EPAS n.v.

Eco Process Assistance

De Prijkels • Venecoweg 19 • B-9810 Nazareth
Tel. +32 9 381.51.30
Fax +32 9 221.82.18
www.epas.be • epas@epas.be

MELISSA

ENGINEERING OF THE WASTE COMPARTMENT

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Final Report

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Solid Loop Design

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	Name	Signature
Prepared by:	Noëlle Michel	
	Farida Doulami	
Approved by:	Dries Demey	

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1 Introduction

The liquefying compartment of the MELiSSA loop is responsible for the biodegradation of human faecal material, toilet paper and inedible parts of plants generated by the crew. The volatile fatty acids and ammonia produced during the anaerobic fermentation process are fed to the second photoheterotrophic compartment inoculated with the bacterium *Rhodospirillum rubrum*. The produced CO_2 is supplied to the photoautotrophic compartment inoculated with the algal strain *Arthrospira platensis* and to the higher plant compartment.

At the pilot plant of the University of Barcelona, the three compartments of the MELiSSA loop (photoheterotrophic compartment CII, nitrifying compartment CIII and photoautotrophic compartment CIVa) are already connected at lab scale and will be validated at pilot scale. In order to validate the whole MELiSSA loop, it is necessary to construct the first compartment at pilot scale (fermentation reactor) for the primary degradation of the waste produced by the crew.

The first compartment will be fed with faecal material and toilet paper, and non-edible parts of higher plants. The faecal material and the plant material need to be collected and processed before entering the liquefying compartment.

This technical note includes the study of the solid loop. As shown in Figure 1, the solid loop consists of the feed to the fermentation reactor and the concentrated recycled stream from the filtration unit. Since part of the solids and particularly lignin are not well degraded in the waste compartment, a periodic drain will be operated in order to prevent solids accumulation. It might be necessary to have an additional treatment of the drain stream depending on the requirements that are needed for further processing.

The solid loop concept presented in this technical note consists of the collection and preparation of the faecal material, non-edible parts of higher plant and toilet paper. Handling of non-degraded residue is also part of the concept.

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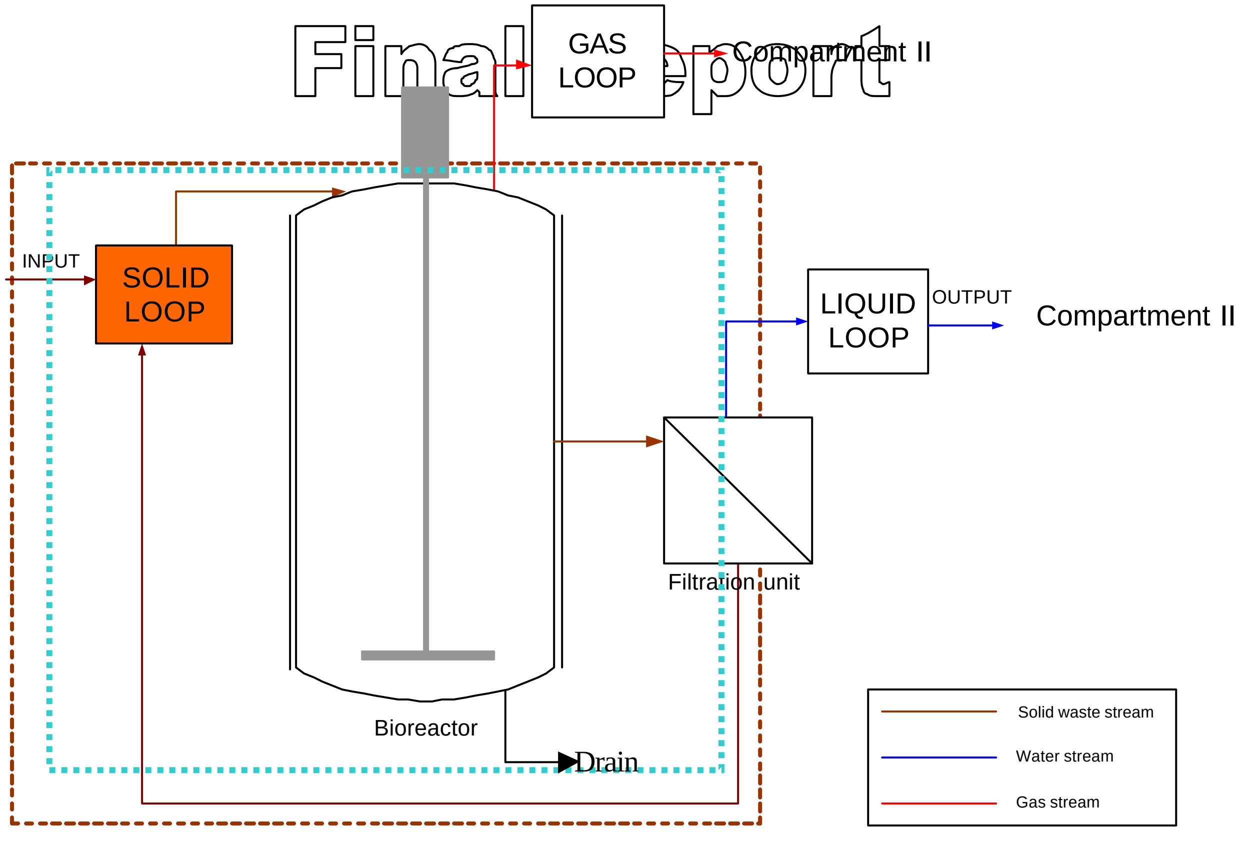

Figure 1: Schematic general design of the waste compartment with indication of the sub-system treated in this technical note

2 Concept of the solid loop

2.1 Requirements of the solid loop

During the MELiSSA meeting on November 29-30th 2001 and the EWC Progress meeting on January 16th 2002 the waste composition was determined. The first compartment at pilot scale will be fed with the total faecal material of one man and wastes (non-edible part) from the Higher Plant Chamber (HPC) when the HPC is calculated to provide 20% of 1 man-diet (per day). So far urine is not wanted to be treated in the first compartment. Indeed, the high ammonium concentration resulting of its degradation would inhibit the acidogenesis. Its handling in the Melissa loop will be investigated. Therefore a separate handling of faecal material and urine is required. Special urine separating toilets have been developed in the framework of ecological sanitation and can be used for collection of faecal material.

It was agreed that the higher plants selected are (in %dry weight) 1/3 lettuce, 1/3 red beet and 1/3 wheat. These crops were selected to be representative of several categories of vegetables: lettuce is rich in fibres, red beet is rich in carbohydrates and wheat straw is a dry and fibrous material, also rich in carbohydrates.. It was agreed that the plant waste would be grinded after harvesting. For toilet paper, the international brand Lotus® was selected during the EWC work meeting on June 27th 2002 since it is easily available all over Europe. The use of the same substrate in the pilot waste compartment (at EPAS, Belgium and then at UAB, Spain) and the fungi degradation tests (ATO) is indeed important; Lotus® double layers white will be used in both companies. The ratio of the different waste materials in the waste stream is presented in Table 1.

Table 1. Composition of the waste material

Material	Amount DW (g/d)	Percentage (%)
Lettuce	54	25.8
Beet	54	25.8
Wheat Straw	54	25.8
Toilet paper	18	8.6
Total plants and paper	***180***	***86%***
Faecal material	***30***	***14%***
Total amount of material	**210 DW g/d**	**100%**

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The aim of the first compartment is to obtain a maximal biodegradation of the waste. The biodegradation efficiency is affected by several factors such as the microbial inoculum, process conditions and the substrate characteristics. The waste is composed of different types of material from which the physical structure is very different. In terms of chemical composition, the materials are comparable and are characterised by a high lignin content. Table 2 presents the composition of human faecal material and related concentrations, determined based on previous experiments carried out at EPAS in the framework of the MELiSSA project.

Table 2. Composition of human faecal material

Human faecal material components	Concentrations (g/L)
dry matter	270-330
ash	35
OM	235-295
N total	12.5
NH4-N	0.6-0.8
VFA	6.5

The following tables show the composition of the edible and non-edible parts of the selected crops in terms of elements (Table 3) and molecule families (Table 4).

Table 3. C/H/O/N/S composition of the selected crops (MELiSSA TN32.3)

	Chemical composition of the digestible part					Chemical composition of the non digestible part				
	C	H	O	N	S	C	H	O	N	S
Lettuce	1	1,7107	0,4464	0,1348	0,0019	1	1.43	0.62	0.017	0.007
Potato/Beet	1	1,6492	0,7750	0,0335	0,0006	1	1.43	0.62	0.017	0.007
Wheat	1	1,6548	0,7215	0,0430	0,0012	1	1.43	0.62	0.017	0.007

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Table 4. Composition of edible part of the selected crops (DW= Dry Weight) (MELiSSA TN32.3)

Crops	Water (% total weight)	Proteins (%DW)	Fat (%DW)	Carbohydrates (%DW)	Fibres (%DW)
Lettuce	95	30.56	5.38	26.89	37.16
Potato/Beet	92	10.17	0.55	76.77	12.51
Wheat	18	13.8	2.35	71.73	12.12

The substrate contains some particulate material (around 9 g/L, meaning 1% of the total fresh weight). The size of the particles must be minimised to ensure an efficient hydrolysis of the substrate. The first compartment will consist of a membrane bioreactor. Membrane bioreactors (MBRs) combine the use of biological processes and membrane technology to treat wastewater. The more common MBR configuration is to have the membrane immersed in the wastewater, although a side stream configuration is also possible, where the wastewater is pumped through the membrane module and then returned to the bioreactor (Till S. and Mallia H., 2001). The membrane is generally used for solid-liquid separation, for bubbleless oxygen transfer or for the extraction of organic pollutants from hostile industrial wastewater. In this context, only biomass separation MBR's are considered. An external ultrafiltration membrane is used to separate the non-degraded particles from the fermentation products in the liquid phase. The membranes that will be used are tubular membranes and have an internal diameter of 8 mm (see TN71.2). This means that the size of the particles must be lower than 8 mm to prevent blockage of the membranes. A particles size smaller than 4 mm is the objective to avoid clogging of the inlet of the membranes. Particles are present under different shapes that result from the initial composition of the different wastes and the grinding method used.

Grinded wheat can for instance mostly present fibrous particles. Therefore the size criteria must be applied to the maximum length of one particle.

The substrate must be collected, treated, stored and fed in a homogeneous mixture in order to guarantee the standardisation of the material used during the demonstration tests. For the future use in the Melissa Pilot Plant, an automated system for waste collection and handling is necessary to ensure hygienic conditions.

This document proposes a concept for feed preparation system. Yet, only a prototype of the collection system will be built and no final system will be delivered.

The solid loop encloses also the drain from the fermentation reactor. It is expected that around 10% of the material fed will need to be treated by additional techniques to remove or destroy the lignin fraction (see MELiSSA TN71.1). Depending on the type of technology that will be selected, an additional treatment such as further concentration or drying of the drain will be necessary.

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2.2 General concept

2.2.1 System components

The waste material (faecal material, toilet paper, non edible parts of higher plants) needs to be collected and processed before entering the bioreactor. The waste material needs to be processed in its natural state, meaning faecal material, beet, lettuce in a fresh way and wheat and toilet paper in a dry way. It is necessary to pre-condition the waste material in such a way that proper composition and physical characteristics for optimal processing are kept. The different treatment steps needed for each waste stream are: collection, conservation, storage, constant conditioning, grinding, buffering and feeding.

2.2.2 Laboratory solution for feed preparation

The methods for feed preparation were already studied for the use in small-scale laboratory experiments. The objective was to obtain a particle size smaller than 1 mm and to determine the biodegradation efficiencies of lab-scale reactors. Due to the different physical characteristics of the waste sources, different grinding apparatus were needed (see Figure 2). Each substrate was prepared separately. After grinding they were mixed, distributed in small pots and frozen at –18°C.

a. Ultra-Turrax® T 25 Basic (IKA)

b. Knife mill Grindomix GM200 (Retsch)

c. Ultra Centrifugal Mill ZM100 (Retsch)

Figure 2. Laboratory grinders for feed preparation

- Faecal material

The faecal material was collected from volunteers and frozen within 8 hours at minus 18 °C. To prepare the reactor feed, frozen faecal material was weighted and put in water in a weight based ratio 1 to 10 of faecal material. The faecal material was crushed by an IKA laboratory dispersing instrument type ULTRA-TURRAX® T 25 Basic suitable to grind particulate material in water (see Figure 2a).

- Lettuce, red beet

Beet and lettuce were obtained from a biological greenhouse (see addendum for quality certificates). They were frozen at minus 20 °C for stocking purposes. After thawing, plants were manually cut into pieces (2-3cm) and introduced in the vessel of the high-speed knife mixer Knife Mill Grindomix GM 200 from Retsch (see Figure 2b). Water was added with a ratio 1 to 5. This mixer produced a homogenous suspension of the plant waste, using two straight knives at different heights, arranged at right angles to the direction of rotation, turning at a speed between 2000 and 10000 rpm in the centre of the mill vessel.

- Wheat straw

The wheat straw used in former experiments was a dry product obtained from biological production. The wheat was stored in a dry location. It was reduced in three following steps: first the straw was cut manually into pieces with a length of 6 to 8cm that were then introduced in a small household glass kitchen robot (Seb Rondo 1000 400W). Fragments of straw with lengths around 0.5-2.5cm were obtained. They were then fed in the centrifugal grinder Ultra Centrifugal Mill ZM100 from Retsch (see Figure 2c) to produce fine powdered wheat. In the mill, the wheat was grinded by shearing the material by means of a high speed turning rotor against a sieve. An inversed sieve with holes of 2mm was used to obtain fine powder with particles smaller than 1mm.

- Conclusion

The different techniques gave the desired results regarding the particles size; after separated grinding, the different substrates were mixed together in the proper ratio. The result was a homogenous fluid with particles smaller than 1mm. However, separating steps and using lab-capacity apparatus make the process inappropriate for preparing the high volumes of substrate needed for feeding the pilot reactor.

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2.2.3 Proposed concept for pilot plant

The general concept of the solid loop is proposed in Figure 3. Faecal material will be collected together using a dedicated separating toilet. Afterwards it will be mixed with water and grinded until the particles size is smaller than 4 mm.

Non-edible parts of higher plants, like roots and leaves will be collected and processed in their natural state. Some parts will be wet and some will be dry (like wheat straw). Different grinding techniques are proposed, adapted for wet or dry parts. The non-edible parts of higher plants will also be grinded until particles smaller than 4 mm are obtained. Tap water will be added until the desired concentration is obtained (see Table 9).

After the grinding step all the waste will be stored in one container and kept at a temperature of 4°C before feeding to the pilot reactor.

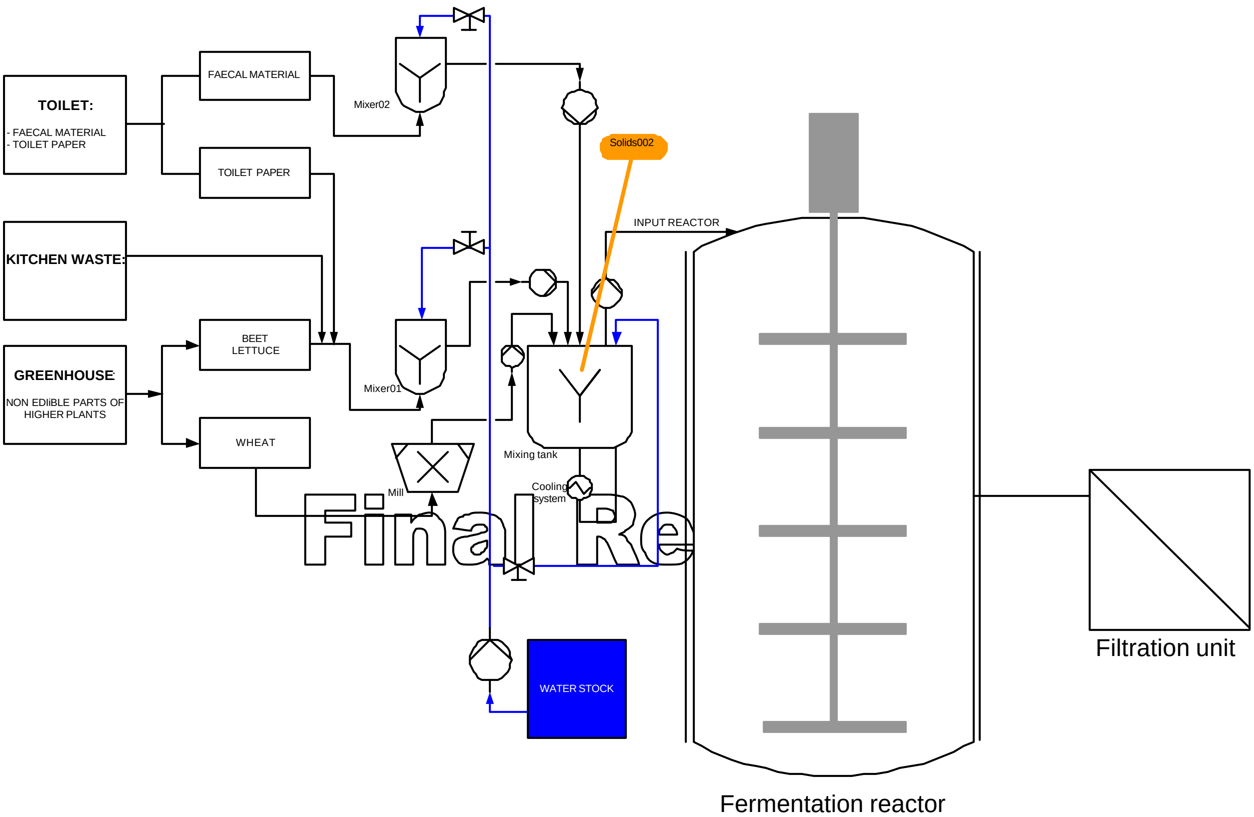

Figure 3: Conceptual scheme of the solid loop

3 Collection / Purchase of feeding material

3.1 Faecal material and toilet paper

Since urine shall not be treated in the first compartment, the solid loop must be equipped with a collection system separating faecal material from urine. The essential requirements for such a separating toilet system are: comfort for the users, little dilution of faeces (for adaptability in the waste preparation step prior to the feeding), and a satisfactory drainage of the different flows.

Such separating toilets or no-mix-toilet have been developed since the nineties, mainly in Sweden. These systems present a great interest in term of recycling, since the separated wastes can be treated specifically. After treatment, urine can be used as a fertilizer. Faeces can be combined with other biological wastes for use in biological gas reactors. In the framework of the EWC project, urine will not be used. The yellow water flow will be connected to the normal sewage collecting system of the pilot plant premises. The black water flow will be directed toward the feed preparation system (Otterpohl R., 2002).

A no-mix toilet can be used like a conventional modern toilet, with the exception that men have to sit during use. The toilet is equipped with two different outlets: one for faeces and paper located in the back part of the bowl, and one for urine, which is closed by a movable plug (see Figure 4a). While the toilet seat is in use, the plug is mechanically opened by a lever (see Figure 4b). Urine flows to the front inlet. The plug closes once the toilet is flushed (see Figure 4c). Faeces and paper are washed away with minimal amounts of water through the rear outlet.

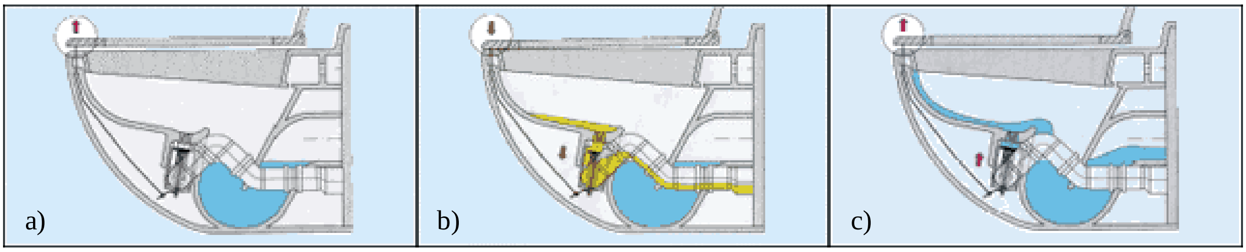

Figure 4. No-mix toilet mechanism (Roediger Vakuum & Haustechnik)

Lotus® toilet paper (double layers white) was selected in a previous meeting by the MELiSSA partners (Mom 29-30/11/2001, Mom 16/01/2002). The toilet paper will be collected separately after use of the toilet and added in its initial dry state to the treatment process of dry material (wheat straw).

3.2 Plant material

In the framework of the MELiSSA project, it is crucial to have the highest possible degree of control on the food for the crew. For this reason it is important to use plants with well-known culture conditions and close from the ones that could be used in space. This means in particular a culture exempt of chemicals. Several options were studied, with among them the possibility to rent a piece of field and to cultivate the plants according to our specific requirements. Another option was however selected: to purchase biologically grown products, with the certification that they are cultivated using only natural pesticides and fertilizers as listed in the regulation of the European Union n° 2092/91 (Regulation n°92/91, 1991). This solution presents indeed the advantage to be easily transferable and reproducible from a European country to another one. Biologically grown plants are cultivated in both Belgium and Spain and are subjected to the same regulation, allowing to test the pilot compartment I at EPAS and then in the pilot plant of Barcelona in the same conditions.

For the testing of prototype and pilot reactors at EPAS, lettuces, beets and wheat were therefore ordered at BLIK Bvba - Belgium. Varieties of crops *Lactuca sativa L.* (lettuce), *Beta vulgaris* (red beet) and *Triticum aestivum* (wheat) were purchased. After delivery they were stored at –20°C at The Freezer company (Nazareth, Belgium). The certificates guaranteeing a bio-culture are added as addendum.

4 Waste material grinding

The different substrates need to be processed in their natural state to a homogeneous solution containing particles smaller than 4mm. Since the natural state varies depending on the material, two different types of requirements must be considered to grind fresh and dry material separately. Moreover, to secure the Filtration Unit, a safety grinding system located at the entrance of the unit can prevent remaining big particles to go into and thus to clog the membrane. After describing the requirements, a list of candidate equipment is proposed. The final selection is done based on the requirements and the collected information, with the purpose to fulfil the different requirements using a minimum of actuators. The selected grinders will be then integrated in an automated solid loop.

4.1 Grinders requirements

As explained above, three requirements families can be distinguished, concerning:

- grinding of fresh material (beet, lettuce, faecal material)

- grinding of dry material (wheat straw, toilet paper)

- safety grinding system of the mixed feed.

Moreover, a pumping element is required to ensure the circulation of the feed preparation loop.

The detailed requirements of grinding systems are listed in Table 5.

Table 5. Grinders requirements

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REQUIREMENTS OF GRINDERS			
Device	Grinder	Grinder	Grinder
Function	To grind Faecal Material, Lettuce, Beet	To grind Wheat straw, Toilet paper	To grind reactor content before entrance in FU
Process requirements			
Load capacity*	max 18,5 kg fresh/batch	max 540gDW/batch	nominal 400L/h (300-900L/h)
Maximum initial particles size	Maximize		
Final particles size accuracy	Particles size < 4mm		
Material grinding capability	Fresh material, frozen	Dry material	Fresh mixture
Sample homogeneity after grinding	Yes		
Working mode	batch		continuous (in-line)
Safety			
Resistance	Resistant to corrosion		
Materials housing	preferably metal		Stainless steel
Temperature range	preferable able to process frozen material	non applicable	must stand 55°C
Leak proof	Yes	non applicable	Yes
Maintenance			
Cleaning	Minimize		
Crewtime	Minimize		
Sheduled maintenance	Minimize		
Spare parts	Readily available		
Accessibility of vital parts	Good		
Energy consumption	Minimize		
Certification			
Certificate EC	Yes		
Guarantee	min. 1 year		
Costprice			
Investment	Minimize		
Operation	Minimize		
Spare parts	Minimize		

*Load capacity: the feed preparation will be performed in batch, with a maximum capacity of 100L per batch corresponding to 10 days of feeding (see section 6.3). Thus the apparatus must be able to handle this load in a minimum of time. The maximum loads for lettuce, red beet, faecal material and wheat straw are determined based on the influent composition (see section 6.2). The capacity required for the FU grinder is dependent on the FU pump, which shall run with a flow rate of 400 to 900L/h.

4.2 Principles of grinding

During the MELiSSA meeting on the 29-30th of November 2001 it was decided to pre-treat the plant material in its natural state, meaning wet, for the non-edible parts of the beet and the lettuce and dry for the wheat straw.

The different techniques of grinding are presented in Figure 5.

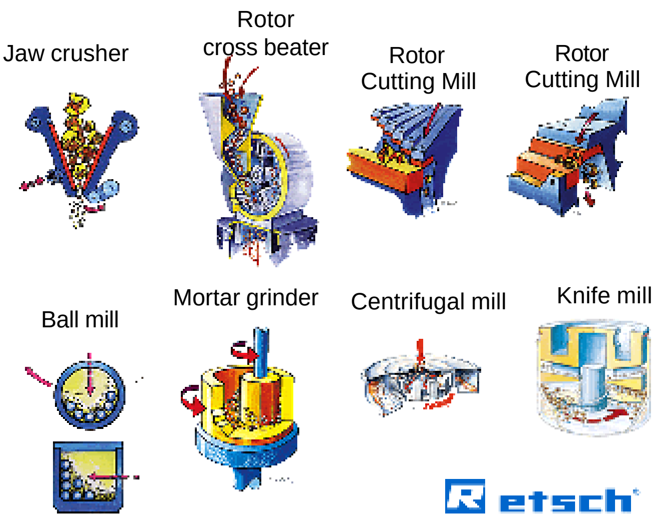

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Figure 5: Different types of grinding mechanisms

- **Striking forces**

Hammer mils and jaw crushers are suitable for rough and preliminary crushing of medium hard, brittle and hard/tough materials. Materials are destroyed by striking forces on the material.

- **Striking and shearing forces**

Ball mills, mortar grinders and beater mill crush the material by striking and shearing forces. By this action, materials have the risk to heat up if the residence time is too high in the equipment. Ultra Centrifugal Mills are used for the fine grinding of soft to medium-hard, elastic, brittle and fibrous materials.

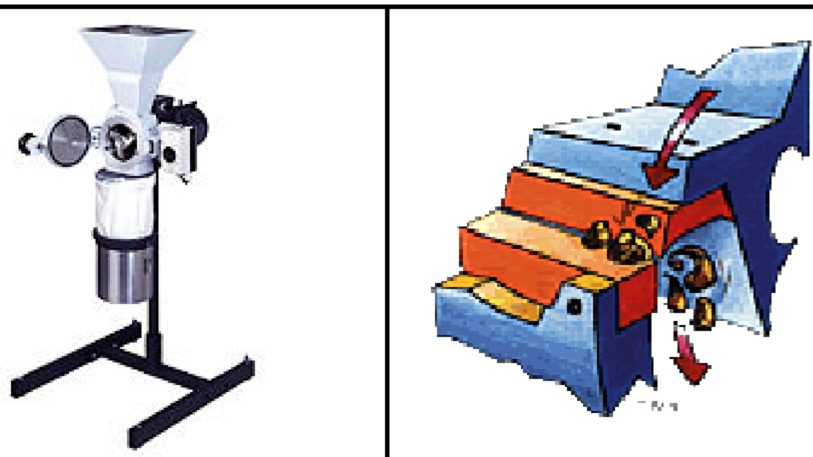
- **Cutting action**

Cutting mills which use knifes to grind the material can reduce soft, medium-hard, brittle, elastic and fibrous materials. They are particularly suitable for preliminary grinding of dry materials such as plant parts, plastics, fodder, spices and drugs, lignite, paper, cardboard, etc.

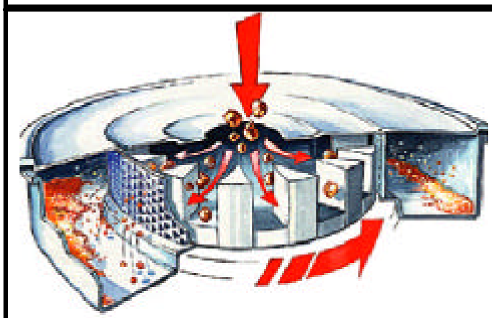
With the cutting knife system and the variable grinding chamber of a knife mill, dry, soft and materials containing fluids can be processed into a homogeneous analysis sample.

4.3 Candidate equipment

The solid waste preparation system of the first compartment must be capable to process organic waste with high water content (beet, lettuce, faecal material) and dry material (wheat). Finally, the substrates must be mixed. Based on laboratory tests and a review of commercial available apparatus, a selection was made of candidate grinding systems (see Figure 6).

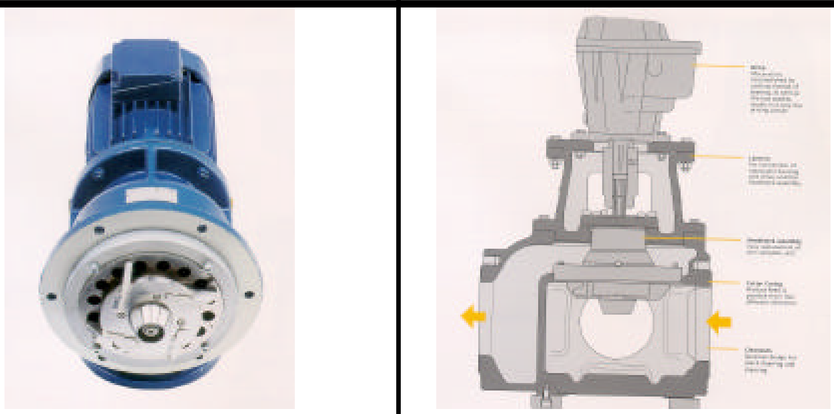


a. Cutting Mill SM 100



b. Centrifugal mill technology

c. Industrial kitchen grinder



d. Grinding peristaltic pump

Figure 6. Candidate equipment for grinding purpose

4.3.1 Grinding dry material

A jaw crusher is not a suitable technique since it allows only rough crushing or pre -crushing of material, and thus provides too big particles size. Rotor and cutting mills are adapted for reducing size of fibrous dry material.

4.3.1.1 A Cutting mill: Retsch SM 100

The Retsch Cutting Mill SM 100 reduces the size of soft, medium-hard, elastic and fibrous materials or mixtures of materials. Long-fibre samples such as straw and voluminous materials such as plastic beakers can be comminuted in a single process without any preliminary size reduction. The final fineness always depends on the bottom sieve used and the properties of the sample.

The standard equipment includes a parallel section rotor with 3 blades and a 5L receiver with filter bag. Three different feed hoppers optimized for feeding different materials are available. Depending on the necessary final fineness, bottom sieves with perforations from 0.25mm up to 20mm can be used.

Size reduction inside the cutting mill is achieved with a cutting and shearing action (see Figure 6a). The feed product passes through the hopper and into the grinding chamber. There it is engaged by a rotor fitted with three knives and is reduced between these blades and the four cutting bars inserted in the housing. The time span inside the grinding chamber is short; as soon as the product is reduced to a size smaller than the perforations in the bottom screen it is discharged for collection in the container.

Test: A test was performed using this machine to determine its suitability in the EWC project. Around 100g of straw were introduced in the mill with a sieve of 1mm perforations. The straw was processed directly in its initial state, meaning fibres of around 10 cm length. It can be noticed that a small proportion of the straw, too light, was retained in the sieve and not cut. The total operation did not exceed one minute. The obtained powder was analysed using a series of sieves with different perforations sizes, from 0.5 to 2 mm. It was concluded that 100% of the powder passed through Ø2mm sieve, 97% through Ø1mm sieve, and 63% through Ø0.5mm sieve. However, this result do not give an exact idea of the particles size, due to the particular fibrous shape of the straw, which can allow a particle longer than the perforation to pass it.

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4.3.1.2 A rotor mill: UltraCentrifugal Mill Retsch ZM100

Centrifugal mills are used for fine grinding of soft to medium-hard, elastic, brittle and fibrous dry materials. Grinding takes place in the mill by the impact and shearing action between the rotor and the fixed ring sieve (see Figure 6b). The feed material passes through the funnel with splashback protection onto the rotor. With the centrifugal acceleration it is hurled outwards with great energy and is precrushed on the wedge-shaped rotor teeth before being finely ground between the rotor and the screen.

The feed material can be introduced manually or via a feed unit controlled as a function of load. The ground material is collected in a tray or in a paper filter bag via a passage receptacle.

Test: This rotor mill is at present used at EPAS to grind wheat straw for feeding the prototype reactor. High fineness is obtained. However, the straw needs to be first cut manually into pieces, and then with the help of a small kitchen robot (see section 2.2.2). This increases considerably the time processing.

4.3.2 Grinding fresh material

4.3.2.1 Grinder for processing industrial kitchen waste

Catering kitchens are equipped with apparatus to process food waste present in rinsing waters. Material is entered together with water at the top of the machine and is cut by turning knifes. The material is removed by the centrifugal force of the rotor on which the knives are mounted. By recirculation of the waste stream a particle size smaller then 4 mm can be obtained. Lettuce, beet and faecal material can be processed in such a disposer.

Test: A qualitative analyse was realised to check the suitability of the industrial kitchen disposer. Whole red beets and lettuces were introduced in the disposer with water and re-circulated several times. Recirculation allows increasing the reduction of particles. Then the mixture was passed through a series of 3 sieves connected together, with perforations of 5, 3.15 and 2 mm. The mixture was slightly spread on the sieve surface (the material being fresh, the particles had a tendency to agglomerate). The flow crossing the sieve was observed and analysed qualitatively. It was observed that:

- Everything passed through the Ø5mm sieve;

- Everything passed through the Ø3.15mm sieve;

- Almost everything passed through the Ø2mm sieve, a few particles were retained.

To conclude, all the particles cut by the kitchen grinder were smaller than 4mm. A major part of them were smaller than 2mm. The grinder is thus suitable for this application.

4.3.2.2 Grinding pumps

To ensure the circulation of wastes in the feed preparation loop, a progressive cavity pump equipped with a grinder can be used. The pump is equipped with a macerator directly combined in its housing, which can reduce faecal material. Some pumps are equipped with an additional sieve to select the size of the particles that are leaving the pump. This type of macerators is mainly used for municipal and industrial wastes. They macerate the solid and fibrous components in the wastewater or sludge, increasing the operating safety and the service life of pumps and other machinery.

The filtration unit is equipped with a Seepex progressive cavity pump that is in charge of the circulation of the sludge in the unit. Thus the use of a Seepex pump can be foreseen in the feed preparation application in order to improve the homogenisation of hardware. The Seepex pumps are adapted to the type of medium treated in the first compartment, which is the major problem in the searching of a pump. Indeed, large particles can be passed through the pump without damage due to the large spherical entrances into the pump. The large capacity range (100cm^3/h up to 150m^3/h) includes the requirements of the feed preparation system. Moreover this capacity is relatively independent from viscosity and solids percentage. Fluid temperatures from –20°C to +180°C can be used, thus the processing of frozen plants can be handled. Pumps equipped with macerators allow both pumping and grinding of the sludge. The macerator consists in a replaceable headstock assembly. Knives are fixed on the headstock at an inclined angle, resulting in a cutting and slicing action in conjunction with a shear plate (see Figure 6d).

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4.3.3 Safety grinding

To ensure a continuous running of the first compartment and especially of the filtration unit, the control of particles size is of high importance. To prevent that particles bigger than 4mm enter the filtration unit and clog it, the installation of a safety system before the filtration unit is proposed, grinding the possible particles exceeding the tolerated size. Macerators can be adapted in line with the filtration unit instruments before the membrane, or even in the housing of the progressive cavity pump (see section 4.3.2.2)

4.3.4 Comparison of the candidate equipment

Next table presents the summary of use, advantages and disadvantages of each possible technique.

Table 6. Comparison of grinding equipment

Apparatus		Use	Advantages	Disadvantages
Retsch Cutting mill SM100		-Grinding of wheat straw	-rapid size reduction of dry materials -Nearly dust-free comminution -shorter operation time -no pre-treatment of straw required -2-years warranty, CE-conform	-particles size larger (maximum 2mm) -small part of sample is not processed and accumulates in the sieve
Retsch Ultracentrifugal mill ZM100		-Grinding of wheat straw	-high fineness of particles (<<4mm: powder) -simple removal of ground material -push-fit rotor for easy exchange and cleaning -can work continuously -2-years warranty, CE-conform	-necessity to pre-cut the straw in pieces <10mm -noisy -Longer operation time
Insinkerator industrial kitchen grinder		-Grinding of fresh material	-particles size <3mm -fast operation	-small part of particles bigger than 2mm
Seepex progressive cavity pump with macerator		-Grinding of feed -Circulation of feed in the feed preparation loop -Safe grinding in filtration unit	- particles size <4mm - corrosion resistant -friendly maintenance with replaceable macerator -insures liquid circulation in feed loop and grinding of material -low power requirement -integration in filtration unit pump	-must not run dry

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4.4 Trade-off and selection

Based on the requirements of the solid loop and the information described above, a screening of the candidate equipment is performed and shown in Table 7.

Table 7. Screening of grinding machines

	Candidate equipment				
Function	Grinding of dry material		Grinding of fresh material	Circulation of feed in the loop	safety grinding in FU
Name	Rotor mill	Cutting mill	Kitchen disposer	Grinding pump	In-line grinder
Brand	Ultracentrifugal mill ZM100	Cutting mill SM100	In-Sink-Erator	Seepex	Seepex
Device	Grinder	Grinder	Grinder	Pump + Macerator	Macerator
Process requirements					
Load capacity	batch: 90g/h / continuous: >90g/h	0,2-50 kg/h	100kg/h	up to 150m3/h	up to 150m3/h
Maximum initial particles size	up to 10mm	max 60x80 mm	whole plants	not applicable	not applicable
Final particles size accuracy	<40 µm	0,25-20mm	<3 mm	<4 mm	<4 mm
Material grinding capability	dry	dry	fresh (with water), frozen	fresh (with water)	fresh (with water)
Sample homogeneity after grinding	yes	yes	yes	yes	yes
Working mode	batch/ continuous	batch	batch	continuous	continuous
Connector type/size	not applicable	not applicable	inlet 165/203mm, outlet 38mm	flange suction DN65 PN16 DIN 2501 / Flange delivery DN50 PN16 DIN2501	flange DN100
Dimensions	400x460x450 mm	560x1560x700mm		1138*245mm	440*561mm
Weight	25kg	64-68kg		35kg	80kg
Safety					
Resistance	resistant to corrosion	resistant to corrosion	resistant to corrosion	resistant to corrosion	resistant to corrosion
Materials housing	stainless steel, tungsten, titanium	stainless steel	stainless steel	cast iron, stainless steel	cast iron, stainless steel
Temperature range	not available	not available	frozen material possible	-20°C-+180°C	-20°C-+180°C
Leak proof	not applicable	not applicable	yes	yes	yes
Maintenance					
Cleaning	dismantlement required	Minimized	Minimized (by flushing water)	Minimized (by flushing water)	Minimized (by flushing water)
Crewtime	high	low	low	low	low
Sheduled maintenance	yearly	yearly	yearly	yearly	yearly
Spare parts	available	available	available	available	available
Accessibility of vital parts	good	good	good	good	good
Energy consumption	600W	1500W	0,9-1kW	750W pump (+1,5-3kW macerator)	1,5-3kW
Certification					
Certificate EC	yes	yes	yes	yes	yes
Guarantee	2-years	2-years	1 year	1 year	1 year
Cost					
Investment	8 741,40 €	5 213,22 €	1 198 €	863 + 3050 = 3913€	3 050 €

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Selection is then realised with weighting the different requirements depending on their importance. Table 8 presents the results of the selection. Selected apparatus can be found in gray at the end of the table.

Table 8. Trade-off of grinders

	Criteria	Weight	Rotor mill Ultracentrifugal mill ZM100	Cutting mill Cutting mill SM100	Kitchen disposer In-Sink-Erator	Grinding pump Seepex	In-line grinder Seepex	Description
	TRADE-OFF							
	Process requirements							
1	Load capacity	100	2	2	2	2	2	=Req=2 , <Req=0
2	Maximum initial particles size	50	0	2	2	2	2	big = 2 , small = 0
3	Final particles size accuracy	100	2	1	1	1	1	=2mm = 2 , <4mm = 1 , =4mm =0
4	Material grinding capability	100	2	2	2	2	2	=Req = 2 , ?Req = 0
5	Sample homogeneity after grinding	100	2	2	2	2	2	yes = 2 , no = 0
6	Working mode	100	2	2	2	2	2	=Req = 2 , ?Req = 0
	Safety							
7	Resistance	100	2	2	2	2	2	=Req = 2 , ?Req = 0
8	Materials housing	50	2	2	2	2	2	=Req = 2 , ?Req =0
9	Temperature range	100	non applicable	non applicable	2	2	2	=Req = 2 , ?Req = 0
10	Leak proof	100	non applicable	non applicable	2	2	2	=Req = 2 , ?Req = 0
	Maintenance							
11	Cleaning	50	0	2	2	2	2	=Req = 2 , ?Req = 0
12	Crewtime	100	0	2	2	2	2	=Req = 2 , ?Req = 0
13	Sheduled maintenance	50	2	2	2	2	2	=Req = 2 , ?Req = 0
14	Spare parts	50	2	2	2	2	2	=Req = 2 , ?Req = 0
15	Accessibility of vital parts	50	2	2	2	2	2	=Req = 2 , ?Req = 0
16	Energy consumption	50	2	0	2	0	0	<1,2kW = 2, =1,2kW=0
	Certification							
17	Certificate EC	50	2	2	2	2	2	=Req = 2 , ?Req = 0
18	Guarantee	50	2	2	1	1	1	>Req=2 , =Req=1 , <Req=0
	Costprice							
20	Investment	100	0	2	2	2	2	=Req = 2 , ?Req = 0
	Total		**1900**	**2100**	**2750**	**2650**	**2650**	

Remark: “Req” corresponds to the requirement described in Table 5 for each criterion. The points are attributed depending on the requirement satisfaction and importance.

5 Drain handling

5.1 Drain necessity and sludge concentration

The solid loop encloses the drain from the fermentation reactor. The integration of a filtration unit results indeed in a retention of the biomass and thus solids accumulation. Since the solids and particularly the lignin are only partially degraded in the reactor, the dry matter (DM) content in the reactor will increase over time. To prevent clogging of the membrane the dry matter should be regulated under a maximum of 50g/L. Therefore, a stabilisation of the dry matter content around 2.5% (25g/L) was defined as a target. This regulation is realised by draining part of the reactor content with a certain frequency. The drain can be taken out using a valve located at the bottom of the reactor. This valve is connected to the receiving system (connection to other reactor, storage box…) which is also uncoupled by a valve. Using two following valves allows to drain by gravity, and avoiding contact between medium and user. The drain material should be further degraded within a dedicated compartment: the Fibre Degradation Compartment (FDC), and when possible sent back to the reactor. Different technologies can be used to handle the drain, depending on the requirements of the selected additional treatment regarding the dry matter content. According to model predictions presented in TN71.1, in the worst efficiency case for the FDC, around 1L/d should be drained from the pilot reactor. Depending on the FDC requirements, frequency and volumes of drain will be modulated. The sizing for the selected concentrating technology will thus depend on the selected method for fibre degradation.

Concentrating technologies have been developed for the treatment of sludge produced in industry such as the food industry. Three different processes can be considered depending on the solid matter content of the sludge (thickening, dehydration, drying, see Figure 7). The water present in the sludge can be classified in different categories depending on its availability. Indeed, the water can be complexed inside the sludge and bonded with colloids and aggregates, which make more difficult to separate it from the solid matter. Moreover, industries often resort to the addition of polymers or lime which improve the dewatering capability of the sludge. However, since the drain from the pilot reactor will possibly be treated in a biological process and then sent back to the reactor, the addition of chemicals is not conceivable. The selection of a concentration technology is also limited by the small scale of the application: most of the existing separators and concentrating systems are indeed sized for industrial capacities. For instance, the mechanical dewatering using filter press and thermal drying can be excluded since these systems are not conceived for treating volumes of a few litres.

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The selection is thus made with regards to the final desired concentration, but also depends on several other factors:

- safety: contacts between user and sludge must be reduced,

- automation: operation and cleaning of the system should be as automated as possible,

- energy, bulk and price reduction.

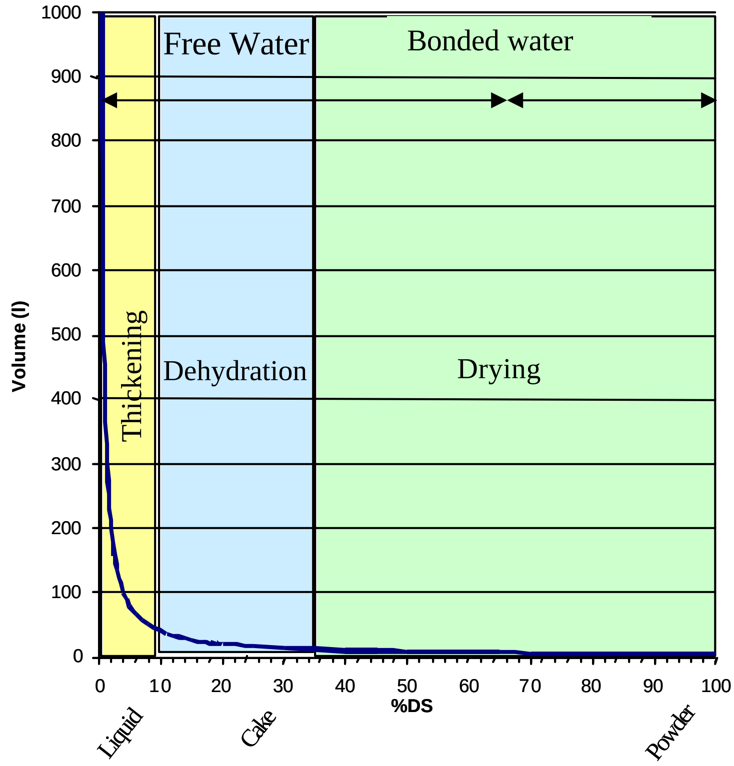

Figure 7. Steps for water removal

5.2 EWC effluent properties

- **Capillary suction time (CST)**

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The selection of a concentration method is based on the final desired concentration but also on the capability of a sludge to release its water molecules. The Capillary Suction Time CST can be evaluated for one sludge and gives indications on the degree of freedom of the water.

The CST measurement requires two separate components: an acrylic filtration unit with electrodes and a timer. The method is rapid and easy to use. A sample of the aqueous system to be tested is placed in the sample cylinder and the suction pressure of the filter paper beneath the sample draws out the filtrate. The filtrate progresses radially in an essentially elliptical pattern with the timer starting when the liquid reaches the first pair of electrodes. When the liquid reaches the third electrode, the timing ceases, the finish lamp comes on, and an audible signal is sounded. The CST reading is indicated to tenths of a second on a counter.

CST analysis were realised on both influent and reactor content of the EWC prototype reactor. The experiment consists in measuring the diffusion rate of a liquid through absorbent paper. The following results were obtained:

- $CST_{Influent}$ = 74s
- $CST_{Reactor\ Content}$ = 78s

Values of CST for classical industrial sludge are generally included between 10s and several hundred of seconds. Thus by comparison, the EWC effluent can be considered as a medicore sludge regarding the water degree of freedom. As mentioned above, this property can be improved by addition of chemicals, but this option eliminates the possibility to recirculate the drain in the Compartment I after treatment.

- **Decantation**

The decantation under gravitair force gives indications in the selection of a concentration method. A test was performed with 1L of effluent put in a settling column. After 2 hours of decantation, two phases were visible:

the concentrate represented 600mL, and the supernatant 400mL. Thus the effluent can be concentrated approximately 1.7 times by gravitair settling (meaning to around 4%). Depending on the desired concentration factor, a decantation method can therefore be selected.

- **Centrifugation**

Centrifugation is a separation process which uses the action of centrifugal force to promote accelerated settling of particles in a solid-liquid mixture. The centrifugation of the EWC effluent, obtained after the biodegradation of human faecal material and plant material, was tested and it could be concluded that a centrifugation at 3000 rpm (1000g) resulted in a centrifugate concentrated 4 times (meaning around 10% of dry matter for the nominal dry matter content of the effluent).

5.3 Possible technologies for drain concentration

- **Concentration up to 5% DM**

  - Use of filtration unit in batch mode

A filtration unit such as the one used with the pilot reactor can be used to further concentrate the dry matter content. The principle of ultra-filtration is the same as for the pilot reactor. Based on laboratory tests performed with this unit, the Melissa cake can be concentrated up to a maximum of 5%. The content of the digester is pumped over the membrane module in cross-flow mode. The cross-flow velocity causes turbulences at the feed side of the membrane so that concentration polarization phenomena and fouling can be controlled. Part of the effluent can be introduced in the filtration unit and continuously concentrated during one day. When the maximum concentration is reached, the filtrate is sent back to the reactor and the sludge is removed for further treatment. The sizing of the unit is influenced by the drain volumes and frequency. The EWC sludge can theoretically be filtered with a flow through speed of around 6L.m^{-2}.h^{-1} (Stephenson *et al,* 2000). The use of a membrane with a 8mm diameter is recommended since the sludge contains particles up to 4mm. Thus for the production of 0.5L/d of filtrate (nominal value), a membrane length of 20cm is sufficient. Therefore, a small capacity is required for an additional filtration unit. A buffer tank of 2L can be used (see Figure 8).

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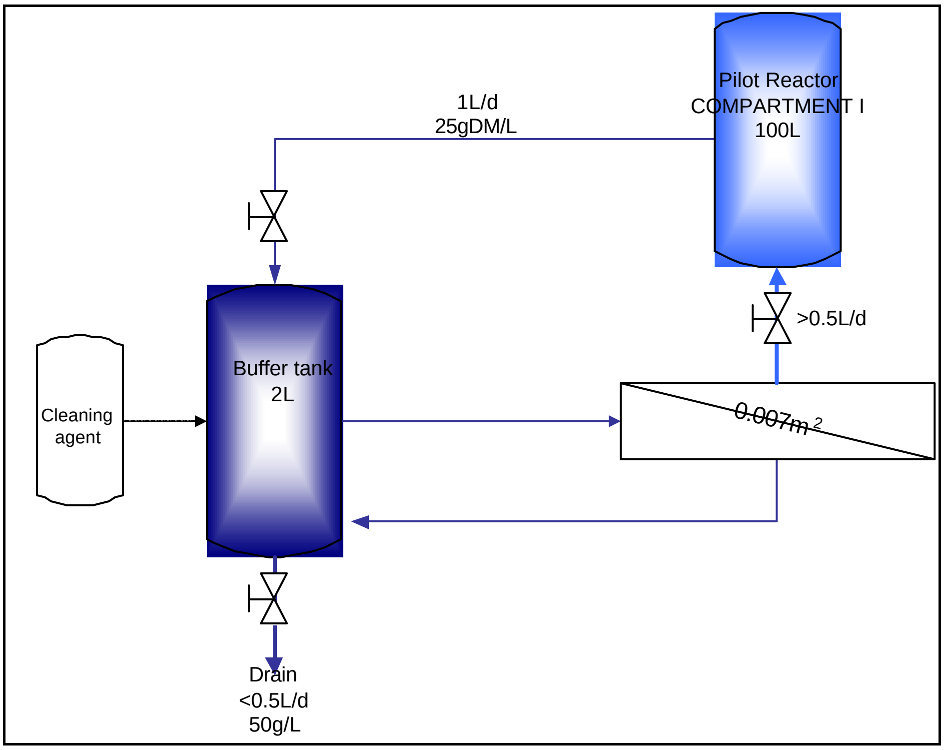

Figure 8. Filtration Unit for drain

- Decantation of reactor content in settling tank

The following concept can be proposed for this technology (see Figure 9). The reactor content is continuously and slowly flowing to a clarifier by gravity when the level of liquid passes the clarifier tube opening. In the clarifier, the solids settle down and the higher phase is slowly and continuously pumped back to the reactor. The use of a clarifier allows to concentrate the liquid around 1.7 times according to experiments carried out at EPAS. Therefore the volume of drain can be reduced. The drain can then be safely handled by connecting the clarifier to a storage tank or to the FDC; the two systems are followed by a valve isolating the connection itself, avoiding contact between drain and user. In case of simple storage, a drain of 6L every 10 days can be possible. In that case a volume of 15L could be proposed for a clarifier.

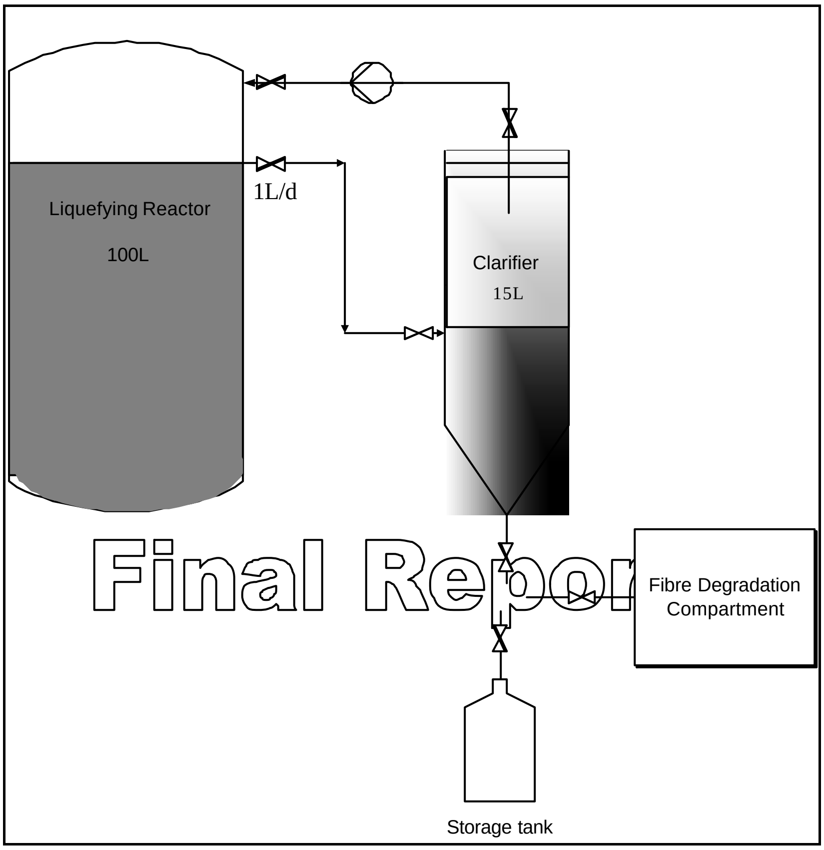

Figure 9. Concept of decantation in settling tank

- **<u>Concentration up to 10% DM</u>**

  - Centrifugation

Centrifuging is suitable for the removal of particles down to 0.5 µm or even lower. Centrifuges can be operated batch wise or continuously (they usually operate with continuous feed flow and batch discharge of solids). The latter can be manual or automatic. Also for continuous centrifuges many commercial types exist.

Most of the centrifuges are adapted to industrial scale. However, some systems for pilot scale are developed for concentrating small volumes of sludge. The separator presented in Figure 10 allows to treat sludge containing bacteria, cell debris, yeast, enzymes, with a flow up to 100L/h. Because of its small capacity, the size of this centrifuge is reduced (500mm x 281mm x 564mm, 40-60kg). It is equipped with a selfcleaning bowl for the clarification of fermentation broth. Besides the centrifuge is equipped with a soft-stream inlet system for the product. This type of inlet reduces the shearing forces occurring when the product enters the bowl. The broth enters the rotating bowl (4) through the product feed (1) and is separated in disc stack (5). The clarified supernatant (light phase) is discharged under pressure by means of the centripetal pump (3). The separated solids are collected in the solids holding space (6) and will be discharged periodically.

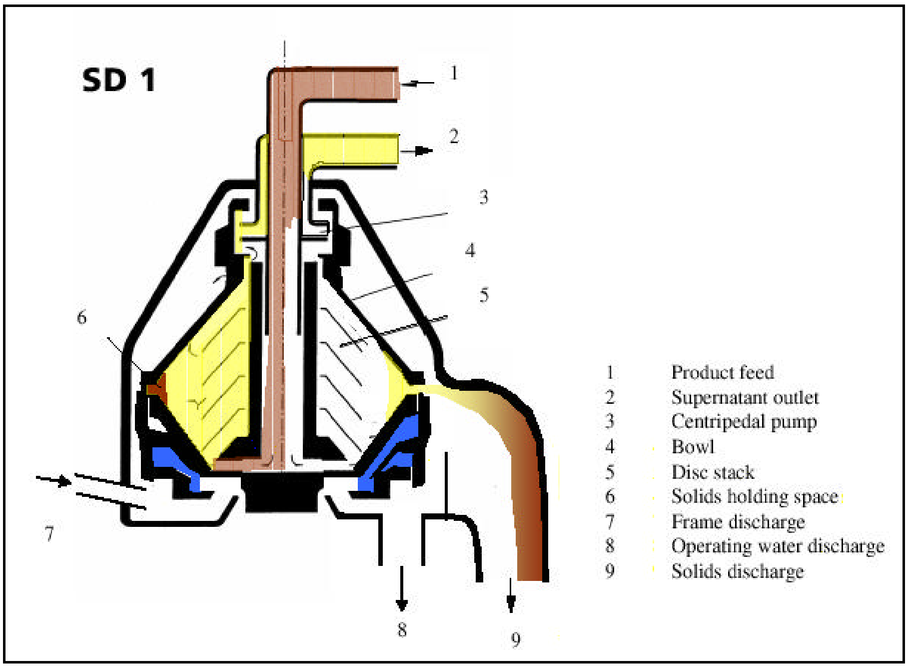

Figure 10. Centrifuge for pilot scale applications

The outlets for supernatant and solids can easily be connected to the solid loop to the corresponding elements of the solid loop. Figure 11 presents the general concept for using of a centrifuge. Given the capacity of the centrifuge, a harvesting of the drain for 10 days can be considered. Thus, 10L can be treated in batch with the centrifuge, fed in by gravity. In this case, a buffer tank of around 15L is required. The product feed can be connected to the inlet on the centrifuge, the supernatant outlet back to the reactor and the solids discharge outlet to a storage tank for instance, depending on the FDC requirements. The automatic cleaning being possible, this method allows a concentration avoiding any contact between user and sludge.

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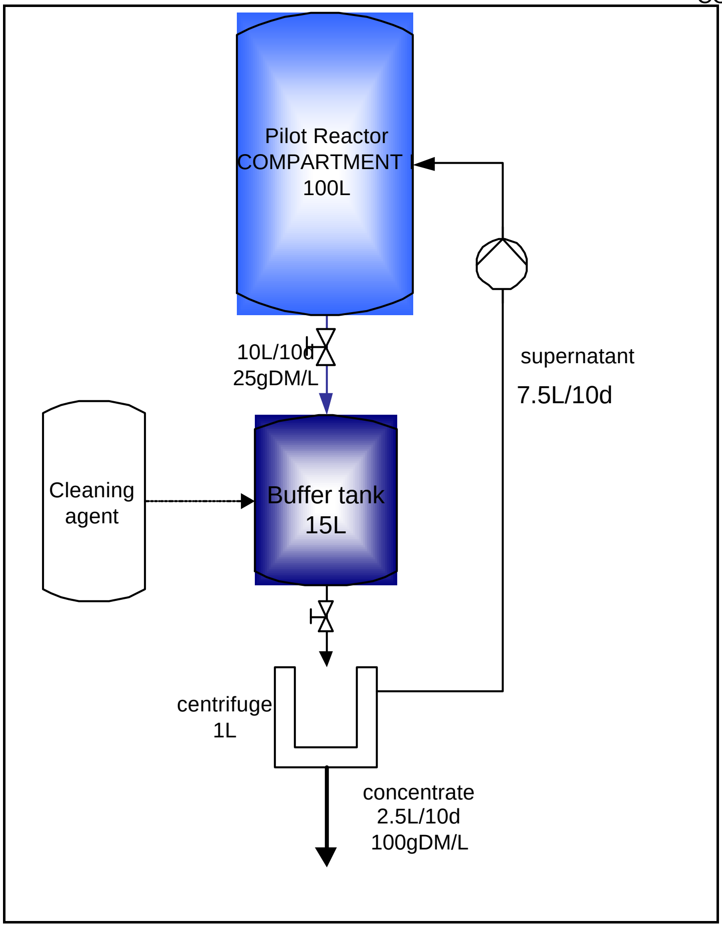

Figure 11. General concept for centrifuge method

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- **Comparison of the possible technologies**

Concentration capacity	Method	Advantages	Disadvantages
Up to 4% (DM)	Decantation	-low energy and machines cost -absence of contact between user and sludge -simple control of the system	-bulky -limited concentration capacity
Up to 5% (DM)	Ultra -Filtration	-possibility of high automation	-limited concentration capacity -maintenance non automated required (replacing membranes) -loss of solids in discharging step
Up to 10% (DM)	Centrifugation	-absence of contact between user and sludge -easiness of cleaning and maintenance	-loss of solids in discharging step (solids can stick on centrifuge walls)

6 Final design of the solid loop

6.1 Detailed concept

The general concept for waste collection, preparation and processing is presented in Figure 12.

Based on the above-mentioned information, and to be able to process the waste in a safe way for the user, it was decided to grind the substrate by introducing the material (faecal material, toilet paper, beet and salad) in a closed and automated loop where the no-mix toilet grinder as well as the industrial kitchen disposer are integrated (mixing loop). The grinding pump allows to maintain the recirculation flow through the mixing loop and also a rough grinding of fresh material. The fine grinding and homogenization of the total substrate is performed by the industrial kitchen disposer. By continuous recirculation of the substrate in this mixing loop, the particles size is aimed to be reduced smaller than 4 mm. The wheat cannot be processed efficiently directly through this loop, since its dry state and its fibrous and hard structure require different grinding techniques to be reduced. Therefore it is individually grinded by means of a cutting mill and afterwards introduced in the mixing loop. The material is diluted until the desired concentration and stored in a collection vessel to be fed to the pilot reactor. The complete processing of the waste is automated. Only the weighting of vegetables and the collection and introduction of wastes are done manually. Therefore the contact between user and possibly unsafe material (meaning faecal material) is minimized.

To prevent particles bigger than 4 mm to enter the filtration unit and thus to clog the membrane, two systems are introduced in the solid loop. A filter with tangential flow is inserted between the waste pre-treatment loop and the collection vessel, in order to select particles size. Big particles are recycled in the mixing loop for additional grinding. Moreover, a small in-line grinder is adapted before the membrane module, in order to grind the particles that could have passed the previous filter. These two safety systems are necessary to ensure optimal running of the whole system and to avoid clogging of the membrane but also of connections and valves.

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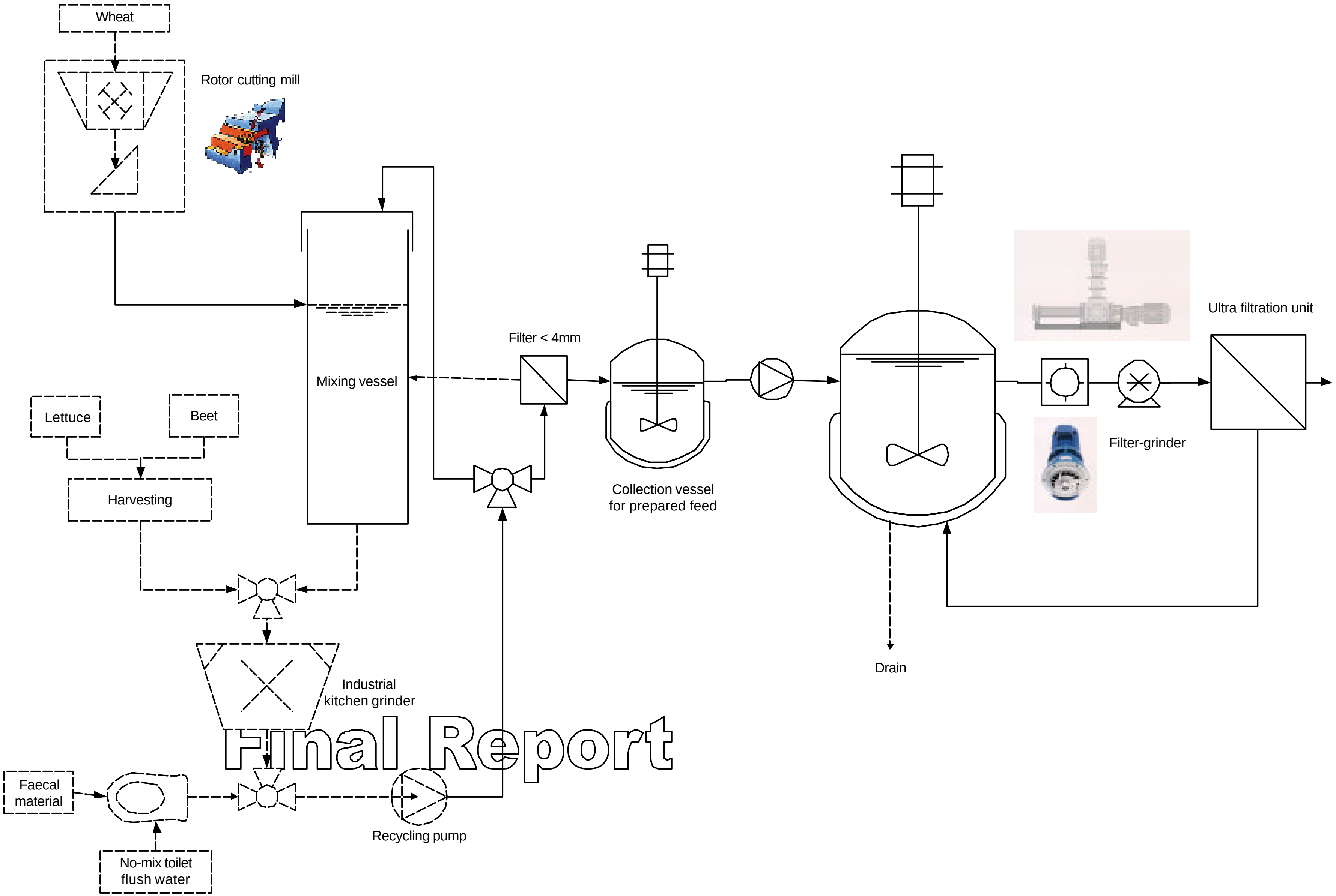

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Figure 12: Concept of collection and pre-treatment of wastes for pilot reactor

6.2 Feeding of the pilot reactor

Given that:

- Fresh faecal material contains around 33% of dry matter
- Fresh lettuce contains around 5% of dry matter
- Fresh beet contains around 8% of dry matter

The feed for the pilot reactor of 100L can be prepared as presented in Table 9.

Table 9. Feed preparation for the pilot reactor

	1 day		**1 week**		**Expected Dry Matter concentration (g/L)**
	Fresh	Dry	Fresh	Dry	
Mass FM (g)	90 g nominal (80-100g)	30g	630g nominal (560-700g)	210g	
Mass toilet paper (g)	-	18g	-	126g	
Mass Wheat (g)	-	54g	-	380g	
Mass Lettuce (g)	1080g nominal (1050-1100g)	54g	7560g nominal (7350-7700g)	380g	21g/L nominal (+/-2g/L)
Mass Beet (g)	680g nominal (650-700g)	54g	4760g nominal (4550-4900g)	380g	
Total Volume after dilution with tap water (L)	10		70		

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6.3 Running and review of instrumentation and sensors

A concept for operation and required instrumentation is developed below (see Figure 13 and Figure 14). Necessary sensors and transmitters are selected based on Technical Note 71.2 (Bioreactor design) when requirements are similar, in order to homogenize as much as possible the hardware of the pilot reactor and its sub-systems. Information for selection of these sensors and actuators is not repeated in this technical note.

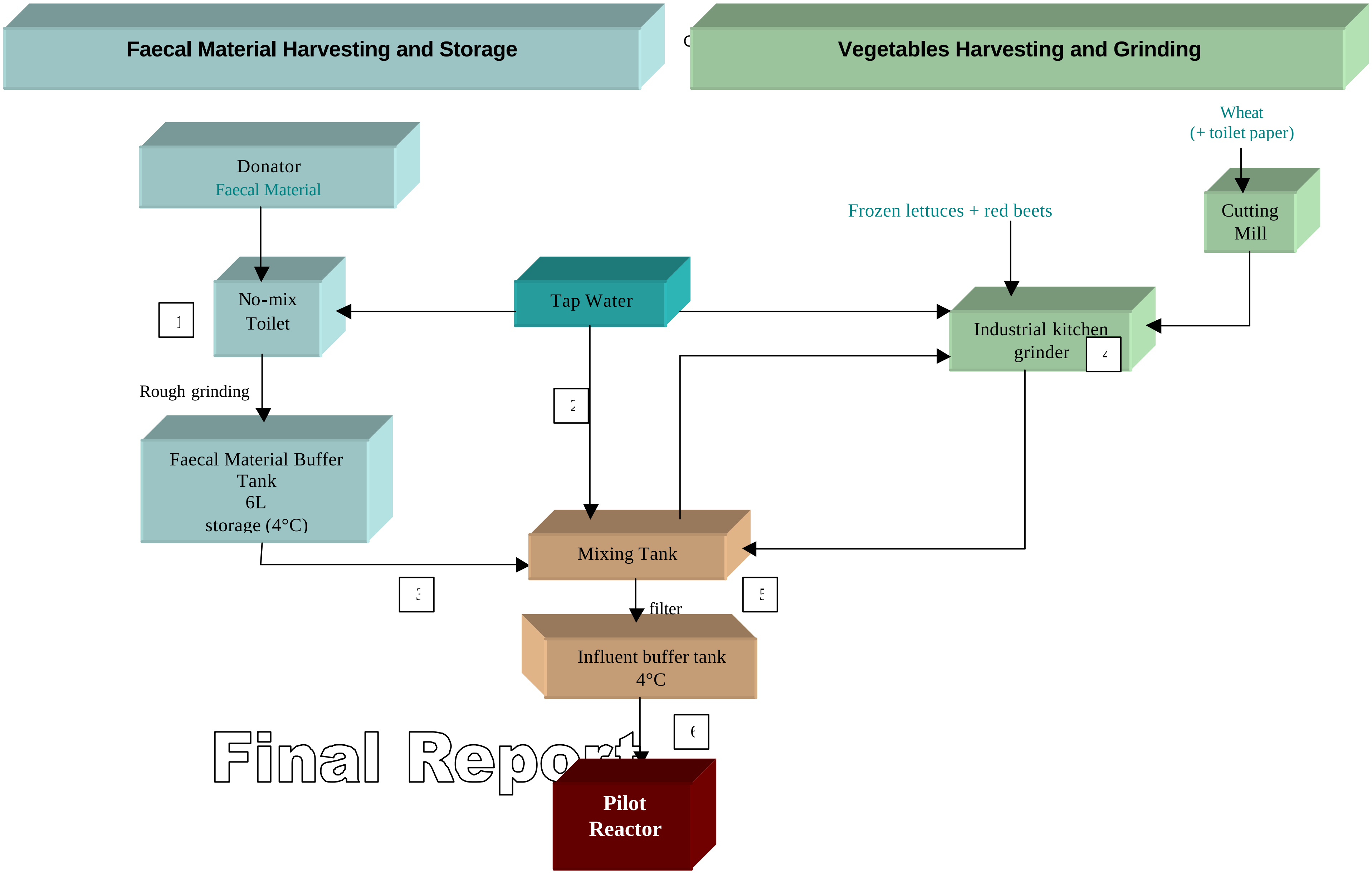

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Figure 13. Feed preparation steps

6.3.1 Faecal material harvesting and storage

6.3.1.1 Toilet grinder

Faecal material is collected directly from a dedicated no-mix toilet equipped with a grinder. This equipment allows to introduce faecal material in the loop with a limited and well-known amount of tap water (added while flushing) and to grind roughly the faecal material using the grinding pump, with regard to user's safety. When flushing, water is added and the diluted faecal material flows to a faecal material buffer tank where it is stored before use (see Figure 13.1).

6.3.1.2 Faecal material buffer tank and instrumentation

Faecal material and toilet paper can be stored in this tank up to the moment of feed preparation, which can be fixed with a time interval up to 10 d. The tank is cooled down to 4°C using a heat exchanger and completely mixed. Liquid level, weight and temperature are measured on-line. The control program calculates the mass of fresh material present in the tank using level and weight measurement.

The flush of a vacuum toilet uses smaller water volumes than classical toilets (around 250mL/flush). Thus the production of faecal material of one man per day (90gfresh/d) will be diluted in a volume of approximately 350mL/d. The highest frequency for feed preparation is fixed to 10d, in this case the maximum liquid volume inside the faecal material buffer tank is 3.5L. For safety the volume of the buffer tank can thus be fixed to 6L.

When preparation of the feeding is started, the user selects the total volume of feed that needs to be prepared (up to 10d of feeding). Then, based on the dry matter content of the faecal material buffer tank, the necessary volume to be introduced in the mixing loop where the feed is prepared is calculated. First, some tap water is introduced in the mixing tank and circulated in the mixing loop to prevent that the pump runs dry (see Figure 13.2). The valve V-S-012 is then opened, the mixing pump PMP-S-002 is started and the faecal material flows in the mixing loop until the determined level in the faecal material tank is reached. This liquid is sent to a closed mixing tank (see Figure 13.3).

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6.3.2 Vegetables harvesting and grinding

Once the faecal material has automatically been introduced in the mixing tank, the different vegetables can be harvested in the mixing loop. The wheat straw is fed manually to the selected rotor-cutting mill (see section 4). After starting of the feeding preparation and harvesting of the faecal material in the mixing tank, the valve V-S-011 is opened and the industrial kitchen grinder (see section 4) is switched on. The powder of wheat, the toilet paper and the whole frozen red beets and lettuces previously weighted are introduced manually in the funnel, together with a small volume of tap water (addition of tap water is necessary to run the disposer). They are processed a first time inside the grinder G-S-001, and then stored in the mixing tank (see Figure 13.4). There, based on the level measurement, tap water is added to reach the necessary total volume and dry matter content. It should be noticed that the volume is a fixed parameter, but the influent composition can slightly vary. Indeed the pilot reactor is aimed to treat the wastes produced by one person per day, which results in possible fluctuations. Afterwards, valve V-S-011 is closed and valve V-S-009 is opened, thus the liquid is circulated through the loop under the force of the pump PMP-S-002. Several passages through the industrial kitchen disposer allow to reduce the particles size. After a determined period the valve V-S-006 is opened on its side to the filter (FIL-S-001), letting part of the influent flowing through the filter. The perforations of 4 mm select the smaller particles and the liquid, which are sent to the influent buffer tank. Bigger particles are recycled to the mixing tank (see Figure 13.5).

Once the influent has been sent to the influent buffer tank, the different actuators of the mixing loop stop and a cleaning procedure can be operated, draining the system from the valve V-S-008.

The mixing tank must be able to contain the total influent of 10d meaning a volume of 100L, thus a volume of 120L is proposed for this tank.

6.3.3 Storage and feeding of influent

The influent buffer tank where the pre-treated influent is sent is cooled down to a temperature of 4°C using a heat exchanger. This temperature is checked by an on-line temperature sensor measurement. The tank is stirred and air tight. pH, electroconductivity and turbidity are measured on-line in order to follow the properties of the influent before its feeding. A sampling port allows to take regular samples to measure the parameters needed (such as VFA, ammonium...). The liquid volume is measured by a level sensor. 10L/d of influent are fed to the pilot reactor, using a peristaltic pump (PMP-001). The pump circulates continuously the influent. At regular time intervals, an automated valve (V-S-002) opens and the influent is released in the pilot reactor, allowing a semi-continuous feeding (see Figure 13.6).

6.3.4 Cleaning/ rinsing of feed preparation loop

For safety reasons, the feed preparation loop must be cleaned after every use. A simple rinsing with water can be foreseen. Moreover, regular cleaning with disinfectant can be applied at longer time intervals. The rinsing is automated to avoid contact between users and the feed itself. Water is supplied in the mixing tank R-S001 from the valve V-S-007. The feed loop is closed from the influent buffer tank (valves V-S-005 and 6) and from the faecal material buffer tank (valve V-S-012). The rinsing water is circulated under force of the pump PMP-S-002. Once the system is flushed, the water can be removed from the mixing tank by opening the valve V-S-008, which can be connected to a sanitary circuit or a storage tank when further treatment in required before wasting. The funnel for plants introduction can be flushed with water during the general rinsing. When the faecal material buffer tank is wanted to be rinsed, water can be introduced in from the valve V-S-014 and valve V-S-012 can be opened to allow flowing in the feed preparation loop.

6.3.5 Control aspects

The system will be entirely automated. Control will be realised in the PLC used for the first compartment.

6.4 Final design

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6.4.1 Listing of hardware

Table 10 summarizes the necessary instrumentation and hardware of the solid loop.

Table 10. Solid loop instrumentation and hardware

Reference	Description	Type	Sub-type
V-S-001	Liquid drain from pilot reactor	Valve	
V-S-002	Connection between pilot reactor and feeding pump	Valve	Automatic valve
V-S-003	Connection between feeding pump and influent buffer tank	Valve	Automatic valve
V-S-004	Sampling port	Valve	
V-S-005	Connection between influent buffer tank and filter	Valve	
V-S-006	Connection between filter and mixing tank and mixing pump	Valve	Three-way
V-S-007	Water supply for mixing tank	Valve	
V-S-008	Liquid drain from mixing tank (cleaning)	Valve	
V-S-009	Connection between mixing tank and V-S-010	Valve	
V-S-010	Connection between V-S-009, V-S-011 and industrial kitchen grinder	Valve	Three-way
V-S-011	Vegetables supply	Valve	

V-S-012	Connection between industrial kitchen grinder, mixing pump and faecal material buffer tank	Valve	Three-way
V-S-013	Connection between toilet and faecal material buffer tank	Valve	
V-S-014	Water supply for toilet	Valve	
R-S-001	Influent buffer tank	Tank	
R-S-002	Mixing tank	Tank	
R-S-003	Faecal material buffer tank	Tank	
PMP-S-001	Feeding influent to pilot reactor	Pump	Peristaltic pump
PMP-S-002	Circulating influent in the influent preparation loop	Pump	
pHS-S-001	pH sensor in influent buffer tank	Sensor	Gel filled pH electrode
pHT-S-001	pH transmitter in influent buffer tank	Transmitter	Transmitter/Controller
ECS-S-001	Conductivity sensor in influent buffer tank	Sensor	Solubridge
ECT-S-001	Conductivity transmitter in influent buffer tank	Transmitter	Transmitter
SS/ST-S-001	Suspended solids sensor in influent buffer tank	Sensor	Turbidity sensor via light transmission
TS/TT-S-001	Temperature sensor in influent buffer tank	Sensor	PT100, -50 °C up to 250 °C
TS/TT-S-002	Temperature sensor in faecal material buffer tank	Sensor	PT100, -50 °C up to 250 °C
LS/LT-S-001	Level sensor in influent buffer tank	Sensor	
LS/LT-S-002	Level sensor in mixing tank	Sensor	
LS/LT-S-003	Level sensor in faecal material buffer tank		
M-S-001	Balance weighting faecal material buffer tank and its content	Balance	
HX-S-001	Cooling influent buffer tank to 4°C	Heat exchanger	
HX-S-002	Cooling faecal material buffer tank to 4°C	Heat exchanger	
BL-S-001	Stirring influent buffer tank	Stirrer	
BL-S-002	Stirring mixing tank	Stirrer	
BL-S-003	Stirring faecal material buffer tank	Stirrer	
G-S-001	Grinding fresh material	Industrial kitchen grinder	
G-S-002	Grinding wheat straw	Cutting mill	
G-S-003	Safety grinder in-line before filtration unit	In-line grinder	
FIL-S-001	Filtration of influent (stop particles >4mm)	Filter	
WC-S-001	Toilet-grinder for faecal material harvesting	Toilet equipped with grinding device	

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6.4.2 Material selection

Hardware and materials of the solid loop are submitted to the same requirements as the bioreactor itself. Detailed information used for material selection can be found in technical note 71.2.

6.4.2.1 Vessels

The material for vessels of the solid loop must be robust, corrosion proof, heat and pressure proof, resistant to chemical sterilisation, and resistant to biofilm formation. The selected material is the same that will be used to build the pilot reactor: stainless steel AISI-316.

6.4.2.2 Tubing

Tubing material must be resistant to corrosion, biofilm formation, chemical disinfection and air and liquid tight. A combination of stainless steel tubing with PVC tubing was already selected for the bioreactor, and will be used in the solid loop construction.

The feed preparation loop must carry plant pieces and faecal material particles of different sizes before their reduction. Thus tubing diameter for this portion of the solid loop must be big enough to handle it. Diameters of 32 to 40mm can be selected, since these sizes are usually used in sanitary circuits and pilot systems, and thus are adapted for draining big particles.

6.4.2.3 Fittings and connections

Tri-weld fittings will be used to weld interface ports onto the different vessels of the solid loop, in order to connect the reactor with different subsystems. Tri-clamp fittings are used to connect different tubings together. Tri-clamp connections offer quick coupling action. They are made of stainless steel.

Sensors will be mounted onto the different buffer tanks. A housing system will serve as an enclosure for the sensors. Ingold ports will be used for connecting these housings. The housings themselves can be provided retractable for sensors that need cleaning and calibration and also not retractable.

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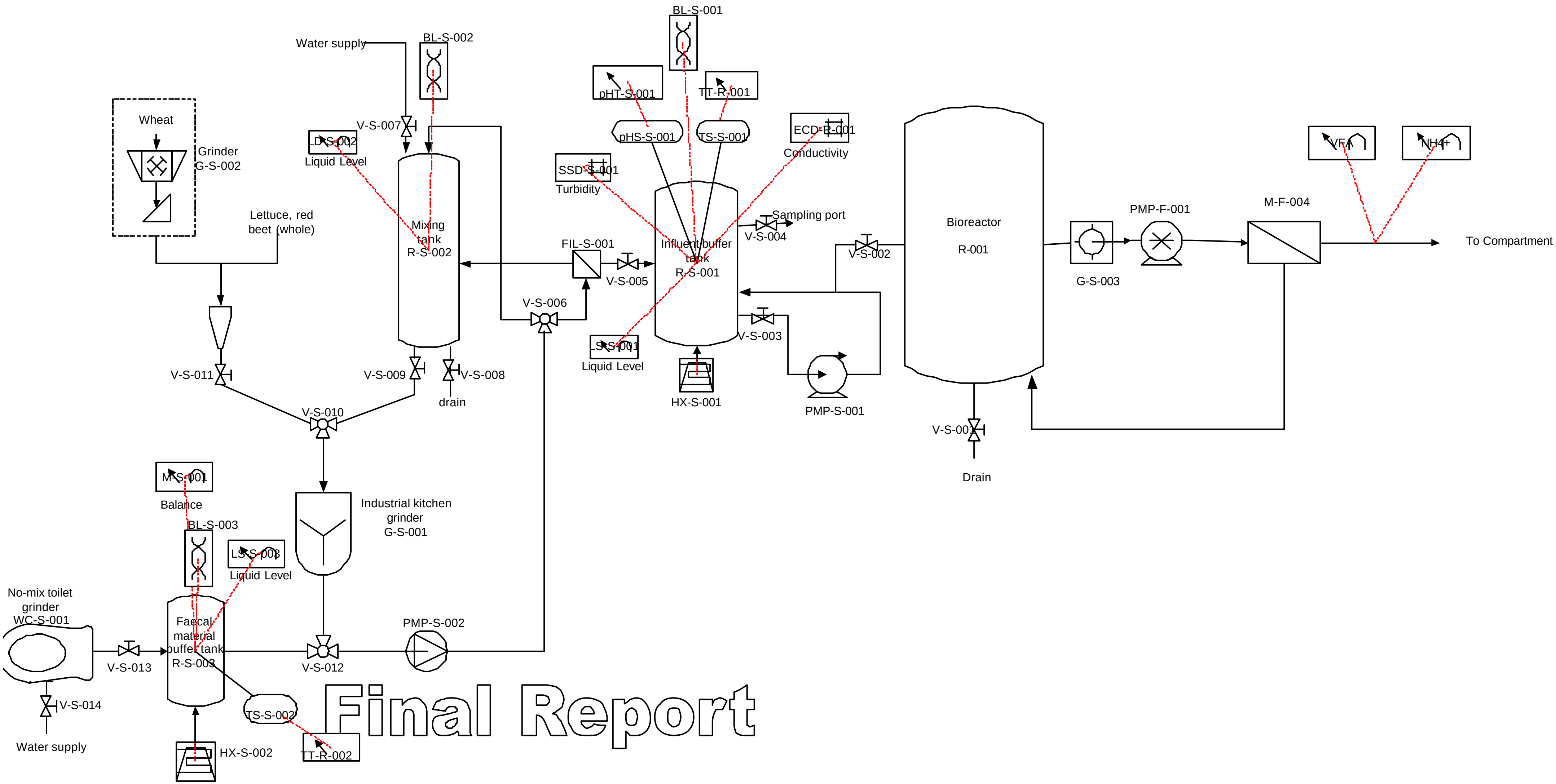
6.4.3 Solid loop design

The solid loop design is shown in Figure 14.



Final Report

Figure 14. Solid loop design

7 Conclusions

The solid loop design proposed in this note allows to prepare the influent of the pilot reactor with consideration for its requirements, in an automated and safe way.

Part of the solid loop will be constructed during the project to enable the processing of the waste, but will not be operated automatically, since this is not in the scope of the project. All waste material will be collected manually.

As mentioned above, a drain from the recycle stream will occur on the reactor. Different technologies are being studied for the processing of the drain. At present, no specific method has been selected and therefore, the detailed modalities of the drain handling and treatment will be developed once its post-treatment has been investigated and selected.

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8 References

-Minutes of meeting MELiSSA meeting 29-30/11/2001

-Minutes of meeting EWC Progress meeting 16/01/2002

-MELiSSA TN32.3: Including of a Higher Plants Chamber in the MELiSSA loop ; Description of a HPC for MELiSSA loop steady state simulations, POUGHON L., June 1997.

-MELiSSA TN71.1: Requirements, performances and sizing of the MELiSSA Waste Compartment, MICHEL N., DOULAMI F., HERMANS V., July 2003.

-OTTERPOHL R., BRAUN U., OLDENBURG M., Innovative Technologies for Decentralised Wastewater Management in Urban and Peri-Urban Areas, Keynote presentation at IWA Small2002, Istanbul, September 2002.

-Regulation European Union n° 2092/91: Règlement du Conseil du 24 juin 1991 concernant le mode de production biologique de produits agricoles et sa présentation sur les produits agricoles et les denrées alimentaires. (www.europa.eu.int)

-TILL S., MALLIA H.: Membrane Bioreactors: Wastewater treatment application to achieve high quality effluent, 64th Annual Water Industry Engineers and Operators Conference, September 2001.

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9 Addendum: Biocertificates of plant material

16/01 2003 11:36 FAX 001/001

07/01/2003 14:00 +32-3-2873751 INTEGRA PAG. 01/01

t.a.v. Veronik Heemans.

BLIK

AFDELING VAN INTEGRA BVBA
DIVISION D'INTEGRA BVBA

FAX

date: 07/01/2003
from: Bert De Caluwe
to: Mr. Jacobs
BRAVA

number of pages (this page incl.): 1

Stationstraat 164 A
B-2600 Berchem
BELGIUM
Tel +32 3 287 37 50
Fax +32 3 287 37 51
E-mail: info@blik.be

Betreft: certificaten producenten 2003

Geachte,

Naar aanleiding van uw vraag van 07/01/2003 willen wij u graag het volgende meedelen:

- Elk jaar vragen wij aan de telers om hun teeltplanning voor het komende teeltjaar door te geven. Deze gegevens worden dan in onze computerbestanden ingevoerd om van daaruit de certificaten af te drukken. Om ons de tijd geven deze gegevens in te voeren hebben wij onze certificaten een geldigheidsdatum gegeven tot 31/03/2003. Dit systeem wordt elk jaar toegepast. De Blik-certificaten voor producenten lopen dus van 1 april tot 1 april van het volgende jaar. Concreet mag u de nieuwe certificaten voor 2003 vanaf begin april verwachten.

Voor verdere vragen mag u ons gerust contacteren.

Met vriendelijke groet,

Bert De Caluwe
Certifiëringsverantwoordelijke landbouw

M.v.g.
Sofie Thielemans

Integra, afdeling Blik Erkend door het Ministerie van Landbouw in het kader van de EG-Verordening 2092/91. Geaccrediteerd door het Ministerie van Economische Zaken in het kader van de normen EN 45011 (BELCERT 048-PR) en EN 45004 (BELTEST 140-I) Certifiëringsorganisatie voor het Belgische logo Biogarantie.

Integra, division Blik Agréé par le Ministère de l'Agriculture dans le cadre du règlement 2092/91. Accrédité par le Ministère des Affaires Economiques dans le cadre des normes EN 45011 (BELCERT 048-PR) et EN 45004 (BELTEST 140-I) Organisation de certification pour le label belge Biogarantie

Blik
Afdeling van Integra Bvba
Statiestraat 164A - B-2600 Berchem
Tel. 03/287 37 50 - Fax 03/287 37 51

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Bij Boer Pol
Kestens Paul 1147/02
René Eversstraat 53
3020 Herent
België

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perceelsnr en/of -naam		opp.(ha)	product	vanaf
1	naast huis	1,1	consumptie-aardappelen	01/01/2002
2	Naast Cumps	1,2	wintertarwe	01/01/2002
3	Achter huis	0,7	zomergerst	01/01/2002
4	Over boerderij	0,2	consumptie-aardappelen	01/01/2002
5	naast de hoge beek	1,7	wintertarwe	01/01/2002

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Voor Integra, afdeling Blik

Hilde Van Duffel.
Datum van uitgifte: 24-0?/2002

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18/01 2003 11:34 FAX 002/002

FROM : ARPOIEL cvba FAX NO. : 054 583727 Jul. 23 2002 10:58AM P1

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Afdeling van Integra Bvba
Statiestraat 164A - B-2600 Berchem
Tel. 03/287 37 50 - Fax 03/287 37 51

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Residu-analyse is niet beschikbaar.

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Persijn Etienne 1451/02
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perceelsnr en/of -naam		opp.(ha)	product	vanaf
1	Voor het huis a	0,20	chinese kool andijvie	01/01/2002
1	Voor het huis b	0,21	spinazie (vers)	01/01/2002
2	Aan Pol	0,15	chinese kool spitskool koolrabi	01/01/2002
3	Molenberg	0,02	rode biet	01/01/2002
4	Aan Maurice	0,25	selderij spinazie (vers) chinese kool	01/01/2002
5	Roeselarestraat	0,25	pastinaak	01/01/2002
6	plastiek serre	0,05	pompoen	01/01/2002

Dit certificaat is geldig vanaf de datum vermeld naast het product en tot 31 maart 2003.

Voor Integra, afdeling Blik

Hilde Van Duffel.
Datum van uitgifte: 29-03-2002

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