Master Thesis

OPTIMISATION OF THE DEWATERING LINE OF THE SOIL WASHING PLANT GROUND UNIT

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Leoben, 07.06.2017

- Lisa Steinecker –

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ABSTRACT

With the aim of optimising the dewatering line of the soil washing plant Ground Unit, experimental studies were carried out in cooperation with the Chair of Mineral Processing at Montanuniversitaet Leoben. The extent of work of this master thesis was divided into three key activities: 1) Flocculation trials on different suspended soils that should indicate the efficiency of flocculants used in dewatering processes and enable plant operators to choose the most adequate flocculant in the future. 2) Soil analyses performed on-site at Ground Unit by means of regular sampling and evaluating parameters that are contributing to the dewatering performance. 3) Comparison between different soils in order to prepare recommendations and a work procedure how to analyse and process so far unknown soils to guard against standstills of the dewatering line. An additional focus appeared while the experimental work in the plant was carried out. Issues concerning processing equipment and the soil washing process were detected and were either improved throughout this thesis or described as future enhancement potentials. Moreover, slight financial savings achieved by flocculant improvements and consequential demand decrease were determined.

KURZFASSUNG

Zielsetzung dieser Arbeit war die Optimierung der Entwässerungslinie der Bodenwaschanlage Ground Unit. Zu diesem Zweck wurden umfangreiche praktische Untersuchungen in Kooperation mit dem Lehrstuhl für Aufbereitung und Veredlung der Montanuniversität Leoben vorgenommen. Die Untersuchungen gliederten sich in drei Arbeitsschwerpunkte: 1) Laborversuche mit unterschiedlichen Flockungshilfsmitteln an Trübeproben der Bodenwaschanlage, um die Effizienz von am Markt erhältlichen Produkten einander vergleichend gegenüberzustellen und dem Anlagenpersonal die Auswahl des bestgeeigneten Flockungshilfsmittels in Zukunft zu erleichtern. 2) Beprobung unterschiedlicher Bodenarten während des Anlagenbetriebs und Durchführung von Analysen zur Auffindung von, das Sedimentations- bzw. Entwässerungsverhalten beeinflussenden Prozessparametern. 3) Erarbeitung von Empfehlungen bzw. Arbeitsrezepturen für die Analyse und Aufbereitung von bislang nicht verarbeiteten Böden, um Stillstände in der Entwässerungslinie zu verhindern. Ein weiterer Arbeitsschwerpunkt wurde im Zuge der experimentellen Arbeiten erkannt. Mängel an den Aggregaten bzw. der Prozessführung konnten entweder direkt behoben werden oder wurden für zukünftig zu setzende Verbesserungsmaßnahmen näher erörtert. Der optimierte Einsatz von Flockungshilfsmitteln und eine daraus resultierende Verbrauchsverringerung ermöglichen zudem moderate finanzielle Einsparungen.

CONTENT

1. INTRODUCTION

In mineral processing, numerous operations are carried out in wet mode. The use of vast amounts of water is inevitable. Without any measures to recover process water, there would be a substantial impact on the economic and environmental issues of a plant. Often, the exploitation of water resources is already prohibited by the government. In some regions water is a scarce resource and has to be used economically. The excessive use of water and its pollution is a serious matter at present and of even more importance in the future. Especially the disposal of polluted wastewater is very difficult and the Austrian mineral processing industry faces difficulties to obtain a licence for in former times commonly used slurry ponds. Attempts to recover wastewater to the cleanest level as possible and reuse it again in the process, in order to achieve a closed water circuit, are being made.

It should be mentioned that in soil washing plants the main focus is based on a decrease of harmful substances in the soil, mainly enriched in the fines. Thus, the main goal is not put on achieving a highly qualitative final product, that has to match highest raw mineral criteria resulting from nowadays state of the art as it is the case in primary mineral processing. The importance of soil washing rises with the degree of pollution in a specific project. Thus, only the harmful fraction has to be treated according to landfill and hazardous waste regulations, which is very costly most of the time. At the best, newly gained gravel and sand products can be reused in the concrete industry or as viable back-filling material from a remediation are instead of raw materials gained from the mining industries.

With regard to the process engineering, the focus is mainly put on dewatering or the separation of solids and liquids. [1] This can be achieved by sedimentation, filtration and thermal treatment. However, due to the high costs and the aim of reusing water, wastewater recovery in soil treatment plants is preferably restricted to non-thermal procedures. In most mineral washing facilities, the common methods are a combination of the previously mentioned treatments. At first, a separation of very fine particles by means of hydrocyclones for instance, followed by a thickener and finally a filtration equipment are used. The thickener is responsible for increasing the solid content of the sludge and removing a large portion of recyclable process water. A final process water recovery and simultaneously decrease in the amount of disposable, contaminated and fine grained residue is achieved by filtration.

However, due to the very fine grain size of the sludge, gravity sedimentation takes very long or does not work at all. This results in the need of flocculants that form larger aggregates in the suspension and thus lead to a faster and hence economic settling of the solid particles in the thickening process. Due to the complexity of the commonly used polymer flocculants, these additives have to be chosen carefully for every specific material. Furthermore, the dosage may not be neglected either. Improper use of flocculants may lead to a failure of the sedimentation process and thus lead to a standstill of the processing plant. In addition, the impact of an extensive polymer consumption on the plant costs are significant as well.

1.1. ASSIGNMENT

At ARGE Ground Unit (Ground Unit), a soil washing plant is in place to process contaminated waste soil, both from projects within voestalpine Stahl Linz GmbH (voestalpine) and from contracts ordered by external companies. The general application of the processing plant is the washing of different soils. Hence, huge amounts of water combined with fine particles arise from the process. The washing water is collected in pump sumps and then transferred to two silo thickeners. When most of the clarified water is removed, the thickened slurry is pumped to the chamber filter presses, where the last dewatering step occurs. The final product, a filter cake, will be transferred either to a landfill, a flotation pilot plant on site or in most cases to a waste incineration plant. The water will be reused for further soil washing. Due to a frequent change in plant feed, the sedimentation behaviour in the thickeners is hard to control. Especially new soil washing tasks with unknown plant feed result in problems.

Due to these issues, the aim of this diploma thesis is to optimise the dewatering circuit of the plant and to evaluate a method that makes the characterisation of different soils in relation to the flocculation process possible. A feed characterisation in advance and sampling of selected product fractions during the running process should result in an estimation for the right flocculants to use, the right dosage, and lead to answers for when the thickening stops working. Furthermore, it should be possible to integrate these analyses into the daily routine of the plant and thus in the final steps a work instruction for the operating staff should be created.

Furthermore, during the work recognized problems that can harm the efficiency of the dewatering or the process in general shall be detected and a viable solution should be found.

1.2. SUMMARY

Throughout the course of this master thesis, the focus was based on optimising the dewatering line of the soil washing plant Ground Unit. Plant standstills caused in the past due to an insufficient dewatering success should be prevented in the future. Hence, it was desired to carry out an experimental setup on-site during a regular work day in order to evaluate relevant parameters that are influencing the dewatering process. Additionally, laboratory analyses were accomplished with different soils and flocculation polymers in order to evaluate a trial procedure that enables a better choice of the right flocculant.

The plant trials and analyses should focus on mineral processing relevant parameters that could give an indication about the processability of the soil. Sampling of different soils throughout this thesis indicated that – even though certain trends in the measured values could be observed – it was difficult to make a direct connection between these trends and the flocculation and sedimentation behaviour.

Furthermore, it became obvious that laboratory flocculation trials in corporation with the polymer delivering company Biomontan are essential. Fundamental trials prior to processing the soil in the plant enable to choose the most efficient polymer and give an indication whether additional reagents like coagulants are needed. Moreover, uncontrolled soil washing is prevented as this often resulted in an insufficient sedimentation in the thickeners.

Regarding the flocculants, it was evaluated that the currently used polymer Fillfloc PA 503 is most suitable for the majority of the tested soils in the trials. However, the experiments showed that for certain samples as rail ballast or the dark “Lux Tower” soil this flocculant is not operating appropriate. This emphasised that choosing the right reagent is important, especially for new projects. In addition, concerning rail ballast, a vast improvement in the quality of the water residue above the settled slurry could be achieved by adding a coagulant prior to the flocculant.

Throughout practical work in the plant a significant number of issues concerning processing equipment and the soil washing process itself could be detected. Hence, it was decided that another focus of this work should be put on optimisations carried out either still during the master thesis or in the future.

Regarding the handling of the flocculants, severe problems were observed due to a mixing of oppositely charged polymers when the soil washing process was changed. This mess and thus the destruction of the efficiency of the flocculants could be prevented by adding a second polymer tank. By these means, cationic and anionic polymers do not get in contact with each other.

Adaptions at the thickener settings in combination with a better control of the flocculant contributed to fewer issues in the sedimentation behaviour of the slurry. Two existing pump sumps were united to one in order to blend the feed of the thickeners, a flocculant flow meter was installed to obtain an exact dosage value and the concentration of the polymer in the tank was reduced to 0.1 m%. Due to these

improvements both thickeners were synchronised finer, which resulted in less fluctuations dosage of the polymer supply system and subsequently contribute to a flocculant demand reduction.

Further alterations were carried out at the twin sand trap. Attempts to improve the drainage in the buckets by adding further drainage holes resulted in a decrease of moisture content of the product Sand 0/4 mm and hence, an improvement in its quality.

These enhancements could contribute to a more stable soil washing process and reduce the consumption of flocculants that led to slight annual financial savings of € 4,275 .-.

In conclusion, the prediction of the dewatering behaviour of a soil was evaluated as difficult from the measured parameters. The percentage of fines in the feed and the pH value were regarded as most important as they are assumed to contribute highly to the flocculation of the particles. Especially the pH value should be controlled throughout everyday plant operation, as certain polymers lose their efficiency when the process water is to acidic or basic. At Ground Unit a pH of above 10, even 11 was observed numerous times. In conclusion, the neutralisation unit for the process water is assumed too small and thus leaves room for further enhancement.

Regarding other measured parameters as PAH, hydrocarbons and loss of ignition in the plant trials, even though a certain behaviour over time could be observed, this did not result in a direct estimation of the flocculation success.

In conclusion, fundamental trials in advance are assumed inevitable for an efficient and controlled dewatering result. They can prevent a stillstand due to problems in the thickeners that resulted in high financial expenses in the past and allow detecting challenges regarding the dewatering circuit in advance.

2. THEORETICAL PART

2.1. SEDIMENTATION

Sedimentation is a way of separating solid particles from a liquid. It is a wide-spread process step in mineral processing. At best, the process achieves a thickened slurry with a much higher solid content than the original feed and a clarified water with insignificant amounts of remaining particles. With regard to the practical use, sedimentation can be divided into two sections: methods driven by gravity or by centrifugal force. Depending on the feed properties, one of these two forces is chosen. The settling velocity of a particle in a fluid is described by Stokes' or Newton's law. The calculation model is chosen, depending whether laminar or turbulent flow conditions occur. According to these theories, small particles take a long time to settle by means of gravity only. Hence, the help of centrifugal force might be necessary [1]. In most mineral processing plants thickeners are the most commonly used dewatering devices, followed by filtration. However, due to the very slow settling velocity of the fines, flocculation reagents are used. The classification of flocculants and their way of functioning is elucidated in 2.2.

2.1.1. DIFFERENT SEDIMENTATION PRINCIPLES

A theoretical sedimentation process can be divided into different sedimentation zones. This phenomenon is demonstrated by using a continuously operating thickener as shown in Figure 1. The feed is introduced at the middle of the basin. Due to a higher density of the slurry in comparison to water, it will already start to move toward the sedimentation zone, demonstrated in Figure 1. The top area of the thickener is referred to as the clarified suspension zone. It should only contain few very fine particles or flocs, that are settling too slow. In this section of the model, we are assuming that the particles are settling discretely, without the influence of their surroundings. At the boundary layer of the clarified and the sedimentation zone, the solid content increases strongly. It is assumed to lie in the range of the feed's solid content. In mineral processing, the phenomenon of zone sedimentation can be hypothesized due to an expected large solid content of approximately 30 vol%. As a conclusion, all particles of this section settle with the same velocity, without the impact of the material properties. Hence, particle size, grain form or density are negligible. The only parameter, influencing the sedimentation is the solid content of the thickening sludge. Nevertheless, in a plant with volatile conditions, this parameter might be hard to control. Finally, at the lowest point of the silo, compression is taking place. As a result of forces applied by the suspension's weight above, further dewatering takes place and the water content of the thickening product is decreased even more. Concerning this model, it should be stated that transition zones could occur as well. However, with respect to this work, the efficiency of the water circuit and of finding the right flocculants are of prime importance. Thus zone-settling is assumed [2].

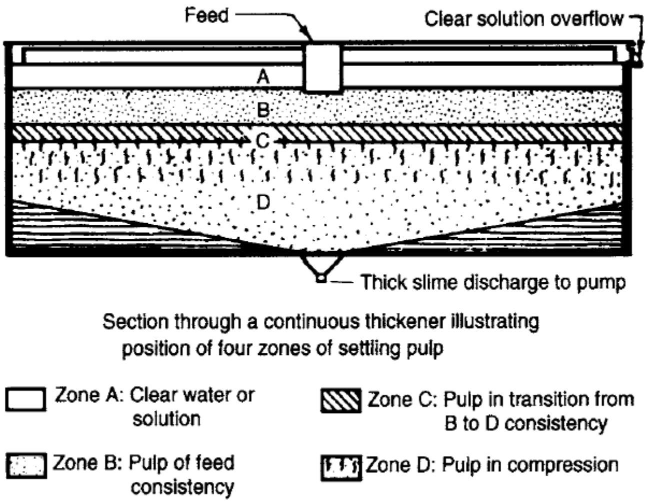

Figure 1: Simplified visualisation of a thickener model and its sedimentation behaviour [1]

Figure 2 represents a graphical relation between the intensity of flocculation and the solid content in a thickening process. According to the relation, the predicted settling behaviour can be estimated.

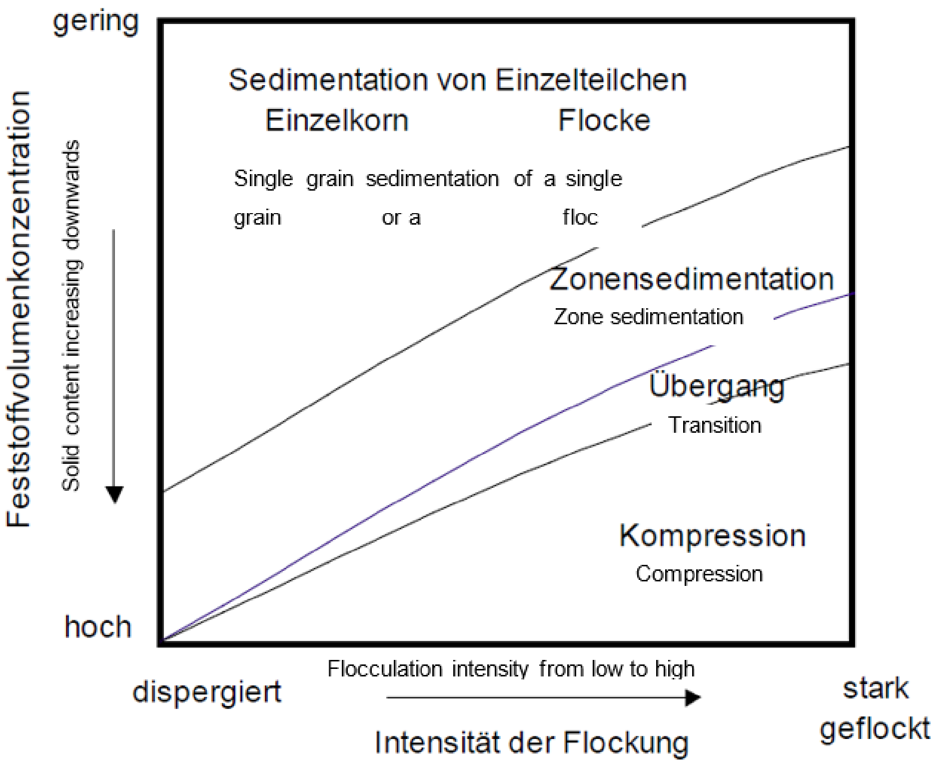

Figure 2: Relation between flocculation intensity and solid content in a slurry [3]

2.2. FLOCCULANTS

Flocculants are usually long-chained polymers. Formally produced from natural resources, these additives are now formed synthetically. [1] The main task of the additives is to support the sedimentation process by overcoming the repellent forces between equally charged small particles and thus forming aggregates that are able to settle in the suspension. If no flocculants are added, electrostatic forces overcome particle attraction through Van der Waals forces and thus lead to a repulsion. This can result in a stabilization of the solid-liquid mixture and is referred to as colloidal stabile. As a conclusion, the aggregates are not able to settle by means of gravity only. Due to this, flocculants are added in most processing plants. The synthetic polymers result in a decrease of the repulsion until particles are able to approach again and form flocs. [4] These small flocs are allowed to grow in size due to the synthetic flocculants, as they form bridges between small aggregates and increase them in size.[5] A simplified display of this phenomenon is illustrated in Figure 3.

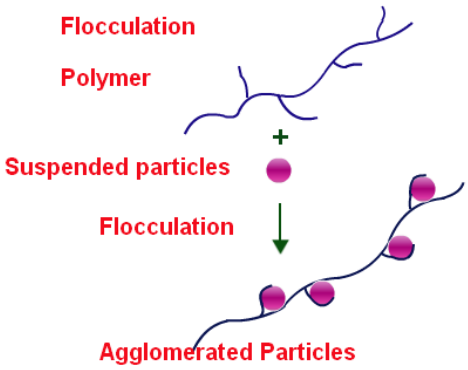

Figure 3: The bridging effect of flocculants on suspended particles [5]

However, the complexity of synthetic polymers should not be neglected. Moreover, the supply of flocculation products by numerous companies on the current market is huge, resulting in a difficult searching process for the right reagents. Thus, profound experiments and trials should be carried out with representative samples from the plant feed in order to be able to guarantee an optimum dewatering process.

2.2.1. CLASSIFICATION

Flocculants used in mineral processing plants can be classified into three main sections, according to their charge:

- Anionic flocculants:
  Most of the anionic polymers are so called homopolymers or acrylamide-copolymers with sodium- (Figure 4) or ammonium salts from acrylic acids. Negative charges in the molecule

chain can attach to the cations in the suspension. The more charges the chain contains, the more the polymer chain will stretch due to repulsion forces. This results in an increase in viscosity.

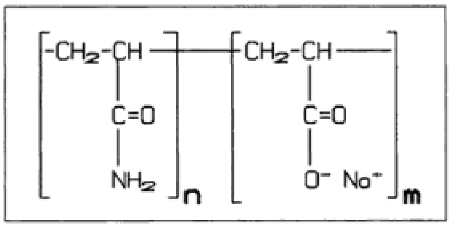

Figure 4: Copolymer from acrylamide and alkali acrylate [6]

- Cationic flocculants:
  Copolymerisation is also present in cationic flocculants, as for instance between acrylamide and monomer amines (Figure 5). In mineral processing cationic polymers are often used for destabilizing already flocced suspensions after the thickener to enhance filtration properties.

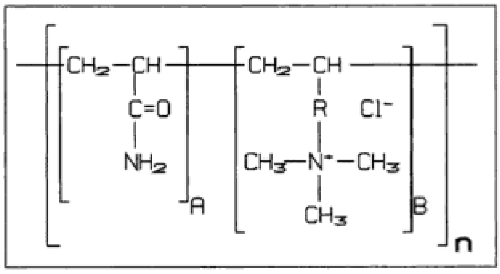

Figure 5: Copolymer from acrylamide and a cationic comonomer [6]

- Non-ionic flocculants:
  Representatives of non-ionic flocculants are polyacrylates, polyvinyl alcohols and polyethylene oxides. Furthermore, numerous derivatives of polyacrylamide (Figure 6) made by copolymerisation with electrically neutral monomers are produced.

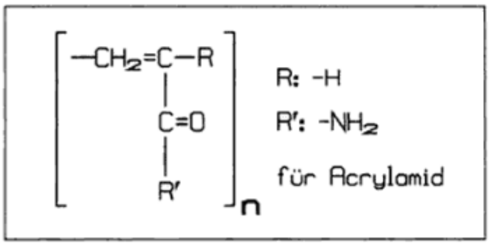

Figure 6: Polyacrylamide for copolymerisation [6]

In addition, a classification according to their molecular weight is essential.

- Low molecular weight:
  Their molecular weight can reach a value up to 100.000 g/mol.
  The viscosity is low.

- High molecular weight:
  The molecular weight can exceed 10 million g/mol.
  The molecule chain length reaches more than 15 µm. [6]
  Already highly viscous, even at low concentrations [4].

2.2.2. USE OF FLOCCULANTS IN MINERAL PROCESSING

In water treatment facilities, the particle settling process is accelerated by the use of flocculants. Depending on the conditions and the requirements for the polymer numerous products are available on the current market. Their use is mainly based on the regeneration of clean water and thus the separation of fines, which cannot be stripped from the fluid by classifying only. The more aggregates repel each other in the suspension, the slower the settling velocity of a grain becomes. Hence, the addition of proper reagents becomes more significant. Different types of slurries cannot be dewatered by gravity without flocculants at all. In addition, it is more economical to accelerate the sedimentation. Whereas in sewage water treatments a high clarity grade is fundamental, in mineral processing plants the dewatering of a slurry and thus a product as dry as possible is desirable. However, when using process water in a closed circuit, a clean overflow of the thickener should be aspired too. In addition, when comparing these two applications, the thickeners are loaded with far higher solid contents in mineral processing. It has already been stated in 2.1.1 that a high solid content in sedimentation leads to zone settling of the particles.

2.2.3. USED FLOCCULANTS AT GROUND UNIT

At Ground Unit, two flocculant categories are used at present. Mostly anionic charged polymers and in exceptions cationic polymers. In the past years, numerous polymers from different fabricators have been proved. However, the standard operation material is now dewatered with the polymer “Fillfloc PA 503” delivered from Biomontan. In the past, it has not been fully tested, whether another flocculant additive would be more effective with other soils. Concerning rail ballast, initial examinations from a former supplier evaluated the need for a cationic polymer. Currently, this is the only feed that requires this additive. However, this plant feed often leads to problems in the running process, especially in the dewatering circuit.

3. EXPERIMENTAL PART

3.1. PLANT DESCRIPTION

The soil washing plant can be split into two processing sections. A dry pre-treatment and a wet classification step. The wet processing part is followed by the dewatering aggregates. With regard to process water, further water cleaning treatments are used. Figure 7 pictures a general flowsheet of the current soil washing plant of Ground Unit. The block flow sheet, including all the machines, is attached in the appendix (Figure 56). The individual steps are described in the subsequent segments. [7]

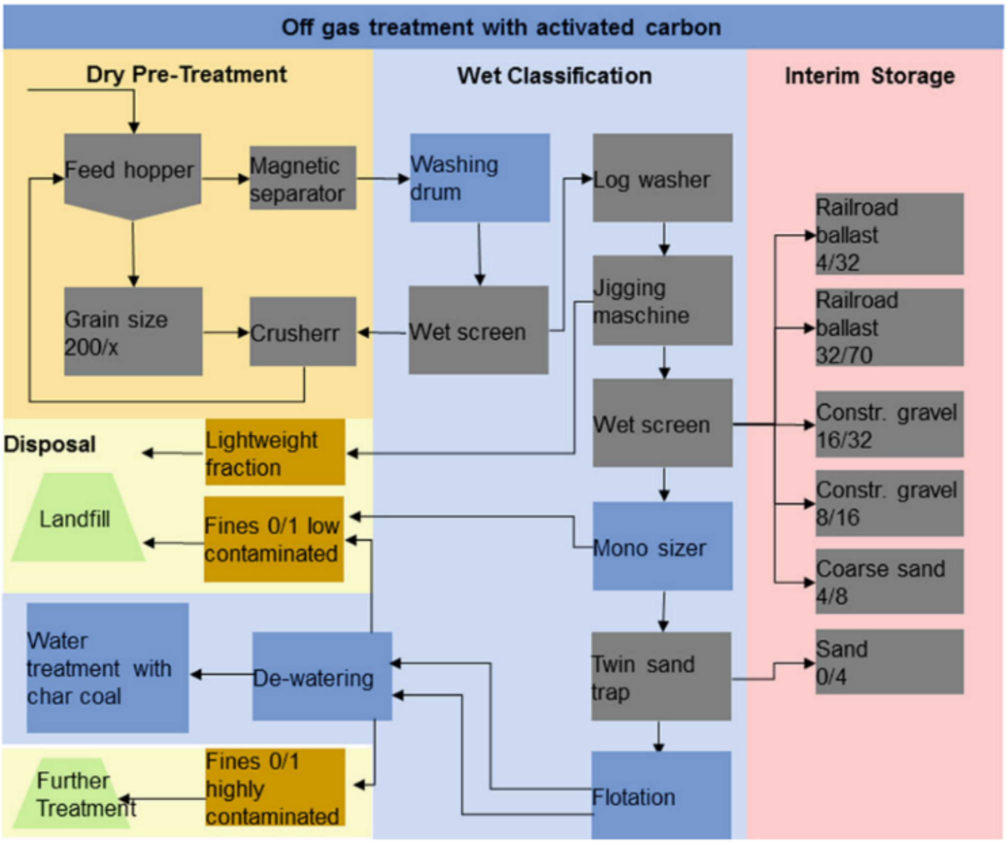

Figure 7: Block flowsheet of the soil washing plant Ground Unit [7]

3.1.1. DRY PROCESSING

At first, the process is started in dry mode, as the feed is loaded into the bunker by wheel loaders. A hopper separates the fraction > 200 mm which is crushed by a mobile crusher and added to the bunker again. An iron fraction is drawn from the feed conveyor belt by two cross belt separators using an electromagnet and a permanent magnet. The iron fraction is handled as a by-product that can be sold for scrap price. [7]

3.1.2. WET CLASSIFYING

The next processing step already requires process water to remove a light fraction by using a washing and sorting drum installed upstream to the flip flow screen. The drum also enables to treat disintegrated loamy lumps. The underflow of the drum often carries wood or light weighted organically contaminated particles. The wet mode operating flip flow screen produces a fraction 32/200 m that is comminuted in an impact crusher and later on added to the plant feed again. The fraction 4/32 mm is transferred to a log washer in order to remove contaminations attached to the grains' surfaces by mechanical impact and shear forces. The fraction < 4 mm together with the majority of the process water is forwarded to the twin sand trap with a scoop wheel. It should be mentioned that there are two discharges, one fine and one coarse sand wheel. However, currently both fractions are forwarded to the same conveyor belt and fused to the final product Sand 0/4 mm.

With the aim of improving the quality of the fraction < 4 mm an upstream sorter was installed during a plant extension in order to separate lightweight particles and contaminations. This is further described in 3.1.4. All slurry streams from the washing steps are pumped to the dewatering section, the soil sludge is thickened and process water is recovered. This is described in 3.2. [7]

3.1.3. DENSITY SEPARATION

After the log washer, the remaining gravel sized aggregates are relieved from fines. This cleaned product undergoes a two-step density separation by means of jigging machines. This enables to get rid of lightweight contaminations such as wood, bricks, plastics, foam slags or organics as for instance grass. Moreover, LD slag can be concentrated in a heavy weight fraction. The remaining enriched middle size gravel is suitable for the reuse in the concrete industry again. [7]

3.1.4. UPSTREAM SORTER

Due to the processing of more and more contaminated soils over the last years, further treatment of the fraction < 4 mm was necessary in order to control the increased amounts of organic pollutants (hydro carbons and PAH[1]). By means of an upstream sorter, lightweight impurities as for instance metamorphosed coals but also plastics and porous mineral particles and fines as silt and clay could be removed. Due to this adaption the entire PAH- concentration could be enriched to 80 m% in the lightweight fraction of the original fraction < 4 mm. This plant extension and the use of more process water resulted in the need of a second dewatering line at Ground Unit. These extensions are visualised in Figure 8. As the focus of the thesis is based on optimising the water treatment circuit, this part of the plant is treated separately in point 3.2. [7]

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[1] Polycyclic Aromatic Hydrocarbons

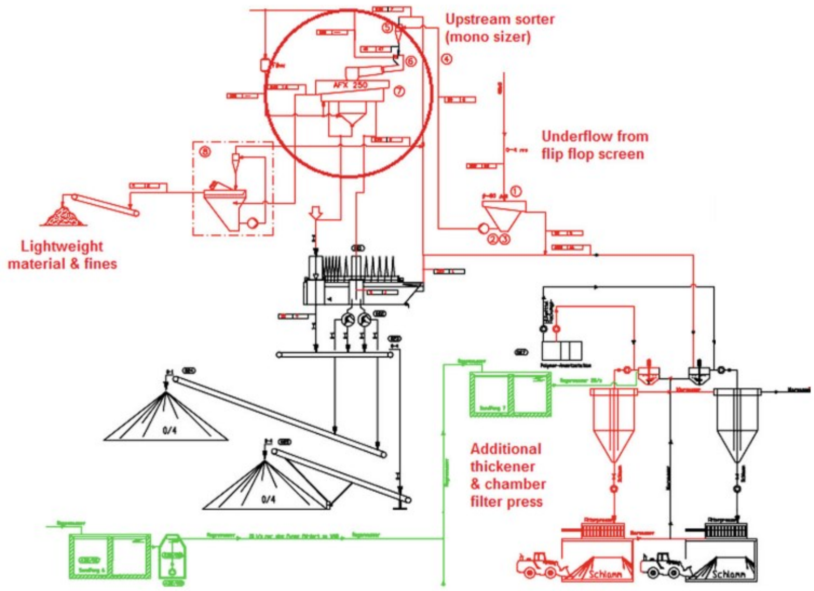

Figure 8: **Flow sheet of the upstream sorter and the dewatering unit. Everything portrayed in red has been extended at the plant, green are the sand traps on site. [7]**

3.2. WATER CIRCUIT

In this diploma thesis, the main focus is on optimising the water circuit. In general, the dewatering section consists of two identical lines, whereas one was added later due to a plant extension (see Figure 8). Thus, the new dewatering line consists of newer aggregates. Each line is made up of a pump sump for slurry collection, a silo thickener and a chamber filter press. Aggregates of the new dewatering line are referred to as “new” whereas aggregates of the old line are called “old”.

All process water streams that are used for washing and therefore loaded with soil fines are collected in two concrete pump sumps. These are separated by a concrete wall. A water exchange is possible by means of exchange holes at the sump bottom. However, it is assumed, that the exchange is incomplete. Thus, there is no sufficient homogenisation between the basins. Furthermore, the water streams to each sump are not the same as they originate from different washing sections and machines. This may lead to fluctuations as well. The old thickener is fed with water from the chamber filter presses and slurries from the washing sieves, hydrocyclones and sand traps. The new thickener is supplied with washing water from the fine sand processing section and the upstream sorter only. This makes it obvious that the sludge condition of both pump sumps is not identical. However, both thickeners are provided with the same amount of flocculants. The automatic online measuring device is taking samples, alternating between the old and the new thickener. Via an optical light barrier, the time the slurry takes to settle until a defined level is measured. The time is taken from the point the sample reaches the tube until the light can pass the sampling tube and reaches the detector. The settling times of both thickeners are middled and the result provides the basis for the flocculant dosage. Thus, ideally both thickeners should operate equal. Otherwise, an accurate dosage is not guaranteed.

From each basin, a vertical pump is delivering the silo thickener discontinuously, depending on the filling level of the pump sump. At this water processing step, most of the water is removed through sedimentation by gravity. The flocculants are added at this step, at the thickener feeding point simultaneously with the slurry from the vertical pumps. Both, these pumps and the pumps of the flocculants are regulated together. The dewatered slurry is pumped from the lower thickener level to an in front of the filtration devices installed collection tank, as they are operating discontinuously. This facilitates as a buffering of the suspension ahead of the filtration. After the filtration step, a soil cake with a desired solid content of 30 m% is ejected and removed by wheel loaders. Depending on the amount of contamination this fraction is forwarded to landfills or further treatment facilities such as incineration plants. [7]

3.2.1. WATER CLEANING

All water streams that are separated from their solid content are forwarded to a process water basin installed underground. This basin is a collection tank for the water that will be used in a closed circuit. The storage volume of this basin compromises 340 m³. The individual water demand of the machines is listed in Table 1. In total an amount of 770 m³/h of washing water is needed in the plant at the same time. For water cleaning purposes, a bypass leads to sand filters, activated carbon absorption units and a CO_2 neutralisation unit for adjusting the pH value of the water. This is significant in particular with highly contaminated soils. At Ground Unit, especially highly alkaline soils are processed due to a high amount of limestone. Only approximately 72 m³/h of the total process water amount is pumped via this cleaning unit and is later on added to the process water basin again. This cleaning line is operating 24 hours, seven days a week. This means that especially during the weekend, the plant is able to clean the process water properly. However, for high contamination during a regular operation week, the cleaning unit is not able to reduce pollution and adjust the pH value. This is argued in more detail in section 4.2. This can especially occur when washing soils from the high priority remediation site "Cookery Linz". [7]

Upstream sorter Stream 1	100	m³/h
Upstream sorter Stream 2	120	m³/h
Washing drum	100	m³/h
Log washer	100	m³/h
Washing sieve 1 (AT301)	250	m³/h
Washing sieve 2 (AT 303)	100	m³/h
Total water	**770**	**m³/h**

Table 1: Required process water amount

3.2.2. FLOCCULANT STATION

The current flocculants conditioning station consists of one overflow tank, divided into three sections. Process water and polymer powder are mixed in the first section, by a fixed dosage through a funnel. The suspension is stirred and passed through the tank via the overflow plates. This guarantees a longer conditioning time and better homogenization. The last section is directly linked with the pipes supplying the two thickeners. From this tank section, the pumps supply the sedimentation facility. Hence, at this point of the process, the flocculants should be stirred well and have the optimum concentration.

For the conditioning aggregate, parameters can be changed and adjusted:

- Amount of water via a flow controller
- Time of the polymer funnel running = amount of dry polymer added to the tank
- Time of water stream added to polymer dosage = amount of water added to the tank
- Time the stirrers are running, after the dosage has stopped

3.3. SOIL DESCRIPTION

The soil washing plant at the site of voestalpine is delivered with numerous different soil categories. A course distinction can be made by forming four groups of soils:

- Regular operation
- Material from the high priority remediation site “Cookery Linz”
- Further contaminated soil
- Rail ballast

In each soil group, further distinctions are made according to the grade of contamination evaluated according to the Austrian landfill ordinance DVO 2008. The measured values are basically inorganic and organic parameters, pH value and conductivity of the eluate. At Ground Unit, especially PAH[2] and hydrocarbons are from high significance. For most soil samples taken, these two values are the crucial contamination value, defining the landfill category.

3.3.1. REGULAR OPERATION

Soils grouped in this category are mainly excavated from construction sites from voestalpine itself. Thus, they are forwarded internally to the soil washing plant. The main aim is a recycling rate as high as possible as gravel and sand regained from the mechanical washing plant can be reused for concrete again. [7]

3.3.2. HIGH PRIORITY REMEDIATION SITE “COOKERY LINZ”

Since 2012 the contaminated soil of the high priority remediation site of the “Cookery Linz” areal is processed as well. Due to the high contamination it is a more challenging feed for the plant. The main aim of highly contaminated soils is the reduction of pollutants in the coarse fractions. This results in a decrease in the amount of filter cake that has to be forwarded to a landfill. Furthermore, if the gravel and sand fractions are washed properly, these fractions can be reused again. Based on the degree of contamination, soil fractions are used for site refill, incineration or classical sand and gravel purposes if possible. [7]

[2] Polycyclic Aromatic Hydrocarbons

3.3.3. RAIL BALLAST

A small portion of the processed soils every year consists of rail ballast from voestalpine. These aggregates are used from voestalpine for their internal transport network and they consist of LD slag. This distinguishes this ballast from normal rail gravel used for public or private transport. The main goal is to strip the gravel from contaminants and fines, produced while its usage. Recycled rail ballast is for internal use on slow speed rail tracks only, as it would not match the requirements for commercial use anymore.

3.3.4. FURTHER CONTAMINATED SOILS

Every soil, that is delivered from another company and does not fit into the above mentioned categories is listed as an exceptional plant feed and thus a new project. Usually these kind of contracts are one-time jobs. These soils can often lead to problems, as there are no experiences with them. Shortly before this master thesis was started, soil from a shooting range in Salzburg was washed and led to huge flocculation problems. The used flocculant did not work properly. Thus, there was no sufficient sedimentation in the thickeners. This led to an overdose of flocculants in the system as the dosage system was adding even more polymer. This resulted in a clogging of the filter cloth and thus the whole dewatering system failed.

3.4. FLOCCULATION TESTS

The first experimental part of this thesis is based on flocculation tests in cooperation with the flocculants deliverer Biomontan. Two main analyses were chosen. Primarily the focus was based on flocculation tests of different soils processed at Ground Unit. Hence, the correct flocculation additive should be evaluated. Furthermore, according to suggestions from Biomontan and Mütek, PCD[3] measurement was tried out. It should give an indication of the efficiency of flocculants.

3.4.1. POLYMER TRIALS

The practical flocculation tests were carried out set up according to the usual procedure of Biomontan´s laboratory. In order to guarantee convenient results, the tests were done by an employee of the company and the procedure and results were documented for reproducibility. A big focus was based on trying out different flocculants. As the range of polymers for flocculation is large, it was decided to prepare a range of eleven suspensions. Starting with a non-ionic and continuing with anionic flocculants. The anionic polymers increase by 5 mol% in their degree of ionic character. The molecular weight is kept constant for the test series. Furthermore, with regards to the preparation, the suspensions are mixed with a solid content of 0.1 m%. Dry powder polymers are used in combination with osmosis water. This type of water keeps the suspension longer stable and active. The stirring time should be 45 – 60 minutes and normal magnetic stirrers are used. However, if the flocculant is not dissolved properly the time has to be extended. Figure 9 shows the already prepared test range of polymers. As shown in this figure, every polymer is equipped with its own syringe. This prevents a mixing of different concentrations. With the small syringes, it is possible to add an amount of 0.1 ml to a soil slurry, which is approximately equivalent to one drop.

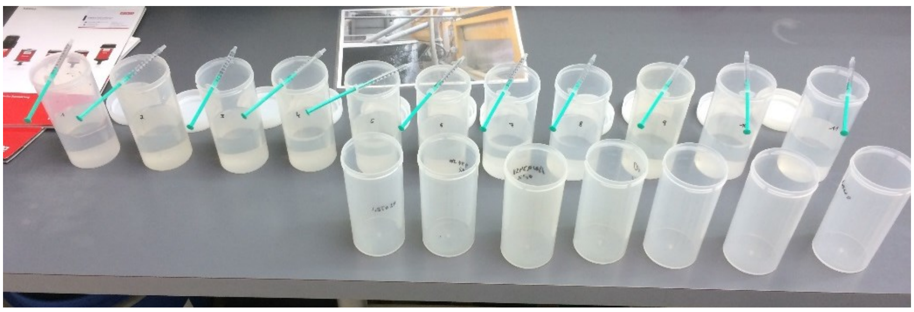

Figure 9: Test range from non-ionic to highly anionic flocculants

[3] Particle Charge Detector

The soil samples tested were already provided as slurries. Thus, the solid content could not be set precisely. For these first assessments, the soil slurries were taken as they were delivered. With regard to the solid content, it should be mentioned, that in the plant, due to an inhomogeneous feed, the solid content can vary as well and is hard to control or set to a constant value. Due to this reason, it was decided not to vary the solid content in these trials, even though it can contribute to the sedimentation behaviour positively.

First trials were carried out with a soil sample "Construction Waste Fine" from the regular operation soils. The samples were taken directly in the pump sump while the plant was running. Due to this, it was identified that flocs started to form already prior to adding the polymer. This might be a result of over-flocculation in the past, as some polymer seems to be left in the water circuit. The slurry is homogenised in the bucket at first by stirring it. Then it was poured into a plastic jug and stirred again. With the jug the sample is distributed to plastic beakers until the 300 ml mark, as illustrated in Figure 10.

Figure 10: Filling the beakers with a well homogenised slurry sample

At first the trial setup was made with special stirrers set up in line shown in Figure 11. This is the more accurate version. However, only four samples can be stirred simultaneously. Thus, no direct comparison of all samples at a time was possible. The device is operated at a speed of 140 rpm for five seconds. The flocculant was added in 0.1 ml steps until a good flocculation result was observed. The quality of the settling effect was judged by the speed of flocs forming, the clarity of the remaining water and the compression of the thickened slurry at the beaker bottom. The trials showed that a difference in the quality of the sedimentation between the flocculants can be evaluated very good by observation.

According to a long time experience of Biomontan, both the trials with the stirrers and the more fast version by shaking the samples by hand showed the same results. However, the second procedure makes a coincident comparison of several samples possible.

With regard to the already familiar soil of Construction Waste, it was evaluated that polymer number eight, which is the currently used anionic flocculant “Fillfloc PA 503” from Ground Unit, showed the most convenient results. Figure 12 illustrates the result of the sedimentation some seconds after the stirrers are stopped. Concerning the quality points mentioned above, this polymer was most successful. Additionally, the sample was stirred again after settling and the trial was repeated in order to show the stability of the flocs. Again, reagent number eight showed the most convincing results.

Figure 11: Flocculation stirrer with polymer 8-11 while stirring

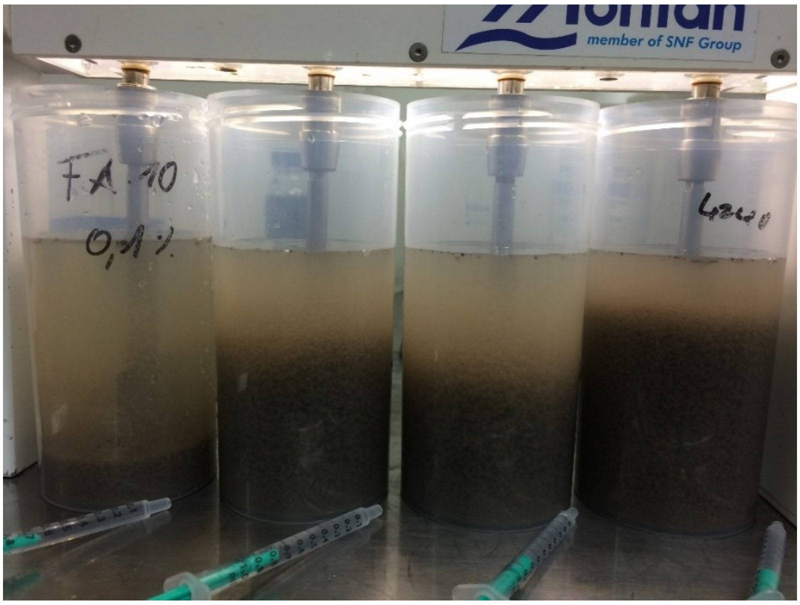

Figure 12: Flocculants 8-11, some seconds after the stirrer stopped

In Figure 13, the faster flocculation trial carried out by hand is shown. The plastic glasses were shaken with two strong movements by rotating the glasses by 180°. Then the samples were placed in line to be able to compare the settling. For a convenient experiment, all samples have to be shaken fast and in a row so that the shaking from the first until the last glass does not take too long. In this case a comparison would not be possible.

Figure 13: Shaking the glasses with two strong shaking movements

As evaluated in the stirring setup as well, Figure 14 shows the same result. Polymer number eight was achieving the best result for this sample, both in the velocity of the settling and the clarity of the water remaining above the thickened slurry.

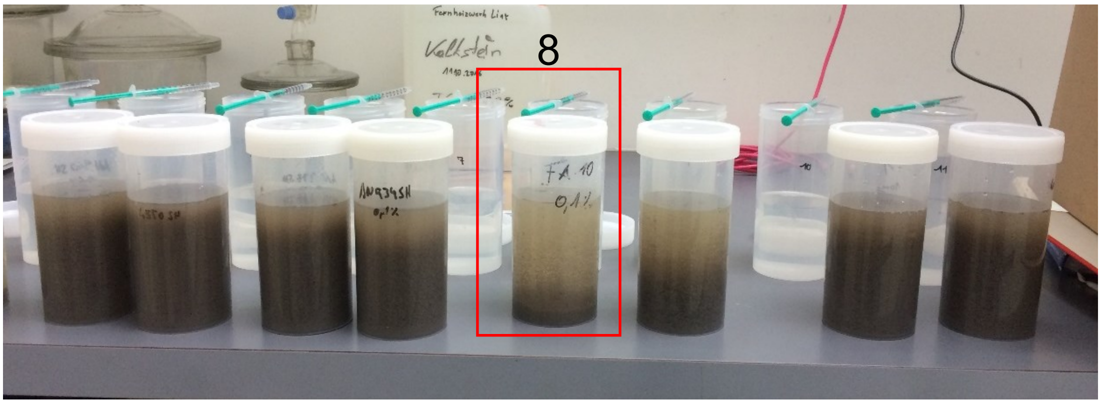

Figure 14: Anionic polymers 4-11; 8 shows the best result here as well

The second soil sample used for the trials was a sample from a future project. The so-called “Lux tower” sample was delivered in two conditions. One very dark sample and a rather light brown one. Regarding the light brown sample, it was observed that even though polymer number eight was not the fastest with the best compression, the clarity of the remaining water was more convincing. Thus, in total, it was decided that the currently used flocculant improved the sedimentation the best way. This is shown in Figure 15 below.

Even though the samples were taken from the same site, “Lux tower dark” showed a different result. Flocculant number one, the non-ionic polymer achieved the fastest and best-clarified result. However, also the on-site used polymer from Ground Unit showed quite convincing sedimentation even though the water was slightly blurred (Figure 16).

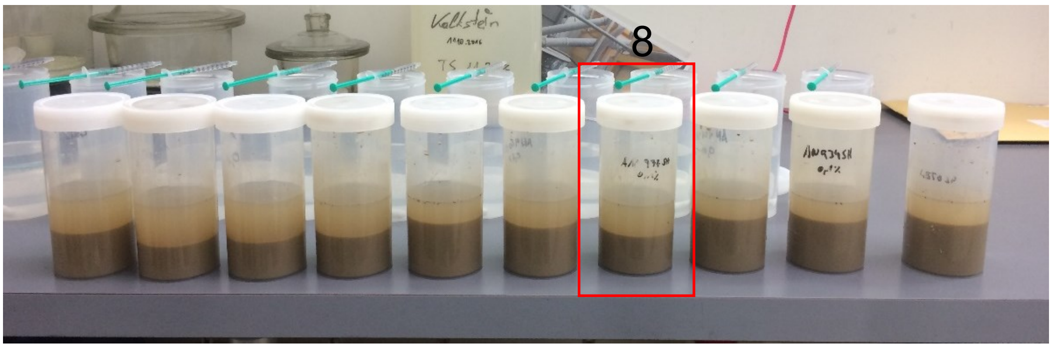

Figure 15: Sample "Lux tower light brown" Polymer 2-11

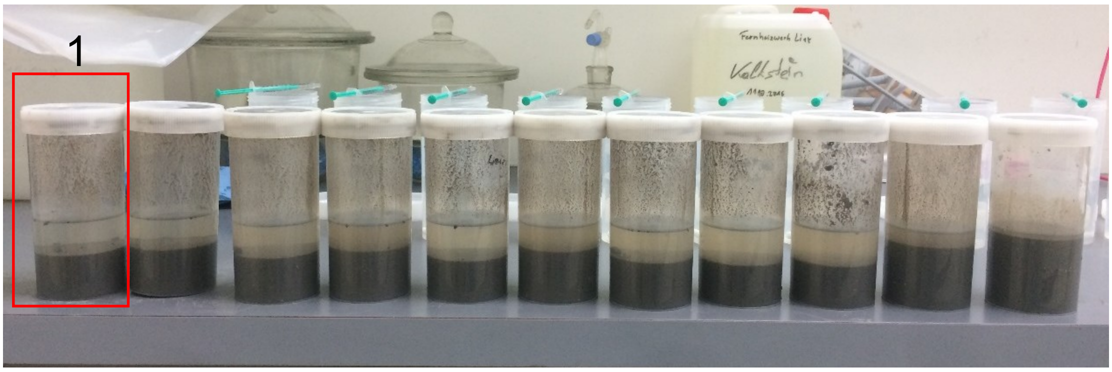

Figure 16: “Lux tower dark”, best result with polymer one

Rail ballast was the last soil that was taken into these trials, as it often leads to problems in dewatering. The thickeners stopped to operate, as the soil slurry was not settling properly anymore and the online dosage system did not stop to add polymer to the thickeners. Hence, over-flocculation occurred. As this feed is not processed very often in the plant, a sample had to be taken with a small wheel loader from the storage pile on-site. To get a representative slurry, the loader shovel was filled with process water (Figure 17) directly from the plant. The soil was mixed with the water in the shovel and via dewatering holes at the bottom, a slurry sample was taken as shown in Figure 18. The coarse fraction of the rail ballast remained in the wheel loader, however this fraction did not contribute to the sedimentation.

Figure 17: Rail ballast sample was mixed with process water

Figure 18: A slurry sample was taken from the bottom holes

Due to the fact that rail ballast is dewatered with a cationic polymer at the moment, five further flocculants with cationic charge were added to the experimental setup. However, the experiment showed unexpected results. Even though it became clear that the remaining water still was cloudy, the cationic flocculants showed the worst results. Figure 19 illustrates that polymer number three supported the thickening the best. The photograph also shows that the samples to the left of the blue marker on the picture showed no good results. Even though these are the cationic flocculants.

As the water could not be clarified successfully, a quick trial with coagulants was carried out. For dewatering applications in a plant coagulants are added prior to the flocculants. It enables very fine particles in the water to form small flocs that can be affected by flocculants and thus form larger aggregates. Thus, this can improve the water quality after the thickener and decrease the flocculant consumption as well. Coagulants are usually added in the range of ppm[4]/ton. Currently the soil washing plant of Ground Unit is not adding coagulants to the system. Hence, a special dosage system should be mounted in the plant if coagulants should be added in the future.

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[4] Parts per million

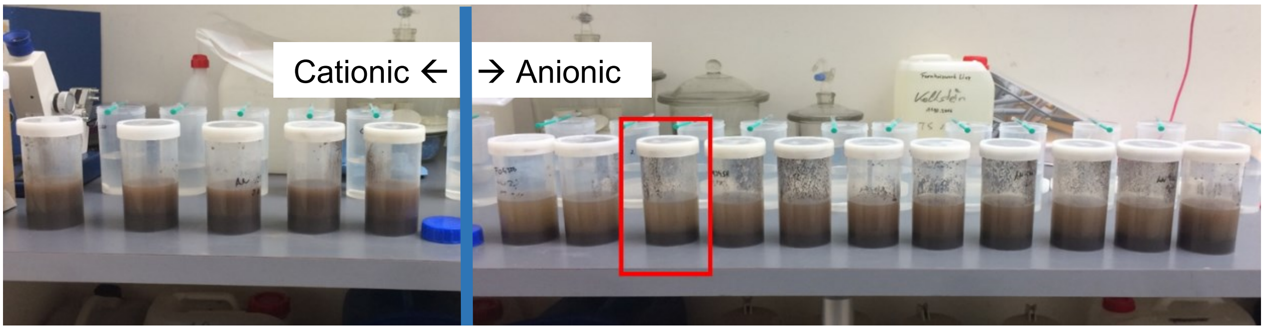

Figure 19: Rail ballast; left 1-5: cationic polymer right 1-11: non-ionic to highly anionic

3.4.2. PCD MEASUREMENT

Particle charge detector measurement was used, as the company Biomontan and Mütek, the supplier of the device, suggested it as a good option to analyse whether the flocculation was efficient. It should give an indication which flocculant is working best. Furthermore, when showing a convenient sedimentation result which reagents requires the least amount of polymer or is working the best. This should lead to a decrease in flocculant consumption. By means of titration it was tried to reach a neutral charging point of a taken sample. The amount of liquid needed for the titration is the relevant indicator.

Trials were carried out by measuring the PCD value with the neutral suspension first. In order to be able to make a comparison, the same sample was tested after the flocculation with a proper polymer. However, already at the first samples it became obvious that the measurement showed no convenient results. Even though the well working polymers were compared with flocculants that did not work well, neither the PCD value nor the amount of titer required to neutralize the sample showed a trend. No indication for good or bad floc forming was shown. Hence, PCD measurement did not show the prospected result. Further trials and examinations with the PCD measuring device of Biomontan were cancelled. It was decided that the practical polymer tests were most successful.

3.5. PLANT TRIALS

The second experimental part of the diploma thesis was build up on first realizations during the starting phase and on information gained from literature research. According to the soil washing process, three main pillars of influence were chosen: solids, flocculants and water (referring to the process water). It was assumed, that with regard to the flocculation process, these three have the largest impact on the process and hence on each other. Figure 20 should visualize this strategy. The experimental setup should show whether there is a connection of the behaviour of the three.

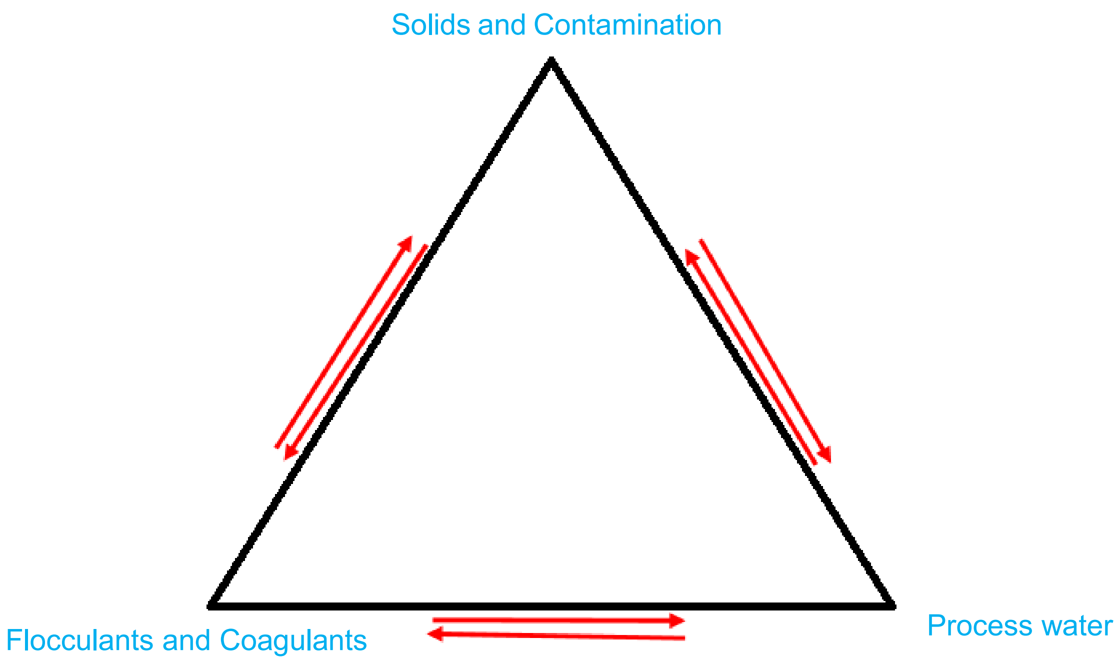

Figure 20: Interaction triangle solids - water – flocculants

It was demanded that the experimental setup should be developed with the aim to carry it out during a usual plant operation day from the company. This required sampling while the machines and conveyor belts were running. Furthermore, the sampling should be feasible for everyday situations later on. This is the reason why certain simplifications were made and accepted. In the following points the different sample categories are described.

In order to gain the behaviour of the analysis results over a time period the experimental setup was designed on taking samples every hour for a total of six times. For better representativity a higher repetition would be necessary. However, the experiments were also used to gain information on the actual production amount of the relevant solid fractions. Thus, the masses of the produced piles were taken at the end of the experimental day. This posed a logistic challenge, as the storage places had to be emptied in advance, the thickeners had to be emptied from slurry as far as it was possible and the filter presses were not allowed to contain any filter cake either. Wheel loaders and dumpers loaded the required grain fractions and weighed them at the platform scale on-site after the sampling day. Special caution had to be taken on the filter cake, as the thickeners and presses take a longer time to forward their feed. Thus, the final filter cake had to be removed and weighed the next day.

As this meant a lot of extra work and logistic steps it was decided to carry out the trials on Fridays, as this would make it easier to stop the plant earlier and the subsequent Saturday could be used to empty and weigh the final piles. Due to economic reasons, shutting down the entire plant during a regular work week is not feasible.

During the thesis time, three different soils were used for the plant trials:

- Construction Waste
- Residual Landfill
- Non Disposable Hazardous Waste

3.5.1. SOLIDS

3.5.1.1. Sample mass

In order to generate a suitable experimental setup, taking representative samples was from great significance. However, according to the wish of the contracting authorities, sampling should still be carried out in a way, that is easy to handle during a normal plant operating day. Hence, referring the sampling method and the amount taken, this should be considered. Furthermore, the samples should be taken while the washing plant was still running.

In the past, a sampling plan of the feed soil was evaluated for other research purposes with reference to the standard EN 932-1 [8]. This standard focuses on the examination procedure of mineral aggregates, especially on correct sampling. As it is a simplified sampling norm, compared to methods described in literature, this option was chosen.

The total sample amount was calculated by the formula:

$$M = 6 * \sqrt{D} * \rho_b$$

Equation 1: Amount of the total sample [8]

M…	mass of the sample	[kg]
D...	maximum grain size of sample	[mm]
ρ_b...	bulk density	[Mg/m³]

The bulk density, needed for the equation above, was evaluated by:

$$\rho_{b=\frac{m}{V_b}}$$

Equation 2: Bulk density

ρ_b…	bulk density	[g/cm³]
m…	mass filled into measuring cylinder	[g]
V_b…	bulk volume of filling	[cm³]

For the calculation, samples from the different soil products were taken and dried to a constant dry mass at 105 °C. Subsequently, a dry sample was filled into a cylinder without compression and the volume was read from the given scale. Furthermore, the mass of the sample was weighted.

The bulk density was evaluated from the products Sand 0/4 mm and Finesand. The calculated sample mass for the Sand 0/4 mm was taken over for the sub products Sand 0/4 mm fine and Sand 0/4 mm coarse. Concerning the filter cake, a proper bulk density was not possible, as the dried cake was compacted too much. In order to get a powdery sample again, the cake would have to be ground. Thus, the sampling amount was approximated with the result from the sand fractions. The results are shown in Table 2.

	ρ(bulk) [g/cm³]	ρ(bulk) [g/cm³]	M(sample) [kg]	M(sample) [g]
Sand 0/4 mm 1.0	1.63	1.66	19.86	19,860.65
Sand 0/4 mm 2.0	1.68			
Finesand 1.0	1.26	1.25	7.51	7,510.04
Finesand 2.0	1.24			
Filter cake	no bulk density possible			

Table 2: Sampled products, their bulk densities and the resulting sample masses

For the feed, examinations of Ground Unit from the past for feed sampling were used. The study of the past showed that a sample of 40 kg from the range of 0/8 mm is adequate for analyses. This value was taken for the plant trials and is not explained in detail in this thesis.

3.5.1.2. Sampled fractions

In order to guarantee an economic experimental setup, certain product fractions were chosen for sampling. Testing every single product of the process would go beyond the scope of this theses and especially for the coarse particles it is assumed that they do not have an impact on the dewatering process. On these grounds especially fine particle products were analysed. The solid samples are listed below.

- Feed
- Sand 0/4 mm
- Sand 0/4 mm coarse
- Sand 0/4 mm fine
- Finesand
- Filter cake
- Slurry pump sump
- Slurry from both thickener underflows

In Table 3 the sampled fractions of the plant trials and the machines of the plant they were sampled from are listed. This table also includes the water samples described in the next section.

Sampled Aggregate	Sample
Twin sand trap	Sand 0/4 mm coarse
	Sand 0/4 mm fine
	Sand 0/4 mm
Monosizer	Finesand
Drop off Filterpress	Filter cake
Pump sump	Slurry pump sump
Thickener	Thickener underflow
	Thickener overflow
Process water basin	Process water
Wheel loader drop off	Feed

Table 3: Sample overview of all samples including the machines they were taken from

3.5.1.3. Sampling points

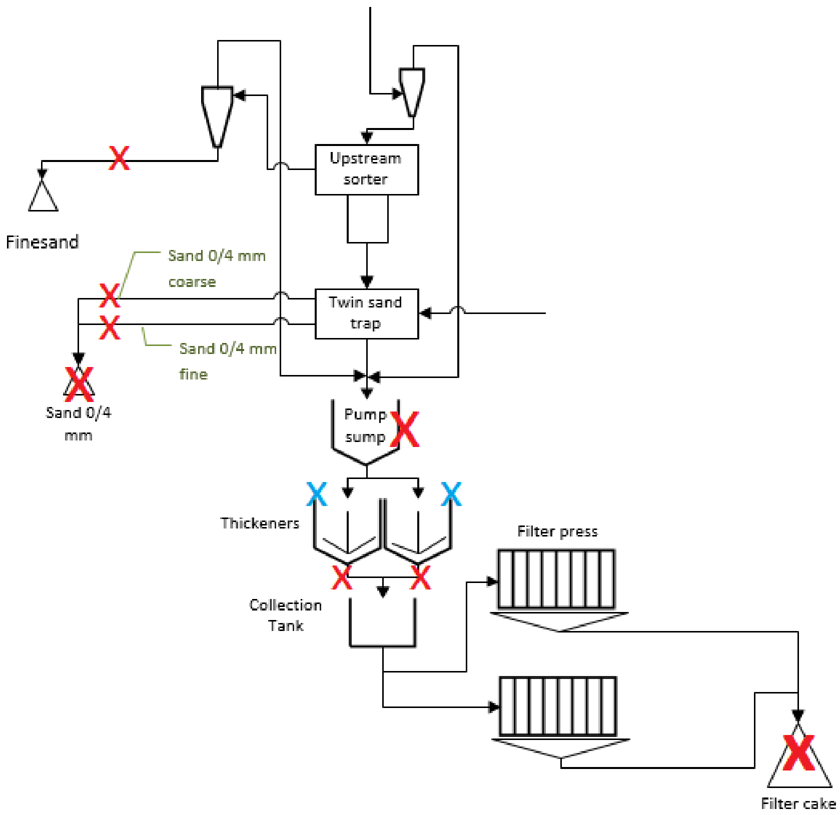

Figure 21: Modified flowsheet with separately shown sampling points

Figure 21 shows a modified version of the original flowsheet, attached in the appendix. The red crosses represent solid samples and slurries taken. The blue crosses show process water sampling points. Not marked on this figure are the feed and the process water sampling point. The feed was taken directly at the grizzly at the very beginning and the process water sampling is described below. The pump sump sample marked in this figure is signed with two crosses, one in each basin. However, the pump sump basin was modified and united to one. Hence, only one slurry sample was taken.

Respectively to the soil products above, the following chapter describes the way of sampling.

- Feed
  Relating to grain size and inhomogeneity the feed was most challenging to take a sample of. It was decided that the samples are taken directly from the pile on the grizzly, when the wheel loader dumped the feed. However, the bucket should be filled with soil from different sections of the pile. This was also the safest way for sampling.
- Sand 0/4 mm
  Due to a very high conveyor belt drop off, the sand was taken from the pile at the very top, where the freshest sand is available. Again, it was important to take the sand not just from any spot. Taking fresh samples from the very top is of importance.
- Sand 0/4 mm coarse and fine
  Both sub fractions were taken directly from the buckets of the twin sand trap. It is significant that the sample is not taken from a bucket, when the water is not drained and it is full of water. This would result in a wrong water content. Sampling from the conveyor belt is not possible as both fractions are dropped on the same belt and thus are mixed.
- Finesand
  This sample could be taken directly under the dropping onto the pile, by holding the bucket under it. This made it possible to reach the whole cross section of the sand in free fall.
- Filter cake
  When taking the filter cake it was important to take pieces from many different pile parts only at the very top and from a fresh cycle of the presses. If no new filter cake has been ejected jet, the sample should not be taken from the old filter cake on the pile from the last filtration cycle. Furthermore, for safety reasons only the front chamber filter press was sampled as it was too dangerous to go behind the first cake pile. Is had to be guaranteed that the person taking this sample could leave the dangerous area if the presses are opening for emptying the chambers.
- Slurry pump sump
  The slurry sample was directly taken from the pump sump. An empty bucket, attached to a rope was plunged into the basin and pulled out again after it was completely filled with slurry. A point of high turbulences was assumed to be the best sampling point, as a good homogenization of the slurry was assumed there.
- Thickener underflow
  Both thickeners are equipped with an outlet at the bottom. With assistance of a hose the sample could be taken directly from the valves into a bucket. The hose prevented the slurry from splashing around. (Figure 22)

Figure 22: Thickener underflow sampling points. Left: New thickener; Right: Old thickener

3.5.2. WATER SAMPLES

With regard to water, three sections of the plant were chosen for sampling.

- Process water from the water collection basin
- Water from the overflow of thickener “old”
- Water from the overflow of thickener “new”

Every sample was taken in a one-litre glass bottle. The process water could be taken at a pipe directly. Before filling the glass bottle, the stream should run for a few seconds.

For the samples from the thickeners, the bottle was placed under the edge of the overflow in order to fill it. The sampling point is shown in Figure 23. The red cross visualizes a point where the bottle is placed to collect water from the overflow. At this sampling point it was not possible to reach the whole water cross section. Furthermore, the thickener silo had to be climbed in order to reach the top. Sampling was carried out by experienced plant workers.

Figure 23: Sampling point of the thickener overflow. On the picture, only the new thickener is visible.

3.5.3. FLOCCULANT SUSPENSION

In order to evaluate the current polymer concentration in the stirring tank, samples were taken for drying analysis. At the beginning, samples were taken from the initial condition of the cationic flocculant, as this was currently used at the plant. As the tank is split up in three sections, it was decided that two samples are taken from each section of the overflow tank. With this method, a deviation of the results between the different tank sections could be evaluated as well. However, especially in the last stirring section the required mass percentage of polymer should be reached. The samples were directly poured into bowls with known masses and after taking the masses, they were placed in the drying oven at 105 °C until a constant mass value was achieved. The mass loss was considered as water, hence the grade of dry polymer could be calculated.

From the first impression, it appeared that the suspension had a very gelatinous consistency and it was assumed that the concentration of the polymer was too high. According to Biomontan, the content should lie between 0.2 and 0.1 m% of dry polymer powder. With the assistance of the system operators the water flow into the tank should be increased. However, during this attempt, it could be detected that the flowmeter of the pipe was faulty. Due to this issue, accurate concentration settings could only be started after changing this part. Further details on the new flow meter implementation are described in section 3.6.2.3.

For the concentration calculation, the dosage of the flocculants conveyor was evaluated by detecting the time and the mass of powder delivered to the tank during this time. An average throughput of 203.81 g/min was determined. The required amount of water for a given concentration could be calculated and converted to litres per hour, as this is the unit given on the flow meter. It was decided that the first changes of the concentration are made by setting the water flow as it was assumed that higher water turbulences in the polymer feed funnel lead to a better dissolving of the powder.

3.6. OBSERVATIONS AND OPTIMISATIONS

3.6.1. CURRENT PROBLEMS

During the first weeks at Ground Unit, while working at the plant and learning from the experience of the workers on site, numerous problems with impact on the dewatering section of the soil washing plant were detected. During the trial days and while taking samples, problems were detected as well, that should be optimised in the future.

3.6.1.1. Online polymer dosage

The dewatering plant from Fraccaroli & Balzan S.p.A. is equipped with an automatic dosage system combined with an online sedimentation measuring device. As relevant parameter, the settling time of the flocs of a sample is measured. This is implemented by a random sample of slurry that is redirected from the thickener to a sight glass. A sensor at the upper section of the glass is detecting whether an optical signal is able to pass through the glass. This is only possible when flocs have formed successfully and have already settled in the glass. According to the settling time of the flocs, the pumps of the polymer work at a certain percentage from 100 %. However, if the process collapses, maybe due to an overdose, the pump is using its full power to add even more polymer. This result in an even higher overdose and thus effects the process negatively. This can result in an overall still stand of the dewatering line.

3.6.1.2. Flocculants station

It was detected that - even though the plan is operated with different polymers - only one conditioning tank is used. However, especially when changing from an anionic to a cationic flocculant serious problems arise. The plant workers do not empty the tank with the current polymer but only change the powder in the feed funnel, which results in a blending of oppositely charged organic materials. It was observed that this reaction causes problems by forming slimy lumps of polymer that were not able to dissolve anymore. Moreover, these lumps started to adhere to the tank wall and the stirrer. This unwanted mixture results both, in a mess in the tank and in destruction of the flocculants. As a conclusion, the sedimentation and floc forming was hindered in the thickeners. The plant operator decided to stop the polymer dosage due to a flocculants overdose. The doubt, that these lumps will react in the future as well, as they do not leave the chamber, cannot be eliminated. However, this makes it impossible to achieve a highly active and pure sedimentation aid.

In addition, the current concentration of the polymer was not checked for a long time, thus it is highly probable that due to changes the setup of the polymer unit is not correct anymore.

Figure 24: Lumps due to polymer mixing 1

Figure 25: Lumps due to polymer mixing 2

Figure 24 and Figure 25 illustrate the problem caused by mixing two oppositely charged polymer types. The Polymer chains react and cause lumps of slime that do not dissolve anymore. They have to be removed from the tank. In the worst case, the whole tank needs to be emptied and cleaned. However, as long as lumps remain in the tank, it is assumed that they react with the newly mixed flocculant and thus have an impact on its reactivity.

3.6.1.3. Differences of the two thickeners

When analysing the plant and its flowsheet, it was figured out that the two thickeners are each supplied by their own pump sump installed outside the plant, realized by concrete basins in the ground. Even though they are connected by holes at the bottom of the separation wall, it was assumed that no significant slurry exchange can take place. Furthermore, slurry streams from different washing sections in the plant were united at each basin, as already mentioned before. This is probably due to the fact that the second thickening line was added later on, after the so called “Finesand processing section” for processing the fines was implemented in 2013. Thus, more water had to be processed and the throughput of the dewatering system was increased by this extension. As a mean dosage value from the online measuring device of both thickener samples is used for the flocculants, different pump sump conditions are expected to cause problems. Especially a difference in the solid content between the two pump sumps can lead to big fluctuations.

Another aspect causing problems was the fact that the new thickener pump is equipped with a frequency converter. Thus, the slurry feed was throttled. The old thickener feed pump on the other hand cannot be throttled electronically. This led to a deviation in the feed quantity.

3.6.1.4. Problems in the product qualities from the Sand 0/4 mm

Based on experiences at Ground Unit, a connection between bad flocculation and the quality of the Sand 0/4 mm are assumed. It can be observed that the sand is far too wet and sticky from time to time and thus leaves the conveyor belt in lumps rather than in sand particles. An unwanted amount of fines in this product is assumed too. Both, additional water and fines however result in a decrease of product quality. The plant operators assume that this is a result of inconvenient flocculation and thus a residue of polymer in the water circuit, that is attaching fine particles to the sand and makes dewatering more difficult.

3.6.2. OPTIMISATIONS

3.6.2.1. Uniting the two pump sumps

Due to the above mentioned inequalities between the slurries of the pump sumps, it was decided at the very beginning of the practical thesis part that the concrete wall, separating the basins, will be removed. By this means, a homogeneous slurry feed should be achieved and thus both thickeners will be fed with the same soil water mixture.

At the beginning of November, the separation wall was torn off and the pump sumps were thus united into one big slurry basin. Already on the first day of operation after this alteration one could see that the turbulences caused by the pumps of the rising pipes and the water inflows are distributing the water by far better in the united sump compared to the two individual basins before, only linked by holes in the wall. Figure 26 and Figure 27 are portraying the former design of the pump sumps. Figure 28 and Figure 29 on the other hand are demonstrating the realized optimisation of the thickener feed basin.

Figure 26: Right pump sump with a view on the separation wall

Figure 27: The two pump sumps with the separation in the middle

Figure 28: The united pump sump, already without concrete wall

Figure 29: Top view on the basin already without wall. The red section is illustrating the removed wall

3.6.2.2. Polymer change optimisation

A possible optimisation that was not carried out yet is the prevention of mixing the two oppositely charged polymers (anionic and cationic). This results in huge problems and should definitely be prevented. If flocculation trials result in the need of a cationic polymer, it is recommended to expand the plant by a second polymer mixing unit. The company decided that this measure should be realized by the same mixing unit as already present in the plant, as this makes handling easier. Thus, the option of a polymer unit using liquid flocculant concentrate is not wanted.

Another option would be to empty the polymer tank before refilling it with an oppositely charged powder. However, due to the mechanism of an overflow tank, this is not easy to realize.

3.6.2.3. Implementation of new flowmeters

During the preparations for the experimental part of this thesis it was observed that the flow meter of the water supply pipe for the polymer tank was faulty. The float was constantly changing its level or got stuck in some cases. It was decided that the damaged flow meter should be replaced (Figure 30). Otherwise an accurate water flow to the tank could not be guaranteed. After the installation of a new flow meter (Figure 31) the flocculant concentration was adjusted new to an adequate value of 0.2 m% dry polymer.

Furthermore, it was discussed that a flow meter (Figure 32) for the polymer dosage pipes would be beneficial. As the online measuring unit is only giving the percentage of the pumps' capacity, no absolute polymer consumption value is obtained so far. Due to this, flowmeters were installed on both pipes. The given value for litre per minute of flocculant was documented for the experimental part. On the second trials the total amount of polymer could be read from the flow meters as well. Due to this alteration, a significant observation was made. Even after switching the flow meters of the two pipes, the old pump was constantly conveying less amount than the newer version. An average dosage difference of 7 l/min was detected during the plant trials. This problem could only be visualized by the flow meters. It is assumed that the pump of the old thickener has already been worn over the years. As a conclusion, either a repair or a total exchange of the pump is recommended.

In the final phase of the master thesis, the wearing parts of both pumps were changed. This lead to an equal dosage into both thickeners. Furthermore, the performance of the pumps was increased. Hence, the online dosage system could lower the percentage value of the online system for the pump output. In addition the time parameters in the system, which stated at which point the dosage should be in- or decreased were altered. All these changes lead to a more constant thickener process and less flocculant consumption.

Figure 30: The dirty and damaged old flow meter

Figure 31: Newly implemented water flow meter

Figure 32: Flocculants dosage flow meter

3.6.2.4. Flocculants concentration

As already mentioned in section 3.6.2.3, the concentration of the polymer in the concentration tank could be adjusted precisely after the renewal of the water flow meter. By taking samples and drying them, it has been evaluated that the polymer was higher concentrated than recommended by the supplier Biomontan. A concentration not higher than 0.2 m% should be aspired. After a concentration of 0.35 m% and higher was identified, the amount of water added to the tank was increased. The increase of water was expected to cause a better mixing of the dry powder into the suspension as well. Soon it was observed that there were less polymer residues attached to the funnel wall and that the powder was transferred better to the tank.

For additional settings, the polymer dosage can be adjusted as well, by changing the running time of the screw conveyor. Via the online system, the speed of the screw cannot be arranged.

After the new settings the online dosage system did not increase the dosage. Hence, the same polymer slurry amount was added to the thickeners, only with lower concentration. This results in a more economic use of flocculants and reduces its consumption.

The polymer drying results can be found in the appendix (Table 11).

3.6.2.5. Adjusting the thickener control

With regard to the control of the dewatering circuit, most of the settings cannot be adjusted by staff of Ground Unit. Settings and adaptations must be made from Fraccaroli & Balzan S.p.A. directly. However, some parameters concerning the thickener and the polymer dosage can be set in the plant directly. For the online polymer dosage, there has to be either a value for the settling time that has to be under- or overshot in order for the pumps to reduce or increase their power. These two time values can be defined. Concerning the lower bound, 2 seconds were currently set in the control. However, due to the fact that the slurry sample is entering the measuring glass with very high turbulences that hinder the flocs from settling, it is assumed that a slightly higher value would be more adequate to prevent an overdose.

Furthermore, on behalf of the plant operators, the difference between the two thickeners and their supply pumps was evaluated. When the slurry in the pump sump reaches a certain level, the pumps start to convey the feed to the thickeners via the vertical pipes. Due to the fact that the new pump is equipped with a frequency converter and the start occurs with a certain delay, it is not running simultaneously with the old thickener pump. This one in comparison has no frequency converter in order to throttle the capacity and it starts immediately with the signal of the filling level of the slurry basin.

The aim was to reduce the breaks between the feeding intervals of the thickeners and to reduce the operating differences between the old and the new thickener as good as possible. It was assumed that a nearly constant pump activity would have a positive impact on the sedimentation. In order to achieve this goal, the pipes were throttled, the new one electronically via the frequency converter and the old one mechanically by a slider. This increased the active time of the thickener supply and thus decreased the passive time. Furthermore, the delay of the new thickener was reduced. These alterations resulted in a more constant thickener operation and less fluctuations in the process. For future refurbishments, it might be viable to replace the old pump by a new model that can be throttled via a frequency converter. This may facilitate the controlling process.

3.6.2.6. Optimising the sand trap

As a faulty operation of the sand trap was recognized during the trials, the operating stuff on site was analysing the problem after the practical part of the trials during the winter revision. It was assumed that due to fine grains the sieve mats tend to clog. It is already known that a regular cleaning of the mats can help. It was also believed that the process water was not able to leave the bucket behind the mat fast enough and hence was returned through the mat and onto the conveyor belt directly to the product. After further examinations this expectation was proven right. The staff dismantled the device as far as needed and added more drainage holes into the bucket by cutting holes. Even though this was only a provisional measure, a vast improvement in the dewatering performance could be observed when starting the plant again. Since this change, the Sand 0/4 mm is optically considerably drier than before.

4. RESULTS

4.1. PRODUCTION AMOUNT

As already mentioned in 3.5, the masses of the overall production amount and the fine fractions were evaluated. Special attention was put on the mass of the filter cake, as this is the fraction going through the thickening process. According to the sieving analysis in the next chapter the particle size distributions of the feed are equivalent. However, the percentages of the produced filter cake in the following tables showed a different result. This difference is assumed to be caused by the fact that the feed sieving was not carried out in wet mode. Hence, adhesive residue on large grains is not reported to the fine fraction.

This result makes it obvious that the amount of fines processed in the thickeners is important. In this example construction waste, operated with the highest throughput produced the least amount of filter cake whereas non disposable hazardous waste had the highest percentage of filter cake. However, the throughput was far less. Hence, caution has to be taken with the throughput of soils that contain a high amount of fines < 100 µm.

Construction Waste 136.6 t/h				
	Feed	**Sand 0/4 mm**	**Finesand**	**Filter cake**
[t]	697.16	199.66	68.90	88.00
[%]	100.00	28.64	9.88	**12.62**
[%]	100.00	51.14		

Table 4: Production amount of the experimental day of the relevant fractions from the soil Construction Waste; including the average throughput

Residual Landfill 105.2 t/h				
	Input	**Sand 0/4 mm**	**Finesand**	**Filter cake**
[t]	511.75	182.35	29.80	134.85
[%]	100.00	35.63	5.82	**26.35**
[%]	100.00	67.81		

Table 5: Production amount of the experimental day of the relevant fractions from the soil Residual Landfill; including the average throughput

Non Disposable Hazardous Waste 54.2 t/h				
	Input	Sand 0/4 mm	Finesand	Filter cake
[t]	269.70	71.65	13.85	81.25
[%]	100.00	26.57	5.14	**30.13**
[%]	100.00	61.83		

Table 6: **Production amount of the experimental day of the relevant fractions from the soil Non Disposable Hazardous Waste; including the average throughput particle size distributions**

The particle size distribution was assumed to have the largest impact on the solids according to Figure 20.

To evaluate a possible impact of a particle size distribution on the quality of the thickening process, grain size analysations were made. The sieving of the feed samples was carried out on site at Ground Unit. The sieving was only done dry, this might led to an inaccuracy in the fine particle range. However, Figure 33 shows that the distributions do not differ a lot from each other.

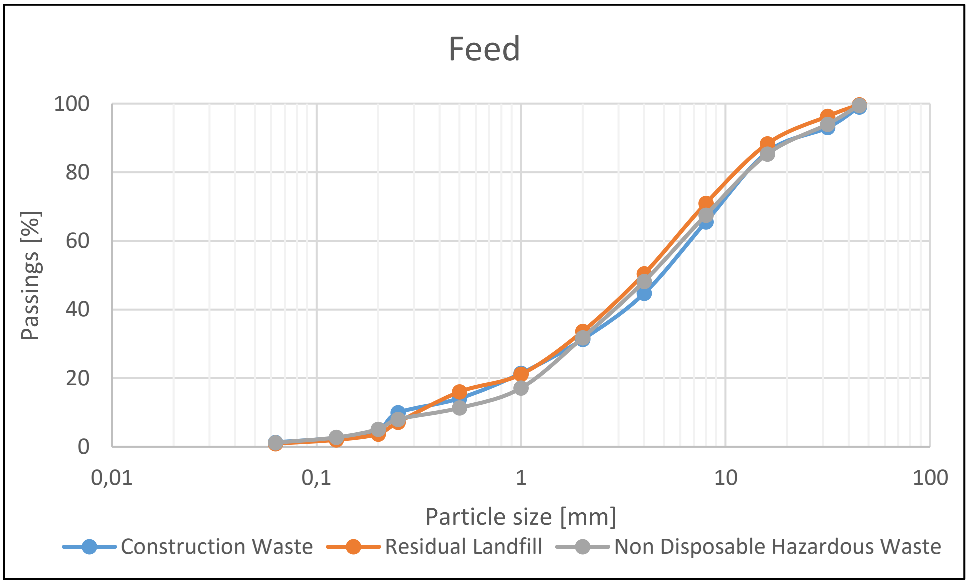

Figure 33: **Graphical illustration of the particle size distribution of the feed**

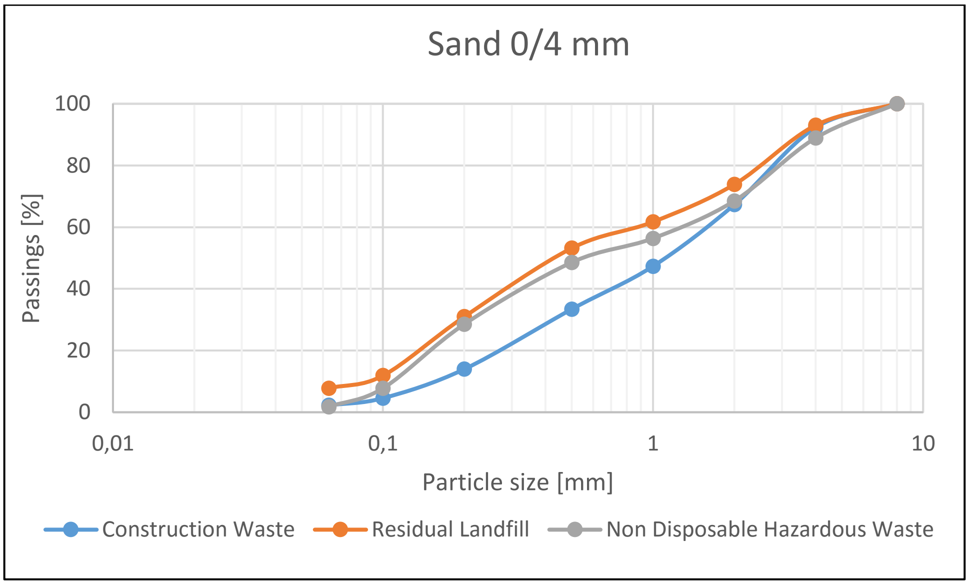

Figure 34: Graphical illustration of the particle size distribution of the product Sand 0/4 mm

Figure 34 shows the particle size distribution of the sample Sand 0/4 mm that was taken from the product pile directly after the drop off of the conveyor belt. It shows that even though they nearly overlap in the coarser size range, the construction waste line starts to drop faster starting from 2 mm. In the range below 1 mm, this sample is coarser than the others. Figure 35 shows the same behaviour. This sample was taken from the sand wheel directly from the buckets lifting the coarse fraction. In Figure 36, construction waste represents the coarsest distribution again. However, residual landfill and non-disposable hazardous waste are switched in comparison to the two previous grain size comparisons. For the analysis results of the filter cake samples, the behaviour is exactly the opposite. Here, the construction waste grain size represents the finest.

With regard to the samples of the sand trap, especially the coarse fraction - which is declared to be from 1 to 4 mm in technical documentations of Ground Unit - shows at least 40 m% of the grains below 1 mm in size. The bucket lifting the product Sand 0/4 mm fine shows an even smaller particle size distribution. For Residual Landfill and Non Disposable Hazardous Waste. At a size from 0.5 mm, over 98 m% of the soil passes the mesh. Only the sample for Construction Waste shows a higher amount of grains above 0.5 mm.

Problems in the plant arise during dewatering the buckets of the sand trap. An indication could be that if the fine grains are too much, the sieve mats are clogged. Thus, water and fines remain in the bucket and remain in the sand product. This can result in a decrease of sand quality due to a high amount of fines and a lot of water remaining.

With regard to the filter cake (Figure 37), the grain size distribution does not vary a lot. For better visualisation, the scale was changed on the y axis for this chart. As these samples show no high difference, it is assumed that is does not impact the flocculation. Regarding the thickening process, zone sedimentation is assumed. Hence, the grain parameters of single grains are not regarded as significant.

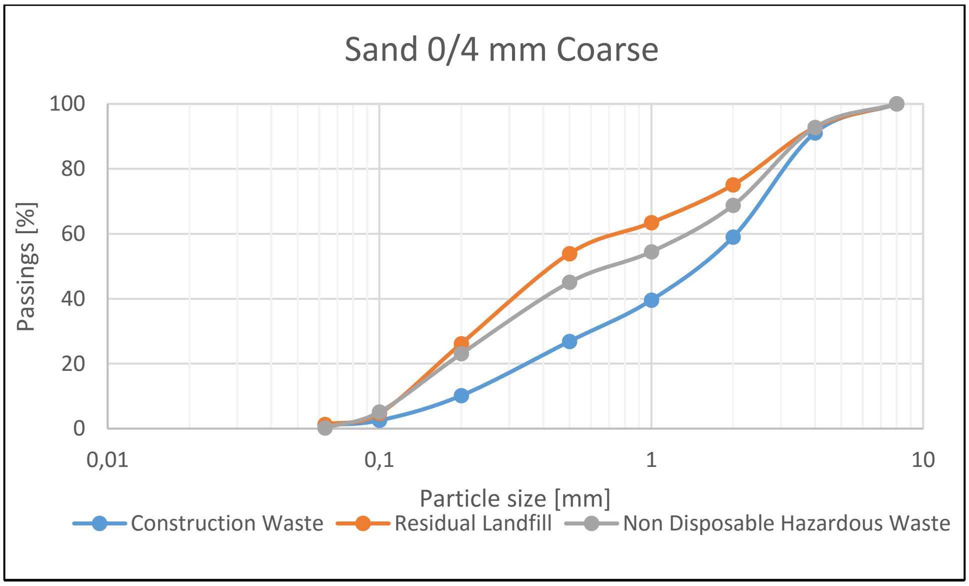

Figure 35: Graphical illustration of the particle size distribution of the product Sand 0/4 mm Coarse

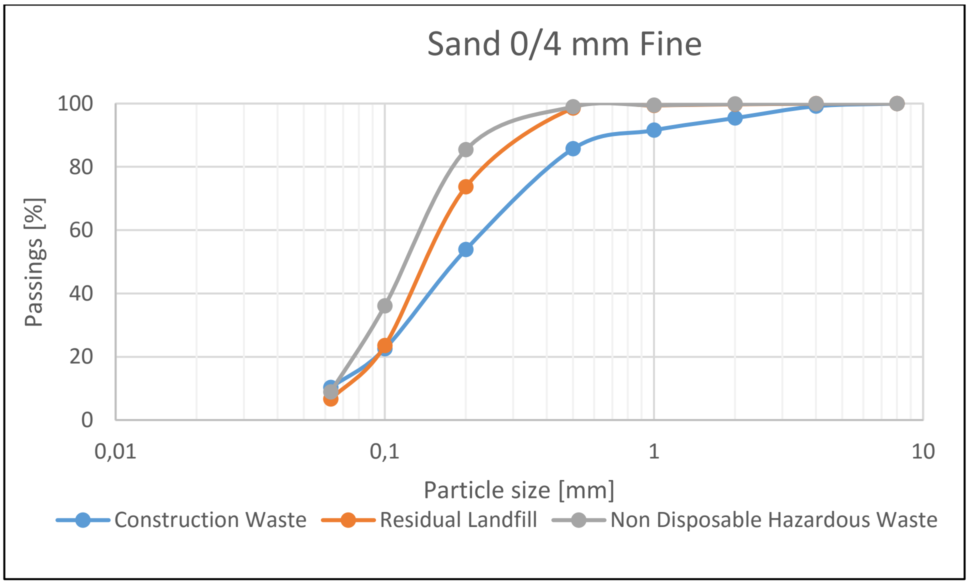

Figure 36: Graphical illustration of the particle size distribution of Sand 0/4 mm Fine

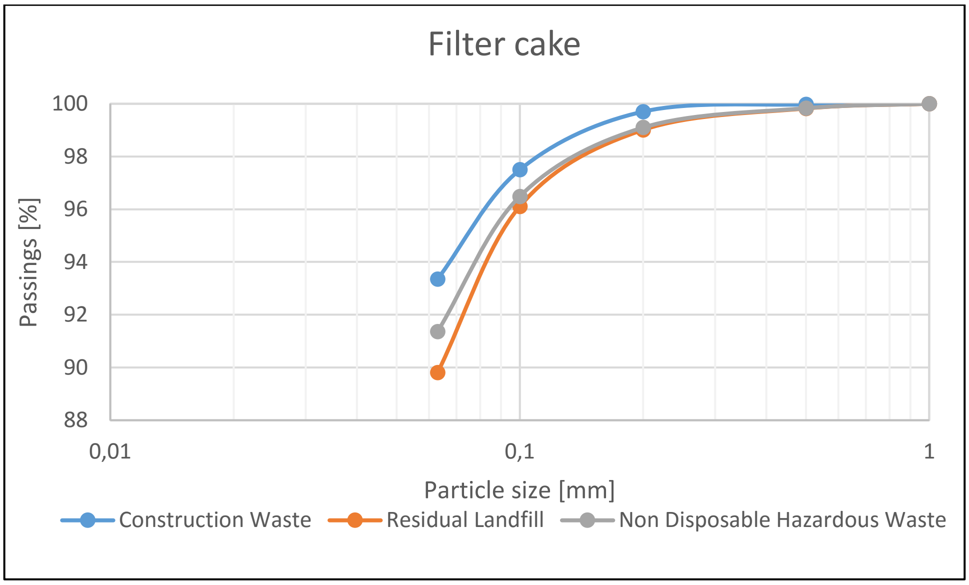

Figure 37: Graphical illustration of the particle size distribution of the Filter cake

4.2. PH VALUE AND CONDUCTIVITY

The pH value can have a large impact on the used polymers, as they can lose their efficiency at a certain pH value.

The pH value was assumed to have an impact on the flocculation result, as flocculant reagents have a specific pH where they operate most efficient. Hence, a pH differing a lot from the neutral value of 7 can cause problems. Furthermore, especially in waste treatment, where a lot of contamination is supposed, it should be considered that certain contaminants start to dissolve at very high (or low) pH values. This results in a contamination of the circuit water.

At the plant trials, a huge difference in pH can already be seen between the different soil types. The figures below visualize the behaviour of the pH value in relation to the time intervals of the taken samples. The water samples from the Construction Waste (Figure 38) shows the highest values, even above 11. However, all soils show a basic trend. Furthermore, in general, it becomes obvious that the value shows a rising trend. It is expected that this problem arises from a too small CO_2 neutralization unit. Hence, the system is not able to neutralize the process water anymore during the week.

In Figure 40, the downwards trend at the beginning is assumed to be caused by a different soil being washed the days before. Thus, the process water is still loaded with different contaminants and ions from a different feed. After some time, the chart starts to rise again however.

The most contaminated soil from the plant trials, non-disposable hazardous waste seeded to be the least alkaline plant feed. The values remain fairly above the neutral level of 7. However, even in these samples a slight upwards trend can be observed (Figure 42).

Changes in conductivity over time (Figure 39, Figure 41 and Figure 43) show the same trend as the pH charts, based on their direct proportionality to dissolved ions. In the case of conductivity in a liquid, OH^- and H_3O^+, relevant for the pH value, contribute most to its measuring output. There was no relation expected between conductivity and flocculation so far.

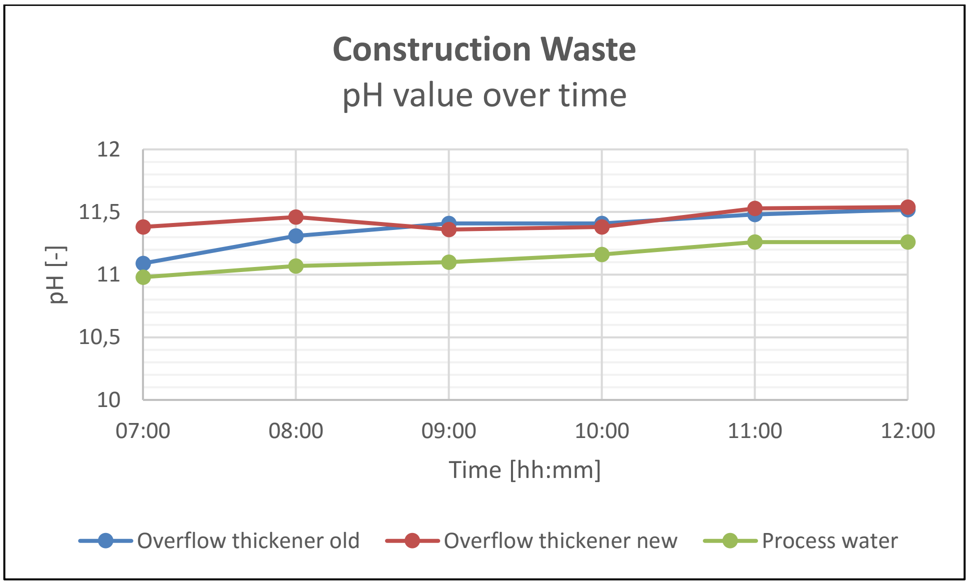

Figure 38: Graphical display of the relation between the pH value and time for the trials of Construction Waste

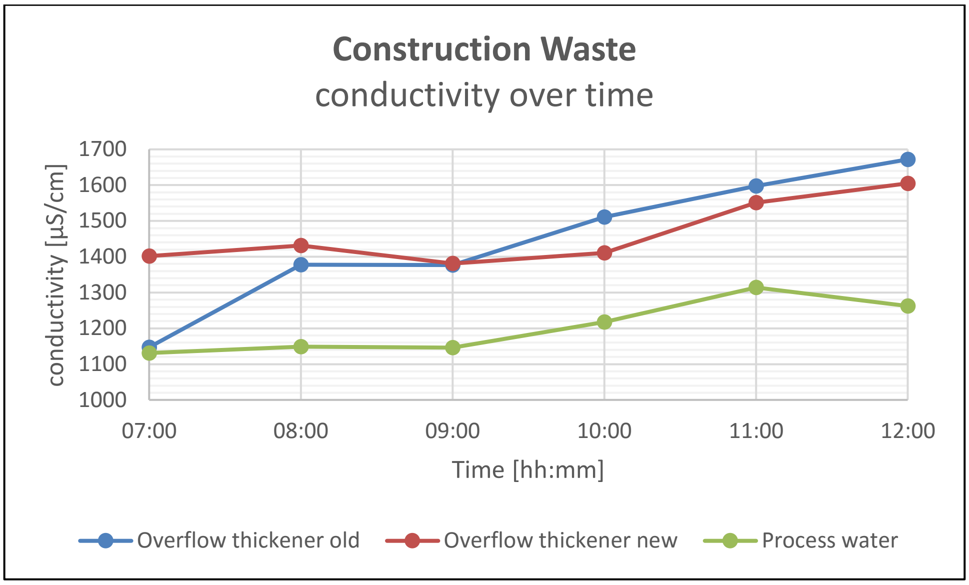

Figure 39: **Graphical display of the relation between the conductivity and time for the trials of Construction Waste**

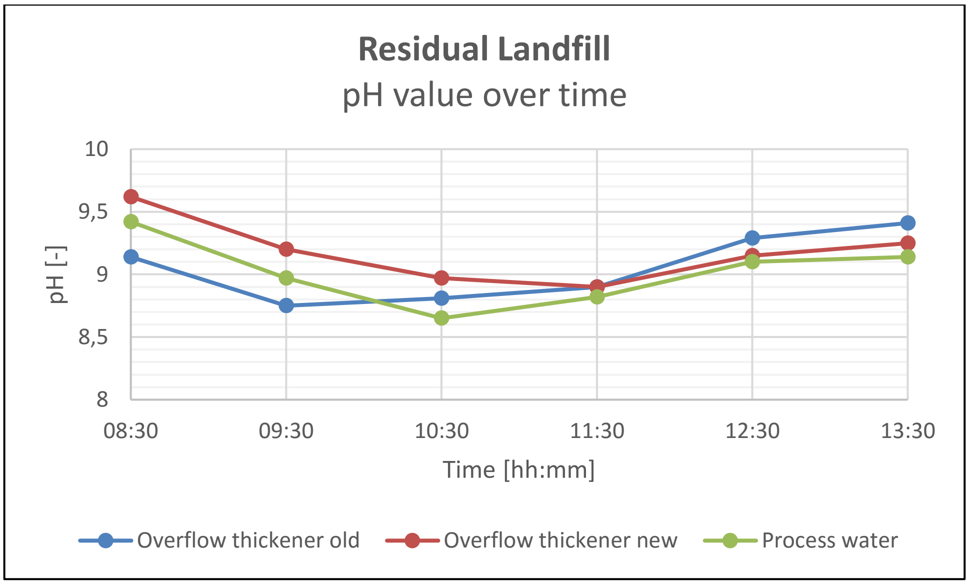

Figure 40: **Graphical display of the relation between the pH value and time for the trials of Residual Landfill**

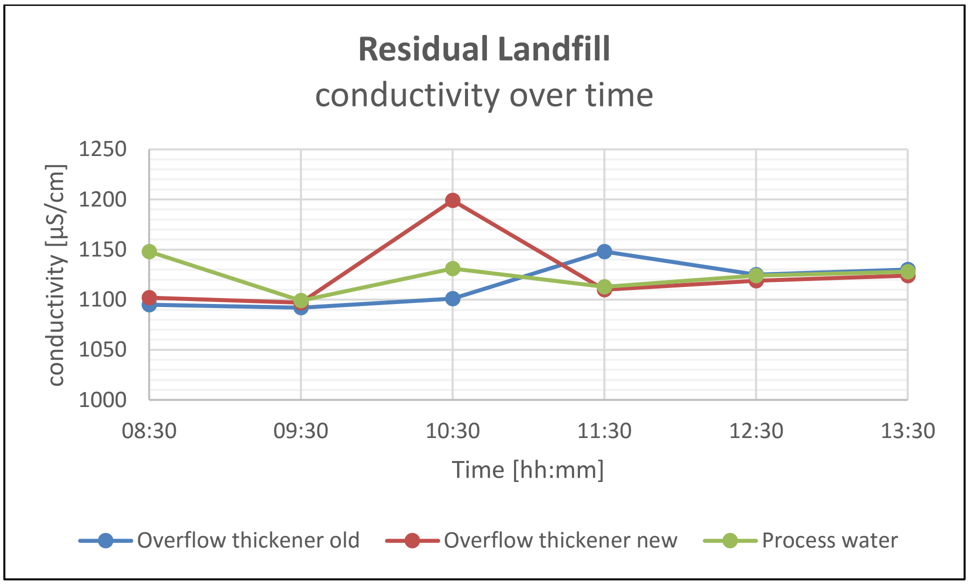

Figure 41: **Graphical display of the relation between the conductivity and time for the trials of Construction Waste**

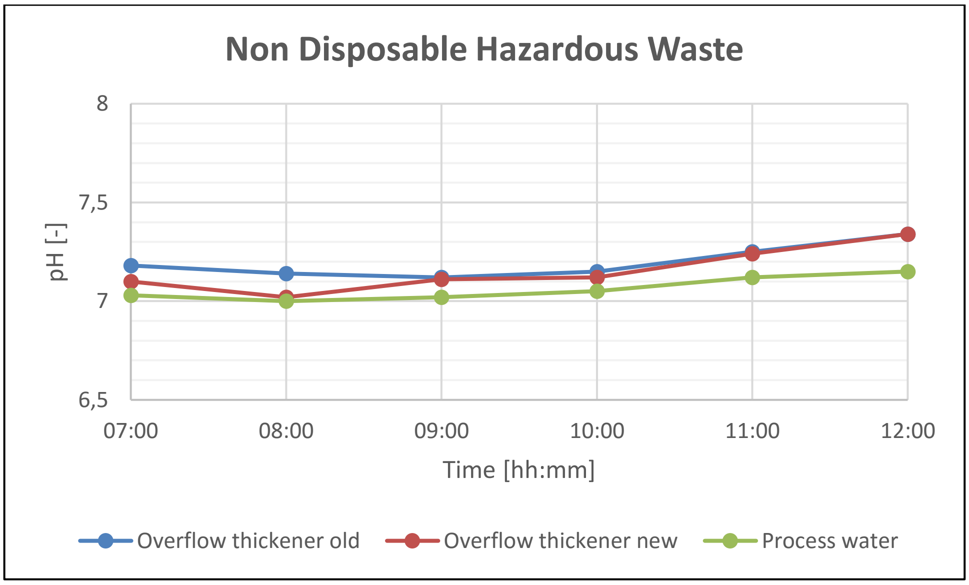

Figure 42: **Graphical display of the relation between the pH value and time for the trials of Non Disposable Hazardous Waste**

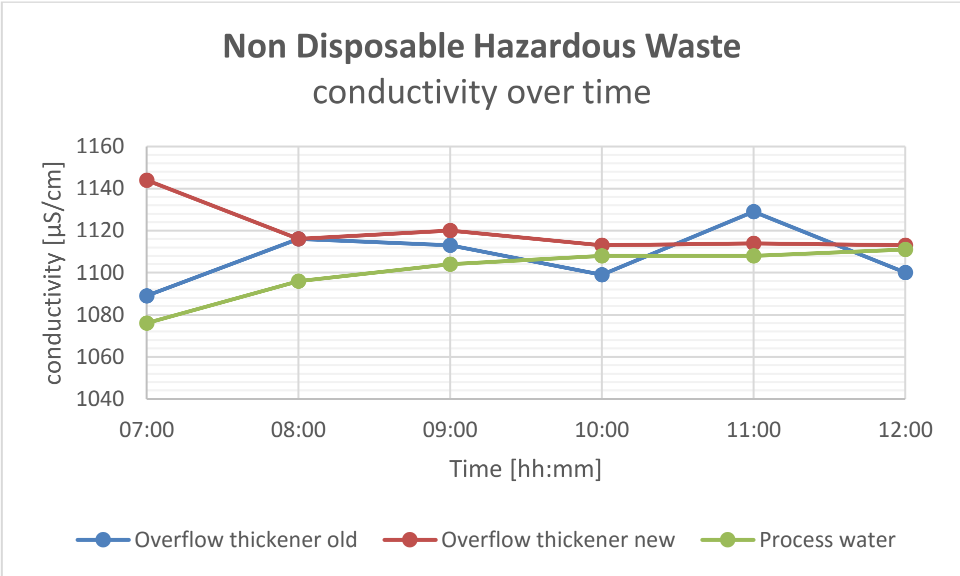

Figure 43: Graphical display of the relation between the conductivity and time for the trials of Non Disposable Hazardous Waste

4.3. HYDROCARBON

The contamination measurements of hydrocarbons of the sampled fractions were carried out, as hydrocarbons are an important measuring parameter for landfills and contaminated soils on site. Furthermore, a possible impact on the flocculation at high hydrocarbon values was regarded as possible. The soil washing plant Ground Unit has to characterise their soils according to the Austrian DVO[5] 2008, an ordinance for landfills [9]. However, the samples show by far lower values than the regulatory values stated in the DVO. Even the category "excavated soil" with the lowest values tolerates a maximum of 200 mg/kg dry mass [9].

It is assumed that the soil fractions used for the trials had no extraordinary contaminations of hydrocarbons. The water samples showed no measurable values. Due to this, no graphical data analysis was possible. Hence, no hydrocarbons enriched. Neither in the thickeners nor in the process water. Even though no direct effect of hydrocarbons on the flocculation polymers could be measured. It is regarded as positive that there is no enrichment of contaminants in the process water.

The relations of the samples over time and measured hydrocarbon values are visualised in Figure 44, Figure 45 and Figure 46.

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[5] Deponie Verordnung

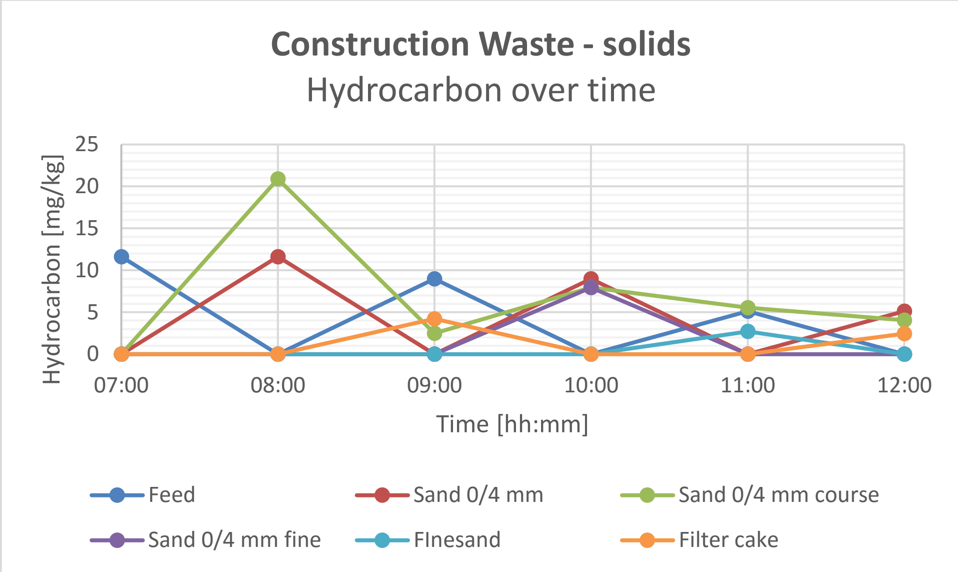

Figure 44: **Graphical display of the measured hydrocarbon value in relation to time for Construction Waste**

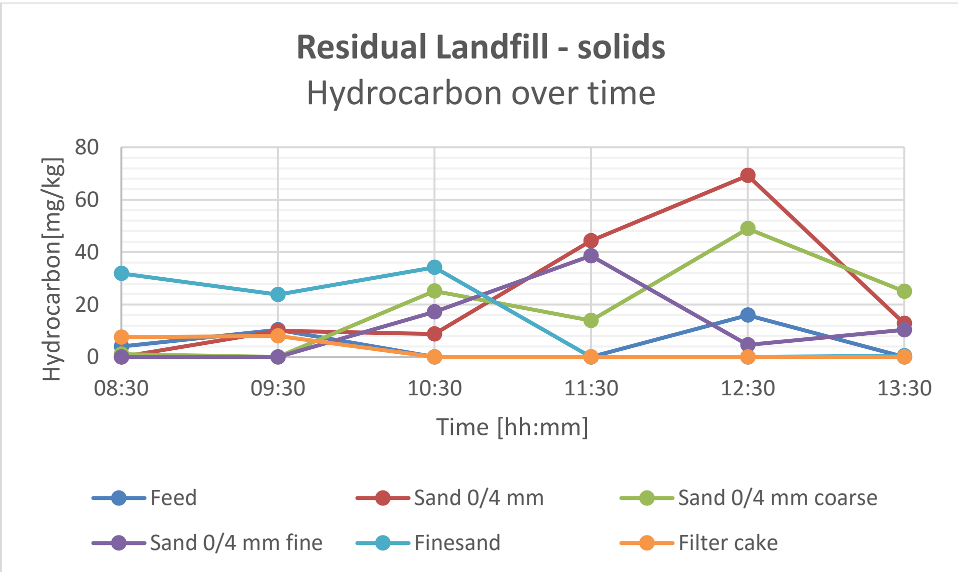

Figure 45: **Graphical display of the measured hydrocarbon value in relation to time for Residual Landfill**

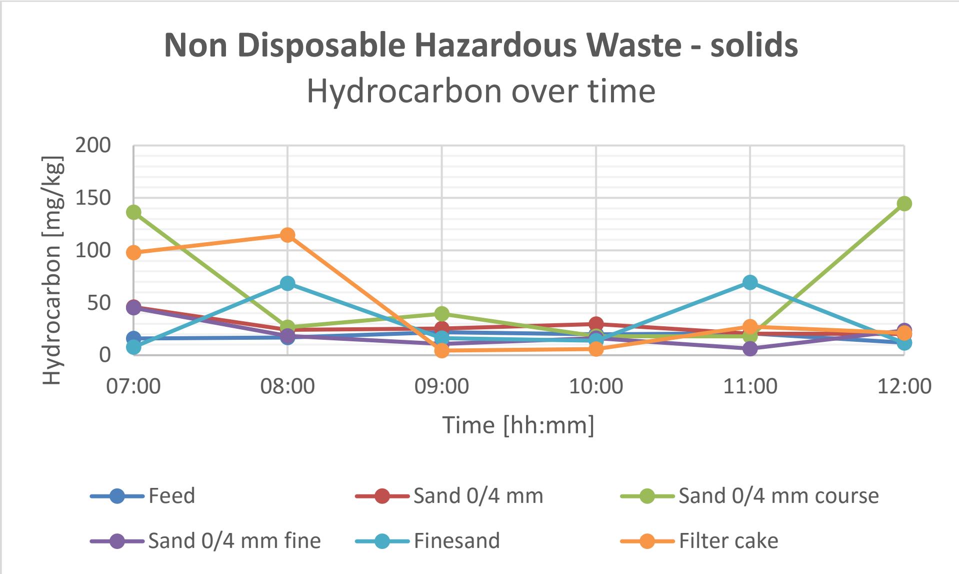

Figure 46: Graphical display of the measured hydrocarbon value in relation to time for Non Disposable Hazardous Waste

4.4. DRY MASS

The dry mass is very relevant for the solid products, as a low water content is desired. A high water content in the filter cake can be an indication for problems with the flocculants due to poor sedimentation or clogging of the filter cloths.

The dry mass of the sampled fraction was taken by drying the soil at 105 °C until the mass stayed constant. The analysis was carried out by the laboratory on site at Ground Unit. Especially the product Sand 0/4 mm was regarded as important, as it seemed to be too moisty sometimes. The thickener underflow is taken into the analysis, as it gives an indication of the degree of dewatering and compression at the very bottom of the thickeners. Furthermore, the two thickeners should be compared. Even the moisture of the filter cake is considered to be important, as a too moisty and sticky filter cake is regarded as not ideal. It often results in a sticking of the cake to the filter cloth in the press.

According to Ground Unit, a desirable moisture grade of a maximum of 30 % is promised by the contracting company. With regard to Table 7, Table 8 and Table 9, only Construction Waste showed a wetter filter cake. However, even though residual landfill delivered a slightly better moisture value, the optical impression of the filter cake was less satisfying. Figure 47 portrays a too wet filter cake from the Residual Landfill trials.

Figure 47: Filter cake of Residual Landfill; the moisture grade seemed too high

With regard to the solid content leaving the thickeners, the values for Construction Waste differ largely from the other two soils. It is assumed that this soil could not compact as much as the others. It is left for speculations whether this is a result of the flocculation or the high feed rate. However, it is assumed that alterations done between the plant trials improved the thickening process.

Construction Waste			
Sample	g(solid) [%]	Std. Deviation [%]	Deviation from collective sample [%]
Feed	88.08	1.46	3.41
Sand 0/4 mm	82.61	6.85	-1.10
Sand 0/4 mm coarse	87.06	4.25	3.04
Sand 0/4 mm fine	67.62	5.85	0.55
Filter cake	68.25	3.10	-0.78
Finesand	70.63	2.85	1.61
Underflow thickener old	25.13	3.80	
Underflow thickener new	28.75	3.85	
Slurry pump sump	2.05	0.76	

Table 7: Evaluated dry mass of the samples taken from Construction Waste

Residual Landfill			
Sample	g(solid) [%]	Std.deviation [%]	Deviation from collective sample [%]
Feed	86.17	5.59	-3.08
Sand 0/4 mm	83.08	6.46	1.90
Sand 0/4 mm coarse	77.83	2.44	-0.26
Sand 0/4 mm fine	70.49	1.05	-0.68
Filter cake	71.59	3.30	-1.12
Finesand	75.05	1.37	-1.46
Underflow thickener old	44.52	3.60	
Underflow thickener new	43.16	1.39	
Slurry pump sump	2.60	0.45	

Table 8: Evaluated dry mass of the samples taken from Residual Landfill

Non Disposable Hazardous Waste			
Sample	g(solid) [%]	Std.Deviation [%]	Deviation from collective sample [%]
Feed	88.51	6.42	0.69
Sand 0/4 mm	77.11	3.42	-0.25
Sand 0/4 mm coarse	79.79	3.23	0.61
Sand 0/4 mm fine	72.99	1.06	2.90
Filter cake	73.86	1.24	0.97
Finesand	75.95	2.53	1.74
Slurry pump sump	1.24	0.66	
Underflow thickener old	40.99	3.97	
Underflow thickener new	40.41	2.62	

Table 9: Evaluated dry mass of the samples taken from Non Disposable Hazardous Waste

4.5. LOSS OF IGNITION

The loss of ignition analysis was carried out with the aim of getting information about the organic amount in the samples. The trial was carried out at the laboratory on site with a maximum of 550 °C. The sample trays were placed in the oven at room temperature. The oven was heated up to the final temperature of 550 °C over a time period of three hours. This temperature was kept constant for eight hours until the oven was switched off automatically.

According to the results of these analyses, it was determined that the loss of ignition could not be taken into further interpretation with regards to the dewatering behaviour. The results showed too high fluctuations of the values and inconvenient results.

For a more fundamental study of the organic amount in the soils, new trials would be necessary. The data of the ignition loss, including standard deviation and variance are attached in the appendix (Table 12, Table 13 and Table 14).

4.6. POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons were analysed, as this parameter is highly important for the soil treatment in the plant. The results show that - despite fluctuations - the filter cake is most heavily contaminated with PAH. Relating to the water samples, no convenient results could be achieved. It is possible that the soils were not contaminated enough to show an enrichment of PAH in the process water. Only the most contaminated plant feed Non Disposable Hazardous Waste showed slight detectable traces of PAH (Figure 53). Thus an enrichment of PAH in the process water that could have a negative impact on flocculation and the dewatering process was not observed. The slurry of the pump sump delivered results but was by far more fluctuating than the analysis of the solid samples. This may be caused by problems of sampling a slurry properly.

The relation of the solid and liquid samples and the measured PAH values are visualized graphically in Figure 48 to Figure 53.

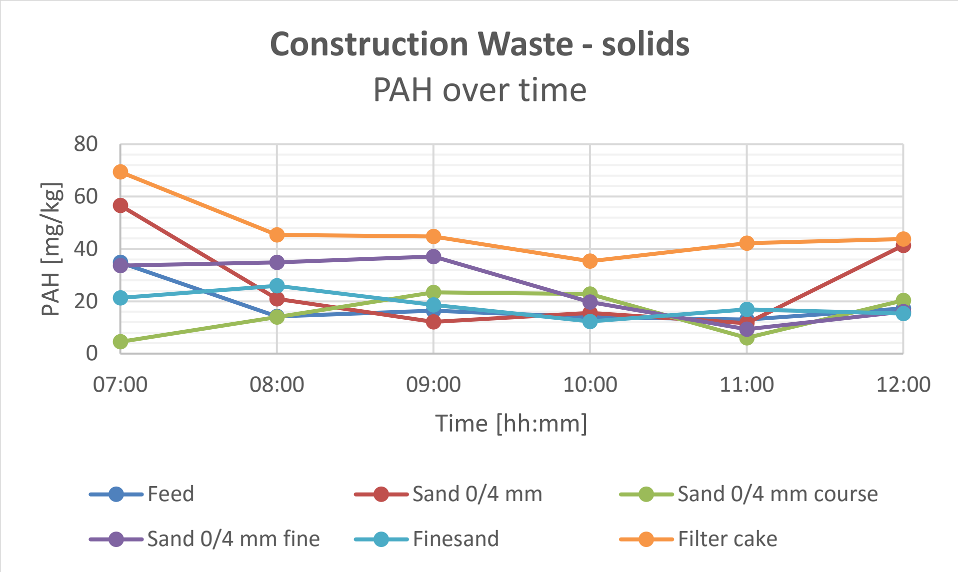

Figure 48: Graphical illustration of the relation between PAH over time from Construction Waste; solid samples

The high peak in Figure 49, from the pump sump sample is assumed to be an exception, as the line declines again afterwards. Fluctuations in the slurry sampling are probable.

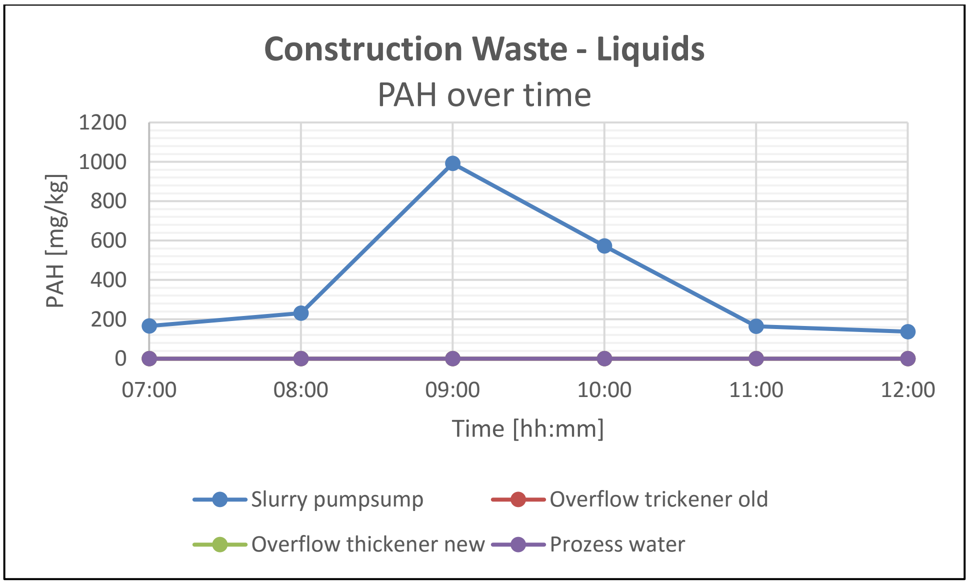

Figure 49: Graphical illustration of the relation between PAH over time from Construction Waste; liquid samples

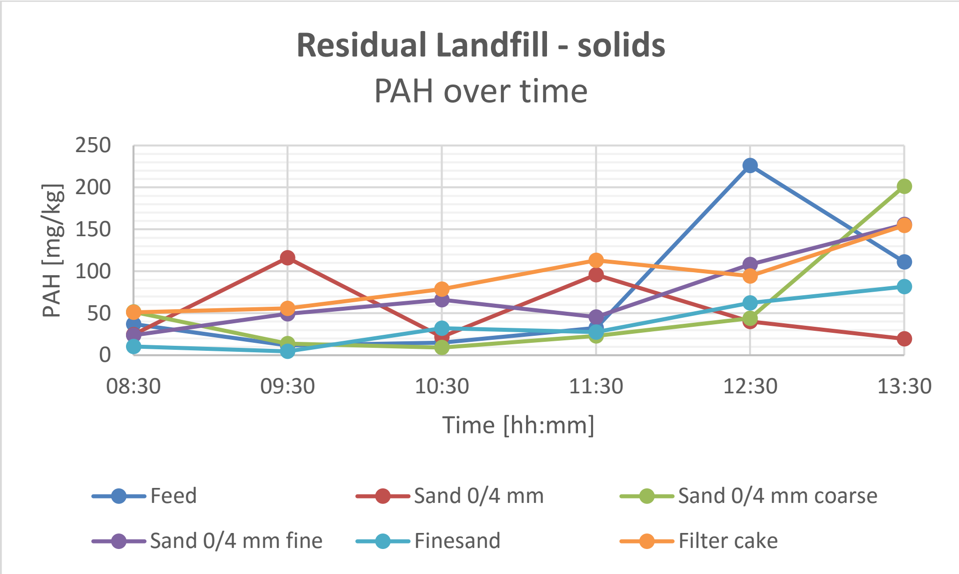

Figure 50: **Graphical illustration of PAH over time from Residual Landfill; solid samples**

Figure 51 shows an upwards trend in the pump sump slurry PAH contamination. Hence, it is assumed that in the case of highly contaminated soils, the PAH value increases to a certain extent in the pump sump slurry. However, the process water does not show the same trend. Thus, the enrichment of PAH in the process water that is running in circuit could not be observed and therefore is not assumed to cause problems in the soil washing process. Figure 50 shows an upwards trend as well for the solid samples.

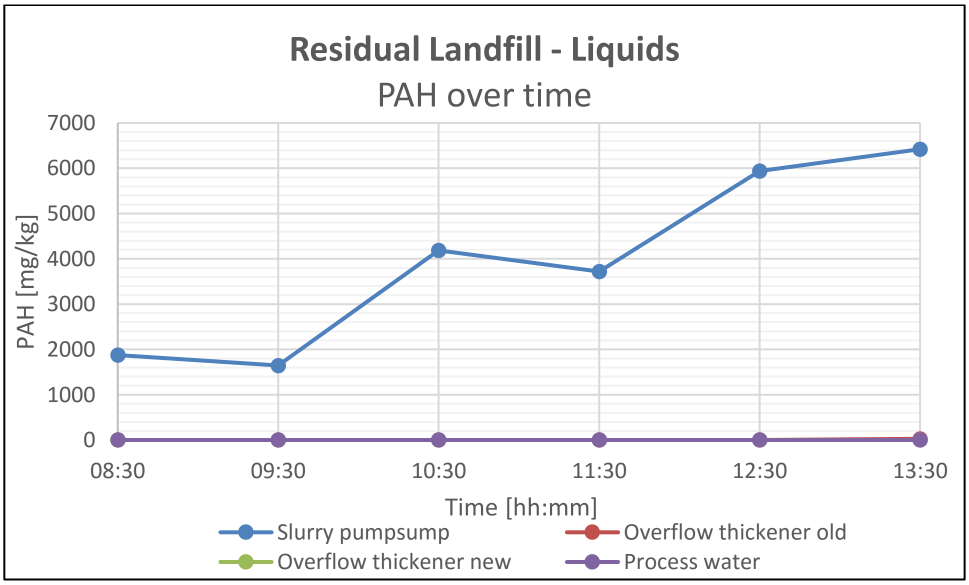

Figure 51: **Graphical illustration of PAH over time for Residual Landfill; liquid samples**

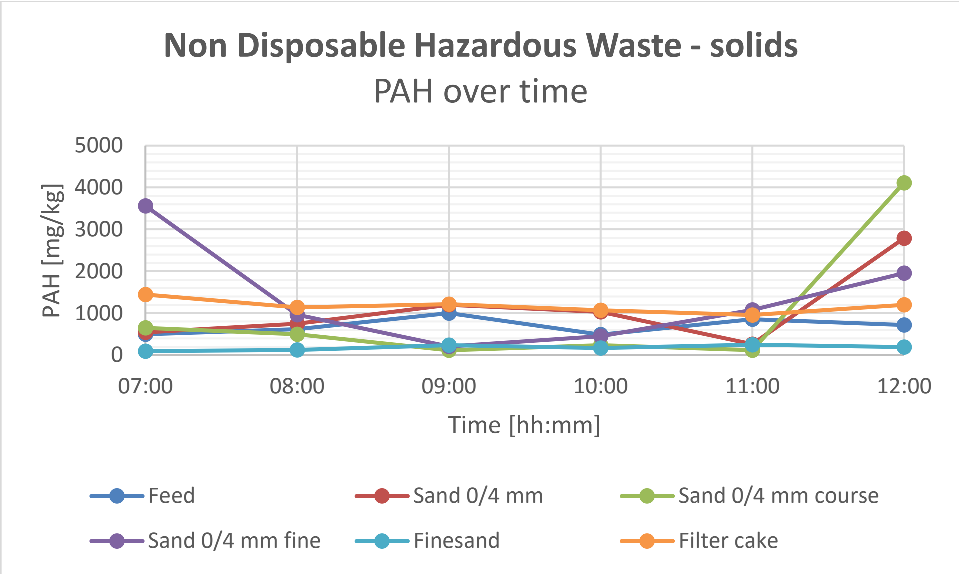

Figure 52: **Graphical illustration of PAH over time for Non Hazardous Waste; solid samples**

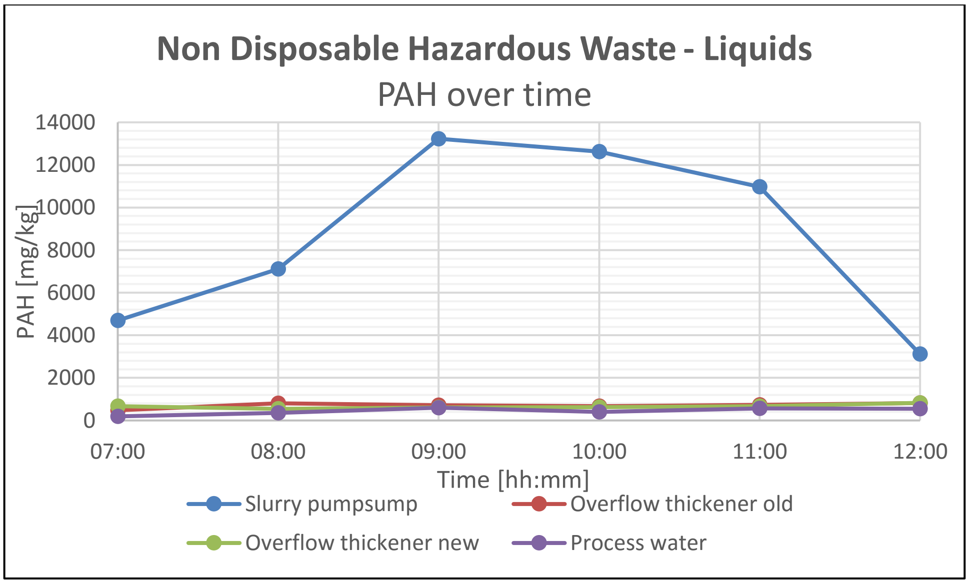

Figure 53: **Graphical illustration of PAH over time for Non Disposable Hazardous Waste; liquid samples**

5. FINANCIAL SAVINGS

After the optimisations described in this master thesis, the demand of anionic flocculants was evaluated. The cationic demand was not added to the calculation as the documentation from the past was not complete. Table 10 represents the data of the demand evaluation in relation to the costs. Only the data from 2013 were taken into account. Before that, a lot of plant alterations and expansions were carried out at the soil washing plant. Hence, this data from 2009 to 2012 is not representative for the current plant condition. The calculations and the data were delivered from supervisor Dipl.-Wirt.-Ing. Günter Hirsch.

The demand for 2017 was prospected by an extrapolation from the last three months. It was assumed that the current polymer dosage and concentration of the polymer are kept constant. According to this calculation by the alterations of this thesis, a total of € 4.275/a will be saved directly by the optimisation of the flocculation.

It should be mentioned that after the plant trials and the interpretation of this thesis, the operating manager of Ground Unit is still making attempts to reduce the solid content of the flocculants mix. Furthermore, optimisations at the plants made it possible to reduce the current consumption further. Thus, it is assumed that the savings will increase in future. A visualisation of the flocculants consumption and the cost reduction is portrayed in Figure 54 and Figure 55.

Year [-]	Demand Floc. [kg]	Throughput Soil [t]	Demand/ton [kg/t]	Price Floc. [€/kg]	Costs/ton [€/t]	Total Costs [€]	Savings [€]
2009	2,600	66,300	0.039	2.85			
2010	2,000	160,400	0.012	2.85			
2011	2,000	246,700	0.008	2.85			
2012	6,000	235,600	0.025	2,85			
2013	6,750	215,202	0.031	2.85	0.0894	19,238	
2014	5,400	228,638	0.024	2.85	0.0673	15,390	
2015	5,000	246,261	0.020	2.85	0.0579	14,250	
2016	5,100	216,762	0.024	2.85	0.0671	14,535	
2017	3,600	240,000	0.015	2.85	0.0428	10,260	**4,275**

Table 10: Financial calculation of the flocculant savings

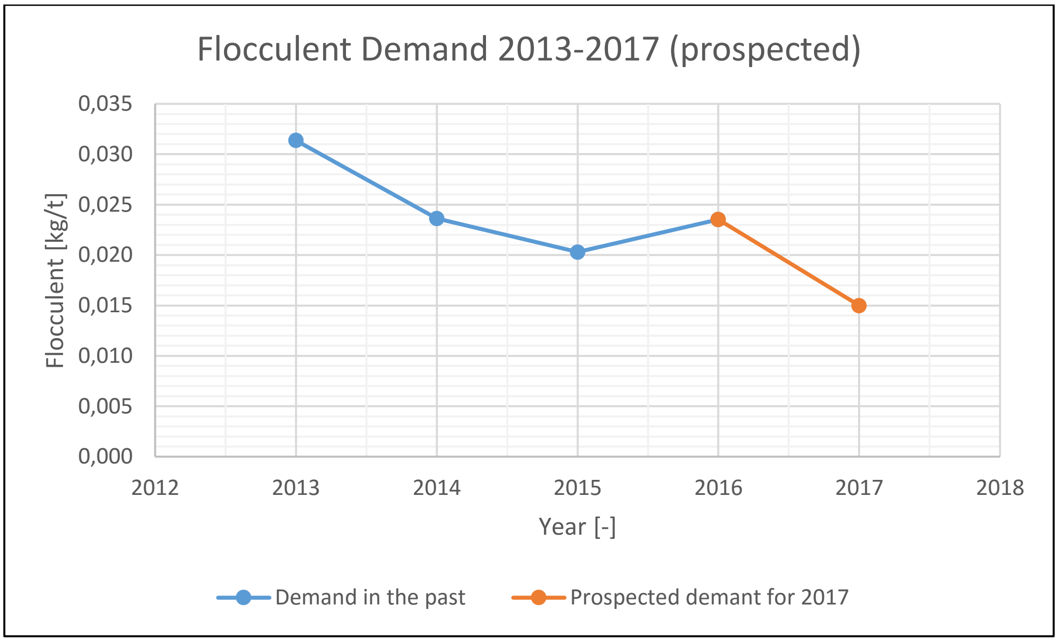

Figure 54: Flocculant Demand at Ground Unit from 2013 until 2017

Figure 55: Cost reduction due to a reduction of the flocculant demand from 2013 until 2017

6. DISCUSSION

The task of optimising the soil washing plant of Ground Unit could be accomplished as part of this master thesis. By altering plant parts as well as the thickeners or the pump sumps and the sand trap, a better and more homogeneous process was achieved. Hence, less problems occurred in combination with the dewatering line. Furthermore, financial savings were obtained by alterations regarding the used flocculants and the dewatering system.

Based on the the soils operated in the plant, it is recommended to make flocculation analysis in advance, especially when the soil is unknown. It is assumed that only practical flocculation trials with polymers lead to a clear result for the right polymer to be used. Furthermore, trials in advance can prevent plant standstills due to a hindrance in the thickening step. Considering different polymers, in case it is necessary to change the flocculant numerous times a year, an improvement of the conditioning tank is recommended. The mixing of two different polymer powders leads to huge problems with sedimentation, as the polymers lose their activity. This problem becomes most risky when a change in polarity is made from anionic to cationic. An emptying of the currently used flocculant and a second polymer tank are recommended.

With regard to the flocculation process and the influence of chemical and physical parameters, not every analysis left satisfying results. Especially the grain size distribution, particularly <100 µm and the pH value are assumed to have the highest impact. Concerning the pH, an increase until a critical value far above neutral was detected. Thus, a better neutralization of the water treatment and neutralization line should be considered. Further parameters relevant in soil waste treatment as PAH and hydrocarbons showed trends, described in the relevant sections of chapter 4. However, no direct correlation to the dewatering process could be made so far. A positive output is the fact that neither PAH nor hydrocarbons were measurable in the process water sample. An enrichment of contaminants in the circulating water stream would have been regarded as unwanted.

Numerous problems seemed to arise from not properly operating devices and plant conditions rather than over-flocculation or the wrong flocculants. A vast improvement could be achieved by synchronizing the old and the new thickener lines, as the polymer feed is evaluating a mean value of the two and both are charged with flocculant the same way. Hence, no individual conditions are considered.

In conclusion, the importance of the newly gained insights can be ranked. Primarily, practical trials with new soil washing tasks are inevitable and should not be neglected as the choosing of a right flocculant has a large impact on the whole process efficiency. Secondarily, an optimisation of the process and its aggregates was tested to be important as well. Numerous problems arose from not efficiently working plant devices. The monitoring of the relevant parameters as for instance pH of grade of fines is another important point to consider, as they are regarded as vital for a sufficient washing process. The dry mass can be taken as a monitoring parameter for the quality of the filter cake as well as for the performance of the thickeners and the presses for instance.

Moreover, not every analysis done in this thesis led to convenient results. Especially the ignition loss showed too high fluctuations and thus was not taken into detailed considerations so far. Analysis values as PAH and hydrocarbons showed certain trends but no direct impact on the flocculation process itself was observed. However, a monitoring of the process water is recommended as it should not enrich any contamination.

The optimisations still leave room for further improvements. By improving the thickener performance and the condition of the flocculation polymer, slightly financial savings could be achieved so far. However, further savings are expected in the future due to optimisations that are not fully carried through.

Throughout this thesis, future tasks are considered that might be interesting for further investigations. These points are listed below.

7. FUTURE TASKS

7.1. SAND TRAP SUBSTITUTION

As the dewatering performance of the sand trap was regarded as not convenient and the mats have a lot of problems with clogging it was discussed that an elimination of the sand trap could be an adaption for the future. A substitution by hydrocyclones could reduce the operating problems even more after the dewatering improvement. Furthermore, hydrocyclones could increase the quality of the product Sand 0/4 mm due to a reduction of the fines.

7.2. SPECIFIC SURFACE AREA

With regard to the consumption of flocculants it was discussed whether an examination of the surface area of the soil would be of use, as the polymer is attaching to the surface of the grains. However, a brief estimation of the surface area of a inhomogeneous multi-disperse soil sample with different grain sizes seemed to be not possible. Is was decided that analysis in this field could be done in the future, however would go beyond the scope of this master thesis.

It was suggested that the soil sample needs to be analysed based on its particle size distribution and in addition on its surface area. However, the type of surface area measurement needs to be decided in advance. Typical measurements carried out at the Chair of Mineral Processing at Montanuniversitaet Leoben are the specific surface area according to Blaine and the specific surface area based on BET[6] measurements.

7.3. AUTOMATISATION OF THE PLANT

It is desired by Ground Unit that the automatisation of the plant and its aggregates should be controlled more by the company itself rather than by external companies. The parameters of operation of a lot of aggregates can only be set by the manufacturer. This should be changed and the plant should be operated more independent from Ground Unit in order to achieve a semi automatization in the future what will help to facilitate the plant operation. In order to learn from past soil washing experiences a “Soil washing handbook” should be generated. This should enable a comparison between similar soils and define plant parameters as the feed rate or the type of flocculant in advance.

[6] Named after the inventors Brunauer, Emmett and Teller

8. APPENDIX

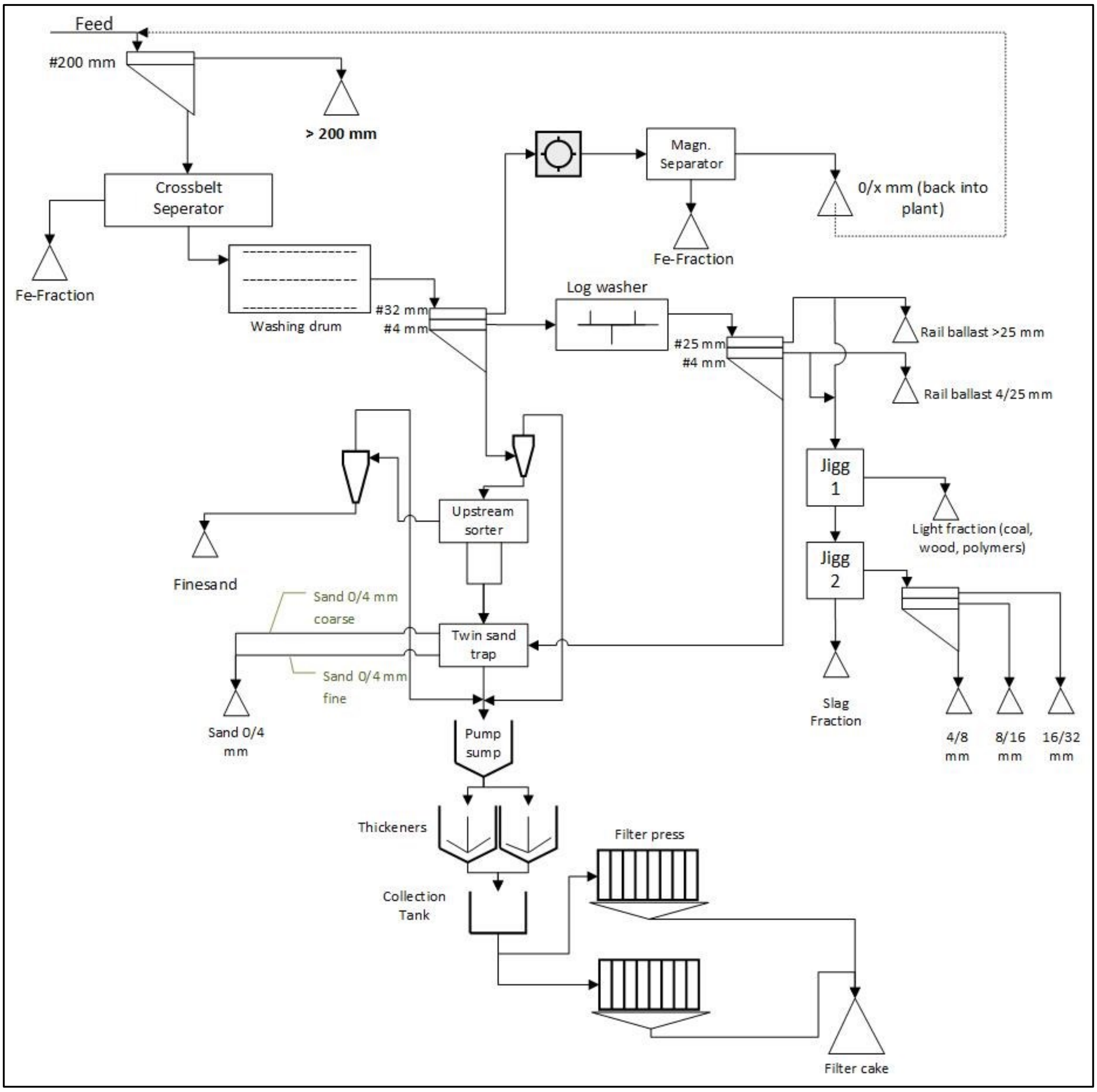

Figure 56: **Simplified flow sheet of the soil washing plant**

Cationic Polymer 2200 l/h water 28.8.		(faulty flowmeter)		
Sample	**Tank section**	**g(s) [%]**	**g(H_2O) [%]**	**m(s) in 1 l H_2O [g/l]**
1	1	0.36	99.64	572.34
2	1	0.37	99.63	592.74
3	2	0.34	99.66	508.69
4	3	0.29	99.71	403.57
5	3	0.35	99.65	534.12
6	2	0.36	99.64	553.14
	Mean	0.34	99.66	
	Standard deviation	0.0303	0.0303	
	Variance	0.0009	0.0009	
Anionic Polymer 2400 l/h water 05.09.		(faulty flowmeter)		
Sample	**Tank section**	**g(s) [%]**	**g(H_2O) [%]**	**m(s) in 1 l H_2O [g/l]**
1	1	0.34	99.66	525.04
2	1	0.41	99.59	704.45
3	2	0.38	99.62	604.43
4	3	0.33	99.67	503.19
5	3	0.35	99.65	541.95
6	2	0.35	99.65	527.49
	Mean	0.36	99.64	
	Standard deviation	0.0293	0.0293	
	Variance	0.0009	0.0009	
Anionic Polymer 2800 l/h 15.11.		(new flowmeter)		
Sample	**Tank section**	**g(s) [%]**	**g(H_2O) [%]**	**m(s) in 1 l H_2O [g/l]**
1	1	0.20	99.80	242.48
2	1	0.21	99.79	260.00
3	2	0.20	99.80	250.12
4	3	0.23	99.77	296.63
5	3	0.20	99.80	249.81
6	2	0.24	99.76	307.65
	Mean	0.21	99.79	
	Standard deviation	0.0169	0.0169	
	Variance	0.0003	0.0003	

Table 11: Polymer drying results

Construction Waste			
Sample	LOI [%]	Std. deviation [%]	Variance [%]
Feed	9.58	8.28	68.59
Sand 0/4 mm	8.73	12.14	147.42
Sand 0/4 mm coarse	3.75	4.71	22.17
Sand 0/4 mm fine	5.55	3.82	14.61
Filter cake	10.97	11.95	142.78
Finesand	2.42	1.42	2.02

Table 12: Tabular presentation of the loss of ignition of Construction Waste

Residual Landfill			
Sample	LOI [%]	Std. deviation [%]	Variance [%]
Feed	6.73	5.35	28.62
Sand 0/4 mm	1.27	2.90	8.39
Sand 0/4 mm coarse	6.56	9.59	92.03
Sand 0/4 mm fine	2.32	3.18	10.11
Filter cake	6.06	3.10	9.62
Finesand	2.98	1.29	1.67

Table 13: Tabular presentation of the loss of ignition of Residual Landfill

Non Disposable Hazardous Waste			
Sample	LOI [%]	Std. deviation [%]	Variance [%]
Feed	10.29	3.84	14.77
Sand 0/4 mm	8.56	5.76	33.20
Sand 0/4 mm coarse	3.22	1.55	2.39
Sand 0/4 mm fine	12.70	12.39	153.49
Filter cake	9.94	1.40	1.95
Finesand	4.25	1.79	3.22

Table 14: Tabular presentation of the loss of ignition of Non Disposable Hazardous Waste

9. LIST OF FIGURES

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