fracture surface connecting rope. A collection of microplastic-sample-collectors are uniformly distributed on the vertical fracture surface connecting rope. The microplastic sample collectors comprise active collectors and passive collectors. They are fixedly installed on the vertical fracture surface connecting rope through collector fixing parts. The upper end of the vertical fracture surface connecting rope is provided with a dragging rope, the other end of the dragging rope is installed on a dragging ship, and the dragging rope can be used for guaranteeing that the vertical fracture surface connecting rope keeps a vertical state during sampling. When used for collecting samples, the system can be used for synchronously collecting the microplastic samples of different depths and different particle sizes, the collection efficiency is improved, and the collection time is shortened.

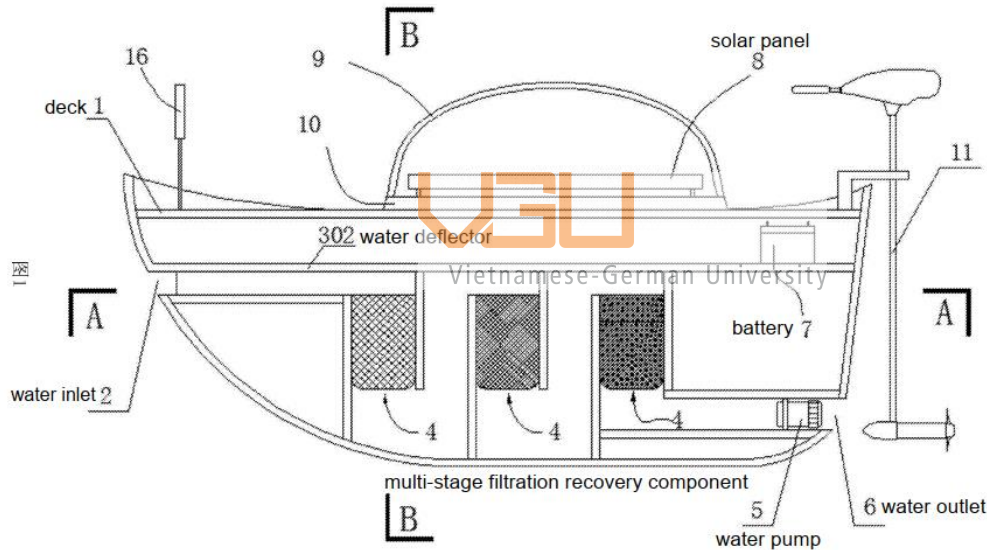


**[CN109018221A] Marine microplastic recycling ship and a recycling method thereof for marine microplastics**

Applicant: FUQING BRANCH OF FUJIAN NORMAL UNIVERSITY

Date of application: 19.07.2018

The invention relates to a marine microplastic recycling ship and a recycling method thereof for marine microplastics. The marine micro-plastic recovery ship of the invention comprises a main ship hull which has a ship cabin, a ship side and a deck, a water inlet at the bow, a filter channel in the body of the boat, a multi-stage filter, a water outlet at the stern, a power supply device;



**[CN000109162265A] Combined device for removing floating garbage of river and collecting micro-plastic particles**

Applicant: SHANDONG MARINE RESOURCE AND ENVIRONMENT RESEARCH INSTITUTE

Date of application: 25.09.2018

The invention discloses a combined device for removing floating garbage of a river and collecting micro-plastic particles. The combined device comprises a large-scale floating garbage collecting blocking net and a plurality of micro-plastic unit collectors, wherein the collecting blocking net is arranged on an upstream river channel of the micro-plastic unit collectors. Compared with the prior art, the amount of the floating garbage and the micro-plastic particles that flow to the ocean through a sea-entering river can be effectively reduced; The main structures of micro-plastic collecting net units are of a modular combined design so that disassembly, recovery or replacement can be quite conveniently carried out. According to the combined device for removing floating garbage of the river and collecting the micro-plastic particles, a multi-stage filtering design is adopted, and a funnel net type design is adopted so that the micro-plastic particles in the inlet water can be efficiently removed, and the frequency of replacing or washing a filter net can be effectively reduced; and the micro-plastic collecting net units are provided with one-way automatic turnover valve devices, the one-way automatic turnover valve devices are started under the impact action of water flow, and are closed when a water body is static or the tidal current is reversed, and therefore, it is ensured that microplastics in a net tool cannot overflow reversely while the microplastics are collected.



Vietnamese-German University

**[CN201158816Y] Surface solid waste cleaning ship**

Applicant: Wuhan University of Technology

Date of application: 26.02.2008

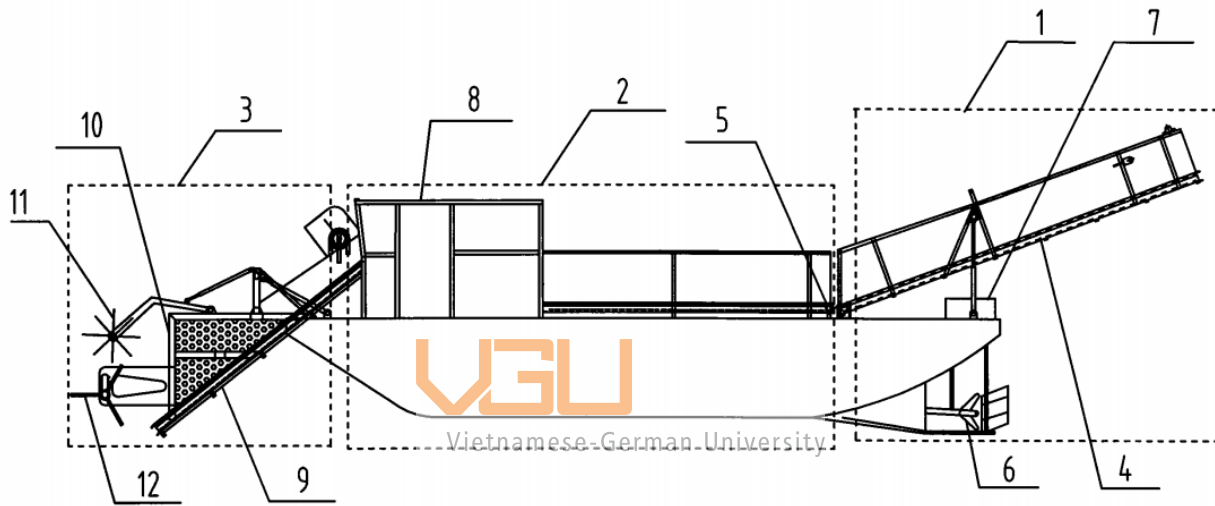
The utility model relates to a surface solid waste cleaning ship, which is a catamaran. The catamaran comprises two hulls; a capture mechanism; a collecting mechanism, a cutting mechanism, and a collecting box. When the ship is moving forward, the drum rotates under the action of the drum driving mechanism, and the water and surface solid waste flows from the nip between the double hulls under the action of the collecting mechanism, and the sieve plate separates the garbage, and the garbage is on the rotating drum. The gums are picked up and rotated with the gums in the shroud to the inlet of the collecting box, the gums staggered through the slots of the carding plates at the inlet of the collecting box, and the garbage is combed into the collecting

box to complete one Work cycle. The cutting mechanism can be turned on to cut the garbage so that the salvage mechanism can more easily salvage the garbage.

**[CN201580540U] Automatic surface cleaning ship**

Applicant: Zhangjiagang Haifeng Water Surface Environmental Protection Machinery Co., Ltd.

Date of application: 23.12.2009



The utility model relates to a rear cabin, a middle cabin and a collection (front) cabin, respectively; link cabin conveyor belts are arranged in 3 cabins; the rear cabin is movably arranged at the rear end of the middle cabin; a propeller is arranged at the bottom of a rear cabin body; a hydraulic engine is located at the top end of the rear cabin body; a cockpit is at the upper end of the middle cabin; the collection mechanism locates at the front end of the middle cabin. There is a right-angle protecting net. Its vertical bar is connected with rotary harrows 12; cutting knife 11 is connected to its horizontal bar. The full-automatic water surface cleaning has the advantages of simple operation, automatic garbage collection, high working efficiency and less laboratory.

**[CN207878423U] River cleaning ship**

Applicant: Zhejiang Puyang Cleaning Co., Ltd.

Date of application: 12.01.2018

A river/channel cleaning device, which solves the problems of large workload and low efficiency when the worker in the prior art transfers the river garbage, including the hull and the driving device for driving the hull movement. The utility model comprises a mounting barrel arranged on the hull, a filter barrel for placing the river garbage, and a compression component for compressing the river garbage. The filter barrel is arranged in the installation barrel and is detachably connected with the installation barrel, and the bottom surface and the side of the filter barrel are opened. There are through holes; by compressing the river waste, reducing the total volume of the river waste and the moisture carried, thereby improving the transfer efficiency of the river waste.

**[US20150251733A1] Low energy consuming garbage patch gathering and classifying equipment and method using catamaran**

Applicant: Hee Jin Kang, Myung Soo Shin, Dong-Kon Lee, Jin Choi

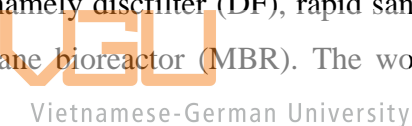
KOREA INSTITUTE OF OCEAN SCIENCE & TECHNOLOGY  
Vietnamese-German University

Date of application: 04.09.2012

By mooring or slowly moving the catamaran in a current through which a garbage patch formed of disused plastic particles over than 90% is drifting, a heap of the marine debris flows into the bow of the catamaran and then is smashed. While the disused plastic particles that have been smashed at the bow of the catamaran is moving from the bow toward the stern by way of the tunnel between hulls of the catamaran, the plastic particles are first classified by differences of densities. These first classified plastic particles are collected and then transferred into a narrow and long inside of the catamaran, being finally classified by a triboelectrostatic action. Thereafter, these finally classified plastic particles are made to be pallets which are to be transported to a land facility for recycling or abandoning them.

### **4.3 State-of-the-art technologies to deal with microplastics**

This section aims to provide a brief overview on methods commonly used to cope with microplastics in water. To be specific, it should be called “wastewater”. Wastewater is any water that has been badly contaminated by organic pollutants, bacteria, microorganisms and industrial effluent or any compound, which results in the deterioration of its initial quality. It can be considered of 2 types: municipal wastewater (liquid waste discharged by domestic residences and commercial properties), and industrial wastewater (liquid waste discharged by industrial and agricultural activities). Dealing with wastewater often requires wastewater treatment plants (WWTPs) before discharge. They can act as a barrier but also as entrance routes for microplastics to aquatic environment. Conventional wastewater treatment with primary and secondary treatment processes can remove MPs from the wastewater up to 99% and most of the MPs are removed already during pre-treatment phases. Despite of the high reduction ability, conventional WWTPs may actually be a significant source of MPs given the large volumes of effluents that are discharged. In their work, Talvitie et al. (2017) reports 4 types of commonly used technologies for tertiary treatments in WWTPs, namely discfilter (DF), rapid sand filtration (RSF) and dissolved air flotation (DAF) and membrane bioreactor (MBR). The work discussed their efficiency in filtering microplastics.



However, in Vietnam, the number, as well as capacity of WWTPs is not enough to handle the amount of wastewater produced everyday. Many direct discharge of wastewater can be found everywhere. The consequence is extremely bad quality of water, often with smells, black colour and a certain amount of litter stuck. The use of nanotechnology to treat water is reported in an effort to save the water resources. The problem that needs to be solved is at a much larger scale than I could deal with, considering the intended end product of this thesis. I, therefore, think that it is not effective to try dealing with microplastics using a small buoyant device.

[31] [32]

## **5 The aim of a new product**

The previous section set light on current protocol in Vietnam as well as other products that are used on the market, which serve the same purpose. This section discusses the reason why a product

customised for the studied country is necessary. With the aim to improve technical function, efficiency while still making full use of the equipment and labour force available, concepts for a new product will be promoted, based on comparisons between currently used equipment and other options available. Remarks are made on pros and cons of alternatives. A requirement list follows, serving as a guideline for the design process.

Generally, improvement should be made on the technical functions. Using boats carrying trash bins is neither safe nor efficient. People can easily fall off the boat when standing, especially if we want to consider the help from inexperienced volunteers, which is common in the country (so that with current labour forces, more rivers can be cleaned). Making the product easy to operate will help in this matter. It also help make use of labour force currently available, does not require new and costly personnel. Currently the sanitation workers have to work from 7 to 22 during highest load days.

At the beginning in 2012, floating debris collection was done every two days. Recently, due to the need to clean the canal for tourism purpose, the workers work every day. There are 50 environmental workers working on 12 engine composite boats in which 3 boats are equipped with a crank. Although the collection on this canal is reported to be very efficient: the group leader is daily checking by motorbike if there is any area that still has some floating debris left, and it is rare to observe any residual floating debris in the canal right after their shift. The working shift is really tough, starts from 6:00 am to 6:00 pm with a one-hour break at noon. The work is temporarily stopped if the water level is too low for the vehicles to move in the canal or heavy rain. It is therefore preferable that a new product can help to ensure their work shift would not expand too much from day to day. The tools at their hand, rakes and nets, are not that efficient. Another preferable feature would be the ability to work in shallow, still water (channels, canals, lakes...), or near the bank, since a lot of litter can be found there. Size and weight of the device is also of interest. The design should be small and transportable (most of the rivers in Vietnam are small and short, connecting provinces). Low cost is always good for a limited budget. Therefore, it does not need to include high-end technology but to focus on the ergonomics. Make use of equipment available. Taking into account the fact that manufacturing technology in Vietnam is lagging behind, it should be easy to produce. Machinery often uses gasoline and diesel. Solar energy is considered since Vietnam is a tropical country.

## 5.1 Task clarification

As mentioned above, for the device to be welcomed and used by customers, there are some criteria to fulfil regarding: low cost, ease of transport, ease of use, ergonomic functional properties, operator safety, and adaptability. To satisfy those requirements, a requirements list is created so that details of those criteria are shown.

In order to facilitate the formation of the requirements list, the mechanism of the system is initially described. A mobile and buoyant system for the river water purification is the main goal of the project that this thesis serves, with the original focus on the extraction of plastics in both the macroscopic and the microscopic range. However as mentioned above, during my work, I recognised plastics are not the only type of debris in the country. It is worth noting that due to the abundance of various pollutants, such a device to deal with microplastics is impractical. Therefore, I aim to concentrate on conceptualising a mobile device to clean up floating debris in general.

Size of the device depends on the intended operating space. In section 3, several potential studied places were identified, typically small channels/canals, streams and maybe small rivers. Work load is also a factor worth considering. So my estimation for the device would be 3 to 5 meters wide, 5 to seven meters long. It is worth notice when we have to collect debris that is near the bank of the water bodies, since the water level here is lower, there is risk of getting into impact with the bank, thus damaging the bank or the boat.

Attention should be paid on safety of the sanitation workers. Within this domain, there are things that we can work on, namely good stability of the boats, protective barriers or device to prevent the workers from falling in the water – similar to what we can see on some fishing boats. Storage of collected debris could also a function we can work on.

Efficiency of the work should be improved. For now, as reported in 2018, every day, workers of Urban Environment Company salvage about 7-8 tons of waste on Nhieu Loc - Thi Nghe canal (with water hyacinth up to 16 tons / day). Workers said sometimes it took them nearly 12 hours of working to clean up all the debris in Nhieu Loc – Thi Nghe Canal, noted that it is only 8.7 km long. In other words, there was approximately 1 ton of debris per kilometer per day in this canal. In the basin of Đôi and Tẻ channels, each day, 42 - 43 tons of rubbish are collected (with water hyacinth up to 60 tons / day). [26] [33]

My idea is to increase capacity/tonnage of the vehicle. Use different mechanism to help the workers collect debris faster with less effort. Use a compressing mechanism to save space on board. The problem, however, is that debris collected is of different categories, for example, there may be organic, plastic waste mixed with vegetation. Thus any attempt to chop up and compress will lead to difficulty in disposing later. Sorting types of debris is also a problem, up to now, most of the technologies used are incapable of separating waste. Collecting and disposing in landfill is the common method. The vehicle should make use of all the equipment that are used in Vietnam, including waste trucks, standard waste bins, other boats that are being used and even the labour. This will help more areas to be cleaned more regularly. Develop passive intervening solution to stop debris from flowing to the ocean, especially at night, or outside working hours.

An Lam	Date: 6.10.2019	Requirement list for a CleanRiverSolution
<b>Changes</b>	<b>D/W</b>	<b>Requirements</b>
		<p><u>1. Geometry:</u> Dimension of the prototype</p> <p>D Length = 5-7m</p> <p>D Width = 3-5m</p> <p>D Depth = 0.5-1m</p> <p><u>2. Kinematics:</u></p> <p>D Moving in still and flowing water.</p> <p>W Rotation at ease.</p> <p><u>3. Forces:</u></p> <p>D Maximum weight of debris to carry <math>\geq 400</math> kg.</p> <p><u>4. Energy:</u></p> <p>W Electrical and/or Pneumatic.</p> <p>D Gasoline, diesel and solar energy.</p> <p><u>5. Material:</u></p>



	D	Temperature range: 20 – 40 degree Celsius.
	D	Humidity: 60-100%.
		<u>6. Safety:</u>
	D	Operator safety
		<u>7. Production:</u>
	W	Easy to produce components, which can be done in Vietnam.
	D	Or can be transported by sea container.
		<u>8. Operation:</u>
	D	Destination: channels/canals, small rivers
	D	Easy to operate
		<u>9. Maintenance:</u>
		Maintenance interval:

## 5.2 Analysis of existing designs

With the task in mind, we try to analyse the existing models to see to what extent they can serve the intended purpose. The new concept should improve the short-comings of existing methods in Vietnam.

Table 4: Comparison between current equipment in Vietnam and CleanRiverSolution

Attribute	Current methods in Vietnam	CleanRiverSolution
Geometry	Small boats: about 1.5m wide, 7.5 meter long  Big boats with crank: about 3.5m wide, 12m long	About 3m wide, 5m long
Kinematics (mobility, working conditions)	Small boats: outboard, or paddles	Good manoeuvrability

	Big boats: diesel engines with rudder.	
Estimated weight carried	Small boats: about 400kg Big boats: about 1 ton	Equal or better
Operator safety	Small boats: easy to slip out of the boats Big boats: more stable, more space to work with	Safe for occasional volunteers who take part in events.
Ease of production	Small boats: easily produced domestically Big boats: can be produced domestically	Simple components and structure. => Can be produced domestically at reasonable price.
Ease of operation	Small boats: 2 workers with handhold nets to manually pick up debris under stilt houses. Big boats with crank: 3 operators (1 boat-driver/crank operator, 2 sanitation workers) to pick up big-size debris	Does not require special skills, so that the device does not disturb the current workforce.
Ease of maintenance	Many shipyards can handle the job.	The parts are easy to replace in common shipyards.

Table 5: Comparison between Omni Catamaran and CleanRiverSolution

Attribute	Omni Catamaran	CleanRiverSolution
Geometry	About 4-5m long, 2-3m wide	About 3m wide, 5m long
Kinematics (mobility, working conditions)	Outboards	Good manoeuvrability
Estimated weight carried	About 700kg (including the engines)	Equal or better
Operator safety	Safe - with barriers	Safe for occasional volunteers who take part in events.

Ease of production	Not difficult	Simple components and structure.  => Can be produced domestically at reasonable price.
Ease of operation	2-3 people onboard. One moves the catamaran, the others can use nets/rakes to lure debris in.	Does not require special skills, so that the device does not disturb the current workforce.
Ease of maintenance	Easy.	The parts are easy to replace in common shipyards.

Table 6: Comparison between Trash Hunter and CleanRiverSolution.

Attribute	Trash Hunter	CleanRiverSolution
Geometry	Estimate 5m long, 3m wide Vietnamese-German University	About 3m wide, 5m long
Kinematics (mobility, working conditions)	Paddle wheels	Good manoeuvrability
Estimated weight carried	Not known	Equal or better
Operator safety	Safe	Safe for occasional volunteers who take part in events.
Ease of production	Difficult to produce in numbers	Simple components and structure.  => Can be produced domestically at reasonable price.
Ease of operation	Requires a bit training to move the device, using conveyors to pull up debris	Does not require special skills, so that the device does not disturb the current workforce.

Ease of maintenance	Difficult. Hard to find the parts.	The parts are easy to replace in common shipyards.
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Table 7: Comparison between Trashbot and CleanRiverSolution.

<b>Attribute</b>	<b>Trashbot</b>	<b>CleanRiverSolution</b>
Geometry	Small, approximately 1m long, 0.6m wide and 0.6m height	About 3m wide, 5m long
Kinematics (mobility, working conditions)	2 motors on 2 hulls; small, better work in still water; not able to rotate	Good manoeuvrability
Estimated weight carried	About 20 kg	Equal or better
Operator safety	Remote control	Safe for occasional volunteers who take part in events.
Ease of production	Can use material available in Vietnam to produce	Simple components and structure.  => Can be produced domestically at reasonable price.
Ease of operation	Using remote control to move the device, skimming litter on the way	Does not require special skills, so that the device does not disturb the current workforce.
Ease of maintenance	Easy to change parts	The parts are easy to replace in common shipyards.

## 6 Design process

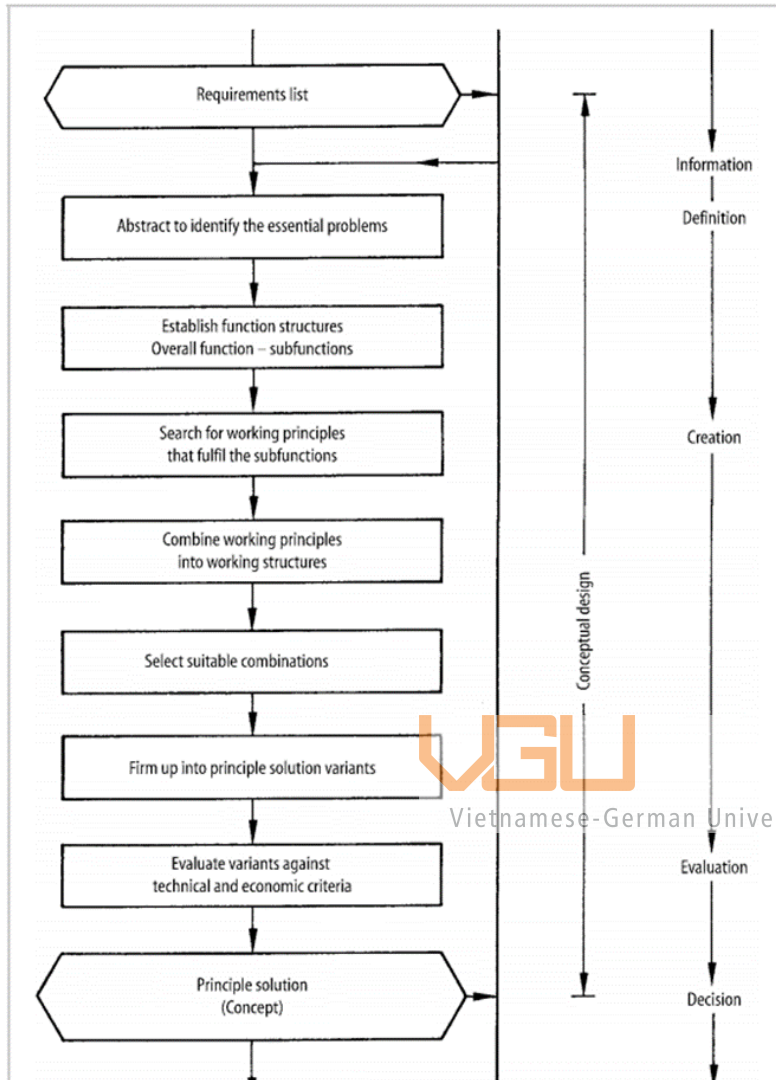


Figure 19: VDI Guideline 2221 [33]

In order to efficiently solve the problem of conceptualising a device to clean up floating debris and fulfilling as many of the aforementioned criteria as possible, a systematic approach is crucial and hence should be used to analyse before coming up with a solution. The thesis try to follow a systematic approach to engineering design as learned in the book “Engineering Design: A Systematic Approach” [34]. It is demonstrated in Figure 19.

The step-by-step illustration of such systematic approach initially enables a better understanding of the needs of the problems. As those needs are identified and listed down, ideas and methods to strike those

problems can be formed and personal preferences of the author are to be eliminated. Moreover, preliminary design sketches, which satisfy the demands and wishes for the fabrication of the prototype, and technical / cost estimation of the device are illustrated.

### 6.1 Abstracting to identify the essential problems

The first phase in conceptual design process is to generalise the requirement of the task. By doing so, the fixed values and limitations are temporarily ignored and, instead of that, the main focus of

the task comes to the headlight. As a result, essential constraints become clear without bias toward any choice of a particular solution.

There are 5 steps in order to form the main focus point of the task. The first step is to eliminate personal preferences. Then any requirements that have no direct bearing on the function and the essential constraints are omitted. The third step is to transform quantitative into qualitative data and reduce them to essential statements. Generalising the results of the previous step is the next step. Finally, we try to formulate the problem in solution-neutral terms.

The result would be “Conceptualise a device to clean floating debris in water bodies in a way easy to dispose”. It is pretty much the same as the theme of the thesis in the beginning. This is due to the demand of the thesis is to develop a new idea to deal with the problems, without too many details to fulfil.

## 6.2 Establishing function structure – sub-functions

After formulating the crux of the problem, the overall function structure of the system is indicated. The overall function is then broken down into sub-functions in order for us to see the problem with a more transparent view. Next, the connection between the sub-functions can be shown by means of block diagram using flow of energy, material and signals. Consequently, the relationship between the inputs and outputs can now be clearly illustrated.

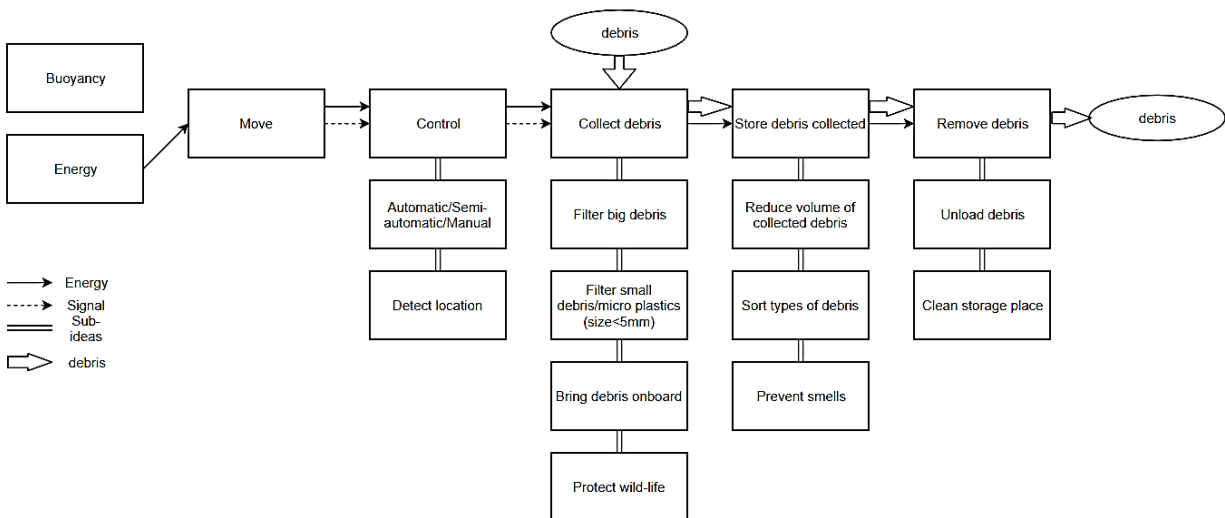


Figure 20: Function structure of the intended device.

In this problem, a buoyant device to collect floating debris is the aim. It is therefore the main function to collect debris. In order to achieve this function, mechanisms needed can be divided into separated tasks. First, it should be afloat by any means. Movement of the device should be taken into consideration, then follow how we can control it. Collecting, then sorting, storage and disposal are remaining tasks to look at. There are several questions to be answered, which help to identify sub-functions of the design: What type of waste would be extracted? How should the extraction be done? How should the storage of the extracted waste be done? How should the garbage be removed from the mobile plant? How is the energy supply of the system carried out? What is the innovation compared to existing systems? Shown above is the block diagram describing the relationship between sub-functions.

### **6.3 Mechanisms that fulfil sub-functions**

When the formation of the sub-functions and their relationship is done, search for appropriate working principles and their combinations has to be conducted. Firstly, a table of sub-functions and solutions is drawn. The sub-functions are the ones brainstormed from the previous steps whereas solutions are for every possible method, way, mechanism, etc. that can solve that particular sub-function. After all the solutions to all sub-functions are listed, approaches that are not feasible have to be eliminated. Next, combinations of these solutions are made. Instead of arbitrarily choosing one solution from each sub-function, decision has to be made so that logically and physically possible associations of the sub-functions are formed.

Table 7 lists possible mechanisms that can fulfil the sub-functions that I know or have read. This means many other possible solutions may have been missed out due to many constraints – namely personnel, time and experience.

It is worth noting that ships are obvious candidate considering a floating device. According to Papanikolaou (2014), designing a ship is an extremely complex process, including the selection of main ship dimensions; development of the ship's hull form (wetted and above-water parts); specification of main machinery and propulsion system type and size (powering); estimation of auxiliary machinery type and powering; design of general arrangement of main and auxiliary spaces (cargo spaces, machinery spaces and accommodation); specification of cargo-handling equipment; design of main structural elements for longitudinal and transverse strength; control of

floatability, stability, trim and freeboard (stability and load line regulations); tonnage measurement (gross register tons). [35]

The thesis, however, cannot afford to touch all the details regarding the designing process of a ship. The thesis's aim is to try providing an overview of my findings, my understanding of the project at the time being. More specific steps can be found in the book "Ship Design - Methodologies of Preliminary Design" by Apostolos Papanikolaou, information of which can be found in references. Internal industrial knowledge can prove helpful for further work on the project. I will try to give illustrations in the sections below before coming to suggestions for a combining solution.

Table 8: Possible mechanisms to fulfil sub-functions for a CleanRiverSolution.

<b>Options/ Subfunctions</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Buoyancy</b>	Floating rafts	Catamarans	Fishing and dinghy boats	Flatboats	Air Cushion Vehicle
<b>Energy</b>	Solar energy	Diesel	Gasoline	...	
<b>Movement</b>	Outboards	Propeller + rudder	Azimuth thrusters	Water jets	Paddle wheels
<b>Control</b>	Manned	Un-manned	Hybrid	...	
<b>Collecting debris</b>	Bucket	Conveyor	Nets/Rakes (manual)	Trapping debris between hulls	Crane
<b>Storage of debris</b>	Directly on board	Garbage bins	Barges	On water surface	...
<b>Disposal of debris</b>	Conveyor	Crane trucks to lift modular pods/barges	...		



## Buoyancy – options to keep the device afloat

There are some options to keep the device afloat. Using barrels to make floating rafts makes sense in we want to build some intervention station like the Mr.Trash Wheel. They are both widely available and affordable.

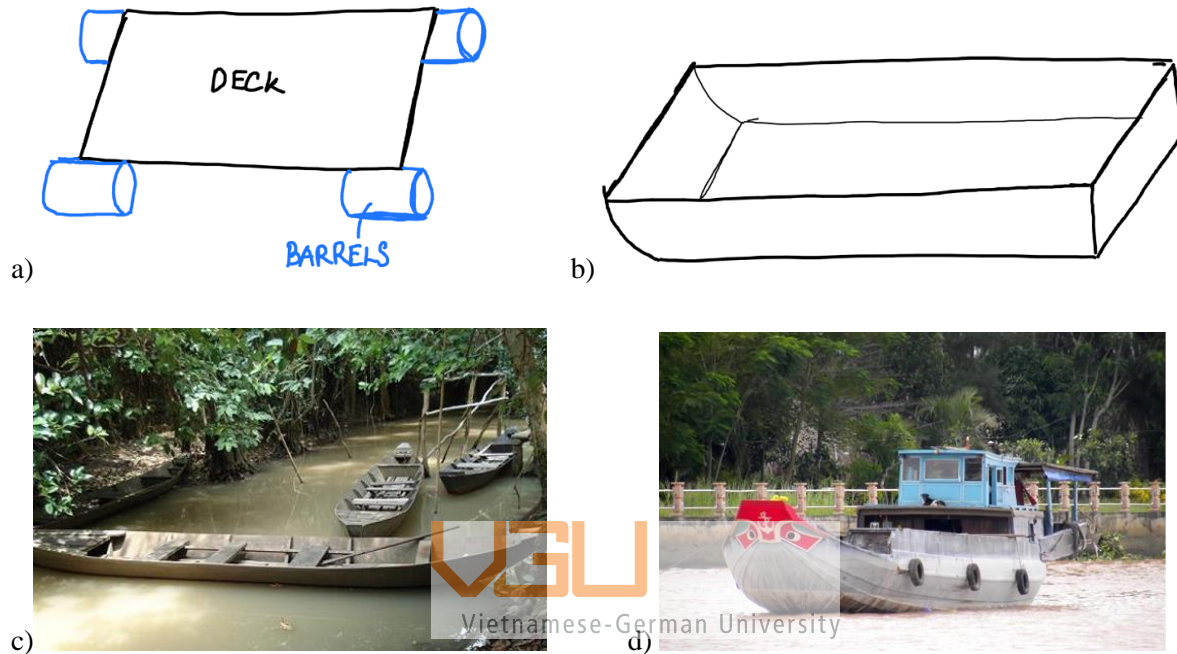


Figure 21: a) Floating rafts; b) Flat-bottomed boat (flatboat); c) Dinghies (Source: Internet); d) Fishing boat (Source: Internet)

For mobile device, boats or ships are logical choice. Consequently, we have to take into account ship hulls design. Fishing and dinghy boats are the most common and widely available at reasonable prices. They are functionally proven designs, which reduces the workload to introduce a cleaning device. Most of current equipment in Vietnam is adaptive design from these. Additional features can be made by orders to shipyards.

An alternative is flat-bottomed boats. They work well in shallow or calm water bodies, such as rivers and channels, canals, because they are less likely to ground (hit the bottom). They are also simple to construct.

The most popular choice used for this type of water clean-up device are catamarans. They are vessels that consist of 2 identical hulls of common shape. Their superior transverse stability makes

them an excellent candidate. Other advantages include increased area of decks per ton of displacement, which provides multi-hull with an economic advantage when transporting light (volumed) cargoes of any kinds, their ability to provide initial stability without any limitations to the elongation of hulls, an increased above-water volume. The same experience has identified some common disadvantages of multi-hull objects: relatively large wetted surface thereby increasing the towing resistance at relatively low speeds, increased structure weight relative to full displacement and increased overall width. [36]



Figure 22: A racing hovercraft. Picture from Wikipedia.

suitable for our case.



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Air Cushion Vehicle, also known as hovercraft, is one option worth to mention. This type of vehicle typically uses one (or more) powerful blower(s) to move its air cushion hull. The design makes the vehicle rising above the running surface, thus able to travelling over water, land, mud, etc. That is quite an impressive ability. The device, however, is noisy when in action.

Its cost per unit is another constraint that makes it not

### **Movement – propulsion systems and engines**

Paddle wheels are the oldest type of movement mechanisms. It can be located at one side or at the stern. Propeller then replaced traditional water wheel.

The familiar choice for small boats is outboards. They are compact, modular, which can be mounted on or taken off easily. Outboards also offer operators good manoeuvrability of boats. That leads to their main disadvantage – their power. Boats sometimes have more than one installed to improve the output.

Another option is azimuth thrusters (they can steer around their vertical axis). They are a special type of propeller propulsion, could be known as stern-vertical or azimuthal propellers. The pod design helps them to rotate 360 degrees, allowing for rapid changes in thrust direction and thus vessel direction. This eliminates the need for a conventional rudder. They come in different set-ups, three of which are Z-drive systems, L-drive systems and Azipods. Z-drive refers to the fact that the rotary motion has to make two 90 degrees turns, thus resembling the letter "Z". L-drive

type of azimuth thrusters has its electric motor mounted vertically. The name refers to the fact that the rotary motion has to make one right angle turn, thus looking like the letter "L". The last type mentioned, Azipod, is an electric podded azimuth thruster, a marine propulsion unit consisting of a fixed pitch propeller mounted on a steerable gondola. This gondola also contains the electric motor driving the propeller. The design is really compact as it does not require the space commonly needed for the engine. What hinder their application are mainly their size and price.

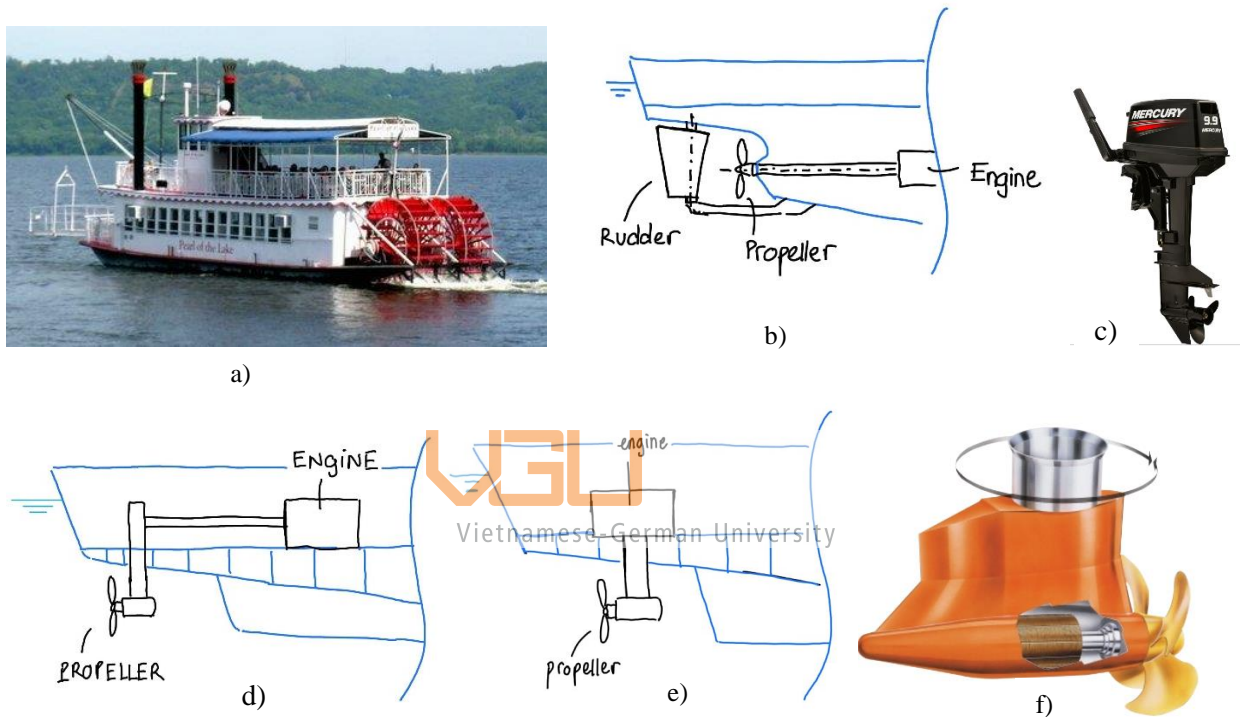


Figure 23: a) Paddle wheel b) Normal rudder-propeller system; c) Mercury 9.9HP outboard; d) Z-drive system; e) L-drive system; f) The Azipod® unit, in which an AC motor sits inside a submerged pod that can be freely steered through 360 degrees. [48] [49] [39]



Figure 24: Voith-Schneider propulsion system [35].

Horizontal Voith—Schneider patent is one special types of marine propulsion. The design is reported to be highly maneuverable, capable of changing the direction of its thrust almost instantaneously (even faster than the azimuth thrusters). They are often found on tugs and ferries. Unlike conventional propellers, here the blades are positioned in a circular pattern on the edge of a round plate, right below the hull. Each blade can rotate about its vertical axis while being rotated with the plate. Thanks to this feature, the angle of the blades can be changed to provide thrust at any direction. Its price however is one big problem for it to be used in everyday device now.

Water jets are mounted inboard in the aft section of the hull. The unit takes in water via an intake on the bottom of the boat, increases the pressure, speeds it up and then discharges a high-velocity jet stream, creating propulsive thrust. By controlling the water stream, its speed and direction when exiting the nozzle, we can do away with transmission system. The water intake and outtake are often directly under the hull, allowing the boat to travel in shallow water. Other advantages that can be listed are quiet and smooth operation, minimal required maintenance.

Air Cushion Vehicles use blowers to produce a large volume of air below the hull. For stability reasons, the air is typically blown through slots or holes around the outside of a disk- or oval-shaped platform, giving most hovercrafts a characteristic rounded-rectangle shape.

Engines are the key in any propulsion system and worth considering. Main machinery or engine types are listed in the book “Ship Design” [35] including steam engines, turbines (steam-powered and gas-powered), diesel engines (Low-speed Medium-speed, High-speed), Otto gas engines, diesel/electric generator set, combined diesel and gas turbines (CODAG), nuclear steam-powered turbines, ‘Green’ environmentally friendly prime or auxiliary energy sources (wind and solar energy), sail foils and solar cells (fuel cells).

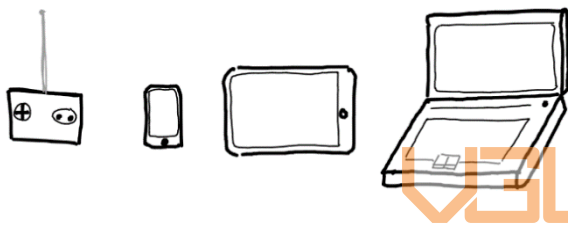
For the case of Vietnam, diesel engines are the most common and can be found easily.

Anchor is also a necessary part for any type of mobile device to stay still, whether in working process (stopping to load a big chunk of debris) or at rest.

## Control of the device operation

Decision must be made on whether the design is manned and un-manned. This will lead to different requirements. For a design that uses labour, ergonomics is the main focus. Therefore, layout design of the device must be clear and intuitive. Needed equipment should be ready on board, and if possible, improvement should be considered. Constraints can be introduced into the design to achieve desired behaviours. For example, safety equipment can be positioned in such a way that workers have to be fully equipped before they can use the tools to collect debris. Belts, working jackets connected to the device could be used to prevent its crew from leaning too far out.

If the design turns out to be un-manned, the complexity of the problem greatly increases. There would be sensor system to detect collectible objects, remote control system and GPS.



*Figure 25: Many options to control unmanned device – remote controllers, smartphones, tablets and computers/laptops.*

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Another option is that the design could be a hybrid, which means it possesses 2 operation modes - manually (using labour) and automatic (in the form of a dock/base) – which means we can settle it there – booms/nets are installed to collect trash passively.

## Collecting of debris

Bucket is used for discontinuous and intermittent work flow. There is a possibility of backflow of trash. A flow guiding device is needed when operating in still water. In short, this method offers low efficiency for the advantage of low energy consumption.

Conveyor, on the other hand, works continuously, hence allows no backflow of trash, but consumes far more energy. This method often works for only small tonnage, offers low load capacity at low speed. This drawback, however, is compensated by its ability to work in still water. It provides quite high efficiency in exchange for high energy consumption.

Trapping debris in middle and dragging them on the surface is another option. This reduces the size of the hulls, since we no longer need to carry the whole load on board. However, to make sure it is a one-way trip for floating debris, a mechanism to trap it inside must be included.

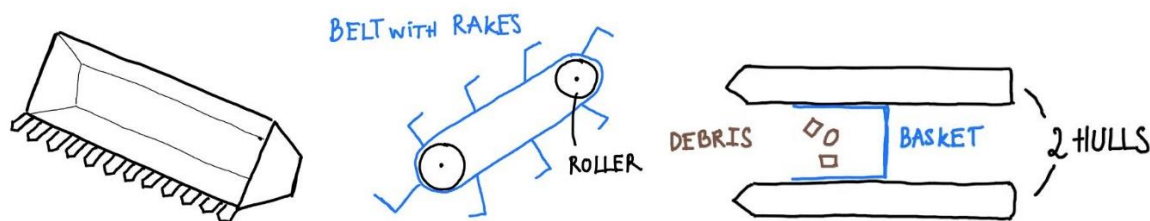


Figure 26: From left to right: Bucket, conveyor, trapping debris between hulls

For fishing boats, one or more crane(s) can be installed onboard. Trash will be lured into a pile by means of collecting booms attached on frames, which are connected to both sides of the boat. Once the booms are full, the task is just like net fishing, except that we now use the crane to pull up the nets and dump collected trash onboard (in dumpsters or storage tanks).

Manual collecting of floating debris using hand nets and rakes is a common method in Vietnam since it is inexpensive and requires no professional skills from the workers. This is especially convenient, considering the fact that official environmental cleaning work is still unpopular in the country. Most of the time, young volunteers participate in clean-up projects in an attempt to raise awareness to their living environments. This method is also suitable to use with dinghies to approach small and/or shallow waterways though it is not efficient.

### Storage of debris

Several options are available, considering current methods. Collected debris can be stored directly on board, like the Trash Hunter/ Aquatic weed harvester shown in Chapter 4. Currently in Vietnam, debris after gathered is put into garbage bins of standard sizes on board. This method makes use of available equipment but does not offer optimal use of space. The Omni Catamaran keeps the trash between its hulls, dragging it on water surface. This is suitable for catamarans, since they offer a great width with good transverse stability but not load capacity (tonnage). Another option, barges, is useful when standard boats with good power, since they provides the greatest capacity.

However, tugging fully-loaded barges is a waste of energy so additional measures to unload the barges, as soon as they are full, are necessary.

### **Disposal of debris**

Disposal mechanisms often relates to the device's means of collecting debris. Currently in Vietnam, after the boats are fully loaded, they return to a pick-up point where crane trucks are used to pull up full garbage bins on board. Then garbage trucks transfer it to waste treatment plants. Barges are made modular, and crane trucks are used to lift the module up and dispose of the contents.

Collecting booms trap the trash that flows through, which is then recovered using boats or pull up via conveyor into dumpsters. Whatever in the dumpsters will be moved to incineration plants. Weed tow boats keep the collected debris on the bucket, and by controlling the bucket, dispose the load into either dumpsters or tugging barges. Trash Hunters/ Aquatic weed harvesters store debris directly on board and then use another conveyor at the stern to unload. Omni Catamarans keep floating debris in the basket pod, which can be pulled up using crane trucks.



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### **6.4 Combination of mechanisms - Working principle**

The next step would be combining working principles into a working structure. A list of variants are chosen that are mostly logical to build. Considering the shallow water bodies that the device is most likely to work in, catamarans and flat-bottomed boats are favourite candidates. Being able to get to corners, where debris often get washed in, means that good manoeuvrability is necessary. Taking into account the conditions in Vietnam, its available labour force, the device should be manned or hybrid. Automatic device, in my opinion, would run into troubles with the possible chaos.

The sum-ups below are written in the order: Variant number – Buoyancy – Movement – Control – Collecting, storage, disposal of debris.

Variant 1 – Catamarans - Azimuth thruster/ Outboards/ Paddle wheels – Manned/ Automatic/ Hybrid - Trap debris between hulls, in a basket - Use a crane truck to pull up the basket.

Variant 2 – Flatboats – Outboards/ Propeller propulsion system – Manned - Nets/Rakes to pull up debris onboard/ Bucket/ Conveyor – Onboard/ Barges - Must have basket or bins for easy discharge/ Crane truck needed.

Variant 3 – Fishing boats/ Dingy boats - Propeller propulsion system/ Outboards/ Azimuth thrusters – Manned - Crane+Nets/ Hand nets+Rakes/ Booms – Onboard/ Trash bins/ Drag on water - Crane truck.

Variant 4 - Floating rafts – no movement – Automatic/ Hybrid – Booms + Conveyor/ Bucket - Barges/ Dumpsters - Supporting boats + crane truck to deal with full barges.

Above are possible combinations for a device concept. Though the first three are straight-forward boats, variant 4 is a bit different and therefore needs a bit description. I think of variant 4 as a stationary floating factory, like Mr.Trash Wheel, used in combination with other service boats. In other words, it will work passively when the workers are not present (for example, at night) and could serve as the rally point for all cleaning devices. We can use the other boats to help unload full dumpsters. All collected debris would be gathered here before moved to waste treatment plants (ideally nearby).



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## **6.5 Evaluating principle solution variants**

After identifying possible variants, we need to evaluate them using the criteria deriving from the system requirements. First, the evaluation criteria are identified. Second, those criteria are weighed based on their importance to the system. Third, parameters are added to make the grading of the system more clearly. Finally, grading and comparison of the variants are conducted.

The table showing grading of the combinations is shown next page. Following the table, reasons for the grading are explained.

Note that the weighing and grading process are subjective and therefore can be improved if the readers have different knowledge and experience.



Table 9: Concept evaluation table.

Evaluation criteria			Parameters		Variant 1		Variant 2		Variant 3		Variant 4		
No.		Weight		Unit	Value	Weight	Value	Weight	Value	Weight	Value	Weight	
1	Small and compact size	0.1	Length, width, height	m	8	0.8	8	0.8	7	0.7	5	0.5	
2	Ability to work in small waterways	0.1	Good manoeuvrability		8	0.8	7	0.7	7	0.7	6	0.6	
3	Ability to work in shallow water	0.1	Weight	kg	7	0.7	8	0.8	6	0.6	5	0.5	
4	Ease of operation	0.2	Requiring no special skills to operate		9	1.8	6	1.2	6	1.2	9	1.8	
5	Operator safety	0.2	Safe working environment (even for volunteers)		10	2	6	1.2	6	1.2	10	2	
6	Ease of production	0.2	Materials can be found in Vietnam		8	1.6	8	1.6	8	1.6	5	1	
7	Ease of maintenance	0.1	The parts are easy to assembly and exchange		9	0.9	8	0.8	9	0.9	6	0.6	
0: worst						8.6	7.1						7
10: perfect													

Small and compact size: the first three variants, namely catamarans, flatboats and fishing vessels, are quite compact and mobile. Only variant 4, floating rafts, are stationary and of quite big size.

Ability to work in small waterways: this ability relates to the device's size and its manoeuvrability. Azimuth thrusters provide better steering flexibility than outboards. The floating rafts are not designed to move.



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Ability to work in shallow water: Catamarans and flatboats are good at this feature. Fishing vessels, since they carry load onboard, require some depth. The floating rafts are of big size, and thus heavier, so they often require some water depth.

Ease of operation: Variant 1 (catamaran), with the podded drive, is easy for the operators to control with only a stick. Variant 4 (floating rafts) is automatic, requires attention to the disposal phase only. The others two require some experience in operating.

Operator safety: Variant 1 (catamaran) moves at slow speed and has good stability. Variant 4 (floating rafts) does not need the workers to be present. Flatboats and fishing vessels, as usual, need further methods to ensure the safety of workers.

Ease of production: Catamarans, flatboats and fishing vessels are commonly found in Vietnam. Variant 4 is more like a factory afloat and would require a lot to produce.

Ease of maintenance: The simpler the components, the easier it is to do maintenance. Another factor is the popularity of the design. Based on those factors, I think the catamaran and fishing boats top this criterion while the floating rafts finish bottom.

## 6.6 Solution concept

The basic idea of the CleanRiverSolution machine is a device of small size, which is easy to produce, convenient to operate. This can be achieved by using the catamaran design, which requires less materials and is quite easy to make. Two separate hulls are connected to a metal deck, made of aluminium or steel. This deck is where the workers stand and walk around to do their job. Barriers are added to prevent them from leaning and falling in the water. The basket is installed using a fit connection. We use a crane truck to move the basket to the space and put it there. On four side surfaces of the basket, bars of metals can be welded on, so that when the basket goes in the slot, the bars press with the deck, which keeps the basket in position. This way, though we may not make use of all the basket volume, it acts as a safety barrier itself. The door is designed so that trash only comes in as the boat move forward. When the boat moves backward, it is self-locked. The boat can be moved by using azimuth thrusters to provide good manoeuvrability. And due to the weight of the engine, we could make change in shape of the hull, like in Figure 24b.

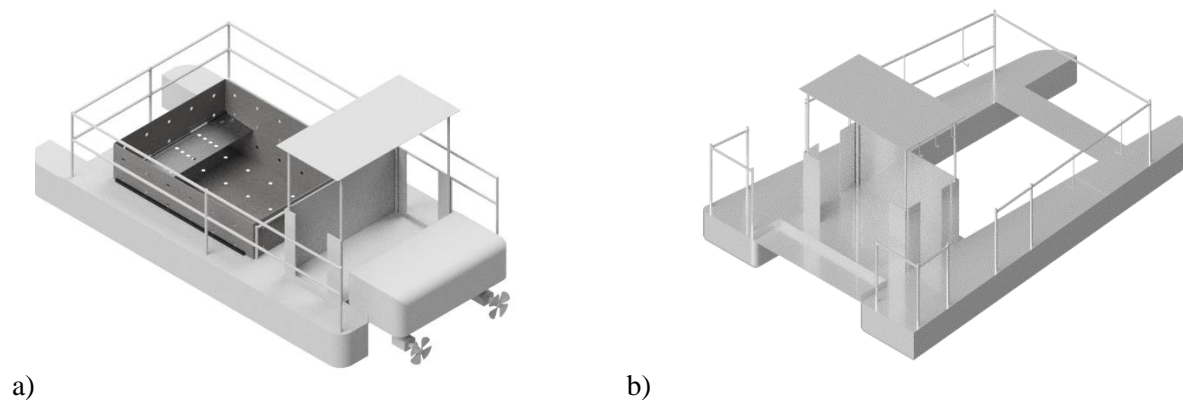


Figure 27: CleanRiverSolution. a) The first outlook of the design; b) A change made to the shape of the hull: the size increases from bow to stern.

## Hulls

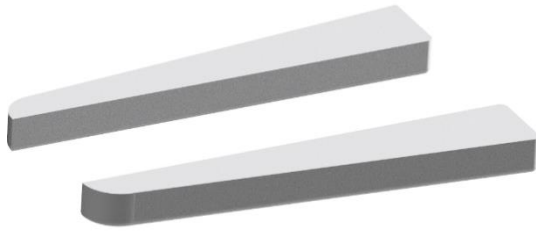
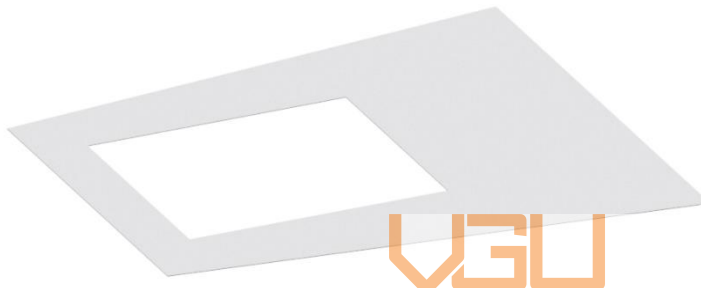


Figure 28: Two hulls of same shape and size

The two hulls can be made of aluminium plates. By bending metal plates in position, using screws to fix them still and welding the plates together, the hulls take shape. Then, special treatment of chemicals, usually special types of glues to prevent water, are needed to finalise the process. Maximal carrying load of the hulls can be calculated by multiplying total volume of the hulls with specific weight of water, dividing by 2 for safety factor.

## Deck



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Figure 29: Deck of the catamaran

The deck is then put on top of the hull, connected by welding or bolts connection. As it is the components that carry weight of workers and engine, calculation is needed to choose the thickness. Reinforcement mesh may be needed.

## Barriers and cockpit

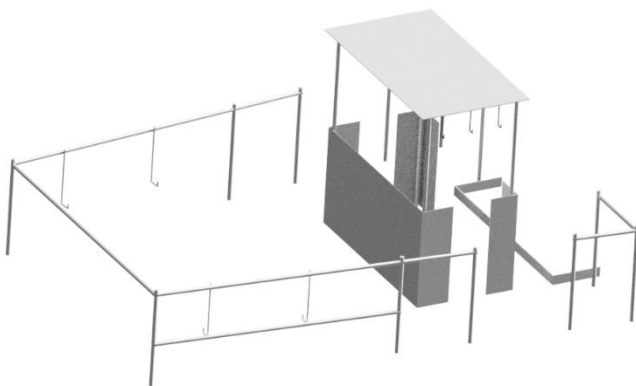


Figure 30: Barriers and cockpit

These bars and metal plates can be welded directly on the deck. Safety harness are added on board, put in a position where workers have to equip them before they can take the hand nets and rakes. Ideally, safety equipment should be put right at the entrance of the boat. Life rings are hung along side the barrier.

## Basket

The basket is shown in Figure 25. It can also be made like open steel flooring. The point is to let water run freely in the basket, while debris going in is trapped inside. The door rotates about an axis in a motion of 180 degrees. Small edges of metals are welded in to constrain the movement of the door, allowing debris to travel in but not out of the basket.

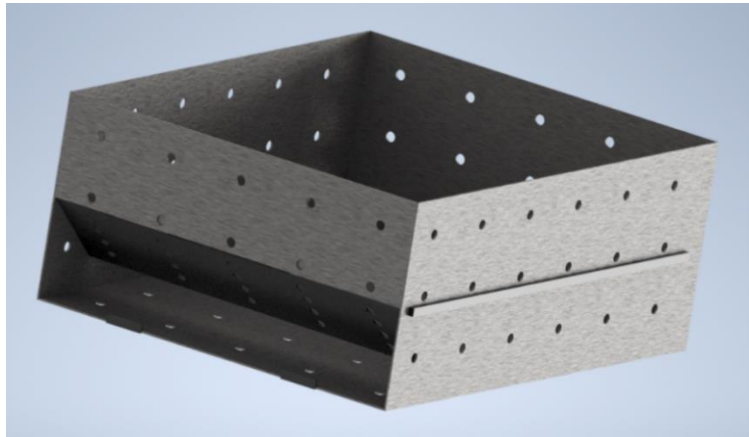


Figure 31: Basket pod to contain debris. Small edges of metals allow the door to be opened in 1 direction only. Metal bars on the sides (one more bar on the other side, not shown in the picture) hold the basket in position.

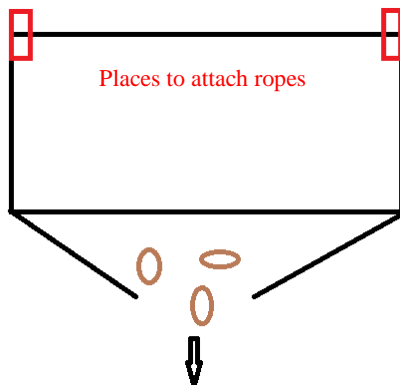


Figure 32: It is able to open the basket at the bottom, by means of simple latches. Four top corners of the basket have places to attach ropes. To unload the basket, first we attach ropes to four top corners to pull it up (using crane). Then as the basket hovers above the truck dumpster, we lift the latches, open the bottom and let debris fall out.

## Propulsion

Although small catamarans usually have outboards as engines, azimuth thrusters would provide greater flexibility in controlling moving directions. The problem is that they are often produced for large ships and adaptive design may be needed.

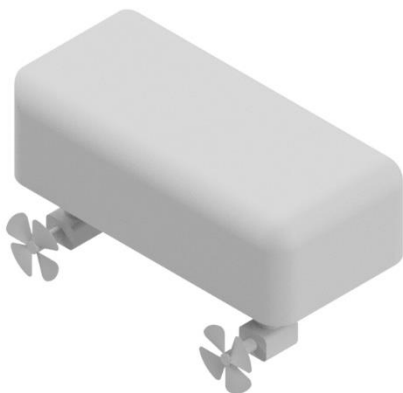


Figure 33: Azimuth thrusters. The propellers are placed in pods, allowing any horizontal rotations.

## Deck arrangement

Improving safety of the operators is one critical requirement of the design, and together with the functionality of the boat, arrangement onboard plays a role in achieving this. One possibility is to allow only one entrance on and off the boat, and then place the safety equipment right at the entrance. This way, as soon as one gets onboard, they see the safety equipment, preventing the unreliability of our mind. It could even be better, if we could put the safety equipment on top of the working tools, or the control panel. So one cannot get to work unless they put on their safety kit. This could prove helpful in cases where people are reckless or underestimate the importance of safety. In this concept, I suggest using the safety harness as it works well in keeping the workers from falling off boat.

The anchor of the boat should be kept at the bow to balance out the weight of the engine.

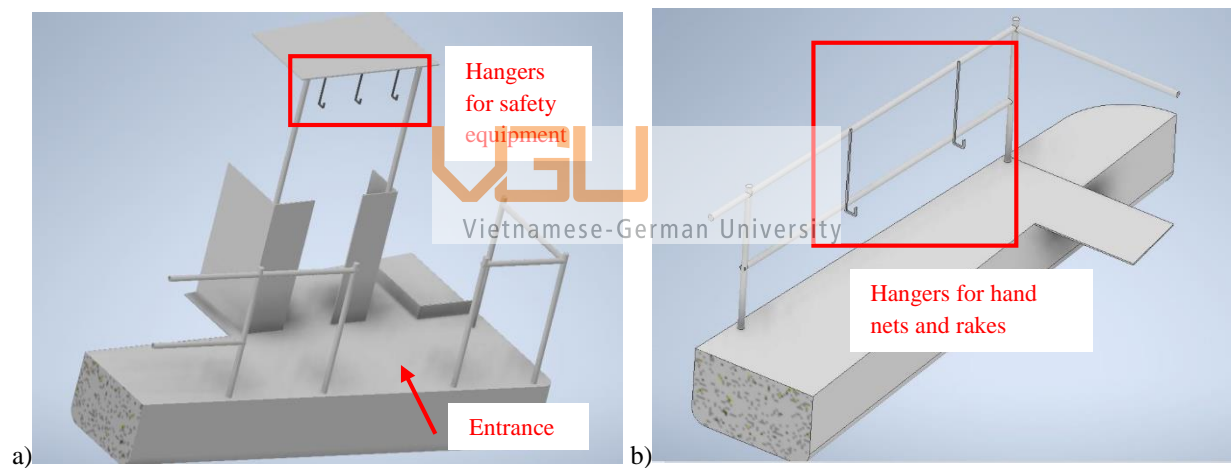


Figure 34: a) As the workers enter the boat, they immediately see the safety harness; b) Hangers for hand nets and rakes are positioned alongside the barriers, the workers can get the tools after they see the safety equipment first.



Figure 35: A picture of a safety harness (sold on [indiamart.com](https://www.indiamart.com)). A worker wears the harness around his body and then attaches the rope to the boat barrier. This way his motion is constrained within the distance of the rope length.

## 7. Discussion and conclusion

The work done up to this point is one part of the CleanRiverSolution Project, which consists of different ideas in many fields. With the hope of contributing to the project, I have tried my best to go through a bit of background research. The process starts with explaining why Vietnam is an interested target, continues with types of floating debris, potential sites for application and then introducing some products that are on the market at this point. Finally, a systematic approach is applied to find out a possible solution for the project.

I am well aware that my work is by no means complete and perfect, it is actually far from that. The more I delve into the subject, the more new knowledge I find. This is such a grand topic that each of the chapter I wrote here is a field itself. What I tried to do, is to give my honest opinions on the subject. I must admit there are many points which I do not fully understand, and thus only attempt to mention them, or give my best interpretations.

In chapter 2, I divide floating debris into 3 categories – plastic, vegetation and others. It is not any officially accepted classification. It was due to my work process that makes it convenient to write as such. I started with the aim of coping with plastics in water, hence I give the lengthy background information, plastics life cycle, how they get into the water and their effects on living life. I used all findings I had found on the subject for this part, to give a look at the big picture. Later, when I tried to focus the work on Vietnam, I found that vegetation and all kinds of trash are present in the water here. There were some, but not so many thorough research attempts, since the country is still developing and not much attention is paid on this subject. In fact, I did base on my experience as a resident here for more than 20 years and admit that I could be subjective. There are parts in the work that do not give any concrete numbers, due to the fact that I cannot find some, but I believe there will be some in the future to prove my points.

Chapter 3 lists several potential sites for the application of this project. They all are notorious places at the time, but things can change and there could be a chance we have to find other places. The reason why I gave those places is that they are well-known (especially, some are familiar to me). And for that reason, they could be the priority target of the city. But further from HCMC, there will always be places to be cleaned in a very long time, I believe.

Chapter 4 discusses several solutions that are being used now, in Vietnam and in the world. It is very likely that there are more methods I have not found. Most of my work was done through searching open-source databases, and I am no expert at this subject.

Chapter 5 and 6 are the design process I learned in class and this is the first time I use it to do a project. By deciding the purpose of the work via requirement list, then abstracting to find the core problem, establishing a function structures, I can clearly see the steps to move forward. Finding possible mechanisms to fulfil sub-functions and combining them into concepts are the most difficult tasks. I tried to read everything I could find online, or from the library (that came up in my mind) and wrote any related things there. The process sure requires tedious work but I think anyone reading this can come up with a different idea, a different way of thinking and new information from other sources.

I tried to sketch the concepts by hand, which helps my thinking, but I am aware better visual illustrations are possible.

If the work is to be developed, I would suggest reconsidering other concepts. I aim at a simple device that does the job while does not disturb the current working culture in the country too much, which is the main reason why other concepts were rejected. But a device like this will not solve the whole problem from its root. It is a chain of actions, starting from preventing people to dump their trash, to collecting what is left over, and finally to waste treatment process.

More researches and testing are needed to finalise the concept. Optimizing of the machine will come later. Dimension, performance and strength calculation are not performed in the context of this bachelor thesis and could be carried out in advance work. Finite element method can be included. Production of prototypes is one open option. Many, many details of a boat are missing out and could provide enhancements to the performance, quality and energy-consumption of the product. Some of them could be, for examples, choosing shapes of the boat considering hydrodynamics, choosing of engines, further developing of collecting, storage and disposal mechanisms, etc.

In conclusion, the development of a river cleaning machine that collect floating debris is needed and will provide an important impact. This bachelor thesis is just a first stone in the project. There is a huge potential for improvement in the mission to make the water bodies in Vietnam clea


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## **Program used**

Microsoft Word 2010

Paint

Autodesk Inventor 2020

Squid (Android)

