Final report

1. Project details

Project title	Automatisk sortering af usorteret dagrenovation Automatic separation of unseparated household waste
File no.	64016-0004
Name of the funding scheme	EUDP
Project managing company / institution	Holm Christensen Biosystemer ApS
CVR number (central business register)	57537728
Project partners	Ellegaard Service ApS Rustfri Service A/S
Submission date	01 May 2021

2. Summary

2.1 English version

Two sad events occurred during this project. A project partner, and later the project manager passed away. The project was, in their spirit, completed by the rest of the project participants.

The objective of the project was to provide a technology, which can conduct a **pre-separation** of mixed wastes like household waste and residual waste into a pure biowaste fraction and at least two other fractions, which are suited for further separation by conventional and upcoming technologies.

The pre-separation should be carried out in an oblong vessel with a water flow **(The Water Sorter**) in which the different components of the mixed waste will be exposed to forces in three directions.

- The water flow will affect all components in a forward direction
- An airstream perpendicular to the water stream will direct high floating components to one side of the water sorter
- Gravity will direct the heavy, sinking components to the bottom, from where they will be un-loaded.

Thereby the waste is separated in 3 fractions:

1. A light, high floating fraction, with plastic bottles, aluminium cans etc.
2. A heavy, fast sinking fraction, with broken glass and porcelain, discarded household tools etc.
3. A low floating fraction, with biowaste and tissue paper

The energy related goal was to provide a larger portion of biowaste for biogas production than what can be obtained by source separation.

The original objective of the project was not obtained. The original waste type: Unseparated household waste had to be abandoned due to changes in EU legislation. The project was therefore changed to attempt separation of residual waste and source separated biowaste.

The separation of both waste types was not satisfactory, and therefore the project didn't produce the technological results expected. This means, that the results cannot be commercialised.

There were some technological results obtained.

- A vessel with a controllable waterflow was manufactured
- A ballistic unloading device, which can separate heavy items (e.g.glass bottle and shoes will sometimes both be high floating and heavy) from the rest of the high floating items was developed
- A skimmer, capable of separating high floating items from low floating items was developed
- A preliminary picker for picking up plastic bags was designed – but still needs substantial development work to be fully functioning
- Unloading system for the sinking fraction was developed and functioning

2.2 Dansk version

Dette projekt har været ramt af to triste begivenheder. En projektpartner og senere projektlederen afgik ved døden. Projektet er, i deres ånd, alligevel blevet gennemført af de øvrige projektdeltagere.

Projektets formal var at tilvejebringe en teknologi, der kan gennemføre en forsortering af blandet affald som usorteret dagrenovation i en ren bio-fraktion og mindst to andre fraktioner, som er egnede til videre sortering med konventionelle eller nyudviklede sorteringsmetoder. Forsorteringen skal gennemføres i et aflangt bassin, hvor affaldets komponenter bliver påvirket af kræfter i tre retninger.

- En vandstrøm vil påvirke alle komponenter i bassinets længderetning
- En luftstrøm vil påvirke de højtflydende komponenter i en tværgående retning og føre disse komponenter til den ene side af bassinet
- Tyngdekraften vil føre tunge komponenter til bunden, hvorfra de vil blive ført ud ved hjælp af transportbånd

Derved separeres affaldet I 3 fraktioner:

1. En let højtflydende fraktion med plastflasker, aluminiumsdåser o.l.
2. En tung hurtigt synkende fraktion med glasskår, porcelæn o.l.
3. En lavtflydende fraktion bestående af madaffald, aftørringspapir o.l.

Det energirelaterede mål var at gøre en større andel af bioaffaldet tilgængeligt for biogasproduktion, end hvad der kan opnås ved kildesortering.

Det oprindelige formål med projektet blev ikke opnået. Den oprindelige affaldstype: Usorteret dagrenovation, måtte forlades pga. ændringer i EU lovgivning. Projektet blev derfor ændret til at forsøge at sortere restaffald og kildesorteret madaffald.

Sorteringen af begge affaldstyper var utilfredsstillende, og projektet producerede derfor ikke de forventede tekniske resultater. Dette betyder, at projektet ikke kan kommercialiseres.

Følgende tekniske resultater blev opnået:

- Der blev fremstillet et bassin med en kontrollérbar vandstrøm
- Der blev udviklet et ballistisk udtagningsbånd, der kan separere tunge genstande som glasflasker (der kan være højtflydende) fra den højtflydende fraktion
- En skimmer, der kan adskille højtflydende komponenter fra de lavtflydende komponenter blev udviklet
- En foreløbig mekanisme til at udtage plastposer fra bassinets overflade blev afprøvet. Den kræver dog fortsat udvikling.

3. Project objectives

3.1 The objective of the project

The objective of the project was to provide a technology, which can conduct a **pre-separation** of mixed wastes like household waste and residual waste into a pure biowaste fraction and at least two other fractions, which are suited for further separation by conventional and upcoming technologies.

The pre-separation should be carried out in an oblong vessel with a water flow **(The Water Sorter**) in which the different components of the mixed waste will be exposed to forces in three directions.

- The water flow will affect all components in a forward direction
- An airstream perpendicular to the water stream will direct light, high floating components to one side of the water sorter
- Gravity combined with mechanical forces at the bottom will direct the heavy, sinking components to the other side of the water sorter.

Thereby the waste is separated in 3 fractions:

1. A light, high floating fraction, with plastic bottles, aluminium cans etc.
2. A heavy, fast sinking fraction, with broken glass and porcelain, discarded household tools etc.
3. A low floating fraction, with biowaste and tissue paper

The energy related goal was to provide a larger portion of biowaste for biogas production than what can be obtained by source separation.

3.2 Energy technology developed and demonstrated

The project developed a separation vessel with a waterflow and the ability to separate and unload a heterogeneous material in three fractions:

- High floating
- Low floating
- Sinking

Further a system was developed for separating the low-floating fraction by unloading. Here ballistic separation was used. This made it possible to separate glass bottles from biowaste in this fraction.

However, tests showed, that many objects can end up in all three fractions. For example, items made of HDPE plastics (High Density Polyethylene – also known as hard plastic) with no air trapped inside (for instance food trays) can sink or float, depending on how they land. This means, that the technology could not be demonstrated successfully for its purpose: Providing biowaste for biogas.

4. Project implementation

4.1 How did the project evolve?

The main events of the project were:

- Design and manufacturing including partial tests and alterations
- Tests of feeding system in Kolding
- Installation at AFLD in Fasterholt
- Death of project partner
- Movement from Fasterholt to Vig – including building a building to house the demo-plant.
- Illness and death of project manager
- Final tests in Vig

Due to technological challenges, challenges caused by illness and death of two project partners and movement of the demo-plant, but mainly due to unsatisfactory separation in the separation vessel, some of the planned activities have not been carried out, and therefore a part of the budget has not been used.

4.1.1 WP 1 Design, construction and installation of the demo-plant and WP2 Operation of the demo-plant

Since WP2 Operation of the demo-plant continuously led to modifications of the demo-plant, WP 1 and 2 are described together.

4.1.1.1 Feeding device

The feeding device has two functions: Opening of plastic bags and dosing of the waste into the separation vessel.

The first version of a bag opener was based on a modified fodder rmixer. The screw conveyers of the mixer were equipped with knives. The first trial at AFLD in Kolding revealed that the knives were worn down very fast. The mixer was therefore refurbished with stronger knives and countercuts and the rotation speed was doubled.

Figure 1 Waste in the first bag opener

Large waste items were a big problem. These items are often found in waste from multi-story dwellings, where the several apartments share large waste containers. On that background, there was an effort to design equipment which could sort out large items. One of the challences by this was, that some of the large items are narrow and long, and therefore not possible to separate by i.e. a grid holding back large items.

The bag opener was changed to a rotating knives drum in an attempt to solve the problem with large items. However large “soft” items like matrasses and carpets would get stuck on the knives. It was therefore modified to avoid this. In order to provide safety, the knives drum was enclosed in a casing.

Figure 2: New bag opener with knives drum, before the safety casing was installed

In order not to let the problems with large items obstruct the project, it was decided to investigate if the system could separate biowaste, so that food within packaging which has wrongly been sorted as biowaste could be separated from the rest of the biowaste.

The new bag-opener still did not work fully satisfactory. Small bags would pass unopened and large bags would get stuck and obstruct the flow. Therefore, other solutions were considered and tested in small scale, but not implemented on the demo-plant. However, both cutting with a string and with a water jet looked promising in small scale.

In an attempt to sort out plastic bags and other plastic foils before the separation vessel, a rotor was designed and manufactured. However, it was decided to make the inflow ramp narrower, since there had been problems with low floating waste blocking high floating waste from moving across the separation vessel. This meant that the rotor could not be installed. The function of the rotor was simulated by removing a part of the plastic bags before they entered the feeding system.

4.1.1.2 The separation vessel:

A ballistic separation for the low floating fraction was developed using the simplified pilot plant from the earlier EUDP project. The ballistic separation was integrated with the conveyor belt for unloading of the fraction. It was established that a speed of 0,8 m/s combined with a toothed carrier would separate items like glass bottles, glass jars and shoes from the bio fraction.

Establishing an even waterflow proved to be a serious challenge, and led to a number of iterations of the design. In the final design, the water stream is provided with propellers and the vessel is separated horizontally to separate the water moving away from the inlet in the upper part from the water moving towards the inlet in the lower part.

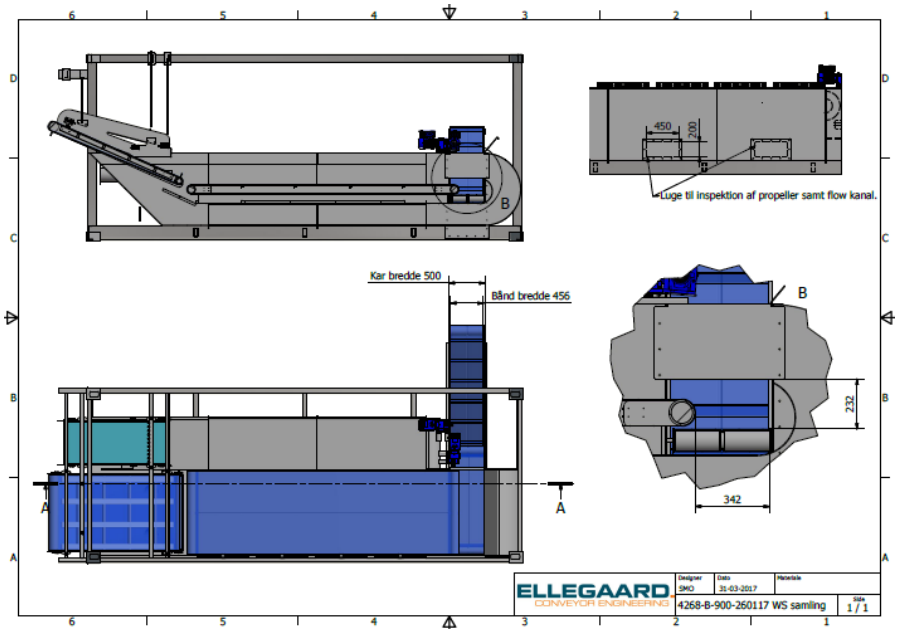


Figure 3 Design of the separation vessel

The first tests of the separation vessel showed that the ballistic conveyor belt was not stable enough, and a new conveyor belt in a stiffer material was manufactured.

The ventilator providing the air stream could not tolerate the humid conditions. The system was altered so the air was led in to a box with variable opening.

In order to supply the air stream, preliminary tests were carried out with water-jets, which seemed promising. So, a system to provide water-jets were added. To further supply the air stream, a rotating skimmer was developed. The inflow of the air stream and the water jets were placed in the first part (the half closest to the inlet

of waste) of the separation vessel and the skimmer was placed in the second half of the separation vessel (closest to the unloading of the floating fractions).

In order to prevent floating items with a large part of the item being under water from moving the part of the vessel for high floating items, a barrier was established. The barrier was just below the surface in the inlet end and just above the surface in the outlet end.

The final tests of the system were carried out at Rustfri Service in March 2021. Photos from the tests can be found in the appendices.

The municipality of Odsherred delivered collection containers with biowaste and residual waste. This means that the waste had not been compressed in the collection vehicle. It is assumed, that the waste is easier to separate when it hasn't been compressed. Had the tests been successful, it would have been necessary to carry out tests with compressed waste as well.

In order to test the separation vessel, without the problems with the feeding system affecting the separation, it was decided to simulate a situation, where the bag opening and emptying was functioning satisfactory. If the separation in the separation vessel would be satisfactory, the development of bag opening and emptying would continue.

All bags were opened, and approximately 85% of the bags were removed before the waste was fed into the separation vessel.

By the ballistic unloading for high floating components, the fast movement of the conveyer belt created some turbulence in the water flow 15-20 cm before the conveyor belt, which to some degree hindered the items in being picked up. This could be solved by unloading by a slower conveyer belt, and transferring the waste to a ballistic conveyor belt subsequently. In order to simulate this, the high floating fraction was pushed the last 15-20 cm towards the belt manually.

The first tests with residual waste showed, that the air-flow and the water jets had very little effect, and therefore the skimmer was moved to the middle of the vessel. The fist tests also showed, that the barrier, which should keep low floating objects from entering the zone for high floating objects also kept objects back, that were supposed to go into the zone for high floating objects, and therefore the barrier was removed.

The first tests for residual waste were not very promising. The main part of biowaste in the residual waste was food which was still in the packaging, and depending on the type of food, the type of packaging, and whether the packaging was intact and closed or open, these items could end up in all three fractions. Tissue paper would as planned mainly go into the low floating fraction, but there were so many other items in this fraction, that using it for biogas after separation with a press, did not seem realistic.

The biowaste fraction showed an extra complication considering bags, since the waste would often be packed in several layers of plastic bags. Sometimes, the inner bags would be packaging, other times it would be waste bags, probably to secure, that runny wastes would not drip out of the outer bag. This will probably make it more difficult to develop a functioning system to open and empty the bags.

The first tests with biowaste showed some promise, since the sinking fraction was almost only biowaste with no plastic foil. The skimmer was redesigned to pick up plastic bags and foils from the high floating fraction. It was a preliminary version of this function. A system for removing the bags from the bag picker was not designed. The bag and foil picker picked up most of the plastic bags and foils, and could have some promise, but would need a substantial amount of development work in order to be fully functioning. Further tests with biowaste were less promising. Objects of the same type, which are not desired in the fraction going to biogas like for instance food still in the packaging would also end up in the sinking fraction, which was otherwise the

cleanest biowaste fraction. This means that all three fractions would still need to undergo a subsequent separation. If a well-functioning post-separation method could be developed, it would probably be more efficient to send all of the source separated biowaste through that.

4.1.1.3 Treatment of biowaste fraction

A press with integrated chopping was designed on basis of a press with a double screw conveyer from Swea in order to avoid having a separate chopper, and thereby simplifying equipment and process for handling the biowaste fraction.

The company Ecogi, market equipment for pre-treatment of source separated biowaste were also interested in the press for reducing water and biowaste content in the residual fraction containing mostly plastic bags.

When the residual fraction was pressed with the press, it could be reduced with about 20%, but micro plastic would be formed in the fraction containing water and biowaste. This is not acceptable, since this fraction is meant to go into a biogas plant, where the residue will be used as fertilizer in agriculture.

A new concept for the press was developed in order to avoid the problem with micro plastic. This implied that the chopping must take place prior to the pressing, and not subsequently as originally planned. The new concept comprised friction pulping of the bio fraction, and integration with a pressurized reactor, which can sterilize the bio-fraction in order to avoid any hygiene issues.

Due to the death of Keld Lunderskov his company Swea was closed, and Rustfri Service entered the project as new partner, who manufactured the main parts of the press.

It was considered to feed the biofraction into the chopper through a rolling mill.

Due to the illness and death of project manager Børge Holm Christensen, the final design and manufacturing of the feeding and chopping for the press, was not carried out.

4.1.2 WP2 Operation of demo-plant

It was planned to carry out full-day operation of the demo-plant in order to establish the capacity of the water sorter (kg waste/hour). However, as described in the previous section, all test runs revealed serious issues, which needed to be corrected before larger scale operation of the demo plant would be relevant. The final tests did not provide a satisfactory separation of the waste, and therefore larger scale operation of the demo-plant have not been carried out.

4.1.3 WP 4 Market research and feasibility studies

The main activity has been to investigate possibilities related to the new situation resulting from new EU legislation, which makes source separation mandatory in the EU. It was decided to investigate residual waste and source separated biowaste as raw materials for the waste separation.

The market research and feasibility studies were planned to be carried out based on results from WP2 Operation of the demo-plant, but since the separation was not sufficiently successful to make it relevant to carry out operation with larger amounts of waste, it was also not relevant to carry out market research and feasibility studies.

4.1.4 WP 6 Test of melting fractionation of plastics

It was expected to be difficult to find recycling possibilities for the plastic separated from the process, and therefore it was decided to carry out preliminary investigations at Gravenhorst, which is an innovative plastic manufacturer with extensive experience in plastic recycling. The aim was to develop a plastic recycling method, where the plastic would be separated according to different melting points. It was the vision, that the plastic could be combined with cellulose fibres and lignin to produce building materials.

For the initial tests, plastics from another test plant at AFLD was used. This fraction consisted mostly of plastic bags from biowaste, and had been washed.

The tests showed, that there was still too much bio-material in the plastic, and that the plastic was too wet. A more thorough washing and drying process would be needed. Biodegradable plastic was a problem. This problem may be able to be solved by biowaste, by extensive communication to the citizens about the importance of avoiding biodegradable plastic, but it will be difficult if not impossible to avoid biodegradable plastic in residual waste.

Gravenhorst assessed, that if the plastic could be washed and dried satisfactory, and the content of biodegradable plastic could be reduced, it would be able to use the plastic with cellulose fibers and lignin for building materials.

Further tests were not carried out due to Børge Holm Christensens illness, and the many other technical challenges.

4.2 Risks associated with conducting the project

4.2.1 Risks anticipated at the beginning of the project

Since the system had been tested in a simplified full scale pilot plant, the technological risks related to the sparation were considered low.

Content of unwanted substances in the biowaste fraction was considered a risk, and there was a work package to investigate this.

Increasing source separation in Denmark was considered a market risk, but there was confidence, that there would be sufficient markets in the rest of Europe.

4.2.2 Risk experienced during the project

4.2.2.1 Risks related to the project participants

Two of the owners of the partner companies died during the project. In one case it led to closing of the company, which made it necessary to introduce a new partner. This led to loss of know how and delay. The other partner that passed away was also the project manager. This also led to loss of know how and delay.

4.2.2.2 Technological risks

- Large items in waste from multi-storey dwellings was a serious problem for the feeding device.
- Opening and emptying of bags proved more difficult than anticipated
- Floating properties of similar items can be very different and this leads to unsatisfactory separation

4.2.2.3 Market risks

During the project EU legislation made source separation of household waste mandatory in all member contiries. This meant that the type of waste, that the separation method was originally meant for, will not exist in EU in the future.

4.2.2.4 Other risks

Due to AFLD hosting another development project at the site in Fasterholt, it became necessary to move the demo-plant. It was decided to move it to the premises of Rustfri Service in Vig. In order to operate the demo plant there, it was necessary to build a new building to house the demo plant. This meant a substantial delay for the project and extra private funding.

4.3 Did the project implementation develop as foreseen and according to milestones agreed upon?

M1: Demo plant ready for operation was met as planned

M2: Report on trials and improvements is considered carried out with this Final report

M3: Report on test results is not carried out in the form originally planned, because the separation was so unsatisfactory, that it did not make sense to make a detailed inventory of the amounts of different waste types in each fraction, capacity of the demo plant etc. However, the results of the trials carried out are reported in this Final report

CM4: Report on market prospects is not carried out in the form originally planned, since the separation was so unsatisfactory, that there are not expected to be any market prospects in the near future.

4.4 Did the project experience problems not expected?

The unexpected problems that the project experienced are described in segment 4.2.2 about risks experienced during the project.

5. Project results

The original objective of the project was not obtained. Realistic trials were delayed due to difficulties with the feeding system. The feeding system was redesigned and adjusted several times, and in the end, a satisfactory feeding system was simulated by opening bags manually.

The original waste type: Unseparated household waste had to be abandoned due to changes in EU legislation. The project was therefore changed to attempt separation of residual waste and source separated biowaste.

As described in segment 4.1.1.2 the separation of both residual waste and source separated biowaste was not satisfactory, and therefore the project didn't produce the technological results expected. This means, that the commercial results were also not produced, and that there are no relevant target groups, and no dissemination.

There were however some technological results obtained.

- A vessel with a controllable waterflow was manufactured
- A ballistic unloading device, which can separate bottles and other heavy items from the rest of the high floating items was developed
- A skimmer, capable of separating high floating items from low floating items was developed
- A preliminary picker for picking up plastic bags was designed – but still needs substantial development work to be fully functioning
- Unloading system for the sinking fraction was developed and functioning

6. Utilisation of project results

The technological results are not considered to be fit for commercialisation for the original purpose of creating a bio-fraction suitable for biogas production. The results obtained may have a commercial potential for separation of other types of waste than residual waste and source separated household waste. However, the project partners do not currently see any obvious possibilities for commercialisation. The development of the technology will therefore not be continued, unless a promising waste type or product type is identified.

7. Project conclusion and perspective

The technology developed did not perform the necessary separation of the residual waste or biowaste. There were too many objects of the same type, which would float in different ways, depending on how they landed in the vessel and whether they were open or not. The conclusion is therefore, that the developed technology will not be commercialized in the near future by the project partners.

8. Appendices

- Add link to relevant documents, publications, home pages etc.

8.1 Photos from final tests

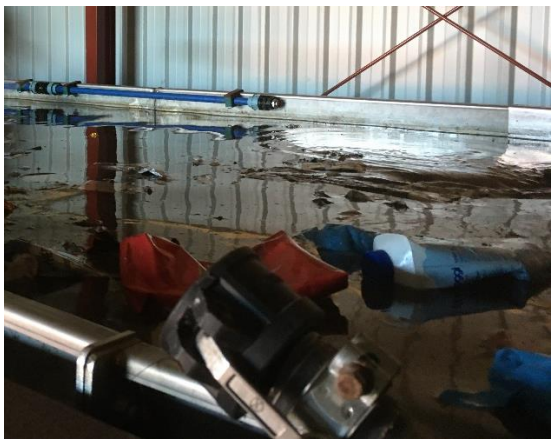
8.1.1 Before loading

In order to simulate satisfactory bag opening, most bags were opened and removed.



8.1.2 Separation of high floating and low floating objects

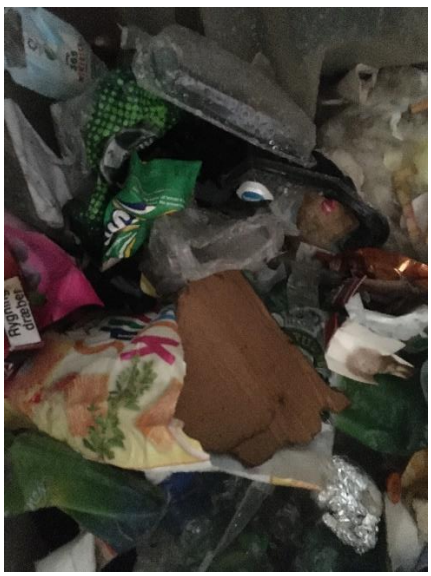
Separation by the skimmer: High floating components are pushed to the near side of the vessel and low floating elements are mainly in the far side of the vessel.




8.1.3 Fractions from residual waste

8.1.3.1 High floating fraction

The high floating fraction comprises plastic foils, cardboard, plastic trays and packaged food.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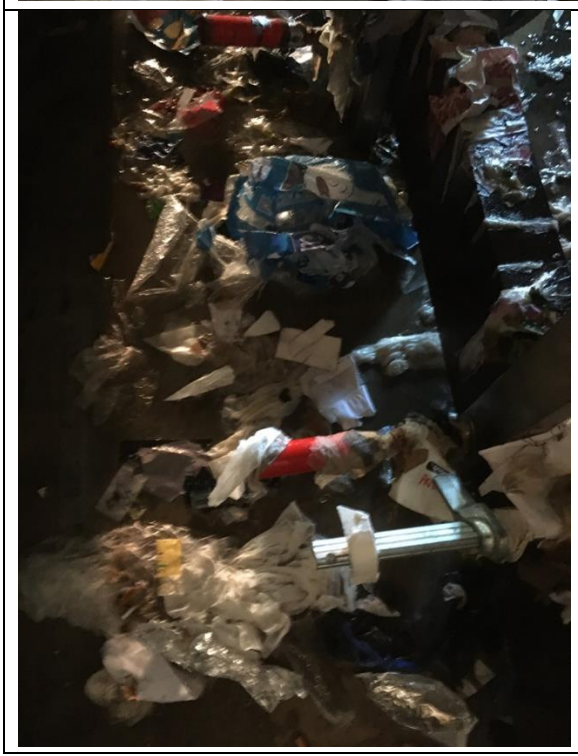
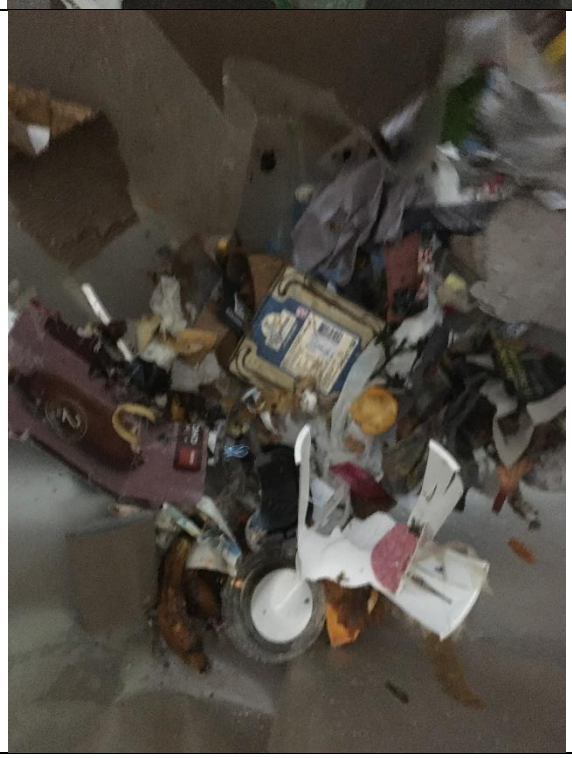
8.1.3.2 Low floating fraction

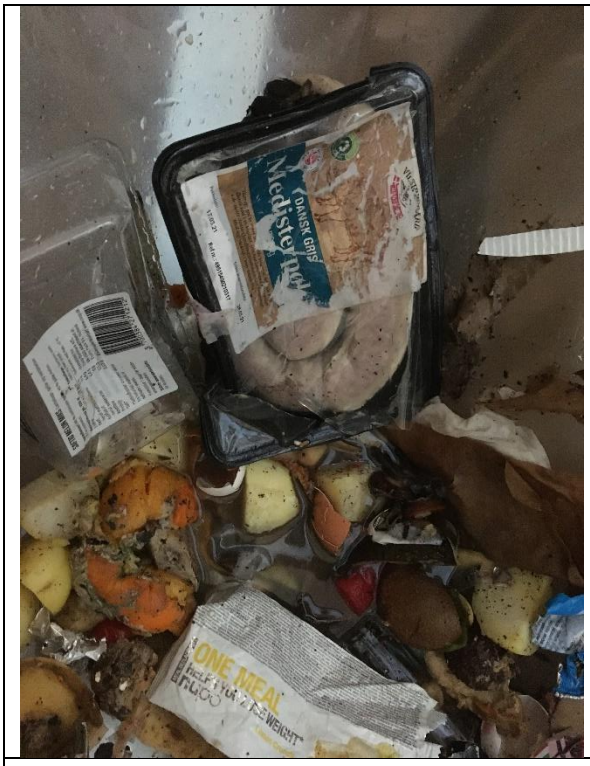
The low floating fraction comprises cardboard, aluminum cans, plastic lids and tissue paper

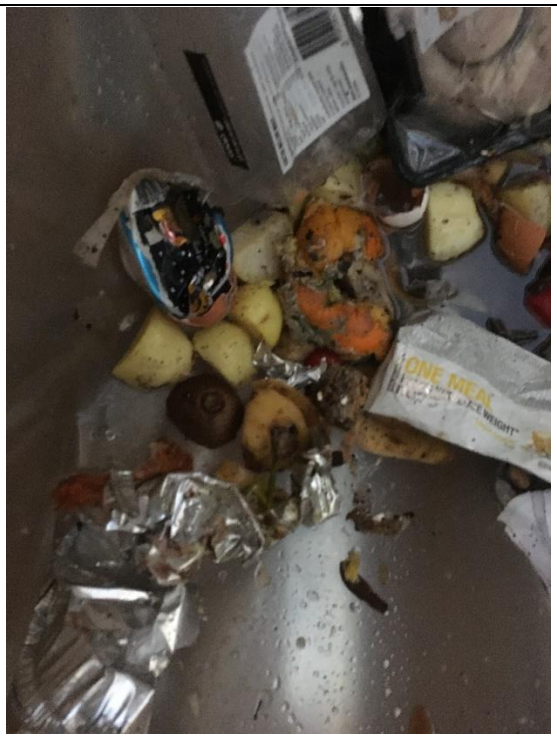




8.1.3.3 Sinking fraction

The sinking fraction comprises bio waste, food in packaging, cardboard, aluminum trays, plastic foil and HDPE plastic.





8.2 Bio waste

8.2.1 Before loading

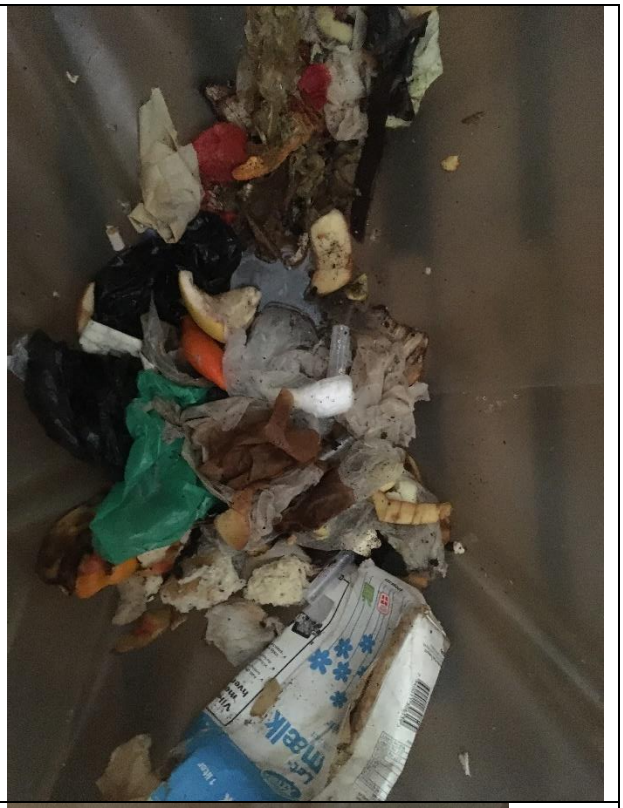
In order to simulate satisfactory bag opening, most bags were opened. In order to test the bag picker, a large portion of the bags were left in the waste.

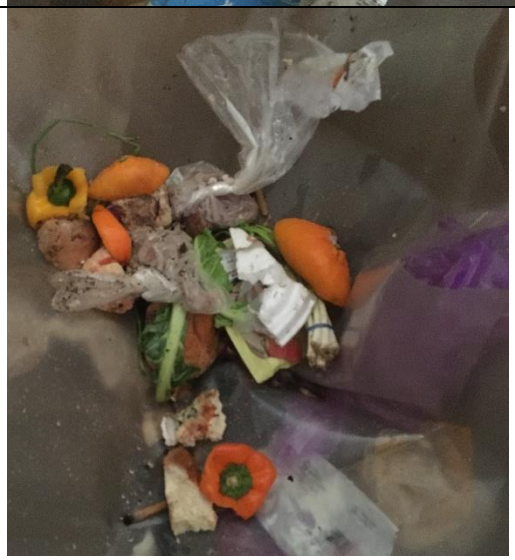
8.2.2 Plastic foil picker

There is not yet developed a system for removing the plastic foils from the picker, but the picker would catch a substantial part of the plastic bags and other foils.




8.2.3 Floating fraction





8.2.4 Sinking fraction