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A study of riverine sources of marine plastic debris in the Öresund area of southern Sweden

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A STUDY OF RIVERINE SOURCES OF MARINE PLASTIC DEBRIS IN THE ÖRESUND AREA OF SOUTHERN SWEDEN

By

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IRAN

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the reward of the degree of

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in
MARITIME AFFAIRS

(OCEAN SUSTAINABILITY, GOVERNANCE AND MANAGEMENT)

2020

Declaration

I certify that all the material in this dissertation that is not my own work has been identified and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

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September 18, 2020

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Abstract

Title of Dissertation: **A study of riverine sources of marine plastic debris in the Öresund area of southern Sweden**

Degree: **Master of Science**

The development of various industries and increasing demand for cheap products have increased plastic production as an inexpensive and multifunctional material. Plastic breaks up into very small particles that can pass into the sewage system or catchment area of the rivers and eventually find their way into rivers and ultimately the marine environment. Plastic debris can come in all shapes and sizes and enter soil, rivers, lakes, ocean, or even air. There is a growing concern about the potential health problems they pose to the ecological system. The plastics less than 5 millimeters and greater than 0.1 micrometers in length are commonly known as microplastics. Macroplastics commonly referred to the particles having a size greater than 25 mm. In order to manage plastic waste more effectively it is important to determine the quantity, type, and source of plastic in the marine environment. In this study, an assessment was made of the concentration of microplastic and macroplastics in sites where rivers enter the sea along the coast of southern Sweden. For this purpose, several samples from different stations near the mouth of Kävlinge and Höje rivers leading to the Öresund are collected. Control sites from beaches away from the river mouths were selected for comparison. Samples obtained from each station were examined and the relative amount of these substances were quantified. The results indicate that the concentration of the plastic contaminants (both microplastic and macroplastics) in the river sites were higher than associated control sites. Surprisingly, the abundance of the microplastics in the mouth of the Kävlinge river with a larger drainage area was higher than Höje river, although Kävlinge river has a catchment from less populated areas. Regarding macroplastics, the concentration of contaminants in the mouth of the Höje river is considerably higher than the Kävlinge river suggesting a correlation between the population of urban areas and macroplastic pollutions.

KEYWORDS: marine debris, microplastics, macroplastics, marine pollutant, riverine transport, land to sea, beach sediment.

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List of Abbreviations

ADF	Advance Disposal Fee
ANOVA	Analysis of Variance
CEPA	Canadian Environmental Protection Act
Df	Degrees of freedom
EPR	Extended Producer Responsibility
EU	European Union
EU-WFD	European Commission-Water Framework Directive
F crit	Critical value of F
F	Factor
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
HELCOM	Helsinki Commission (The Baltic Marine Environment Protection Commission)
IMO	International Maritime Organisation
MARPOL	Marine Pollution (International Convention for the Prevention of Pollution from Ships)
MS	Mean squares
MSFD	Marine Strategy Framework Directive
NGO	Non-Governmental Organisation
OSPAR	Oslo and Paris Commissions (Convention for the Protection of the Marine Environment of the North-East Atlantic)
P-value	Probability value
SNMMP	Swedish National Marine Monitoring Programme
SS	Sum-of-squares
UNCLOS	United Convection of Law of the Sea
UNEP	United Nations Environment Programme
UWWTP	Urban Wastewater Treatment Plants
WMU	World Maritime University

WWF	World Wide Fund for Nature

1. Introduction

Over the last few decades, the demand for plastic products has been increased owing to their social and economic benefits (Andrady & Neal, 2009). In 2016, about 322 million tons of the plastics were manufactured worldwide (PlasticsEurope, 2016). Durability, lightweight, corrosion-resistance, and cheap price of plastic products are the main reasons for the enormous usage of these products in various industries and sectors (Andrady & Neal, 2009; Andrady, 2011). For instance, the utilization of the plastics products, which are commonly lighter than other products, in vehicles has helped to reduce carbon dioxide emission (Andrady & Neal, 2009). Although plastics have many positive values, they cause numerous problems for the environment (Barnes et al., 2009; Thompson et al., 2009; UNEP, 2005).

Because of the excessive use of plastics, especially single-use plastics, these pollutants comprise about 10% of the total waste produced in the world (Pambudi et al., 2019). Plastic debris can be introduced to the environment as a result of indiscreet disposal. Eventually, these plastics would find their way into marine environments through rivers, streams, and wind (Thompson et al., 2005). Therefore, a considerable amount of plastic debris enters the oceans annually (Jambeck et al., 2015; OSPAR Commission, 2010). Due to this, plastic debris throughout global water bodies (both surface and bottom water of seas, lakes, oceans, and rivers) is ubiquitous (Eriksen et al., 2014; Ling et al., 2017). For example, in 2010, it was estimated that between four and twelve million tons of plastics have been transported from land into our oceans (Jambeck et al., 2015). According to Neufeld et al. (2016), if current production rates continue, by 2050, oceans are predicted to contain more plastics than fish by weight, and by then, 20% of total oil production will be consumed by the plastic industry.

As a result of the growing plastic pollution even in very remote areas of the world oceans, such as high seas and deep-seas, global concerns have risen (Peeken et al., 2018). The ocean floor is the main sink for plastics (Bergmann et al., 2017). The abundance of marine plastics in these environments has caused numerous negative impacts (Mattlin & Cawthorn, 1986). For instance, plastic debris has been shown to act as vectors for toxic chemicals (Teuten et al., 2009), and such concentration of the pollutant on the plastic debris can be up to one million times higher than their surrounding environment (Koelmans et al., 2016; Mato et al., 2001). For several reasons such as fragmentation effects, their size, and high abundance, plastics cannot easily be removed from marine environments. In addition, plastics are a resistant material; therefore, the risk of negative impacts on marine animals is continuously increasing by their accumulation in the environment (Stolte et al., 2015).

Plastic are classified based on their size, shapes, or other features. Plastic debris greater than 25 mm is known as macroplastics (Romeo et al., 2015). The macroplastic debris is released to the environments over time and because of various phenomena degrades to the smaller size plastics. Different kinds of plastic degradation are classified as (i) Biodegradation by organisms (microbes), (ii) Photo degradation by light (like sunlight), (iii) Thermo-oxidative degradation by slow oxidative breakdown, (iv) Thermal degradation by high temperatures, and (v) Hydrolysis by water. The integrity of various kinds of plastics depends on their average molecular weight. During chemical degradation process, the average molecular weight of the polymer decreases and consequently, the material will become weaker and suitable to transform into powdery fragments (Andrady, 2011).

Microplastics (0.1 µm–5 mm in size) are not readily detectable with the naked eyes. Moreover, resin-pellets may mix with sand and consequently cannot be simply distinguishable (Andrady, 2011). During the last decades, the abundance and polymeric characteristics of these particles have been investigated in several locations around the world, for example, the beaches of Malta island in the central Mediterranean (Turner & Holmes, 2011).

Microplastics are considered as widespread and recalcitrant contaminants of the global environment (Arthur et al., 2008; Barnes et al., 2009; Cózar et al., 2014). The number of plastic contaminants varies according to their size. A study by Erni-Cassola et al. (2017) shows that there is a direct correlation between decreasing particle size and increasing their number. There are also different forms of microplastics, which are (i) direct produce like pre-production pellets, (ii) particles of macro plastic that have derived from the large plastics after degradation, (iii) microfibres from washing mashies and disposed cloths, and (iv) tire and road paint fragments (Coppock et al., 2017).

Plastic debris negatively affects marine fauna in various ways. Due to the different range of particle sizes of plastic debris and their distribution throughout the world oceans, they can fall within the optimal prey size for various aquatic species. Therefore, plastics are bioavailable for interaction and ingestion for marine animals at multiple trophic levels (Boerger et al., 2010; Germanov et al., 2018; Lusher et al., 2017). Ingestion of these plastics by marine birds, mammals (Mallory, 2008; Lusher et al., 2015), fishes (Bellas, 2016), zooplanktons (Desforges et al., 2015), and other marine species (Dekiff et al., 2014; Gregory, 2009; Laist, 1987) are reported. According to Rios and Moore (2007), at least 44% of marine birds ingest plastics. Such consumption of plastics can cause death (Koelmans et al., 2016).

In 2009, a study revealed the presence and increasing trend of microplastics in the zooplankton samples collected from winter cruises in the Southern region of California in 1984, 1994, and 2007 (Gilfillan, 2009). Additionally, in 2015, in the north and west of Ireland, a study about microplastic ingestion by oceanic cetaceans indicated the presence of microplastics in the whole digestive system of these marine mammals (Lusher et al., 2015). A further microplastic study has been conducted in the Baltic Sea using Zooplankton samples collected within the Swedish National Marine Monitoring Programme (SNMMP) (Gorokhova, 2015). Since the microplastics have entered the marine food web, they might get into the human food and digestive system via seafood consumption (Van Cauwenberghe & Janssen, 2014).

In the last few decades, various studies about the occurrence, distribution, and characteristics of plastic debris in the marine environments have been carried out. Thompson et al. (2004) sampled sediment from 17 beaches and found that microplastics were common contaminants in all of the sample sites. To understand the long term trend of microplastic in the pelagic zones, plankton samples have been collected and tested since the 1970s along two routes between Sule Skerry and Iceland as well as Aberdeen and the Shetland Isles. The existence of microplastics was confirmed in the samples collected during this testing. The quantity of microplastics has considerably risen over the decades.

Galloway et al. (2011) reported that the presence of microplastics in 18 sample sites from several countries (Australia, Azores, Chile, Japan, Mozambique, Oman, Philippines, Portugal, South Africa, United Arab Emirates, United Kingdom, and the United States) and found evidence that the wastewater of the washing machines was a source of microplastics. They estimate that more than 1900 fibres can be generated and released to water by a single wash of a dress. By the combination of on-site experiments with washing machine wastewater measurements, it has been concluded that one of the main sources of marine microplastics is urban sewage-effluent that discharges directly into the rivers and oceans (Browne et al., 2011).

Eriksen et al. (2014) has also used data collected from 24 expeditions between 2007-2013 across North Atlantic, South Atlantic, North Pacific, South Pacific, Mediterranean Sea, Indian Ocean, Bay of Bengal, Australian coasts, and an oceanographic model to estimate the total number and weight of plastics across the world. According to this study, a minimum of 5.25 trillion particles (14,400-268,940 tons) is floating in the world's oceans.

The international scientific communities globally have a clear focus to address these problems. The Marine Strategy Framework Directive (MSFD) was adopted by the European Union in 2008 to preserve the world oceans and seas. The reduction of marine litter by 2020 is one of the key goals of this framework (European Commission, 2008). However, this goal cannot be achieved without appropriate knowledge about the characteristics, abundance, distribution, and sources of different kinds of marine litters (Schönlau et al., 2020). The European Commission-Water Framework Directive (EU-WFD) continuously monitors and evaluates marine recipients and provides relevant information about chemical status, biodiversity, and the ecology of marine and coastal areas. This monitoring can offer useful information about microplastic concentration areas and the abundance of plastics as a result of human activity. Also, such knowledge will be helpful to assess the ecological and environmental impact of various types of plastics (Haave et al., 2019).

The Baltic Sea is a semi-enclosed water body that has a narrow connection with the North Sea through the Danish strait. This is a shallow sea with low salinity, and it has a limited number of tides; therefore, water moves very slowly (Korpinen et al., 2010). Furthermore, the Baltic Sea's water is separated into two horizontal layers with various salinities. Very limited water exchanges occur between the top and bottom layers which cause a shortage of oxygen for the bottom layer. Considering restricted and low water exchange between the layers and with open seas, the sea is more vulnerable to being contaminated by plastic pollutants or any other pollutants (Feisel et al., 2008; Korpinen et al., 2010). According to HELCOM (2018), about 70% of marine litters in the Baltic Sea are plastic debris. Furthermore, as a result of industrial and household activities around the Baltic region with more than 85 million populations, there are high environmental pressures on the ecosystem of this sea (WWF, 2018).

The distribution and abundance of microplastics at the beaches along the Baltic coast in Germany (Warnow and Order/ Peene region on Rügen island and the Rostock coast) were evaluated by Stolte et al. (2015). The Peene outlet entering the Baltic Sea, and Jade Bay had a higher number of microplastics due to the higher human activities in this region (Stolte et al., 2015). Also, a survey was performed between June 2015 to January 2016, on the coast of the Kaliningrad region in the Baltic Sea to assess the concentration of microplastics and mesoplastics and macroplastics in this region. The result presented 1.3 to 36.6 microplastics per kilogram of sediment in the Kaliningrad region. As stated in the report, there was not a meaningful difference between areas with more human stress and other areas where were less affected by human activities (Esiukova, 2017).

In a study conducted by Constant et al. (2019), the abundance of the microplastics in a selected region of the Mediterranean Sea was studied. They investigated the distribution of microplastics in beach sediment in the Northwestern Mediterranean Sea by collecting samples on beaches of the western Gulf of Lion for a couple of successive months. The results show that the highest concentration of plastic debris was nearby river mouths and also touristic areas as well as the upper beach. In the mentioned research, overall 63% of 15,664 items were fibres (Constant et al., 2019).

Siegfried et al. (2017) introduced a modelling method for calculating the amount of microplastic exported from European river basins to the Baltic Sea, North Sea, Black Sea, Mediterranian Sea, and the Atlantic Ocean. The amount, types, and sources of microplastics that are introduced to these seas from different river basins was calculated by this modelling approach. Furthermore, this model has been used to predict two scenarios for the future trends of the exporting microplastics to the marine environment from rivers up to 2050 (Siegfried et al., 2017).

1.1. Research objectives

This study aimed to extend the current knowledge regarding the quantification and sources of plastic debris, focusing on macroplastics and microplastics in the nearshore sediment of the Öresund area. The specific areas for the study involved the mouth of Kävlinge and Höje rivers (located in Skåne County, Sweden), to provide additional suggestions on how to protect the marine environment in the studied region. Due to human activities along the rivers, plastic debris is predicted to accumulate at river mouths. Therefore, sample locations in the mouth of rivers were chosen to evaluate the amount of microplastic and macroplastic in coastal sediments.

1.2. Research questions

This study addressed the following research questions:

- Are rivers a significant source of plastics for the marine environment?
- What are the dominant types of plastic debris in the mouth of rivers and control sites?
- Is there any relation between urban populations and abundance of the plastic debris?
- What are the current regulations for prohibiting the disposal of plastic debris?

2. Methodology

2.1. Project location

In recent years the Öresund (The strait between Denmark and Sweden) has received a lot of attention due to increasing anthropogenic activities impacts (Bystedt, 2018; Nielsen, 2001). The Öresund is a narrow and shallow strait between densely populated areas of eastern Denmark and Scania (Skåne) in southern Sweden (Figure 1). Two major cities that are located on each side of the strait are the capital city of Copenhagen in Denmark and Malmö in Sweden. These two cities are connected through the Öresund Bridge that spans the strait. The Öresund region has a population of about four million (2018) and a population density of 192/km^2 (Aziz, 2020). Due to populated urban areas around this strait, it has a high probability of contamination by microplastics (Bystedt, 2018).

Figure 1: The geographic location of the Öresund (Oresndkmtee, 2020)

Sampling locations were selected on the Swedish side of the strait in the vicinity of Malmö. Two study rivers were selected on the coast of the Öresund, the Kävlinge and Höje rivers. For each river a site at the mouth of the river was sampled and compared with a control site located at least a few kilometres away from the immediate influence of the river. Coordinates of sampling sites are given in Table 1. The catchment areas and geographic maps of both rivers are shown in Figure 2.

Table 1 : Geographic locations of the collected samples (Collection date: May 2020)

S/No.	Location Name	Coordinates	No. of Samples
1	Kävlinge river	55° 43' 57"N 12° 59' 55"E	4
2	Kävlinge control	55° 44' 04"N 12° 57' 32"E	4
3	Höje river	55° 40' 34"N 13° 03' 32"E	4
4	Höje control	55° 40' 45"N 13° 03' 30"E	4

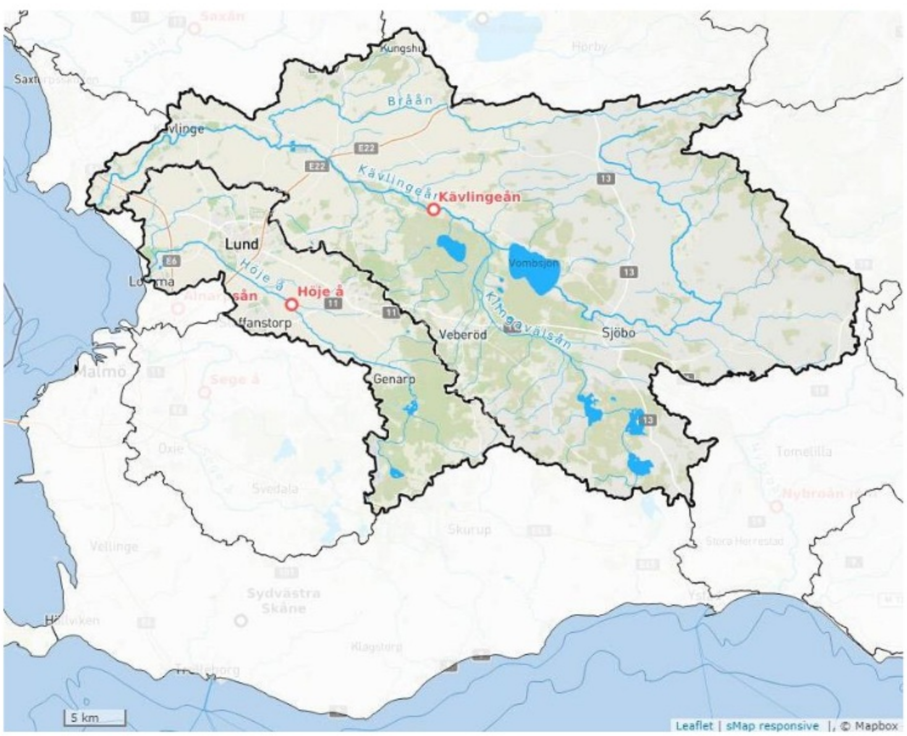

Figure 2: Drainage areas of the Kävlinge and Höje rivers (Image from https://vattenatlas.se/)

Kävlinge river (Kävlingeån in Swedish, between the town of Kävlinge and its mouth is known as Lödde å), is about 90 km long river is located in Scania in southern Sweden. It springs from lake Vombsjön and after passing by Revingeby, Kävlinge, Furulund, and Löddeköpinge municipalities, in the area near Vikhög, flows into the Öresund (Nationalencyklopedin, 2000). The total drainage area of the Kävlinge river is about 1200 km^2 and the approximate number of urban inhabitants in this area is about 100,000 (Statistics Sweden, 2019). The main urban areas in the drainage area of the Kävlinge river are Eslöv (Partially), Kävlinge, Sjöbo, Södra Sandby, Veberöd, and Furulund.

Höje river (Höje å in Swedish) is about 35 km long river in Scania in southern Sweden (Håkansson, 2017). It starts at the Häckeberga lake in the Lund municipality and after passing the Lomma municipality leads to Öresund. A natural harbor is formed in the mouth of the Höje river in Lomma. The drainage area of the Höje river is about 320 km^2 and the approximate number of urban inhabitants in this area is about 190,000 (Statistics Sweden, 2019). The main urban areas in the drainage area of the Höje river are Lund, Staffanstorp, Lomma, Dalby, Hjärup (Partially), and Genarp. Population data regarding the main urban areas in the basin of Kävlinge and Höje rivers are given in Table A. 1 (Statistics Sweden, 2019).

2.2. Sampling for microplastics

To collect the sediment samples, two locations with two different sampling sites (total four sampling locations) on the coast of Öresund and near the mouth of the Kävlinge and Höje rivers were chosen (Figure 3). For the purpose of comparison in the case of each river, a control site far away from the mouth of the rivers and on the coast of the Öresund has been selected. The selection of the sampling locations in these sites provided the opportunity for the comparative evaluation of the microplastic pollution in these areas. From each sampling location, four sediment replicates with a total of 16 samples were collected. In each sampling location, the selected spots were placed at a distance of about 50 meters.

Figure 3: Sampling locations on the beach of the Öresund (Image from https://vattenatlas.se/)

In each of the selected locations, sediments from the riverside or coastal regions were collected using a 7.3 cm diameter and 106 cm length, core sediment sampler (Figure 4). The wet sediments were stored in plastic bags and labelled according to the geographic locations. The collected samples from all locations were transported to the laboratory for further analysis.

Figure 4: Collecting sediments from sites using a core sampler

2.3. Laboratory preparation of the sediment samples

After collecting the sediment samples from the two locations Kävlinge and Höje (river & control), the samples were brought to the laboratory and they were allowed to dry for about a week (Figure 5). Next, the samples were sieved using a Sieve No. 18 (Figure 6). Then the sediment samples were weighed using a precision balance (precision was 0.01 gram). Three grams of sediments from each sample were separated and stored on a Petri plate to be used for microscopic identification (Figure 7). During the various steps of collection and preparation of the sediment samples, efforts were made to avoid contamination of the sediments.

Figure 5: Drying of the sediment samples

Figure 6: Sieve used for sediment samples

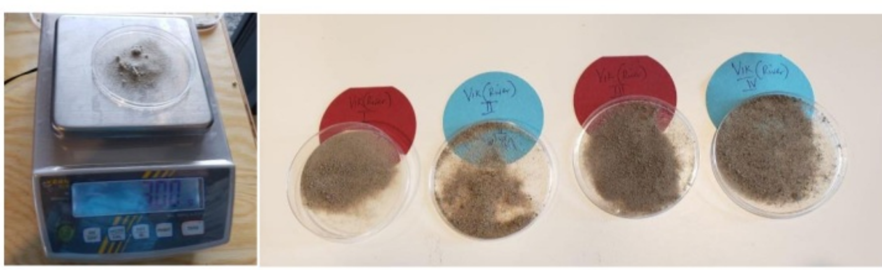

Figure 7: Dried and weighed samples

2.4. Data collection of microplastics

To study microplastics in the sediment, a Euromex iScope Microscope (euromex.com, model IS.1153-PLi) was used. For this purpose, dried sediments were distributed evenly on the Petri plate under the microscope. Then 20 random images with the magnifying factor of 40 were taken from different spots of the sediment in the Petri plates and the number of microplastics in each image was counted. The sub-samples of microscope images were taken using the microscope which is shown in Figure 8.

There are some defined criteria to discriminate microplastics using optical microscopes (Costa et al., 2010; Hidalgo-Ruz et al., 2012), which are as follows:

- They should not have cellular structure.
- Fibres should have the same thickness all along their length.
- The colour of fibres and particles should be homogenous.
- Particles should not be shiny.
- Fibres should not look like twisted flat ribbons.

During observation of the microplastics under the microscope, these criteria were taken into account. The mentioned criteria were then used to distinguish microplastics by Nor and Obbard (2014), and Cole et al. (2011).

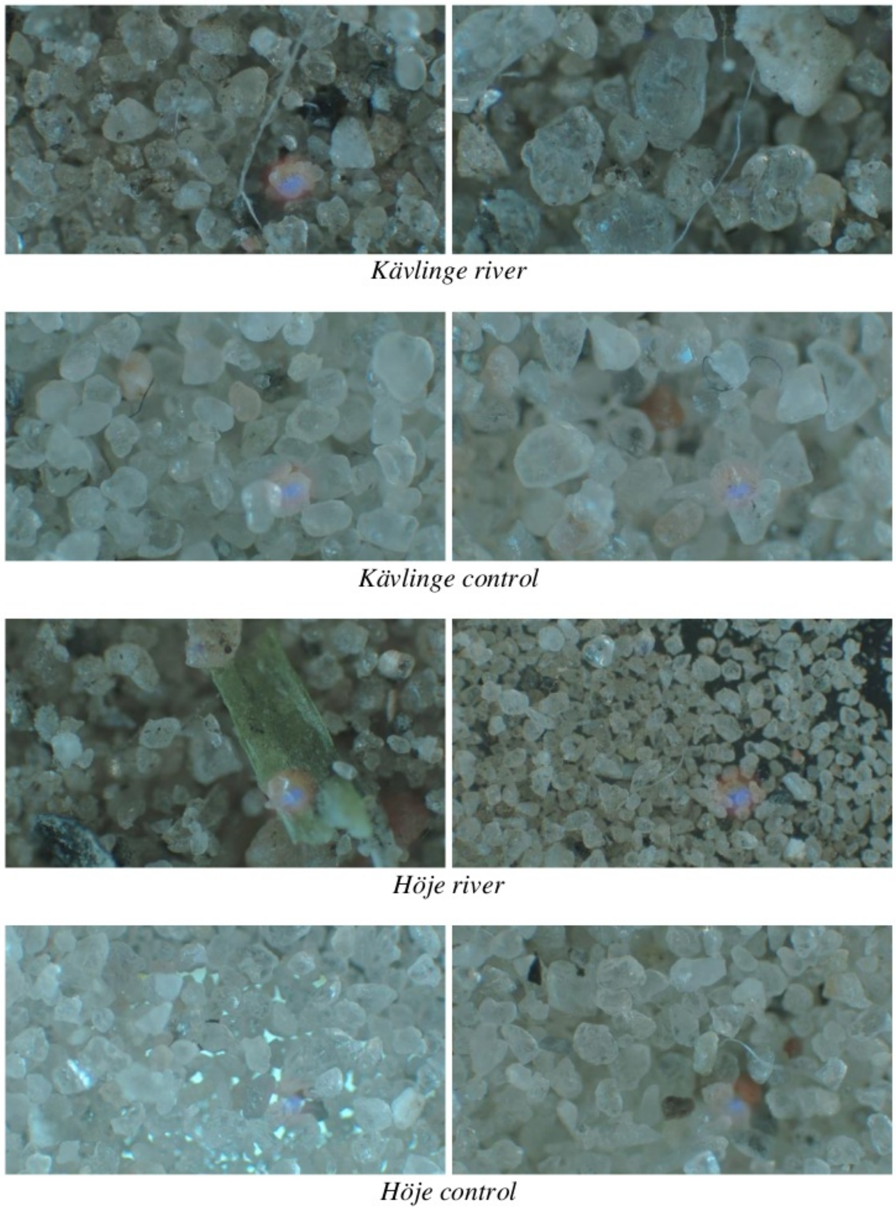

Figure 8: Microplastics observed in the sediments from different locations

Microplastic debris may come in different materials, shapes, colours, and forms. In this study, based on the observation of the collected samples, the microplastics have been grouped into two categories of fibres and particles. In this method it was easier to identify fibres whereas it was difficult to recognise plastic particles from sand because of the shape and colour of the sediments in the samples. Considering these challenges in distinguishing between microplastics and other objects from the images, plastic-like objects were identified and based on their shape and colours were classified in two different categories as follows:

- **(Plastic)** where the particle/fibre is definitely plastic.
- **(Perhaps-plastic)** where the particle/fibre looks like plastic but not definite.

In each image, these plastic-like particles were counted and summarised for all 20 images. The total number of plastics-like particles in the 20 images associated with each replicate was recorded and tested in an Analysis of Variance (ANOVA).

2.5. Data collection of macroplastics

In this study, macroplastics were additionally collected and counted at the locations where the microplastic sediments were collected. To collect the macroplastic debris and have a comparable base between different locations the covered distance and sampling durations for all sites are set to be the same. For this purpose, in each site collected samples by one person in a 5-minute duration along the 50 meters are counted. Figure 9 illustrates a few of the samples that were collected or observed in the sites. The collected data for macroplastics at different sites were compared in order to reveal the impact of the anthropogenic activities in the concentration of the macroplastics.

Figure 9: Macroplastics collected from sampling locations

2.6. Analysis of Variance (ANOVA)

ANOVA is a powerful statistical method available to test if the difference between the two groups of experimental results is significant (Fisher 1919, 1992). In other words, it is used to test groups to see if the observations are different.

In this research, the ANOVA is used for hypothesis tests. Considering the nature of the research which was a quantitative study, using ANOVA helped to easily distinguish between the null hypothesis and alternative hypothesis. This distinction is carried out using the p-value obtained from running the ANOVA in MS. Excel. In the ANOVA when the calculated p-value is less than the predefined significant level (α), this means that the null hypothesis can be rejected. However, if the calculated p-value is higher than the significant value (α), the hypothesis has to be rejected and the alternative hypothesis is accepted. In this research similar to the ecology field, the value of the significance level as recommended by most researchers is taken to be 5% ($\alpha = 0.05$) (Sawyer, 2009).

3. Results

In the following sections collected field data are analysed for both microplastics and macroplastics data.

3.1. Data analysis of microplastics

The average number of identified microplastics in the collected samples for Kävlinge river and Kävlinge control were 17.25 and 2.00, respectively (Figure 10). For Höje river and Höje control, these numbers were 12.25 and 5.00 (Figure 11). The combined data for Kävlinge region, Höje region demonstrate that the average concentration of the microplastics and uncertainty of the results (represented by error bars) in river sites were higher than associated control sites (Figure 12). These data for both Kävlinge and Höje regions for all four replicates are provided in Tables A. 2-6.

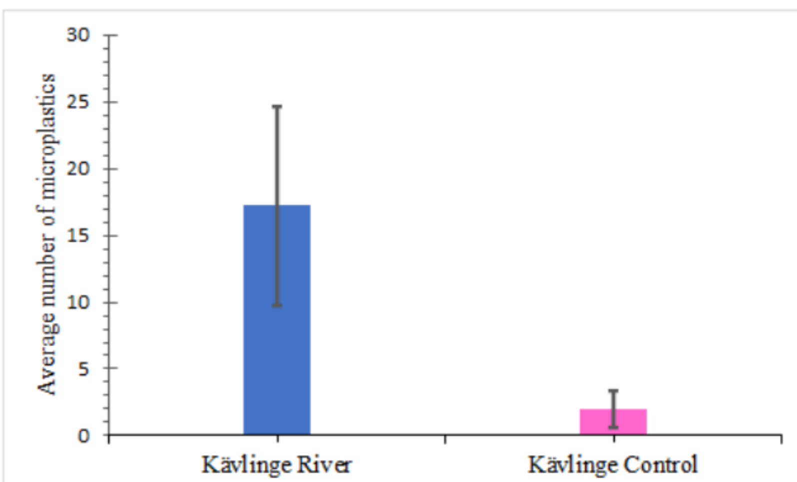

Figure 10: Average number of microplastics in samples of Kävlinge region (error bars represent the standard deviation of the four replicates)

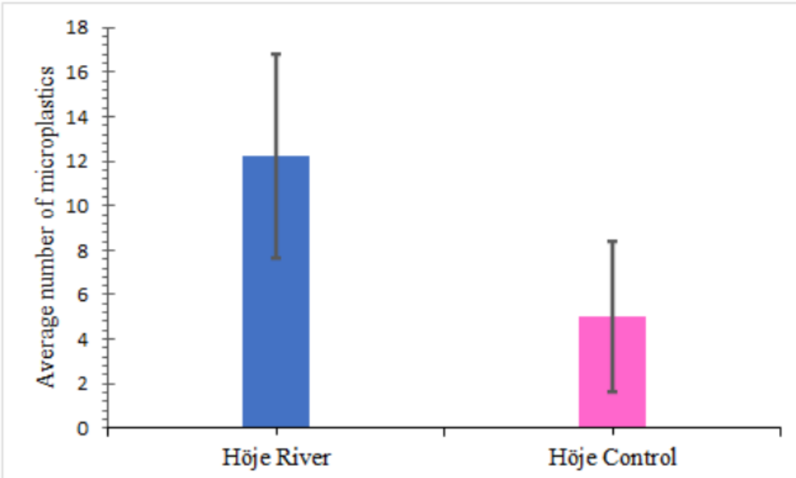

Figure 11: Average number of microplastics in samples of Höje region (error bars represent the standard deviation of the four replicates)

Analysis of varieties (ANOVA) for the microplastic data of sediment samples from the Kävlinge region and Höje region, was carried out, and the detailed results are provided in the appendix Tables A. 7 and A. 8. Based on the analysis of the variance the p-value for the Kävlinge region and Höje region, were obtained 0.0069 and 0.0433, respectively. The p-values of the data in both cases was less than the significance level (α=0.05); therefore, we do reject the null hypothesis, as the differences between river site data and control site data are statistically significant.

Comparison of the p-values of the Kävlinge region and Höje region reveals that in the case of the Höje region this value is much smaller than the Kävlinge region. This means that the difference between microplastic data in the river site and the control site of the Höje region is less likely to happen because of random variation.

A similar analysis using the combined data of the both Kävlinge region and Höje was carried out. The p-value of the ANOVA for this case was 0.0004, that was much lower than each individual region. The detailed results are provided in Table A. 9.

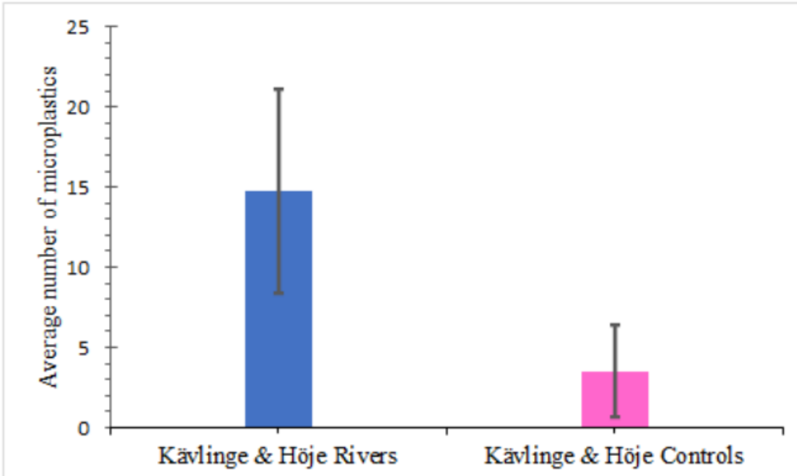

Figure 12: Average number of microplastics in samples of control sites (error bars represent the standard deviation of the four replicates)

Results of the microplastics in the rivers of Kävlinge and Höje are demonstrated side by side, in Figure 13.

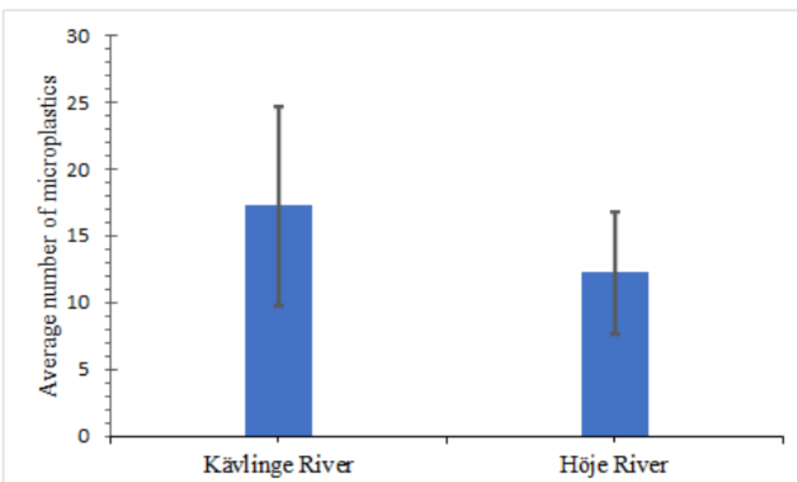

Figure 13: Average number of microplastics in samples of river sites (error bars represent the standard deviation of the four replicates)

The outcomes of ANOVA analysis for these data are shown in Table A. 10. Although the average value of microplastic in the Kävlinge river is rather higher than the average value of microplastics in the Höje river, the p-value for ANOVA analysis in the river sites was 0.2965, which was higher than the significance level ($\alpha = 0.05$).

Observations regarding the average number of microplastics in specimens of control sites in Kävlinge and Höje regions are shown in Figure 14. As shown, the average number of microplastics in the Höje control site is higher than the Kävlinge control site; however, considering that the p-value of these data was 0.1515 (Table A. 11), which was higher than the significance level ($\alpha = 0.05$), these differences may come from natural randomness. Comparing the p-value of control sites with the p-value of river sites reveals that the p-value in the control sites is lower than river sites (0.1515 < 0.2965). Both cases are greater than the significance level; however, the probability of the obtained difference between the average values in the control sites under the null hypothesis is lower than the river sites.

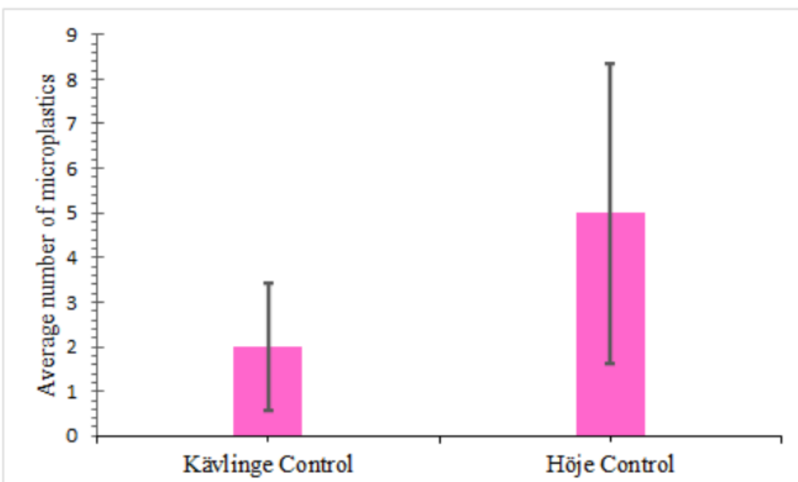

Figure 14: Average number of microplastics in samples of control sites (error bars represent the standard deviation of the four replicates)

3.2. Type and shape of the microplastics

From 69 microplastic identified in the Kävlinge river, 68 were fibre while only one particle was observed. This means that 98.55% of the observed microplastics were fibre and only 1.45% were particles. In the control site of the Kävlinge, all the 8 microplastics that were observed were fibres (100.00% fibres versus 0.00% particles).

Similarly, in the Höje river from 49 observed microplastics, 47 were fibres and two were particles (95.92% fibres and 4.08% particles). In the control site of the Höje, all 20 observed microplastic were fibres (100.00% fibres and 0.00% particles). The percentage of fibres and particles are summarised in Table A. 12.

3.3. Data analysis of macroplastics

The numbers of macroplastics collected by one person in five minutes in the 50 meters of the Kävlinge river mouth and control site were 7 and 3, respectively. In the case of the Höje river, the numbers of collected macroplastics in the mouth and control site were 98 and 8, respectively (Table A. 13). In both cases, the concentrations of the macroplastics in the river sites were more than associated control sites. As expected, in the mouth of rivers, macroplastics accumulate because of the uncontrolled disposal of the plastics waste along rivers. Furthermore, especially in the case of the Höje river, since the mouth is located in the neighbourhood of Lomma city, this concentration is higher. The results of the macroplastic pollution, for the Kävlinge region (both river and control sites) and Höje region, have been presented in Figures 15 and 16, respectively. The difference between the concentration of the macroplastics in the mouths, in the river site of Höje and Kävlinge regions are demonstrated in Figure 17. As shown in this Figure, there is much more macroplastic pollution in the mouth of the Höje river. The comparison of the results of the macroplastics reveals that the control site of the Höje river Kävlinge holds more macroplastic debris. The numbers of macroplastics in the control sites of the Höje and Kävlinge rivers are compared in Figure 18.

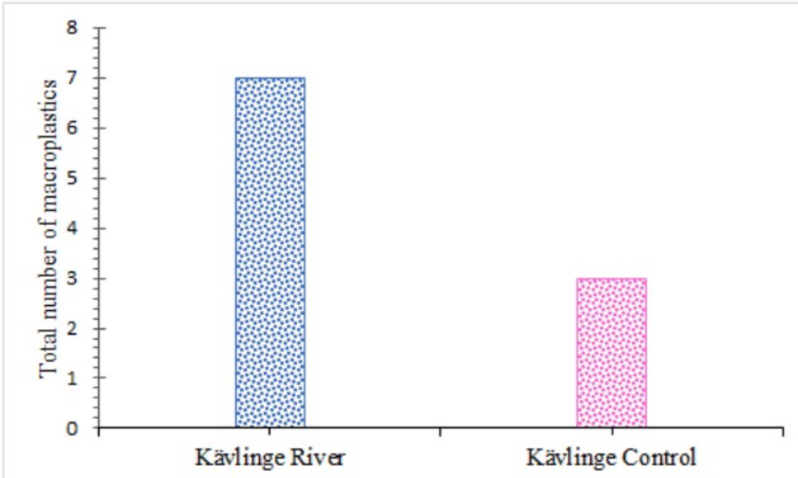

Figure 15: Total number of macroplastics collected in the Kävlinge region

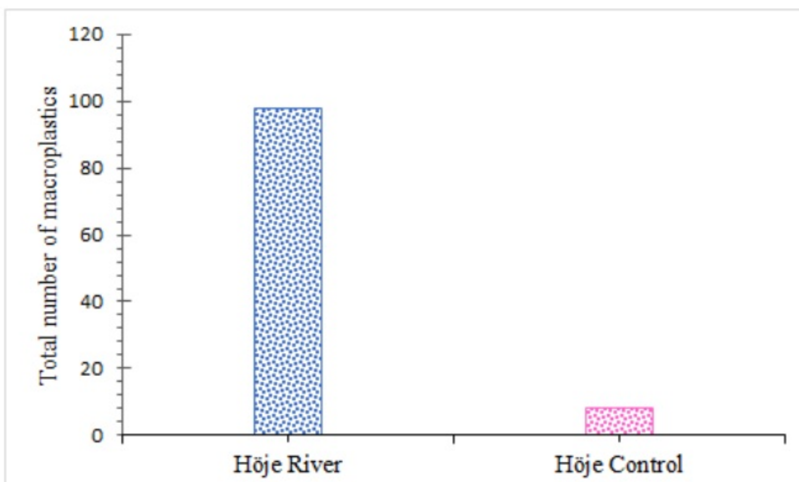

Figure 16: Total number of macroplastics collected in the Höje region

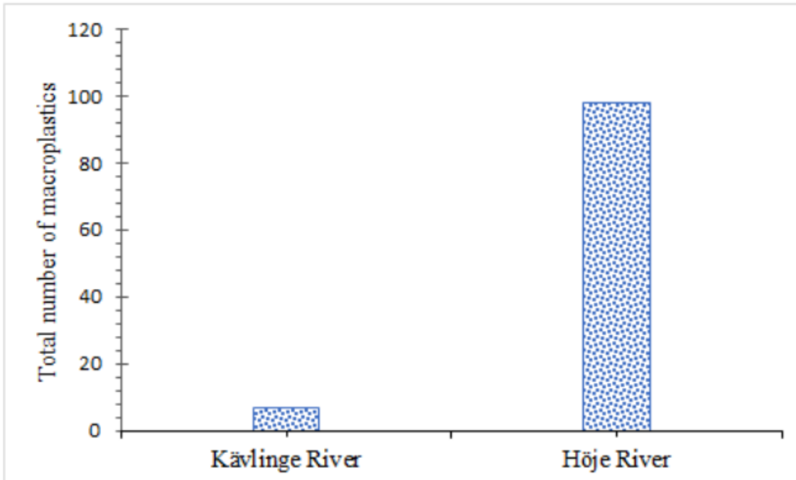

Figure 17: Total number of macroplastics collected in river sites

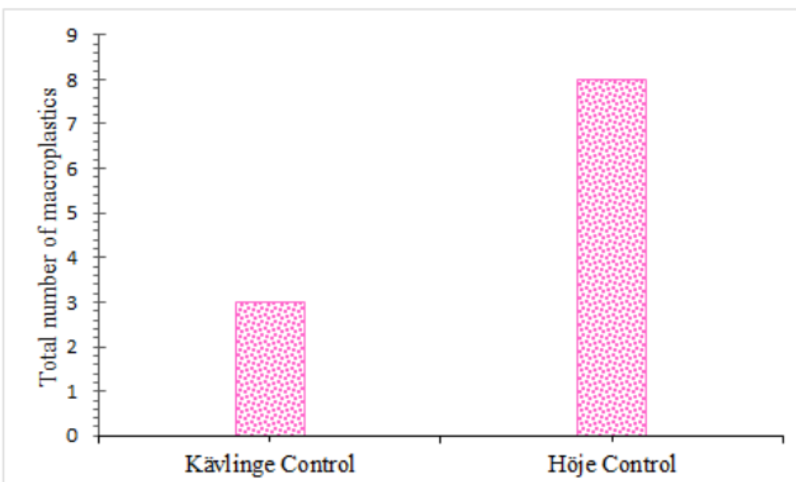

Figure 18: Total number of macroplastics collected in control sites

4. Discussion

Marine plastic pollution is a worldwide problem that should be addressed globally by the effort of the researchers and policy-makers (Abbott & Sumaila, 2019). Local and regional data collections and studies are important in respect to the fact that these studies can help policy making and progress toward a global solution. The current study focused on plastic pollution in a small region in the mouth of Kävlinge and Höje rivers in southern Sweden. The results of the observations and analysis of collected data reveal that the concentrations of the microplastics in the mouth of both Kävlinge and Höje rivers are higher compared to associated control sites. This means that the rivers are a significant source of microplastic particles to the Öresund. This is in agreement with what has been found in many other parts of the world (Constant et al., 2019; Sathish et al., 2019).

The results suggest that the size of population of the catchment area of the rivers was not an important factor in the concentration of the microplastics in the mouth of rivers. It was expected to see a larger concentration in the mouth of Höje with higher populations in comparison with the Kävlinge river, but the results did not confirm this. On the contrary, the average number of microplastics in the Kävlinge river was slightly more than the Höje river. The length of the rivers, area of the basins, or other factors may be the cause of this difference. Control sites of the microplastics for both rivers have a relatively low concentration of the microplastics as expected. These sites were selected in a location to serve as a benchmark for the natural conditions of the area.

Similarly, the macroplastic data of the river sites and control sites for both Kävlinge and Höje rivers have been collected. As expected, in the collected data the concentration of the macroplastic contaminants was higher in the mouth of the Höje river. This river passes from few populated urban areas such as Lund, Staffanstorp, and Lomma that carry the uncontrolled plastic debris to the mouth of the river where the water current reduces the plastics accumulate in that region. Moreover, numerous businesses exist in the mouth of the Höje river that can be the cause of plastic contamination in that region. For other sites, no significant microplastic pollution was observed. The results of the microplastics and macroplastics observations are separately discussed in the following subsections.

4.1. Microplastics

Depending on the geographical location and environmental situation of the study sites, the abundance and distribution of the microplastics can be variable (Berglund et al., 2019; Cole et al., 2011; Gewert et al., 2017; Haave et al., 2019; Ryan et al., 2009; Stolte et al., 2015; Van Cauwenberghe et al., 2013; Wessel et al., 2016). Human activities and cities are some of the most influential factors in the concentration of microplastics (Constant et al., 2019; Gewert et al., 2017; Sathish et al., 2019; Stolte et al., 2015). In a study about the occurrence and characteristics of microplastics in beach sediments of Tamil Nadu, India, it has been observed that microplastics concentrate near marine (Chennai coast) and river mouth because of different anthropogenic activities like recreation, religious activities, fishing (Sathish et al., 2019). Nevertheless, some other studies did not find a meaningful relationship between the concentration of microplastics and population distribution and human activities (Esiukova, 2017; Hengstmann et al., 2018). For instance, the number of microplastic particles per kilogram of sediment was counted at the beaches on Rügen in the Baltic Sea. In this region, there was no significant difference between various areas used for diverse human activities. Furthermore, fibres were dominant in all the beaches of the region (Hengstmann et al., 2018).

According to the collected data from Kävlinge and Höje sites and ANOVA on these data, the differences between river site data and control site data in both cases are statistically significant. Considering the fact that the rivers pass some urban areas, anthropogenic activity in the basin of the rivers produces pollutants that discharge into river water, and this increases the concentration of the microplastics in the river sites.

However, as expected, in the control sites that are less associated with human activity, the concentration of the microplastic pollutants is relatively low. The results of the ANOVA for the combined data of both rivers also confirms this observation. This finding is in line with some previous studies conducted in other river sites (Constant et al., 2019; Sathish et al., 2019).

In this research, the prevailing types of microplastics observed in the collected samples were coloured and translucent fibres. However, plastic particles rarely were identified during the visual examination. Some translucent fibres were unnaturally bright; therefore, they were recorded as perhaps-plastics, and they were not included in our analysis (Table A. 6). Nevertheless, due to the particle shapes and colours, it was more challenging to be distinguished from sand grains. As stated in several other studies, and as also confirmed in our results in Table A. 12, the major portion of the microplastics in the marine environment is fibres (Browne et al., 2011; Esiukova, 2017; Graca et al., 2017; La Daana et al., 2017; Mason et al., 2016; Stolte et al., 2015; Van Cauwenberghe et al., 2013). In a study conducted in 2017, the most common particle in the salty sediment of urbanised beaches of the Baltic Sea was transparent fibres, and the composition of the majority particles was Polyester (A common fabric) (Graca et al., 2017). According to another study about microplastics in the Baltic Sea surface water, the number of plastic particles in the offshore area close to the central part of Stockholm was about ten times more than in other parts. Fibres were more dominated among other microplastics in the samples (Gewert et al., 2017).

As denoted in the results section, the difference between the number of microplastics of two river sites is not significant. The population in the catchment area of the Höje river is higher than the population of the Kävlinge river basin. It was expected to have more microplastic pollution for the Höje river. However, the results of our observations did not confirm this. This might be because of the influence of other parameters such as the area of the basin and the length of the river that compensates for the difference between the results. It should be noted that the catchment area of the Kävlinge river is 3.75 times (1,200 km^2/320 km^2 = 3.75) of the catchment area of the

Höje river. Also, the length of the Kävlinge river is 2.57 times (90 km/35 km = 2.57) of the Höje river, while the population of the Höje river basin is 1.9 times (190,000/100,000 = 1.9) of the population of Kävlinge river basin. Longer rivers may provide more time for bigger plastics to break down into smaller pieces.

Based on the data obtained from the European Commission (2016), most urban areas are located in the catchment area of the Kävlinge river have a compliant Urban Wastewater Treatment Plants (UWWTP). In this catchment area, Furulund does not have its plant and in the case of the Urban areas located in the basin of the Höje river, Dalby, Hjärup, and Genarp are the cities without any plant. The total generated load of the UWWTPs in the Catchment of the Kävlinge river is almost twice as the catchment area of the Höje river (Table 2).

Table 2: Wastewater treatment plants in the major urban areas located in the of the basin of Kävlinge and Höje rivers (European Commission, 2016)

Kävlinge river		**Höje river**	
City	**UWWTP Generated Load (p.e.)***	**City**	**UWWTP Generated Load (p.e.)***
Eslöv	240,000	Lund	118,000
Kävlinge	40,000	Staffanstorp	15,000
Sjöbo	14,000	Lomma	10,100
Södra Sandby	7,500	Dalby	No plant
Veberöd	5,800	Hjärup	No plant
Furulund	No plant	Genarp	No plant
Total	307,300	Total	143,100

* Wastewater treatment plant generated load in the units of population equivalent

The map of the wastewater treatment plants and outlets for wastewater around the Kävlinge and Höje rivers are shown in Figure 19. As can be seen in the map there are several treatment plants near both rivers; however, considering the longer length of Kävlinge river and the higher concentration of the plants and outlets for wastewater in the vicinity of this river might be the reason for the abundance of the microplastic in the mouth of this river.

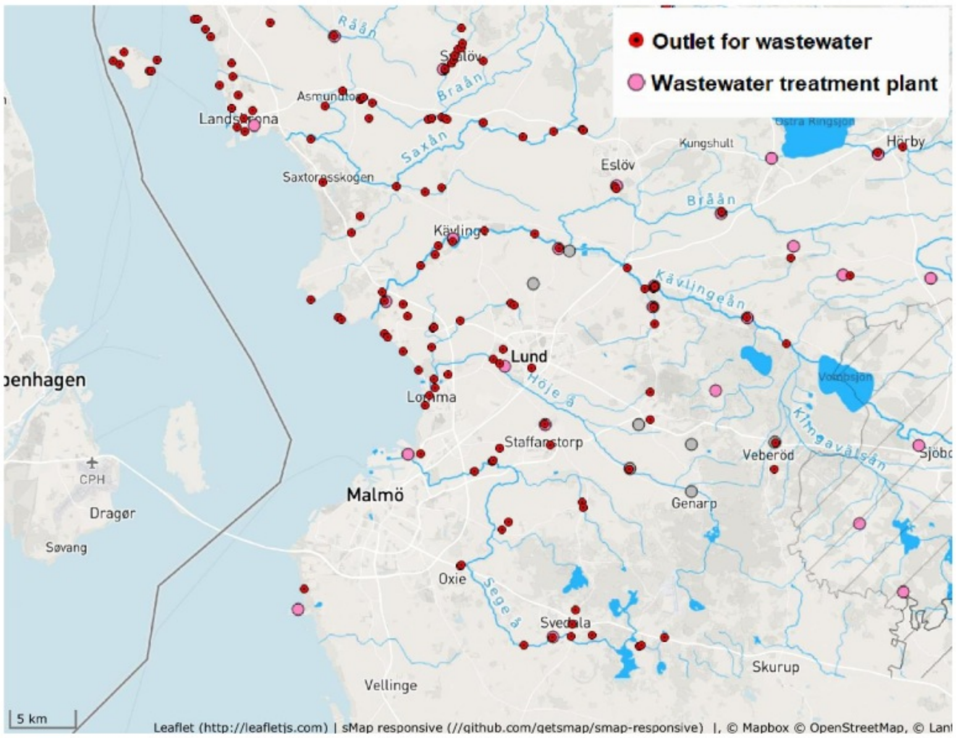

Figure 19: Wastewater treatment plants and outlets for wastewater near Kävlinge and Höje rivers (Image from https://vattenatlas.se/)

In some studies, it is indicated that although water treatment plants reduce the concentration of microplastics, still plastics remain in the sewage effluent (Martin & Eizhvertina, 2014). Synthetic fibres have been mostly found in the sewage sludge in the treatment process (Zubris & Richards, 2005). Some previous studies find out that a notable amount of fibres enters the sewage system by washing clothes (Browne et al., 2011; Magnusson, 2014). In other studies, also sewage outlets were concluded to be the main source of microplastics in the rivers and marine environment (Duckett &

Repaci, 2015; Horton, 2015). However, atmospheric fallout is also a source of synthetic fibres in the marine environment (Dris et al., 2016).

In addition, studies show that the amount of microplastics in the aquatic animals and organisms living in the vicinity of wastewater treatment is higher than animals living in the location that is not affected by any water treatment plant (Constant et al., 2019; Murphy et al., 2016). In a recent study, conducted by Berglund et al., (2019) along the Höje river, the occurrence of microplastics in the duck mussel, has been investigated. According to this study, all duck mussel samples were contaminated by the microplastics (fibres and particles). Moreover, the samples collected from the downstream near Lund city with a wastewater treatment plant had higher concentrations of microplastics compared to the samples collected from the upstream site near rural areas (Berglund et al., 2019).

In the case of our study, there are some sewage treatment plants near the Kävlinge and Höje rivers that process and filters a considerable part of microplastics. However, according to our obtained results, still, the majority of microplastics, especially fibres (Table A. 12), enter into the river and consequently find their way to the Baltic Sea. A higher concentration of the microplastic in the Kävlinge region may be due to the existence of plants and the high flow rate of the sewage in the catchment area of the Kävlinge river. However, the quality of the treatment plants, filtration, and the number of the steps are a few of the parameters that can affect the concentration of the plastic debris and pollution downstream.

Furthermore, sometimes sludge from wastewater treatment plants is used as a fertilizer in the agricultural industry. This sludge contains a high concentration of the microplastics that enter the soil and ultimately washed into the rivers. Considering the large area of agricultural fields in the catchment area of Kävlinge river, the runoff from these fields can be one of the main sources for the higher microplastic pollution in this river (Eriksson et al., 2010; Leslie et al., 2017; Berglund et al., 2019).

4.2. Macroplastics

Existing businesses and people traffic are some of the reasons for the abundance of plastic pollution in the mouth of the Höje river. This high pollution also impacted the control site of the Höje river, since a comparison between the control sites shows a higher amount of macroplastics in the Höje region. Höje region in comparison to the Kävlinge region hosts lots of touristic activities that lead to the consumption of a high volume of the single usage plastics; therefore, that could be one of the major causes of macroplastic pollution in that area. It should be noted that in the case of macroplastics, sometimes the structure and shape of the surface rocks or gravel can increase the macroplastic pollution of the area. The coarse material and cracks between the large rocks can be a good trap for macroplastic to stock and accumulate there. This kind of surface was observed in the Höje region and might be another cause for the high concentrations of macroplastics in that area. In the case of flat and fine surfaces, rain, tides, wind, and other environmental phenomena can move and spread the macroplastics that lead to less accumulation of the macroplastics. This is also confirmed with previous studies that beach materials can act as a trap for macroplastics (Hengstmann et al., 2017).

4.3. Policy issues

As explained in the previous sections, marine plastic pollution should be resolved by international and national regulations. Although some international conventions address marine plastics pollution, there is a gap in international Instruments to deal with this issue (Vince & Hardesty, 2018). Article 192-237, Part XII of the United Convection of Law of the Sea (UNCLOS), is about the protection and preservation of the marine environment. Nonetheless, this convention does not address the different type of contaminants in detail, also it does not include technical issues (Palassis, 2011). Furthermore, Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL) is preventing the disposal of the plastic waste generated by ships at sea, and it has entered into the force since 2013. According to this convention, states are responsible to provide disposal facilities in their ports and terminals. They should present the list of these facilities for the International Maritime Organization (IMO) as well (IMO, 2015). Yet, implementing this regulation is challenging, because different countries in the world are in various stages of management of their waste (Ryan, 2015). The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA), governed by the United Nations Environment Programme (UNEP), provide a structure to tackle transboundary issues of the marine plastic problem (Kershaw et al., 2011).

Recycling is one of the proposed solutions to solve plastic pollution (Ten Brink et al., 2018). However, due to the constitution of plastic materials, recycling them is challenging (Groh et al., 2018). One of the other ways to reduce plastic pollution is by using biodegradable plastics. Nevertheless, these relatively new materials do not degrade in the marine environment (Napper & Thompson, 2019). Furthermore, these kinds of plastics may mislead users and even cause more environmental problems, since it has not been proven that biodegradable plastics are completely safe and they do not have any dangers to the environment (Haider et al., 2019).

Single-use plastics is one of the most problematic kinds of plastics for the environment. Different governments all around the world have different strategies to reduce the consumption of these disposable plastics like plastic bags or bottles. Some European countries like Germany (in 1991) and Denmark (in 1994) intervened to decrease the amount of this debris. In this regard, enforcing customers to pay tax for the plastic bag consumption in the big retail stores was one of their strategies to control the consumption of single-use plastic bags (Ritch et al., 2009; Xanthos & Walker, 2017). Since 2002, many other countries like Bangladesh, Ireland, South Africa, and India have also passed some legislation to introduce some kinds of bans and impose a levy on the use of plastic bags (Clean Up Australia, 2015; Dikgang et al., 2012a; Xanthos & Walker, 2017). In some countries, the thickness of plastic bags is a determinative factor for implementing levy (Dikgang et al., 2012a). One of the simple ways of implementing tax for single-use products is a “waste disposal fee” policy. However, the “Advance Disposal Fees” policy (ADFs) is more achievable. This means adding disposal cost as a visible surcharge to the final price of a product at the sale point. Currently, this policy is used in many countries (Dikgang et al., 2012b; Rivers et al., 2017; Wagner, 2017). Another approach in order to reduce plastic pollution is the introduction of reusable shopping bags and producing lighter plastic bags (Xanthos & Walker, 2017).

Extended Producer Responsibility (EPR), is a model that was first outlined by Sweden in 1990 (Lindhqvist & Lidgren, 1990). Since then, some other European countries have also been using this model to manage their plastic waste and marine plastic issue. In fact, by implementing this scheme, the manufacturers are financially responsible for tracking, managing, and recycling of their product’s packaging. Then, this financial source is used as an incentive for recycling industries and other producers that produce environmentally friendly products, like reusable bags and containers (Sachs, 2006). Additionally, many European nations use power plants for producing electricity and heat, by using wastes including plastic wastes as fuel. (waste- to energy process) (Themelis, 2003).

Besides the aforementioned methods (bans, taxes, and fees, EPR), subsidies and incentives are useful tools to increase the recycling and production of environmentally friendly products (Abbott & Sumaila, 2019). Education is another powerful tool to increase public awareness about the importance of the issue. In this regard, voluntary intervention like non-governmental organisations (NGO) campaigns can be helpful in the awareness-raising process (Abbott & Sumaila, 2019; Xanthos & Walker, 2017). Social norms are an influential factor in individual behaviour. In the case of plastic consumption and disposal, social norms can also be effective. Thus, campaigns and other advertising tools could be very effective in terms of changing habits and behaviours (Thaler & Sunstein, 2009). Defining standards to limit the number of particular types of polymers in some products is also another tool that has been used to manage and control plastic pollution (Acuff & Kaffine, 2013).

Microbeads are produced and used in cosmetic products like face cleaners and toothpaste (Chang, 2015). There is a limited intervention to control the increasingly produce of these plastics. However, since 2014 nations have started to implement certain policies to reduce these products. The Netherlands was the first country that reported its aim to eliminate microbeads from personal care products by 2016 (Xanthos & Walker, 2017). In 2015, Austria, Belgium, Sweden, Netherlands, Luxembourg provided a joint statement to seek microbeads usage ban in the European Union (EU) (Council of the European Union, 2014). Microbeads have been classified as toxic material by the Canadian government under the Canadian Environmental Protection Act (CEPA) since August 2015 (Pettipas et al., 2016). The United Kingdom also announced its intention to ban the usage of microbeads in cosmetics by the end of 2017 (Xanthos & Walker, 2017). The short-term and long-term results of the implementation of these strategies should be assessed regularly. For this purpose, periodic monitoring and measurements are necessary (Xanthos & Walker, 2017).

Even though recently some regulations and restrictions have been imposed on the production, consumption, and disposal of the plastic debris especially single-use plastics, and microbeads, still there is no specific regulation for synthetic fibres and the textile industries. As specified under indicator 10 of the MSFD, disposal of the microplastics in the environment should be addressed from its source (Dris et al., 2016). Therefore, it is necessary to limit the production of microfibres using tools such as restrictions, taxation, public awareness, and subside on environmentally friendly alternatives. Moreover, similar laws and regulations should be imposed on the washing machine factories and UWWTPs to provide efficient filtrations for microplastics and fibres.

4.4. Benefits and limits of the current study and recommendations for future studies

There are numerous methods for extraction, identification, and quantification of microplastics in the marine environment. Some methods are using advanced equipment and provide very accurate results; however, these methods are expensive and complex. Each of the proposed methods in the literature has its pros and cons (Alvarez-Zeferino et al., 2020).

In this study, microscopic observation and imaging processes have been used in order to distinguish the microplastics from other particles. For visual separation of microplastics smaller than one millimetre, using a microscope is necessary (Song et al., 2015; Duis & Coors, 2016). This method has several positive advantages and a few limitations that are summarised below.

The visualization method has several advantages as follows:

- It requires very elementary tools to conduct experiments. The only relatively expensive equipment is a microscope that is accessible in any common environmental laboratory.
- It can be completed in remote areas with fewer laboratory facilities.
- The number of steps is limited.
- The experiment does not involve harmful chemicals.
- It does not require an extensive amount of time and effort.

Besides the numerous benefits and advantages of the microscopic observation that has mentioned, there were a few limitations in this method that are mentioned below:

- The identification of the microplastics in this approach is less accurate. For instance, coloured sediments can be seen as plastics, or some plastic particles can be mixed with sands.
- Since we only observed microplastics of the top layer of the samples under the microscope, the results will be comparable; however, it cannot be defined per unit of the volume or weight.
- Due to the nature of the method, the composition of the microplastics cannot be determined. Determining the composition can help to trace back the source

of microplastics to the industries having a higher share in the contamination and restricting those industries.

Considering the huge consumption of the cheap single-used plastics materials in the developing countries most of these countries face plastic debris issues. On the other hand, these countries have lots of economic problems. Therefore, the existence of easy and cheap approaches for identification of the microplastics will be very useful. That is why the proposed method of this study could be practiced as a popular method in developing countries. To some extent, this will help to easily monitor microplastic pollution which is an initial step to control plastic debris issues. In addition, in developing countries management of the harmful chemical waste is a challenging issue. Thus, this method will be favourable because it does not need to use any harmful chemicals that may endanger the health of the monitoring experts and the public.

This study reveals the microplastics concentration in the Kävlinge river is slightly higher than the Höje river; however, in the current study based on the collected samples and ANOVA, this trend was not significant. For future studies, a specific pattern between two rivers by more replicates can be determined. Furthermore, it would be beneficial to study the UWWTPs and their effects in microplastic pollution of the rivers in detail. In addition, the impacts of these plastic pollutants on the biodiversity and food chain of the strait should be studied.

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Appendices

Table A. 1: Population in the major urban areas located in the of the basin of Kävlinge and Höje rivers (Statistics Sweden, 2019)

Kävlinge river		Höje river	
City	**Population**	**City**	**Population**
Eslöv (Partially)	33,793	Lund	124,935
Kävlinge	31,705	Staffanstorp	25,396
Sjöbo	19,226	Lomma	24,834
Södra Sandby	6,306	Dalby	6,302
Veberöd	4,850	Hjärup (Partially)	5,607
Furulund	4,359	Genarp	2,962
Total*	100,239	Total*	190,036

* it should be noted that these data do not include population in the rural areas

Table A. 2: Collected data from Kävlinge river

Photo No.	Sample 1			Sample 2			Sample 3			Sample 4		
	Plastic	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**
1	0	1	0	1	0	0	0	1	0	0	0	1
2	0	0	1	0	1	0	0	1	0	0	1	0
3	0	0	1	1	0	0	0	0	1	1	0	0
4	0	1	0	1	0	0	3	0	0	1	1	0
5	1	0	0	4	0	0	0	1	0	0	1	0
6	0	0	1	2	0	0	1	0	0	1	0	0
7	1	0	0	1	0	0	1	0	0	2	0	0
8	0	0	1	4	0	0	2	1	0	1	0	0
9	1	0	0	1	0	0	2	0	0	0	0	1
10	0	1	0	0	0	1	0	0	1	0	0	1
11	0	0	1	2	0	0	0	0	1	0	0	1
12	0	1	0	1	0	0	2	1	0	2	0	0
13	1	0	0	0	0	1	0	1	0	2	0	0
14	0	0	1	1	0	0	3	0	0	2	0	0
15	0	1	0	2	0	0	2	0	0	2	0	0
16	0	3	0	2	0	0	0	0	1	0	1	0
17	2	0	0	2	0	0	1	1	0	2	0	0
18	1	0	0	1	0	0	1	0	0	0	0	1
19	0	1	0	0	0	1	1	0	0	0	0	1
20	1	1	0	0	0	1	0	0	1	0	0	1
Total	8	10	6	26	1	4	19	7	5	16	4	7

Table A. 3: Collected data from Kävlinge control

Photo No.	Sample 1			Sample 2			Sample 3			Sample 4		
	Plastic	Perhaps-plastic	Non-plastic	Plastic	Perhaps-plastic	Non-plastic	Plastic	Perhaps-plastic	Non-plastic	Plastic	Perhaps-plastic	Non-plastic
1	1	0	0	0	0	1	0	0	1	0	0	1
2	0	0	1	0	0	1	0	0	1	0	0	1
3	0	0	1	1	0	0	0	0	1	0	0	1
4	0	0	1	0	0	1	0	0	1	1	0	0
5	0	0	1	0	0	1	0	0	1	0	1	0
6	0	0	1	1	0	0	0	0	1	0	0	1
7	0	0	1	0	0	1	0	0	1	0	0	1
8	0	0	1	0	0	1	0	0	1	1	0	0
9	1	1	0	1	0	0	0	0	1	0	0	1
10	0	0	1	0	0	1	0	0	1	0	0	1
11	0	0	1	0	0	1	0	0	1	0	0	1
12	0	0	1	0	0	1	0	0	1	0	1	0
13	0	1	0	0	0	1	0	0	1	0	0	1
14	0	0	1	0	1	0	0	0	1	0	1	0
15	0	0	1	0	0	1	0	0	1	0	0	1
16	0	0	1	0	0	1	0	0	1	0	0	1
17	1	0	0	0	0	1	0	0	1	0	0	1
18	0	0	1	0	0	1	0	0	1	0	0	1
19	0	0	1	0	0	1	0	0	1	0	0	1
20	0	0	1	0	0	1	0	0	1	0	0	1
Total	3	2	16	3	1	16	0	0	20	2	3	15

Table A. 4: Collected data from Höje river

Photo No.	**Sample 1**			**Sample 2**			**Sample 3**			**Sample 4**		
	Plastic	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**
1	1	1	0	1	1	0	0	0	1	0	2	0
2	1	0	0	1	2	0	0	2	0	0	0	1
3	0	0	1	1	1	0	0	1	0	0	1	0
4	0	0	1	0	0	1	0	0	1	3	0	0
5	0	0	1	0	2	0	1	0	0	1	0	0
6	0	1	0	0	0	1	1	0	0	3	0	0
7	1	1	0	0	1	0	1	2	0	2	0	0
8	0	0	1	1	0	0	0	1	0	0	0	1
9	2	0	0	1	0	0	0	0	1	1	1	0
10	1	0	0	3	0	0	0	1	0	0	0	1
11	0	1	0	1	0	0	1	0	0	0	0	1
12	0	0	1	1	0	0	0	0	1	1	0	0
13	0	0	1	1	1	0	0	1	0	0	1	0
14	0	1	0	1	0	0	0	0	1	1	0	0
15	1	0	0	2	0	0	1	0	0	0	0	1
16	0	0	1	0	0	1	0	1	0	0	1	0
17	0	1	0	1	0	0	0	0	1	1	0	0
18	0	1	0	0	1	0	0	1	0	4	0	0
19	0	0	1	0	1	0	2	0	0	0	0	1
20	0	1	0	0	0	1	3	0	0	0	0	1
Total	7	8	8	15	10	4	10	10	6	17	6	7

Table A. 5: Collected data from Höje control

Photo No.	Sample 1			Sample 2			Sample 3			Sample 4		
	Plastic	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**	**Plastic**	**Perhaps-plastic**	**Non-plastic**
1	0	0	1	0	0	1	0	0	1	0	0	1
2	0	0	1	0	0	1	0	0	1	0	0	1
3	0	0	1	1	0	0	0	0	1	0	0	1
4	0	1	0	1	0	0	0	0	1	0	0	1
5	0	0	1	0	0	1	0	1	0	1	0	0
6	0	0	1	0	0	1	0	0	1	0	1	0
7	0	0	1	0	1	0	0	0	1	0	0	1
8	0	0	1	0	1	0	0	1	0	2	0	0
9	0	0	1	0	0	1	1	0	0	1	0	0
10	0	0	1	0	0	1	2	0	0	0	0	1
11	0	0	1	0	1	0	0	0	1	0	0	1
12	0	0	1	0	0	1	0	0	1	0	0	1
13	0	0	1	0	0	1	0	0	1	0	1	0
14	0	0	1	0	0	1	0	0	0	1	0	0
15	0	0	1	1	0	0	1	0	0	0	0	1
16	0	0	1	0	0	1	0	1	0	1	1	0
17	0	0	1	0	0	1	0	0	0	0	0	1
18	0	0	1	1	0	0	1	0	0	0	0	1
19	0	0	1	2	0	0	2	0	0	0	0	1
20	0	0	1	0	0	1	0	0	1	1	0	0
Total	0	1	19	6	3	12	7	3	10	7	3	12

Table A. 6: Average number of microplastics in the samples

Sample No.	Kävlinge river		Kävlinge control		Höje river		Höje control	
	Plastic	Perhaps-plastic	Plastic	Perhaps-plastic	Plastic	Perhaps-plastic	Plastic	Perhaps-plastic
1	8	10	3	2	7	8	0	1
2	26	1	3	1	15	10	6	3
3	19	7	0	0	10	10	7	3
4	16	4	2	3	17	6	7	3
Average	17.25	5.5	2	1.5	12.25	8.5	5	2.5

Table A. 7: Analysis of variance (ANOVA) on microplastics data of Kävlinge region

Source of Variation	SS	df	MS	F	p-value	F crit
Between Kävlinge river and Kävlinge control data	465.125	1	465.125	16.155	0.0069	5.987
Within Kävlinge river and Kävlinge control data	172.750	6	28.792			
Total	637.875	7				

Table A. 8: Analysis of variance on microplastics data of Höje region

Source of Variation	SS	df	MS	F	p-value	F crit
Between Höje river and Höje control data	105.125	1	105.125	6.519	0.0433	5.987
Within Höje river and Höje control data	96.750	6	16.125			
Total	201.875	7				

Table A. 9: Analysis of variance on microplastics data between rivers and control sites (both Kävlinge and Höje)

Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F crit**
Between river sites and control sites data	506.250	1	506.250	21.000	0.0004	4.600
Within river sites and control sites data	337.500	14	24.107			
Total	843.750	15				

Table A. 10: Analysis of variance on microplastics data of river sites

Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F crit**
Between Kävlinge and Höje rivers data	50.000	1	50.000	1.307	0.2965	5.987
Within Kävlinge and Höje rivers data	229.500	6	38.250			
Total	279.500	7				

Table A. 11: Analysis of variance on microplastics data of control sites

Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F crit**
Between Kävlinge and Höje control data	18.000	1	18.000	2.700	0.1515	5.987
Within Kävlinge and Höje control data	40.000	6	6.667			
Total	58.000	7				

Table A. 12: Percentage of the fibres and particles in microplastic samples

Sample No.	Kävlinge river		Kävlinge control		Höje river		Höje control	
	Fibres	**Particles**	**Fibres**	**Particles**	**Fibres**	**Particles**	**Fibres**	**Particles**
1	8	0	3	0	6	1	0	0
2	25	1	3	0	15	0	6	0
3	19	0	0	0	10	0	7	0
4	16	0	2	0	16	1	7	0
Total	68	1	8	0	47	2	20	0
Percentage	98.55%	1.45%	100.00%	0.00%	95.92%	4.08%	100.00%	0.00%

Table A. 13: Number of macroplastics in the different locations

S/No.	Locations	Sampling duration [min]	Distance covered [m]	Number of macroplastics
1	Kävlinge river	5	50	7
2	Kävlinge control	5	50	3
3	Höje river	5	50	98
4	Höje control	5	50	8