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A Study on Physical Separation Techniques for Recovery of Metals from Municipal Solid Waste Incineration (MSWI) Bottom Ash

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HELSINKI UNIVERSITY OF TECHNOLOGY **Abstract of Master's Thesis**

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In this thesis suitable physical separation methods have been studied and experiments have been carried out for metals recovery from MSWI bottom ash. The literature study included an overview of the composition and variations of MSWI bottom ash, the factors influencing the bottom ash quality and the usual processing practices.

In the experimental part a bottom ash sample was first characterized. Characterization was important with regard to the mechanical processing of bottom ash, because it gave a good overview of bulk properties and the distribution of mechanically separable metals in different particle size classes. The experimental process flowsheet designed was based on the literature study and the bottom ash characterization.

The process developed included wet screening of the bottom ash into three particle size classes: +6.25mm (Coarse), 0.18-6.25mm (Medium) and sludge of 0-0.18mm (Fines). Wet screening proved an efficient way for washing the small fraction to the underflow. The Fines product was 32w-% of the total dry output. It was delivered for treatebility tests to Salvor Oy.

The Coarse and Medium products were processed with magnetic and eddy current separators and the performance of the processes were assessed. The Coarse and Medium magnetic products were both 7w-% of total dry output. Recovery of iron from bottom ash was possible with good recovery. From the Coarse fraction 87% of iron was recovered at a grade of 25% and from the Medium fraction 71% of iron was recovered at a grade of 20%. In addition, magnetic separation step remover environmentally harmful elements from bottom ash, such as Sn, Ni, Zn and Cu, possibly improving bottom ash's environmental quality at the same time. The amount of coarse nonmagnetic metal product was 3w-% of total dry output. For particles larger than 6.25mm also the recovery of nonferrous metals is possible by traditional eddy current separation. The recovery was good (85% for grey nonmagnetic metals and 90% for red nonferrous metals) with metal grade of around 55%. The tested nonferrous metals separation steps, eddy current separator and pneumatic shaking table for Medium fraction did not work.

The results showed that for many environmentally harmful elements the concentration in Fines higher than for the produced Granulate products. The process results indicated that the environmental quality of MSWI bottom ash can be already improved by removal of the finest fraction by wet screening.

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Diplomityössä tutkittiin metallien talteenottoa jätteenpolttolaitoksen arinatuhkasta fysikaalisin erotusmenetelmin. Kirjallisessa osassa kuvailtiin arinatuhkan ominaisuuksia, erityyppisten fysikaalisten erotusmenetelmien soveltuvuutta arinatuhkan metallien erotamiseksi arinatuhkasta, sekä mahdollisuuksia arinatuhkan teolliseen prosessointiin.

Kokeellisessa osassa arinatuhka aluksi karakterisoitiin, jonka avulla saatiin yleiskäsitys sen ominaisuuksista, metallien erotettavuudesta sekä jakautumisesta arinatuhkan eri kokoluokkiin. Kokeellisessa osassa käytetty prosessikaavio suunniteltiin saatujen karakterisointitulosten ja kirjallisuus-osassa tehtyjen päätelmien pohjalta.

Prosessissa arinatuhkanäyte märkäseulottiin ensin kolmeen eri kokoluokkaan: +6.25mm, 0.18-6.25mm sekä 0-0.18mm lietteeksi. Märkäseulonta osoittautui tehokkaaksi menetelmäksi hienojen partikkeleiden pesemiseksi suurempien partikkelien pinnalta alitteeseen. Lietteen massa oli kuivamassaltaan 32% koko tuotteen massasta. Liete toimitettiin erikseen käsiteltäväksi Salvor Oy:lle.

Molemmat magneettiset tuotteet (+6.25mm ja 0.18-6.25mm) olivat kuivamassaltaan 7% prosessin tuotteista. Prosessissa saavutettu +6.25mm magneettisen tuotteen saanti oli 86%, 25% rautapitoisuudella. 1.18-6.25mm magneettisen tuotteen saanti oli 71%, 20% rautapitoisuudella. Magneettisella erotuksella saatiin erotettua lisäksi ympäristölle haitallisia raskasmetalleja, kuten Sn, Cu, Zn ja Ni, joten magneettisella erotuksella voi olla vaikutusta arinatuhkan ympäristölaatuun. +6.25mm ei-rautametallituote oli 3% kaikista prosessin tuotteiden kuivamassasta. Kyseiselle kokofraktiolle oli mahdollista saavuttaa hyvä saanti (85%-90%), tuotteen metallipitoisuuden jäädessä välttäväksi (55%). Testatut erotusmenetelmät (pyörrevirtaerotin sekä pneumaattinen tärypöytä) ei-rautametallien erottamiseksi kokofraktiosta 1.18-6.25mm eivät tuottaneet tyydyttävää tuotetta. Kokeissa käytetty prosessikaavio soveltuu metallien esirikastukseen jätteenpolton arinatuhkasta. Saavutetut metallituotteen vaativat jatkorikastuksen ennen kuin niitä voidaan käyttää raaka-aineena metallien tuotannossa.

Jo karakterisointitulokset osoittivat että alle 2mm fraktio sisälsi huomattavasti korkeampia pitoisuuksia hiiltä sekä raskasmetalleja, kuin karkeat kokofraktiot, joten jätteenpolton arinatuhkan ympäristölle haitallisten aineiden liukenevuutta ympäristöön on mahdollista vähentää jo pelkästään märkäseulomalla hienofraktio erilleen.

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Espoo, November 19th, 2006.

Maaria Kinnunen

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ABBREVIATIONS

Abbreviation	Description
APCD	Air pollution control device
DOC	Dissolved organic carbon
MAC	Maximum allowed concentration
MSW	Municipal solid waste
MSWI	Municipal solid waste incineration
N.A.	Not Available
NF	Non-ferrous
NVOC	Non-volatile organic carbon
w-%	Mass percentage
WTE	Waste-to-energy

PART I LITERATURE STUDY

1 INTRODUCTION

The purpose of this study was to investigate and further recommend technically, economically and environmentally feasible processing procedures for optimal metal recovery from municipal solid waste incineration (MSWI) bottom ash.

MSWI bottom ash is one of the solid residues of the incineration process. Other than bottom ash, incineration process converts municipal solid waste (MSW) into carbon dioxide, water, fly ash and air pollution control residues. Bottom ash is the largest waste stream and it corresponds 80-90w-% of total solid residues of the incineration process [1-7]. Bottom ash contains grate ash, that is transported through the bottom of the stoker grate, grate siftings, and economizer ash from which the grate ash is the largest fraction [1, 3, 4]. The total mass of waste of the incineration process ranges from 30% to 35% of burnt waste by weight and 10% by volume [1, 2, 4, 5]. The volume reduction is greater than mass reduction because heavier components like iron remain after incineration while lighter components such as carbon are released in a gaseous form [1].

Until recently, the fraction of incinerated waste in Finland has increased fairly slowly. In 2004, 236 000 tons of MSW was incinerated. This is only 10% of all MSW produced. For example in Sweden the incinerated amount of MSW per capita is five times larger than in Finland and of European Union countries only Greece incinerates less [16].

There has been plenty of discussion about increasing of the share of incineration in waste treatment in Finland. The reason for this is that European Union landfilling legislation provides that EU-countries should decrease the landfilling of biodegradable waste from the level of 1994 to 35% by the year 2016 [17]. In 1994, 2.1 million tons of biodegradable waste was landfilled in Finland [16]. There are several different operational and legislative tools for reaching the required level of biodegradable waste: 1) Waste prevention and reduction of the total amount of waste 2) Increasing the recycling rate of waste 2) Biological treatment-, composting- and/or 4) Incineration of waste. The main advantages of MSWI are that the process reduces dramatically the volume of waste, simultaneously producing energy [1]. Because in Finland the solid waste management strategy is developing towards incineration of municipal solid wastes, the amount of ashes generated is likely to increase.

An incineration process is not the final waste treatment stage. The remaining problem is the treatment of incineration residues. MSWI bottom ash is a highly inhomogeneous slag material that is difficult to handle [12]. It contains ferrous and non-ferrous metals, ceramics, glass, other non-combustibles and unburned organic matter [6, 8-11]. Heavy metal content and high leaching values are the reason that the incineration residues are recommended to be managed as hazardous waste [8].

MSWI bottom ash is highly contaminated and it is mostly landfilled worldwide. In general, there is large difference in the MSWI ash treatment technologies in different parts of the world, reflecting differences in the level of industrialization, lack of land for landfill, consumption habits, wealth of the country and legislation. For example in densely populated areas such as Germany, the Netherlands and Japan, the MSWI bottom ash treatment and the utilization is preferred over landfilling, provided that unacceptable environmental impacts or health hazards are prevented. Due to the leaching of contaminants, MSWI bottom ash landfilling may also have long-term consequences for the environment. Also, considerable quantities of metallic elements are lost through landfilling of incineration residues [13]. The disposal solutions chosen for these residues should therefore be sustainable in terms of environmental impact and energy and resource consumption. [1, 14, 15, 19, 20]

The recycling of incineration bottom ash is a respectable option for waste minimization and recovery of resources. Using established techniques of mineral processing, it is possible to convert the incineration residues into marketable products, such as metallic materials and possibly secondary construction materials. The metallic materials groups are of particular importance when considering the economic and natural resource cycles.

Figure 1 shows a material cycle from producer to final disposal. Before incineration the metals are recovered at the front stage recycling from MSW. The remaining waste is incinerated and metals are further recovered from the incineration ash. The rest of the incineration waste is used as secondary building material or disposed of to landfills. The recycling rate and reuse of MSW has increased and the volume and the amount of landfilled waste have greatly decreased due to incineration. [18]

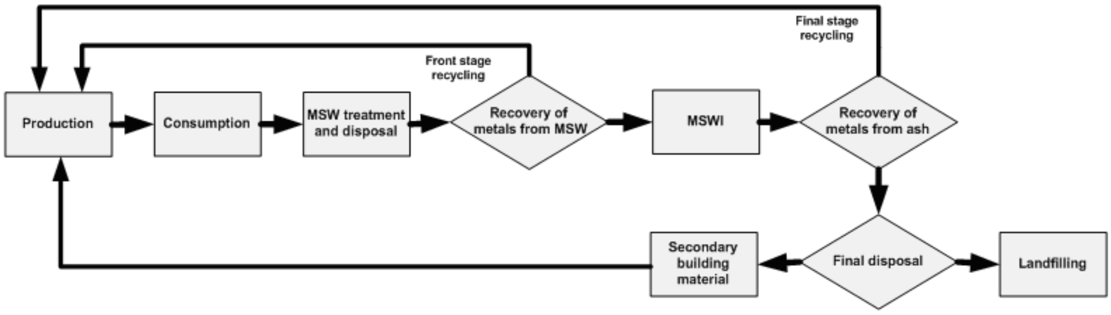


Figure 1-1 *Material flows for consumer goods lifecycle [18], modified*

In order to recycle bottom ash, an effective process with high metal recovery has to be developed and the product quality must comply with strict regulations, such as quality requirements for raw material of metal refining industry, civil-engineering specifications and environmental requirements. If possible, the profits from the marketable products should also compensate at least part of the processing costs. After treatment the metals are used as raw material for metal production. The mineral product of bottom ash can be used for example as an aggregate substitute for asphalt or cement without binder, or it can be used in brick products. It has also been used as filler material in base layers of building foundations and road construction and daily cover substitute material at landfill sites. If the quality requirements for these purposes are not possible to reach, the minimum requirement is that the quality standards for landfilling should be satisfied. [1, 15, 19, 20]

The first part of this thesis is a literature survey of bottom ash characteristics and applicable physical separation methods for bottom ash treatment. In the second part, a bottom ash sample from the MSWI plant of the city of Turku, Finland, is characterized and processed. The overview on the composition and variations of MSWI bottom ash and the factors influencing the bottom ash quality are reviewed in Chapter 2. Different types of physical separation methods are described in Chapter 3 and the established bottom ash processing is reviewed in Chapter 4. Chapter 5 is an introductory section for the experimental part. The characterization of material is described in Chapter 6. The characterization holds an investigation of relevant parameters affecting physical separation of metals from bottom ash. The result of the characterization is discussed in Chapter 7. The characterization study gives the required data needed in the selection of suitable separation techniques for bottom ash processing. The processing is described in Chapter 8 and the process products and their quality are discussed in Chapter 9. Chapter 10 concludes the most important results and findings and gives recommendations for possible future studies.

2 BOTTOM ASH PROPERTIES

Bottom ash bulk properties can be defined by the properties of the particles in bottom ash. Physical separation is based on the differences in these properties of the particles. In order to design and operate physical separation processes for recycling, the essential properties should be understood. An important feature is that all bottom ash particles have their discrete properties and therefore the property of the bulk bottom ash is discontinuous. Properties like size; density, shape, magnetic susceptibility, color and chemical composition are examples of direct physical and chemical properties. The property can also be indirect like degree of liberation or floatability. In addition, a property can be defined in economical or ecological terms, like valuable metal concentration, toxicity or health effects. The bottom ash is extremely inhomogeneous particulate solid, which usually contains larger, compounds of slag and pieces of scrap metals. [21]

2.1 Factors Affecting the Quality of the Bottom Ash

The incinerator bottom ash contains metal objects, glass sinters and small amount of partially burnt material. The composition of bottom ash is mainly determined by the composition of municipal solid waste (MSW) feed, combustion conditions, and the type of incinerator and the air pollution control devises (APCDs) [1, 5, 22]

2.1.1 Municipal Solid Waste, Input Material

Municipal solid waste (MSW) contains paper, plastics, textiles, food wastes, yard wastes and the organic materials as well as inorganic materials such as glass, metal scrap and diverse other consumption and industrial wastes. Almost all of these components contain some quantity of the heavy metals which are categorized as toxic at certain concentrations: lead, cadmium, chromium, mercury, and nickel [23]. The main fraction of incinerated waste is household waste, however various types of industrial waste streams can also be added, depending on the industrial activities in the surrounding area [24]. Figure 2-1 shows the average composition of MSW in Finland.

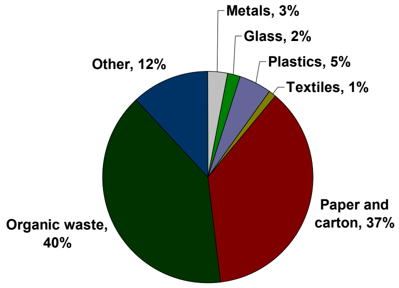


Figure 2-1 *Composition of municipal solid waste in Finland in the 1990's (Finland's environmental administration [25])*

Colored newsprint, plastic house ware, Ni-Cd batteries are sources of cadmium and chromium. Also wood and textiles product might contain chromium. Major sources of mercury are paper, fiberglass and alkaline batteries. Mixed paper plastic film, house wares, wood, textiles, PVC and small appliances contains some lead [23, 26]. Pre-classification of input material results in a reduction of content of some elements. For example the separate collection of small electrical appliances might significantly reduce the amount of incinerated copper [27]. The main origin of Antimony in household waste is flame-proofed products such as curtains, bedding clothes and the plastic covers of home electrical appliances [26, 28].

Waste input has also a great influence on chloride and sulfur and the calcium-silica ratio (Ca-/Si) in bottom ash. The addition of industrial and demolition waste has been found to increase the sulfur content, and the addition of plastic to increase the chlorine content. Selective collection of waste glass for recycling has been found to increase in the Ca/Si ratio. The Ca/Si ratio has been found significantly influencing bottom ash reactivity towards carbon dioxide, higher Ca/Si ratio increasing bottom ashes carbonation potential. [24]

Also the mechanical pretreatment of the waste to be burned effects the metal concentrations. Shredding of the bulky waste for incineration feed has been found to affect the ratio of metal concentration distributed between fly ash and bottom ash. The concentrations of Cd, Pb, Sb, Se and Sn in fly ash, and Cu, Sb and Zn in bottom ash increases while increasing the amount of shredded bulky waste in feed. [13]

2.1.2 Incineration Process

During the combustion process organic compounds are converted to carbon dioxide and water, hydrogen chloride, sulfur dioxide, nitrogen oxides, carbon monoxide and trace organics. The inorganic matter contained in MSW leaves the system as incineration residues [1, 23]. Depending on the incineration conditions, bottom ash may still contain some residual organic matter and unburned particles [24]. The structure of the incinerator and combustion parameters like temperature and air distribution in combustion different points of combustion process, and the physical and chemical form of MSW particles containing the metals are the main factors influencing the quality of burnt waste [1, 23]. Generally, the facilities with higher combustion temperatures and longer combustion times has been found to have more melt products in the MSW residue. [4]

Many types of grates and combustion chambers have been designed and developed. Subject to the incineration process the residence time of bottom ash varies from 30 up till 45 minutes on the grate of the furnace. During this period of time the temperature of the waste fraction goes from 25°C to 1500°C and back to 300°C when is cooled in a wet quench. During this incineration process with complex conditions of combustion, the bottom ash is formed by melting and crystallization [4].

The burning conditions are among the factors which determine the partitioning of heavy metals to the bottom ash and fly ash during combustion of MSW [1, 23]. For instance the leaching value of copper in the bottom ash has been found to be significantly reduced by incineration with proper dosage of oxygen [1, 29]. The optimal amount of oxygen increases the temperature and leads to decreased amount of unburned organic material. Some metals have higher transfer rates to the fly ash as the furnace temperature increases [13].

The quality of the bottom ash can also be controlled by screening out the coarse fraction (+40mm) which contains unburned material. After removing the ferrous and nonferrous metals the remaining unburned material is fed back to the incineration. This is an established practice in the Netherlands [1].

2.1.3 Post Treatment of Bottom Ash

Because of a rapid cooling after incineration, the bottom ash is thermodynamically unstable and fresh bottom ash has a high reactivity, mainly because of high contents of amorphous and highly reactive silica and lime [6]. The bottom ash is often stored for a couple of months before it is disposed or reused [6]. During storage, several reactions for example hydration-, carbonation-, reactions of iron and aluminum and weathering of glass phases take place [1, 24, 29-31]. Because of these reactions the mineralogical characteristics will change and the leaching values of bottom ash will decrease after a period of weathering. The factors influencing to the ageing process are temperature, moisture content, amount of oxygen and carbon dioxide, gas flow rate and the residence time [1].

2.2 Physical Properties

Properties like size; density, shape, magnetic susceptibility, color and chemical composition are examples of direct physical and chemical properties. The property can also be indirect like degree of liberation. [21]

2.2.1 Particle Size Distribution

Bottom ash particles are distributed over a range of sizes. The particle size distribution is important because many processes, such as metals recovery, depend very much on the particle size. Figure 2-2 shows the cumulative particle size distribution of bottom ash from different literature sources and the values attained from this study. The values are shown in Appendix I and in section 7.2. The graph shows that up to 40% of bottom ash by weight is smaller than 2mm and up till 80% by weight is smaller than 10mm. The graph also shows that the particle size distribution is somewhat similar, regardless the location of the MSWI plant.

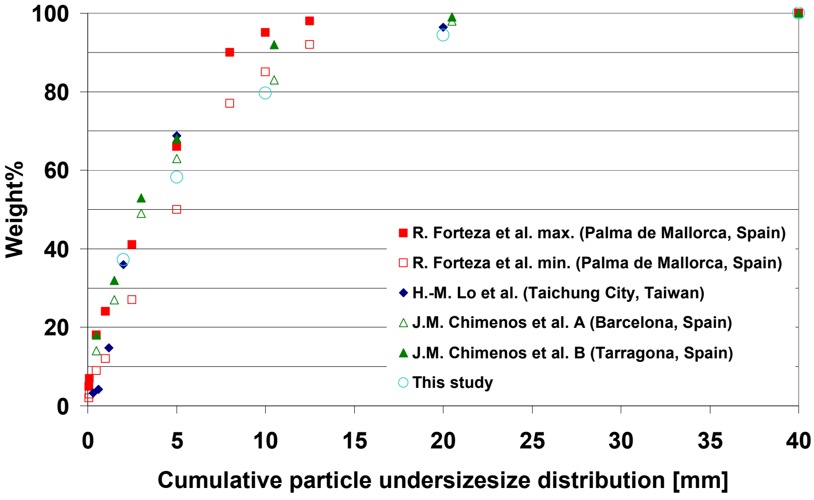


Figure 2-2 *Cumulative particle undersize distributions of bottom ash [9, 32, 33]*

2.2.2 Particle Shape

Fragments of waste stream glass, ceramics and non-fused metal are angular with sharp, well-defined grain boundaries [10]. Metal particles with a grain size of less than 12mm are predominantly solidified in spherical particles. In the coarser classes, however, long, as well as some cases flat, metallic parts are often found. These are frequently wires, wire mesh, pipings, cutlery etc., whose edges heave partially melted and re-solidified into rounder shapes [34]. The shape coefficients (Feret) of bottom ash is widely dispersed with values between 0.03 and 0.72, the most of the bottom ash particles having shape coefficient lower than 0.3, a 5mm bottom ash particle having a shape coefficient of 0.3 and 30mm particle shape coefficient of 0.15 [32]. For instance a perfect spherical particle has an shape coefficient of 1, a aluminum flake 0.1 and a thin and long copper wire 0.01.

2.2.3 Specific Gravity and Bulk Density

Bottom ash is very porous lightweight aggregate with high specific surface areas. It has dry bulk density approximately of 950kg/m^3, density around 1520kg/m^3 (1500-2000kg/m^3 for fine fraction (<100mm) and 1800-2400kg/m^3 for coarse fraction (>100mm)) [8, 35]. A common feature for all particles are gas bubbles, most likely formed during boiling of the melt products. Bubbles comprise between 10-25% of the volume of the particles, therefore providing for a significant measure of particle porosity. [10]

2.2.4 Moisture Content

In modern MSWI-plants, the water content of produced bottom ash ranges from 15% to 25% because of the quenching. This moisture content is important factor for dust control and has an major effect on the physical processing of bottom ash. [8]

2.3 Chemical Composition

Bottom ash is a heterogeneous mixture of slag, silicates, alkaline and alkaline earth compounds, chlorides, sulfates, ferrous and non-ferrous metals and their compound and unburned organics. Non-incinerated material is 1-5 w% of bottom ash. [1, 8, 11]

As a result of a rapid cooling process, vitreous material is formed. The main chemical contents of bottom ash are oxides of silicon and aluminum. Such composition makes it possible to reuse the bottom ash as a secondary building material because of its high reactivity. However its chloride, sulphates and oxides of alkali and heavy metal components can cause environmental problems. [1]

The heavy metals can be classified according to their degree of volatility. During incineration process the elements with high boiling temperature remain in the bottom ash, while more volatile elements with low boiling temperature are end up in the air pollution control residues [5, 23]. During the incineration Fe, Cu, Cr, and Al and Si remain mainly in bottom ash. Iron and aluminum are mostly fed to incinerators in metallic form and their oxides are very stable and no volatilization occurs during incineration of MSW. The behavior of copper on incineration of MSW is similar to that of iron. Also Cr compounds are not considered thermally mobile during incineration and therefore they remain mainly in bottom ash [23]. Mg and Al have the same tendency [5]. Ni, a less volatile heavy metal, is more concentrated in the bottom ashes. However, two thirds of Pb, Zn and As remains in bottom ash despite their high volatility. [5, 13, 35-37].

The elements present in a proportion higher than 1% in the ash are: Si, Fe, Ca, Al, Na, C and O, which is the most predominant element (ca. 40%). Approximately 80-90% by weight of the bottom ash consists of these Major elements. Many of the elements are present as oxides and O is therefore also a major element for all the residues. Minor constituents (0.1-1 %) include Ti, Cl, Mn, Ba, Cu, Mg, K, Zn, Cr, Pb, Mn and Ni. Some of the minor elements and many of the trace elements (e.g., Pb, Cu, Fn, Cd and Hg) are enriched in the bottom ash [8]. Trace constituents (<0.1%) contains up to 31 elements. In the bottom ash there is also variable amount of unburned materials. The low percentage of unburned material indicates good combustion at the temperature and remaining time inside the furnace [8, 10, 14, 33, 36]. The maximum and minimum values of chemical composition of bottom ash are shown in Appendix I.

Various metal particles are found in the ash, such as small pieces of pure iron or bronze. The scrap metal (7-10w-%) consists of non-ferrous and ferrous metals, such as tin plate, aluminum, copper, brass. The thermal conditions during waste incineration lead to a complete or partial melting and even to an oxidation of metal components. Contact between the melted pieces of scrap and other components results in the formation of new minerals with low degree of liberation [11]. The proportion of ferrous metals in coarse fractions is the majority of the total ferrous metals. Only a very small percent of ferrous metals is in fine fractions (<10mm) [1]. For steel scrap, because of the water cooling system applied, steel suffers a top-layer degradation process which gives rise to a corrosion product layer that fully covers the steel [40]. Ferrous metals accounts from 4w% to 15w% of the bottom ash [8]. The non-ferrous metals however are mainly present in the fine fractions (<10mm). Also, the smaller the particle size, the higher is the heavy metal content [41]. The non-ferrous metals, such as Al, Cu, Pb, Sn and Zn, account for 0.2% to 2% of bottom ash by weight [1, 15, 26, 34].

Some of the elements in bottom ash for instances Ba, Cu, Mo, Sb, Br, F, SO_4 cause environmental problems because of high leaching values; others for example Al and Cu-Zn-alloys may cause technical problems when reusing the bottom ash as a secondary raw building material because they may cause a reduction in mechanical properties and durability of products. [1].

2.4 Leaching Properties

The leaching of contaminants is an important property when using bottom ash as raw material for construction. Table 2-1 shows the range leaching on some harmful elements on Danish MSWI bottom ash (used liquid/solid ratio: 0.5 l/kg). MSWI bottom ash is in the special category because some elements have too high leaching values, like Cl, Na and sulfate as well as the heavy metals Cu, Cr, As, Ni, Cd and Pb, which are especially critical. [15]

Table 2-1 *Concentration levels of contaminants in leachates from MSWI bottom ash [14]*

Typical maximum levels of concentration in leachate	MSWI bottom ash
>100 000 mg/l	
10 000-100 000 mg/l	
1 000-10 000 mg/l	SO_4^{2-}, Cl^-, Na, K, Ca
100-1000mg/l	NVOC, NH_4-N
10-100mg/l	
1-10 mg/l	Cu, Mo, Pb
0.1-1 mg/l	Mn, Zn
0.01-0.1mg/l	As, Cd, Ni, Se
0.001-0.01 mg/l	Cr, Hg, Sn

Worldwide, leaching of heavy metals such as Cu, Pb, and Zn is reported to exceed the local limit values substantially [20]. Because of its hazardous elements leaching, the use of bottom ash is still under control. The fine fractions also contain small amount of organic residues and as small particles have a larger specific surface area, these particles may be responsible for a considerable fraction of heavy metal and salt release For instance leaching value of Cu is high because organic matter forms complex compounds with Cu [1]. Bottom ash pH values ranges from 10.65 to 12.3 [24].

2.5 Liberation of the Bottom Ash Particles

Liberation of particles is an important property for material recycling. The liberation degree describes to which extent the valuable materials are apart from the contaminants. Few examples of liberation are shown in Figure 2-3.

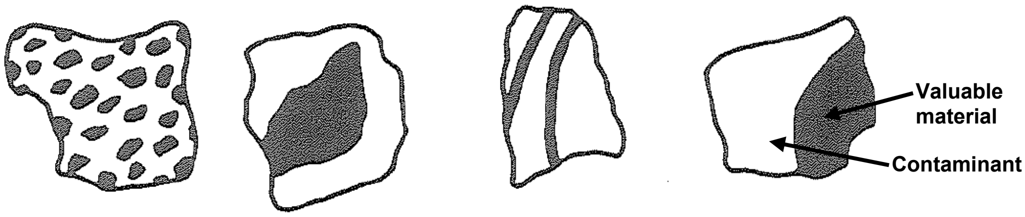


Figure 2-3 *Examples of liberation of particles [49]*

The most usual type of non-liberated particles in bottom ash is agglomerates that are glued together by molten metals and glass. In general 85% of the bottom ash is composed of melt products [4]. In many cases, metal fragments are partially melted and surrounded by opaque glass. Small peaces of unmolten glass are also present [10]. Another type of typical non-liberation, especially for recycling materials, is mechanic attachment (e.g. steel screw attached to plate of aluminum).

In a study which was made for bottom ash of two Korean stoker-furnace type MSWI plants, iron containing particles are most abundant (47-63%), followed by CaCO3-containing (10-17%), carbonaceous (14-17%), and Si and/or Al oxide-containing particles(6-15%) [42]. Complex oxides are extremely Fe rich with varying proportions of Al, Ti and in some cases Cr.[4]

3 PHYSICAL SEPARATION

Based on the materials properties distribution within the material bulk, a separation application is chosen which is suitable for separating the valuable materials from non-valuables. In physical separation processes materials are separated due to their different properties. In practice separation processes exploits several material properties at a time. An example is an eddy current separator, where separation is based on the electromagnetic properties of particles, but in reality also particle size has a great effect on the separation performance. Any physical separation processes are based on particles movement and so particle size has an effect on the performance of any physicals separation methods. The bulk material consists of particles with property distribution and property value distribution; there are no particles alike within the bulk. The valuable and non-valuable materials may also have overlapping properties such as particle size and density. All this effects the separability of the wanted element and determines what type of separation is possible under ideal conditions. This makes physical process design very challenging. [21, 43]

In general, recovery of the valuable components from the feed consists of liberation, classification and separation. There are several different types of mechanical separation techniques frequently applied in mining and recycling industry. First the valuable materials are liberated by size reduction, after which the particles are classified by size. Then valuable materials separation are separated from non-valuable by gravity concentration, magnetic separation, electrostatic separation, flotation, or by color separation. [1, 22, 44].

There are three major groups of variables that affect the outcome of physical separation in recycling. The first group is related to the material properties. These material properties effect to the operation parameters (group 2). These two together determine the separation efficiency. The third group affecting separation is economical. Any separation should have a target product quality based on economical performance. All these aspects combine and affect the overall performance of the separation process. [21, 43]

Material properties and chosen separator process gives the limits for the separation efficiency. Some valuable materials are lost to the tailings and some non-valuables may be misplaced in concentrate. These inefficiencies cannot be avoided. However it is possible to minimize the inefficiencies. The result of the separability and separation efficiency is expressed in grade, the mass of valuable material in the product, divided by the total mass of the product, and in recovery the mass of valuable material in the product, divided by the total mass of valuable material in the feed. Finding the optimum grade and recovery of the total valuable components against the lowest possible processing costs is one of the tasks of separation technologies [21, 43, 44].

Fines recovery is essentially less efficient than the recovery of coarser material. Thus, the processing costs increases strongly with decreasing particle size. This is caused by capacity limitations of a number of separation techniques crucial for recycling, which demand a monolayer for efficient separation for example, magnetic separation. Most know processes, have a minimum particle size which can be effectively recovered. [44, 46] The applied size ranges for common physical separation methods are shown in Appendix II.

Figure 3-1 shows the general selection of processing routes and operation design for different sized materials in recycling industry. Smaller particles usually need a different separation treatment than large particles. In processing of relatively large (>4mm) particles, the following techniques are applied: manual sorting based on visually observed properties, separating ferrous particles by magnetic separation, separating nonmagnetic metal particles by eddy current separation and separating different materials by density separation methods. For particle sizes smaller than 4mm the principles are the same, but used separation devices are different; magnetic and nonmagnetic metals separation and density separation applications are designed especially for treatment of small particle sizes. In addition there are some additional treatment methods for liquid removal such as for example hydrocyclones and sedimentation, separation of organics by using flotation and separating the soluble materials by washing. [45]

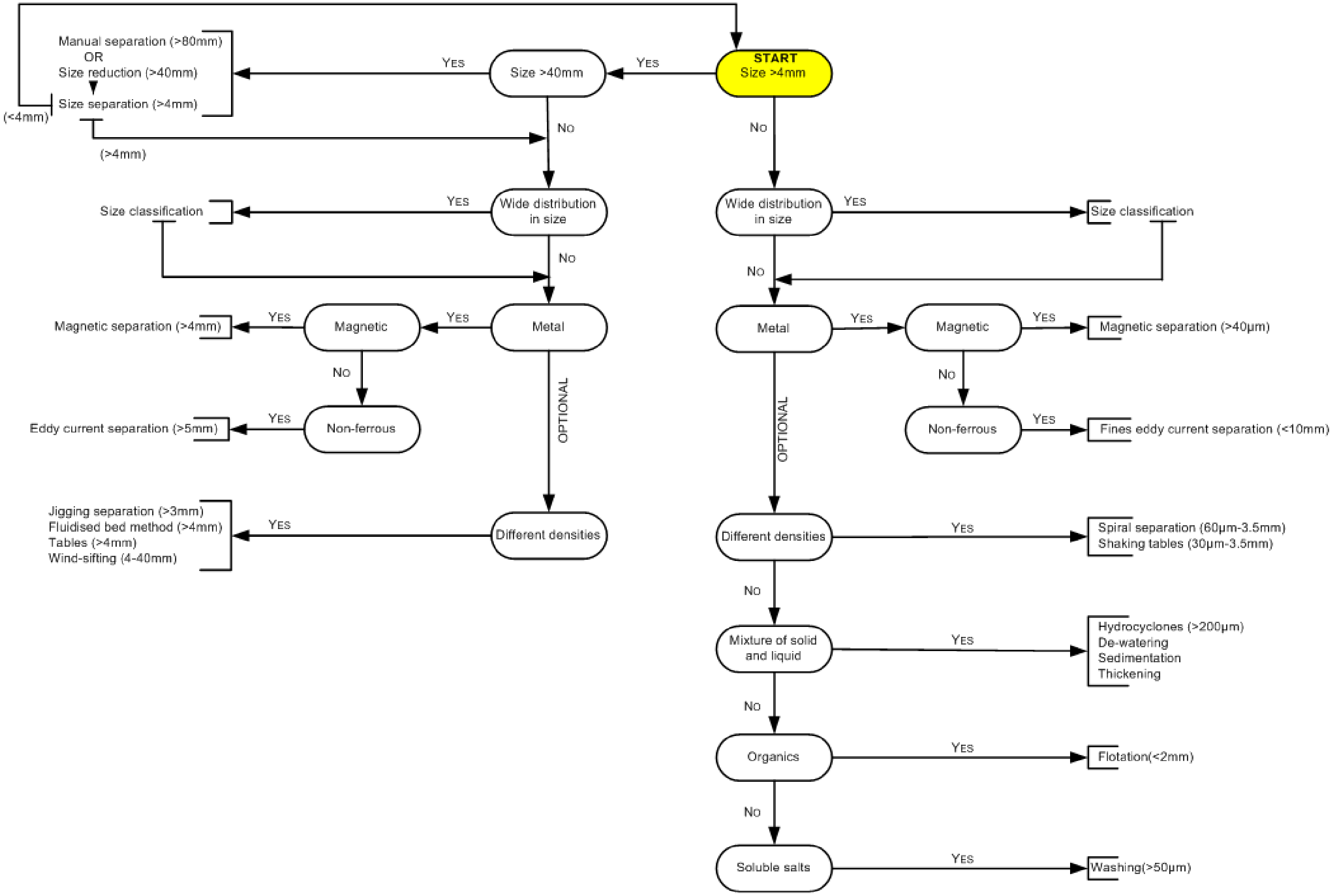


Figure 3-1 *Processing routes for different sized granulate materials (modified from [1])*

3.1 Physical Separation Methods

In this chapter the most commonly used physical processing methods and the parameters effecting the separation are reviewed. These are size reduction, size classification, separation methods based on magnetic and electric properties and separation based on density. In addition, there is an example of physical separation method described in more detail in each category. The described applications are applied in the experimental part of this thesis.

3.1.1 Size Reduction

The goal of size reduction (comminution) is to reach wanted particle size, shape and liberation of valuable and hazardous components. The other goals for size reduction are increasing the surface area available for chemical reaction or production of material with desired treatment-, use-, or storage properties [47]. In recycling technology size reduction is often the second step in the chain of concentration of metals and other materials after disassembly, demolition and collection. [48, 49]

Particle breakage is achieved by the application of force. There are different ways in which forces can be applied to the material, this determines the comminution device and the produced particles size ranges. One type of comminution is where the forces are applied through rigid surfaces or by impact against surfaces moving a certain constrained path. This type of comminution device is called a crusher. The forces can also be delivered through the free motion of unconnected media (rods, balls, or pebbles) within a comminution vessel. This type of device is called a mill and the operation is called grinding and milling . The method used for size reduction depends on the wanted particle size. Crushing is appropriate when material larger than about 10mm is required. If the particles must be smaller than 1mm, grinding is usually used. [43, 47, 49]

The largest faction of bottom ash, such as many non-metallic secondary raw materials are brittle. These materials are preferably fragmentized by impact or pressure. Jaw, impact, and roll crushers are the most frequently used devices. There are also ductile metal particles in the bottom ash. Often, the particle size of brittle components is several times smaller than ductile components, which makes metals separation by screening possible. If the particle size difference between the ductile metal particles and the brittle components is not sufficient, the material can be selectively crushed before screening separation. For ductile materials cutting and shearing are the main size reduction mechanisms [43, 48].

3.1.2 Screening

Separation and cleansing techniques work in different size ranges. Industrial screening is used for sizes from 300mm down to around 40µm, though efficiency decreases rapidly when particle size becomes smaller [47]. In order to remove contaminants from MSWI bottom ash effectively, the ash should be wet screened into several fractions. Most separation processes would perform optimally with uniformly sized feed. As this is virtually never the case in practice, it is important to limit at least the size range of the material [48].

Screening is defined as the separation of a particle population in two or more size fractions screen. If a perfect separation could be achieved, all the particles larger than the screen size, would report as an oversize product. However, the result of screening is never perfect; some oversize product contains undersize particles, and the undersize still some coarse material since mesh openings may vary or are damaged. The extent to which particles are misplaced to the wrong product stream is an indication of the inefficiency separation. [43, 48, 49]

In recycling industry screening is carried out for numerous reasons, depending on the application: splitting in several size classes, to ensure that the size of particles is in the optimum range for efficient processing; separation of materials (ductile and brittle materials, such as glass and metal, or organic fraction from mixed household waste); to ensure that a material particle size distribution is corresponds the market demand; undersize removal before crushing; recovery of Heavy Medium Separation (HMS) solids; desliming (removing particles below 0.5mm) and dewatering [47, 48]

Large number of variables such as material properties, screening method and parameters affect screening efficiency. The material properties effecting the screening result are particle shape, bulk density, moisture content, electrostatic charge, percentage of size fraction near the screen size. Near screen size material may cause blinding of the screen. The screening parameters effecting the efficiency are screen movement, screen angle, screen size and loading. [43, 47, 48]

Phenomena, what often effects the screening efficiency is that of very fine particles adhere to larger particles or to each other as a result of electrostatic attraction or surface tension arising from small amounts of moisture. The first case is true for bottom ash if it is dried and the latter goes to the bottom ash straight from the incineration process. The best solution for this problem is initial wet screening. [49]

Completely dry or completely wet materials are relatively easy to screen. The finer the size the less moisture is tolerated without disturbing screening process and some materials such as clays have very low moisture tolerance. In screening damp materials like bottom ash, the efficiency of screening is severely affected by moisture bridges between particles, leading to agglomeration. This causes blinding and excessive adherence of fines to oversize. In general, large variety in properties of the particles in bottom ash makes screening more sensitive for blinding [44]. At certain moisture percentage (around 4%-10%) the point with "maximum stickiness" has been reached. Drying or wet screening can be used to decrease the stickiness. Drying has the disadvantage of being expensive, possible dust problems, and possibility of cementing particles together. Wet screening has the advantage that it encourages the passage of small particles. Also after wet screening, a drying step may be needed, depending on the process design. [48, 49]

3.1.2.1 Circular Motion Screen

Circular motion screens are vibratory screens that vibrate about its center of mass. An example of circular motion screen is shown in Figure 3-2. The screen has a motion generator situated on the centre of gravity of the screen. The drive consists of a single or double eccentric mass force wheels and it can rotate clockwise or anti-clockwise depending on the required retention time. The advantage of circular motion is the self cleaning effect: a particle stuck into mesh experiences forces in all directions promoting its loosening. The transport velocity depends on the inclination of the screen (usually 12˚-25˚). Also ball trays and ultrasonic devices may be fitted below the screen surfaces to reduce blinding. [47, 48]

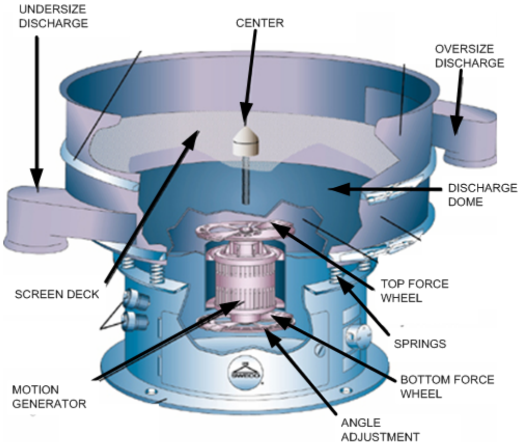


Figure 3-2 *Circular motion screen design (Sweco) [50]*

3.1.3 Separation Based on Density

Gravity concentration methods separates the particles from each other based on their relative density. In a density separator the feed material is split into fractions of lower and of higher density. Often in these methods the separation is influenced also by particle size and shape.

The principles of gravity concentration can be applied in many ways and several types of separation methods are available. These are for example sink float separation in medium, separation in air, separation in particle bed and separation in a thin film of flowing water. These separation methods can be divided into two groups: relative and absolute separators. A relative separator splits the feed into a part of higher density and lower density. Here the cut density will depend on the feed. An absolute separator has a fixed cut density determined by constant density of medium. [43, 47, 48]

In sink-float separation methods the material is immersed in a fluid that has a determined density between material particles wanted to separate. The particles with higher density than the medium will float and the particles with lower density will sink. This technique provides the most precise separation that can be achieved by gravity-separation techniques. Sink float can be performed in water or another liquid with higher density, in a suspension of water and solid material (heavy medium separation) or in a suspension of air and a solid material (dry fluidized bed). [43, 47, 48]

The separation in particle bed is carried out in a fluid that has a density lower than any of the particles present in the particle bulk. All the particles sink through the fluid until they the bottom level or the particle bed on it, the heavier particles forming a layer at the bottom of the bed. When the bed is split by a plane of stratification, two or more products containing particles of different densities are formed. The settling rate of the particles is also influenced by the size and shape of the particles. Example of this type of separation is jig separator [43, 47]

In separation in a thin film of flowing water, the particles settle on an inclined surface with a thin film of flowing water on top. Particles with different densities move in different directions and this way can be separated. Examples of this type of separation are shaking table and spirals separators. [43, 47]

In separation in air, separation is achieved in air instead of fluid. This type of process is called pneumatic gravity concentration. An example of this type of separation is a pneumatic shaking table. [43]

In recycling the separation of a mixture based by density is important. It is applied for the separation of: light (Al, Mg) and heavy non-ferrous metals (Cu, brass, Zn, Pb, stainless steel) from metals mixture; separation of aluminum and magnesium from each other; separation of metals from non-metals; separation of combustible from incombustible non-metals; cleaning and separation of polymers; concentration of bio-organic waste; removal of non-organics from organics; and cleaning of contaminated sands. [48].

3.1.3.1 Pneumatic Shaking Table

Pneumatic shaking table (Figure 3-3) is similar to wet shaking table but it does not use medium. The feed size is usually from 2 to 20mm. For the best operation, the size distribution should be narrow, like in any density separation methods. Top feed size should not exceed two times the minimum feed size. The material is spread out in a few centimeters thick bed on a flat, inclined, porous surface. The feed should be ideally optimized so that the particle layer is spread all over the table with same thickness. Air is blown vertically through the bed from below of the surface and the surface is shaking. The amplitude of shaking, the amount of air and the inclination of the table can be adjusted. Shaking and airflow cause the segregation of the bed, so that heavier particles are located in lower layers. The particles movement on the table depends on their shape, size and density. From products right to left (see Figure 3-3) particles have the following order: 1) fine heavies (concentrate and product 2), 2) coarse heavies and fine lights (product 3 and 4) 3) coarse lights (tailings 1 and tailings 2). [43, 44, 47, 48]

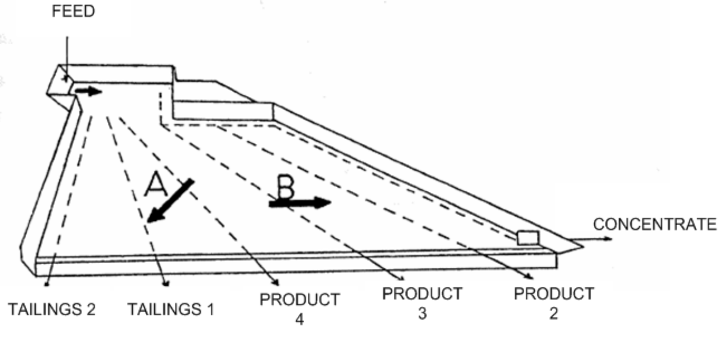


Figure 3-3 *Working principle of pneumatic shaking table. A shows the direction of inclination and B the direction of shaking movement[51]*

3.1.4 Magnetic Separation

The operational principle of a magnetic separator is based on the magnetic properties of treated materials and of the magnetic field. The property of a material that determines its response to a magnetic field is the magnetic susceptibility. The magnetic force is directly related to magnetic susceptibility of material. Materials can be divided into two groups based on their magnetic susceptibility: paramagnetic materials which are attracted by a magnetic field and diamagnetic materials which are repelled by the magnetic field [49].

There are two categories of magnetic separation equipment: low intensity and high intensity magnetic separators. The low intensity magnetic separators are being used mainly for ferromagnetic minerals e.g. for recovery of ferrous scrap in recycling industry. The high intensity magnetic separators are used for minerals with lower magnetic susceptibility. Both, low and high intensity magnetic separators can be carried out either wet or dry. There are also two types of magnets: permanent or the electromagnetic. The advantage of permanent magnets is that they do not require energy to produce the magnetic field unlike electromagnets. Electromagnets are typically applied when extremely high field strength is needed . [43, 48, 49]

In recycling four main types of magnetic separators are frequently used for the separation of ferrous metals; cross belt, line belt, pulley and drum separators. Magnetic separators are also applied for recovery ferrous, steel cans or tramp iron from solid waste in recycling industries as well as for bottom ash treatment to recover ferrous metals from the ash. [48]

3.1.4.1 Magnetic Roll Separator

Low intensity magnetic separator (Figure 3-4) in which the feed is separated to magnetic and nonmagnetic particles by stationary magnets inside the rotating drum. The rotating drum moves the conveyor belt. The magnetic metals are dragged with the conveyor belt until they are out of reach from the magnets and are thrown into magnetic product [43]. The non-magnetic particles are thrown to nonmagnetic product by centrifugal force. The possible parameters to optimize the performance are the feed rate, belt speed, the position of magnets and the splitter position

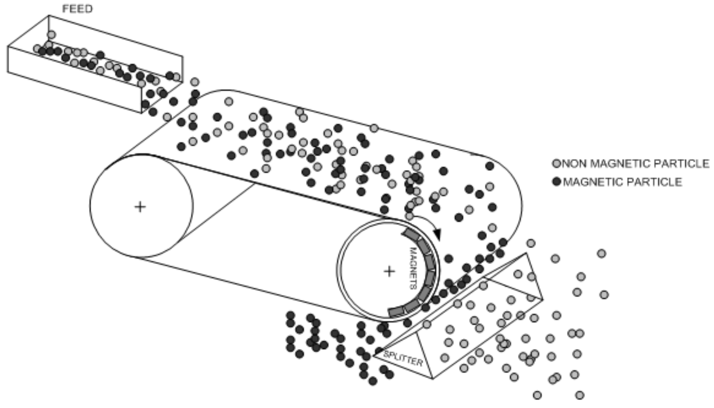


Figure 3-4 *Working principle of magnetic roll separator*

3.1.5 Eddy Current Separation

Eddy current separation is an effective way to recover non-ferrous metals from non-metallic materials after the ferrous metals have been removed. Eddy current separators are widely used in recycling industry, lately also for bottom ash treatment for concentrating non-ferrous metals from mixture and for the separation of different non-ferrous metals from each other.

The working principle of eddy current separator is shown in Figure 3-5. When metal particle is entering to an alternating magnetic field caused by a fast spinning magnet rotor, eddy currents are generated inside the particle that opposes the field applied. The metal particle will be accelerated and deflected by the magnetic field. The resulting force depends on the strength of the magnets and the conductivity of the particle. Eddy currents will be generated inside the metal as long as it is in this field. [48, 52, 53]

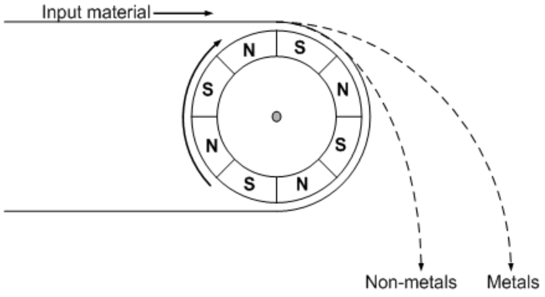


Figure 3-5 *Working principle of eddy current separation*

The magnitude of the resulting force depends on several material parameters: mass of the particle, particles electrical conductivity, density of the particle, particle shape. Also operational parameters such as magnet intensity and velocity of the particles relative to the magnets have great effect to the separation efficiency. The conductivity/density relationsihip difference between different materials is what makes the separation possible. This relationship for aluminum is the highest (14M^2/Ωkg) and is zero for nonmetals. [48] Other factors that effects the particle movement are the friction and the elasticity of the particle-belt contact, the initial orientation of the particle in relation to its irregular shape and particle-particle interaction. [53].

Figure 3-6a shows the deflection of metal particles as function of particle size and Figure 3-6b how particles deflection depends on the shape of the particle. As shown in Figure 3-6a, for larger than 10mm particles, an adequate difference between deflection for different metals can be reached. The diagram also shows the conductivity/density relationship for aluminum is highest as it's deflection is longest and goes down to lead which has the shortest deflection of all metals except stainless steel which goes even lower. Figure 3-6b shows that spherical particles have the shortest deflection and particles with plate shape is ideal for generating magnetic field inside the particle, which also poses the longest deflection. [55]

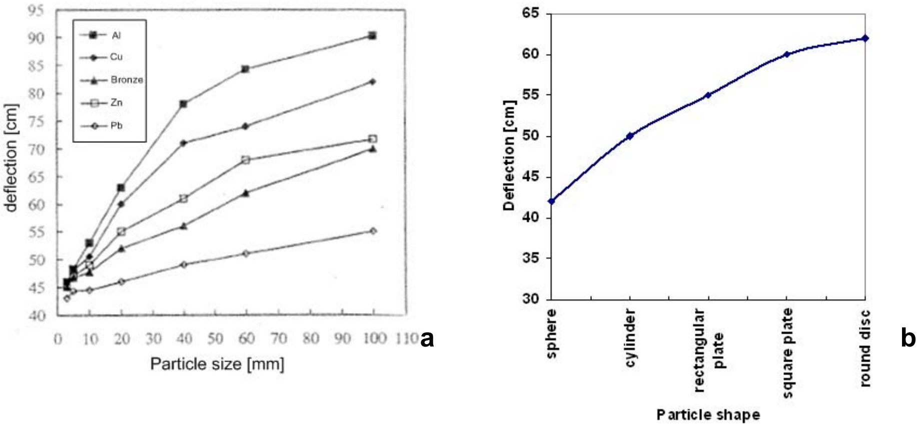


Figure 3-6 *a) Deflection as a function of particle size b) Dependence of particle deflection on various particle shapes [55]*

In eddy current separation process, the material is fed as a monolayer on the conveyor belt in order to avoid nonferrous particles lying on top of other particles. The reason is that if the particles are placed on multiple layers on top of the conveyor belt, the active zone of the magnetic field of the top layers of the feed may be out of reach of the magnets. Particles in feed interact with each other because the rotor accelerates the nonferrous particles with respect to remaining particles, which are simply moving with the same velocity as the conveyer belt [53]

The optimum grade and recovery is possible to reach with favorable combination of feed rate, rotor speed, and particle liberation and size distribution and by selecting a splitter position just beyond the trajectories of the nonmetals. [53]

There has been a pilot plant test made fro treatment of 116tons of bottom ash in Delft University of Technology, The Netherlands. The test showed that with eddy current separator it was possible to recover 1.25tons of nonferrous metals from size fraction >10mm with 91% grade with almost 100% recovery. [1]

3.1.5.1 Eddy Current Separation for Fine Particles

The traditional eddy current technique only works economically on coarse particles (>5mm). This is problem for bottom ash processing because more than half of the mass is fines (<10mm).

There are two new separation techniques; magnus separator and wet eddy current separator especially designed for removing non-ferrous metals from smaller than 10mm sized material mixture.

Magnus Separator

Magnus separation is a new type of eddy current separator discovered by the Department of Applied Earth Sciences In Delft University of Technology. It can remove fine non-ferrous metals particles from 500microns to 10 mm [56]. The capacity of the Magnus separator is 6 tons/(hour x m width) with estimated cost of 0.8 Euro/ton [1].

The operation principle of magnus separator is shown in Figure 3-7. There is a rotating magnet in the magnus separator like in eddy current separator. The rotor creates a selective rotation of metal particles of feed by a magnetic coupling between the eddy currents induced in the metal and the rotating magnetic field. A spinning particle while moving through fluid experiences a force perpendicular both to its direction of motion and to axis of rotation [56]. This phenomena is called a magnus effect. The metal particles are deflected because of Magnus effect [1].

There has been laboratory tests made in Delft University of Technology for treating 1-10mm fraction of bottom ash. Also the pilot plant experiment for 116tons of bottom ash mentioned earlier included magnus separation for removing nonferrous metals from fraction smaller than 10mm. In a pilot plant test with magnus separator 0.18 tons of nonferrous metals were recovered, however with poor grade and recovery. The result of laboratory tests was that the leaching values of several environmentally hazardous elements (e.g Cu, Ni, Pb and Mo) have been reduced due to the Magnus separation. [1]

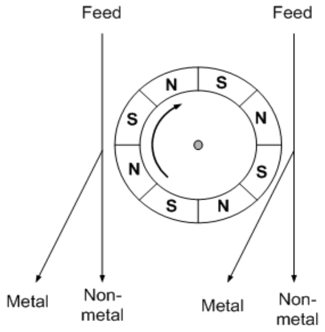


Figure 3-7 *Operation principle of magnus separation*

When separating fine aluminum particles from nonmetallic particles, magnus separator has higher grade and recovery for 4-6mm particles sized than for 2-4mm particles. [54]

Wet Eddy Current Separator

The idea behind the wet eddy current separator is to glue the particles to the conveyor belt surface. Typically for smaller than 5mm particles this adhesive force is approximately as strong as the gravity force. The rotating magnetic field spins the conductive particles this makes the water bonds between the belt and these conductive particles to break. The result is that metals are separated from nonmetals, which are dragged along the belt until they are mechanically removed. [54]

For wet eddy current separation minimum15% of moisture content is needed for effective water layer formation. Wet eddy current separation grade is better for 2-4mm particles than for 4-6mm particles, because the gravity force increases while the particle size gets larger. [54]

When comparing the magnus separator and wet eddy current separator for separating fine aluminum particles from nonmetallic particles, better separation results with better grade and recovery can be achieved with wet eddy current separator. [54]

4 BOTTOM ASH PROCESSING

Bottom ash is typically disposed of in specially engineered landfills, or after treatment used in construction applications, such as road base and in concrete [7].

Bottom ash contains variable concentrations of ferrous and non ferrous metals. Such metals can be separated by physical separation methods from the ash and used as raw material in metal refining industry. Removal of ferrous and non-ferrous metals also produces a better quality bottom ash.

The common techniques used in recycling industry are size separation, density separation, magnetic separation and eddy current separation. Magnetic separation has been used for recovery of ferrous metals from bottom ash for a long time already, recently also eddy current separation has been applied in bottom ash processing for recovery of non-ferrous metals. [1, 33, 45]

Bottom ash is a complicated mixture of granulate material mixed with heavy metals, organic and soluble salts. Also the bottom ash quality varies between countries and different incineration plants. The way that pollutants are physically or chemically bonded in waste materials is not known well enough. In addition there is not enough information about the environmental or technical quality of generated product. Also, starting up a treatment plant is very costly, while economical benefits are low or unknown. Therefore selecting suitable treatment technique is not easy due to the uncertainties in techniques and process feed materials. [1]

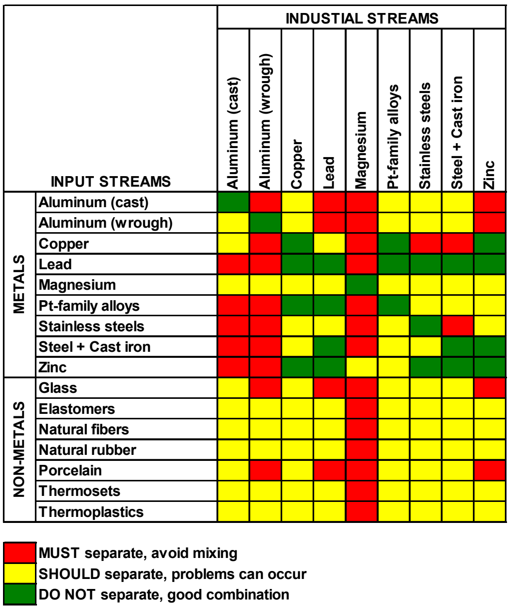
4.1 Targets

The primary objective is the maximum possible yield or recovery of those recoverable materials with good sales prospect, i.e. the ferrous and non-ferrous metals, at the same time meeting their quality requirements. Depending on the legal requirements of the end use of recycled materials, the products also need to meet certain environmental quality criteria. [1, 11, 18]

Physical processing generates four different material groups: 1) Ferrous metal product, 2) Non-ferrous metal product, 3) Mineral residue e.g. glass, ceramic, porcelain, (so called granulate material), and 4) Wastewater if the process is wet. [11]

The quality standards for the metal product are appointed by the producer and buyer. The value of the product is based on the metal content and on the world market price. For the nonferrous metal product, if the product contains excessive quantity of impurities, the price paid is reduced by the cost of separation of the impurities and disposal of these materials. In addition to aiming for the maximum possible nonferrous metals yield, measurements must also be implemented to ensure acceptable purity of the product. [11]

Figure 4-1 shows the material grouping in metal production. Red color shows the material combinations which materials must be separated from industrial metal streams before the material can be used as feed material for industrial metal production processes. Yellow color shows the material combinations which should be separated and green materials which should not be separated, because it is a good combination, e.g. usual alloying material for that particular metal. According to Figure 4-1, Aluminum and magnesium are very sensitive metals for impurities. Magnesium tolerates nothing else but zinc, which certain extent also might cause problems. Also wrough and cast aluminum should be separated from each other. Cu, Pb, Zn and Pt-family alloys do not need to be separated from each other, except in the case of Pt-family metals production, where Zn must be separated. For steel, cast iron and stainless steel production copper is a harmful element. Steel and cast iron requires stainless steel removal. Porcelain and glass are harmful for wrought aluminum, lead and zinc production. Generally speaking the nonmetals should be separated from metals in any case, because they might cause problems in metals production. [57]



		INDUSTIAL STREAMS								
	INPUT STREAMS	Aluminum (cast)	Aluminum (wrough)	Copper	Lead	Magnesium	Pt-family alloys	Stainless steels	Steel + Cast iron	Zinc
METALS	Aluminum (cast)	🟩	🟥	🟨	🟥	🟥	🟨	🟨	🟨	🟥
	Aluminum (wrough)	🟨	🟩	🟨	🟥	🟥	🟨	🟨	🟨	🟥
	Copper	🟨	🟥	🟩	🟨	🟥	🟩	🟥	🟥	🟩
	Lead	🟥	🟥	🟩	🟩	🟥	🟩	🟩	🟩	🟩
	Magnesium	🟨	🟨	🟨	🟨	🟩	🟨	🟨	🟨	🟨
	Pt-family alloys	🟥	🟥	🟩	🟩	🟥	🟩	🟨	🟨	🟨
	Stainless steels	🟥	🟥	🟨	🟨	🟥	🟨	🟩	🟥	🟨
	Steel + Cast iron	🟥	🟥	🟨	🟩	🟥	🟨	🟨	🟩	🟩
	Zinc	🟥	🟥	🟩	🟩	🟨	🟨	🟩	🟩	🟩
NON-METALS	Glass	🟨	🟥	🟨	🟥	🟥	🟨	🟨	🟨	🟥
	Elastomers	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟨	🟨
	Natural fibers	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟨	🟨
	Natural rubber	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟨	🟨
	Porcelain	🟨	🟥	🟨	🟥	🟥	🟨	🟨	🟨	🟥
	Thermosets	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟨	🟨
	Thermoplastics	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟨	🟨

🟥 MUST separate, avoid mixing
🟨 SHOULD separate, problems can occur
🟩 DO NOT separate, good combination

Figure 4-1 *Material grouping in recycled metals feed in metallurgical processes [57]*

4.2 Established Bottom Ash Treatment

Four different bottom ash processing flowsheets will be reviewed in this section, two industrial flowsheets and two pilotplant test flowsheets. All of these are based on the same principle: first sizing into suitable size fractions and sorting out unburned fractions, magnetic separation to remove ferromagnetic metal scrap and the eddy current separator for separation of nonferrous metals. Some of them have a comminuting step to break up fused together components

Scmelzer reported in his pioneering article, a process for metal recovery from bottom ash. In the pilot operation (Figure 4-2), the bottom ash was first dried and then screened into two size fractions, 0-4mm and 4-45mm. The both size classes were treated separately with magnetic separator and eddy current separator, the nonmetallic product of 4-45mm was returned to the feed. The pilot plant test result was that from 62.6w-% of processed ash, 35.5 w-% magnetic materials and 1.9 w-% non-ferrous materials was recovered from the bottom ash. The magnetic material contained 20-30w-% Fe. After further processing with impact crushing, screening and wet magnetic separation, fine scrap with 90-95% Fe and iron concentrate with 50-55% Fe were produced. The non-ferrous material mainly comprised of Al, Cu and Zn. By further wet gravity separation, light product containing 95% Al and heavy product with Cu 52.1-61.2%, Zn 25.2-36.5%, Pb 1.2-3.5%, Sn 0.67-1.46% and Ag 0-2.0% were obtained. [34]

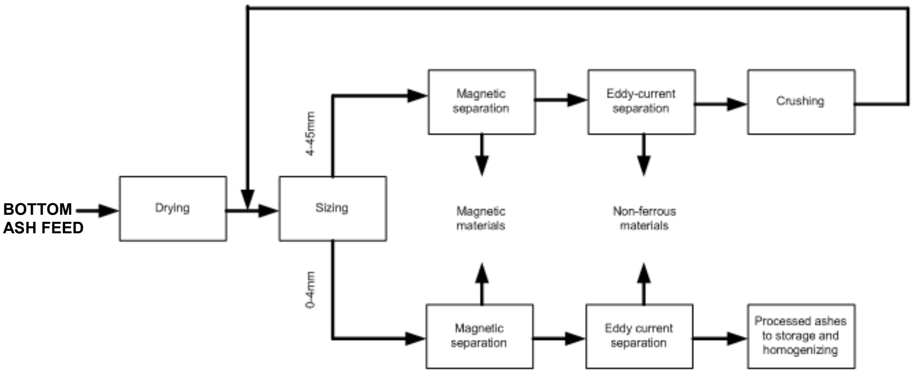


Figure 4-2 *Recovery of metals from incineration residue [34]*

Figure 4-3 presents the flowsheet of a German plant in which bottom ash is processed dry. This flowsheet is concentrated on metals separation from larger than 32mm particles. First, the larger than 300mm particles (e.g. wood, concerete and large lumps of metal) are separated with bar screen. Material smaller than 300mm mainly contains metal scrap which is fused together with glass and other mineral components. Next the ash is screened with

32mm vibrating screen. An overheadmagnet removes the magnetic components from the screen undersize and the magnetic fraction is combimned with the 32mm screen oversize. Underflow of 32mm screen is called ash product, which is one of the final products of the process. There was no separation step for nonferrous separation for smaller than 32mm material. The coarse material combined with the smaller than 32mm magnetic fraction is fed to a shredded, in which impact stress effects selective comminution. The ductile metal particles remains noncomminuted and the brittle slag particles are ground. From the shredded material magnetic particles are separated with magnetic drum separator and discharged as Fe-product. The nonmagnetic product is fed to 12mm a flip-flow screen, from which the underflow is combined with the ash product. The overflow of 1mm screen is fed over a magnetic pulley and the separated magnetic product is discharged as Fe product. The nonmagnetic product from magnetic pulley separator is feed material for eddy current separator which separates the nonferrous metals into a non-ferrous metal product. The tailings of eddycurrent separator is termed as non-burned material and is returned to waste incineration process. The achieved Fe yield from this process is 96.9% and the nonferrous metals yield only 11%. [11]

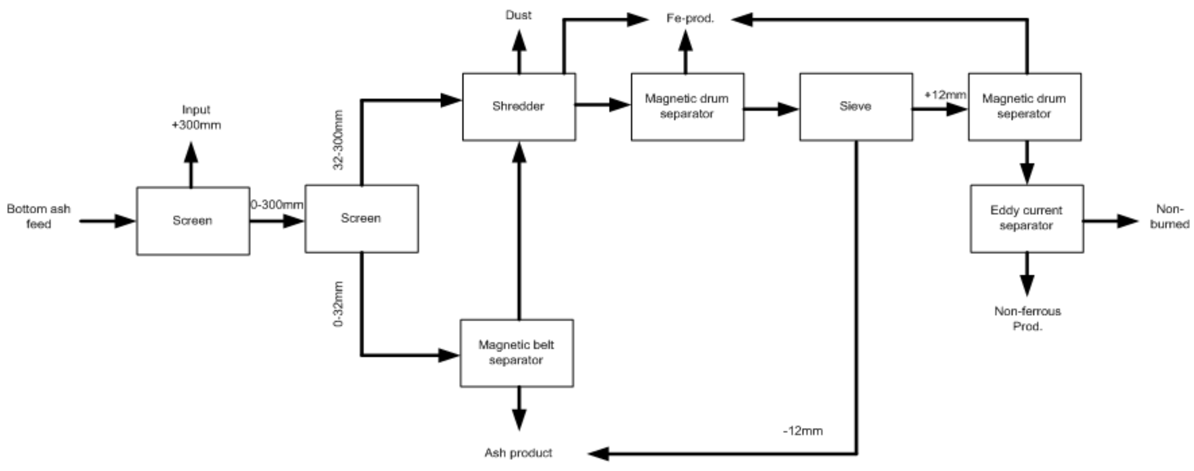


Figure 4-3 *Flowsheet of the bottom ash processing [11]*

The tailings of the process are recycled bulk materials. They are sold, for example as building aggregate or road construction materials. Depending on its content of harmful substances, the material is located into different classes. If the extra cost incurred for the recycling options is unacceptable or if there is no market for the recovered products, treatment of the process tailings is dependent on the directives on domestic waste disposal. [11]

Figure 4-4 shows the MSWI processing plant at Rugenberger Damm in Hamburg. The flowsheet is very similar to the one in Figure 4-2, but it includes an additional fines removal stage. The tailings of the fines and coarse particles processing is combined together and the combination is screened with 10mm screen. The overflow of the screen is fed to a wind shifter and the light weight material is discharged into bunker. The underflow of 10mm screen is combined with the heavies product of windshifter and the combination is stored for 3 months, which is necessary to assure reduced leachates. The matrial in storage is either fed back to the treatment process or delivered to the customer. In this process by-products of bottom ash processing that are recovered for re-use include metals, mainly ferrous metal which is extracted by magnets, and non-ferrous metals such as aluminum, brass, copper and stainless steel, which are recovered with the assistance of eddy current separators. The amount of steel recovered is about 2.5% of the waste input. Non-ferrous metals are recovered at a rate of about 0.25% of waste input of which about 40% is stainless steel (ferrous). After incineration the metal is sterile, and once the metal has been cleaned from adhering bottom ash in a separate process the metal can easily be sold to scrap dealers [58].

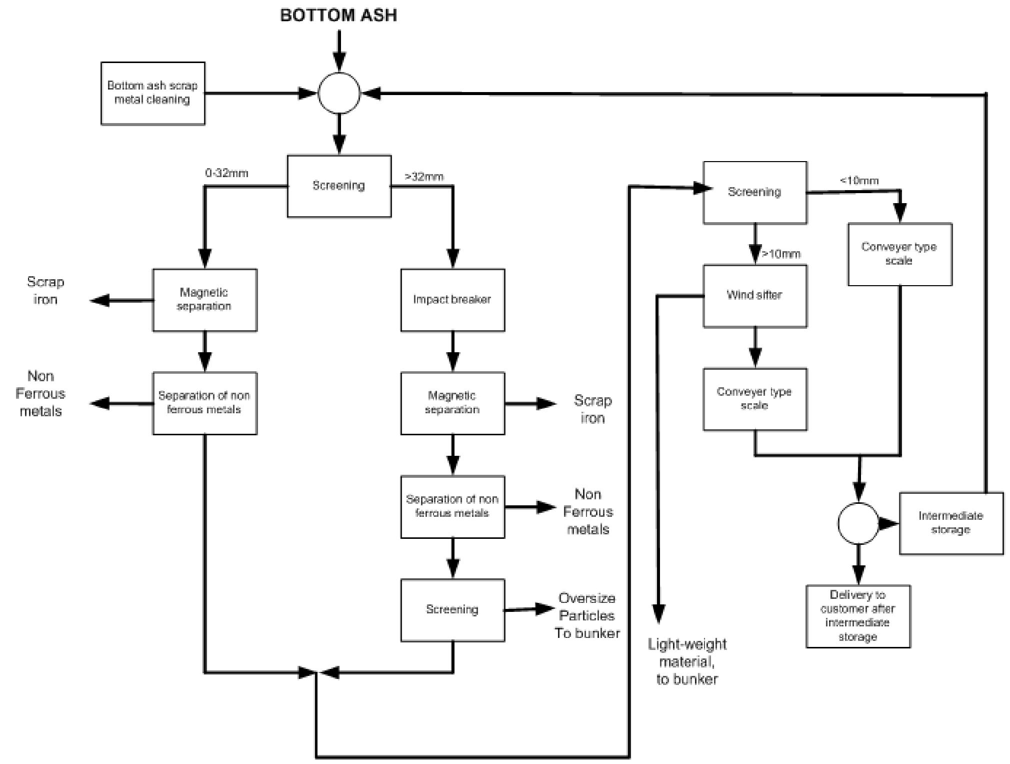


Figure 4-4 *Treatment of bottom ash in MSWI plant at Rugenberger Damm in Hamburg, Germany [58]*

In the Netherlands and German MSWI plants ferrous and non-ferrous metals and coarse materials (>40mm) are rmoved from bottom ash. However, current process does not yet produce products that meet the environmental requirements because the major non-ferrous metals present in fine fractions (<10mm) still remain. Also, the soluble salts are not removed by such dry process. [1]

To overcome the shortage of current treatment in contaminants reduction, more effective separation and cleansing techniques was developed non-ferrous metals removal from fine fractions (<10mm), and for soluble salts removal. Figure 4-5 shows the developed flowsheet for pilot plant experiment for treating the bottom ash of MSWI plant of Amsterdam [59]. The ash was first wet screened into three fractions: the smallest fraction with a particle size smaller than 2 mm, the fine fraction with particle size range of 2-6mm, and the coarse fraction with a particle bigger than 6mm. Every size fraction had approximately one third of the weight of the total bottom ash mass. The coarse fraction (6-40mm) was processed by a magnetic separator to remove magnetic iron/steel particles and eddy current separator to remove coarse non-ferrous metals. The fine fraction (2-6mm) is firstly processed by eddy current separator to get rid of the fine granular fraction that does not contain any non-magnetic metal particles but may contain magnetic particles. A small fraction of non-magnetic particles is obtained by this separation step. To remove non-ferrous metals from this non-magnetic fraction, a wet magnus separator is applied and it separates the fine non-ferrous metals. The generated sludge is heavily polluted by heavy metals and soluble salts. Especially the leaching value of Sb in sludge is much higher than that in other products. Therefore the process to treat the smallest effectively concentrates contaminants in the sludge. By this process 1.2w-% of total feed mass 6-45mm nonferrous metals and 0.1w-% 0-6mm nonferrous metals were recovered. The fine nonferrous metals were not successfully recovered and it is suggested that reason for that were non-optimal conditions of the nonferrous separation for fines. [1]

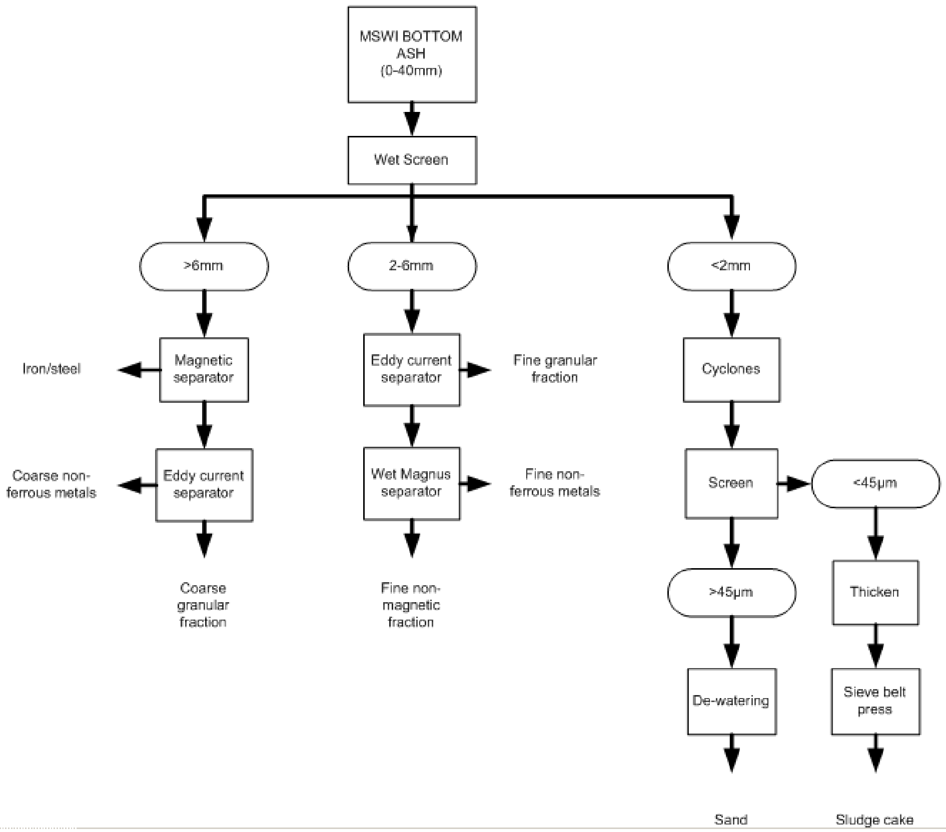


Figure 4-5 *MSWI bottom ash treatment processes in the Amsterdam pilot plant [1]*

4.3 Dry Process versus Wet Process

The MSWI bottom ash is damp, with moisture content of between 15 and 20%. This makes it difficult to separate fine metal particles from the ash. When the ash is treated by a dry process, some fine metal particles cannot be separated because they stick to non-metal particles due to moisture [1] The second problem is that the combination of a small amount of residual organic matter in the large surface area presented by the fine fraction creates leaching values for heavy metals such as copper that are above accepted levels. [59]

Although dry separation has a potential for low operation costs by savings a water circuit and prevents corrosion or expensive drying steps, washing is a simple way to remove organics and soluble compounds from the ash [44, 46]. In the washing process, readily and poorly soluble components can be distinguished. For example bromides and chlorides such as KCl and NaCl are easily extracted by water [60]. Poorly soluble components e.g. heavy metals can only be partially removed by washing. Extraction of other trace metals requires a significant addition of acid to reduce the pH to acidic levels [1]. Water applied in the washing treatment is the major factor for process costs. For economical and environmental reasons volume of washing water should be kept to a minimum, at the same time the keeping the solubility of the contaminants maximal. Although there are benefits from washing process, it tends to generate a wastewater problem, in which metals and salts are dissolved. Disposal of the generated wastewater needs to reduce the concentration of contaminants by wastewater treatment. [1]

In general wet concentration yields higher product qualities, and the simultaneous washing may often be favorable. For finer particles (<1mm), wet concentration is practically the only effective way of concentration. Disadvantages are often higher costs due to additional maintaining a water circuit, corrosion, and especially fines treatment and its related water cleaning, filtering, drying and sludge disposal. Dry concentration techniques have also poorer performance than the wet concentration methods. When the material is already wet, it is preferable to continue with the wet concentration technique. [48]

In Denmark there has been study on the effect of combining ash washing in lab and pilot scale with removal of small grain sizes below 100-125um. A positive effect on leaching could be observed for sulfate, Na, As, Cd, Cr, Pb, Zn, Mo and organic matter. Using additives in washing process mainly affected sulfate and Mo leaching. Also technical properties of the ashes were improved [15]. Similar results were obtained from the Amsterdam pilot plant experiment [1].

PART II EXPERIMENTS

5 INTRODUCTION TO EXPERIMENTS

The purpose of the experiments was to investigate suitability of the selected physical separation methods for metals recovery from municipal solid waste incineration (MSWI) bottom ash and to evaluate the characteristics specific to bottom ash affecting the separability of the metals. A secondary goal was to investigate the environmental properties of process products. The principle initiative behind the study was to improve the overall recycling rate of the bottom ash and to reduce its environmental footprint

The material for the experimental work was provided by the Turku incineration plant, in Oriketo. In this plant 47 000 tons of non-sorted municipal solid waste (MSW) is incinerated yearly and 2 500 t of bottom ash is produced. The process of the incineration plant is shown in Figure 5-1 .

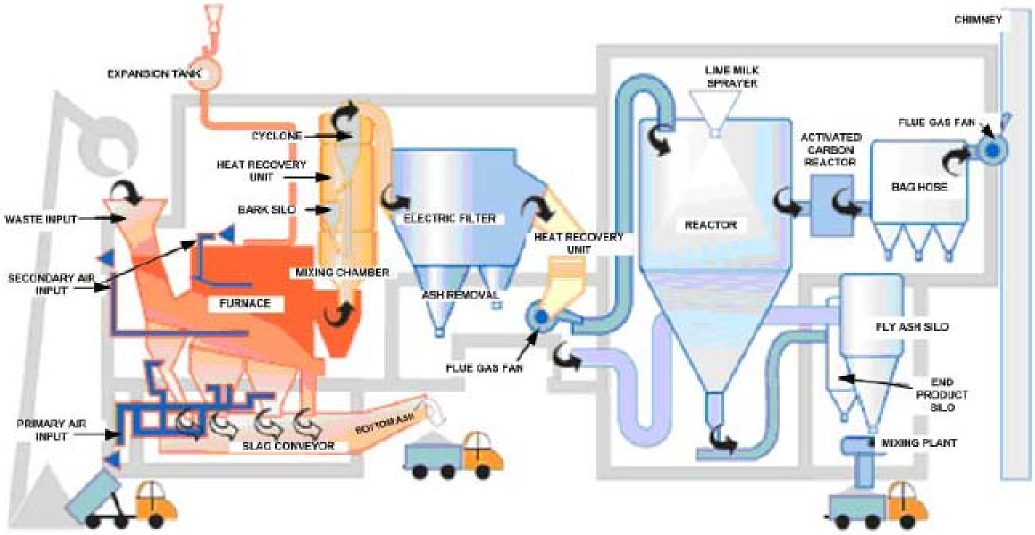


Figure 5-1 *Incineration process in the Turku municipal solid waste incineration plant [61]*

5.1 Samples

The sample was taken from different locations of the incineration bottom ash pile of the plant. The sample consisted of six 200 liters barrels of wet bottom ash. The ash was first screened by Kuusakoski Oy with a 40mm screen. This removed most of the steel, other large metal pieces the large unburned material. The total amount of removed material is unknown. After primary screening the sample was delivered to the Geological Survey of

Finland in Outokumpu. The overview of the experiments is shown in Table 1-1. The author was not involved in the sampling procedure, so the representativeness of the sample is unknown.

Table 5-1 *Bottom ash characterization and processing experiments*

PART I: BOTTOM ASH CHARACTERIZATION		
PROPERTY	**CHARACTERIZATION METHOD**	**CHARACTERIZATION SAMPLE**
ENVIRONMENTAL QUALITY	1. Leaching tests 2. Chemical analysis: XRF	Untreated bottom ash
MOISTURE CONTENT	Wet and dry weighing	Untreated bottom ash
SIZE DISTRIBUTION	Wet screening	Untreated bottom ash sample for characterization
COMPOSITION	1. Handpicking, 2. Chemical analysis: XRF, ICP	Samples of particle size classes
MATERIAL DENSITY	Submerging particles	Handpicked particle classes
PARTICLE SHAPE AND LIBERATION	Visual perceptions/ photographs	Handpicked particle classes
PART II: BOTTOM ASH PROCESSING		
TARGET	**PROCESSING METHOD**	**PROCESS SAMPLE**
PHYSICAL SEPARATION	1. Wet screening with centrifugal inclined sieve 2. Magnetic separation with magnetic drum separator 3. Nonmagnetic metals with eddy current and pneumatic shaking table	Untreated bottom ash
PRODUCT ANALYSIS	1. Handpicking , 2. Chemical analysis: XRF, ICP (GTK) 3. Leaching tests (VTT)	Samples of process products

First the sample was characterized, which holds the determination of relevant parameters for physical separation of metals from the bottom ash. These consist of characterization of particle classes by estimating the bottom ash particle size, shape, density, composition, valuable metal and contaminant content and state of liberation. The characterization was carried out in order to gain insight of the properties of bottom ash and to evaluate the potential of metals recovery. Based on the characterization, separation techniques were selected and the process flow sheet was designed for the experimental work. Finally the quality of the final products was analyzed.

All the experiments were carried out by author, most of them in the pilot plant of Geological Survey of Finland, located in Outokumpu, Finland. The Eddy Current experiments were performed in Luleå University of Technology, Sweden.

6 BOTTOM ASH CHARACTERIZATION

Characterization of the test material holds screening of the sample in order to estimate the particle size distribution of the bottom ash, measurement of the water content and the bulk densities, determination of the chemical composition and the leaching properties of the original material as well as chemical analysis of different particle size fractions.

6.1 Sampling Method and Sample Treatment

First, barrel E1 (see Figure 6-2) was dried in a drying oven for 72 hours in 75 ˚C. The dry weight of barrel E1 was measured in order to estimate the water content of the material.

The original total sample was divided into desired samples using splitting technique. The used sampling device is shown in Figure 6-1. The splitter type was RK 64 with 10mm width chutes and with a lever released hopper. The openings were adjusted to 40mm width. This way material was going through 8 openings to both trays. The splitter divides the material into two different samples, assumed to be sufficiently similar to each other.

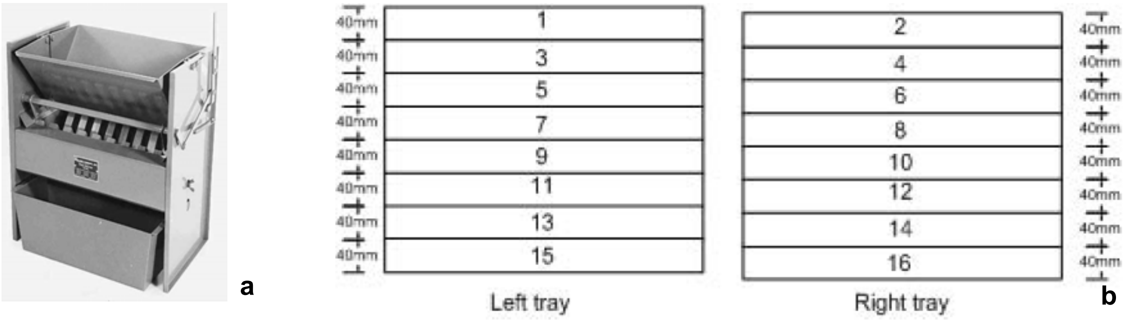


Figure 6-1 *a) Riffle splitter [62], b) splitter openings to different product trays*

Figure 6-2 demonstrates the complete splitting procedure and sampling flow sheet. Stages **SAMPLING I** and **SAMPLING II** are described in more detail in Table 2-1.

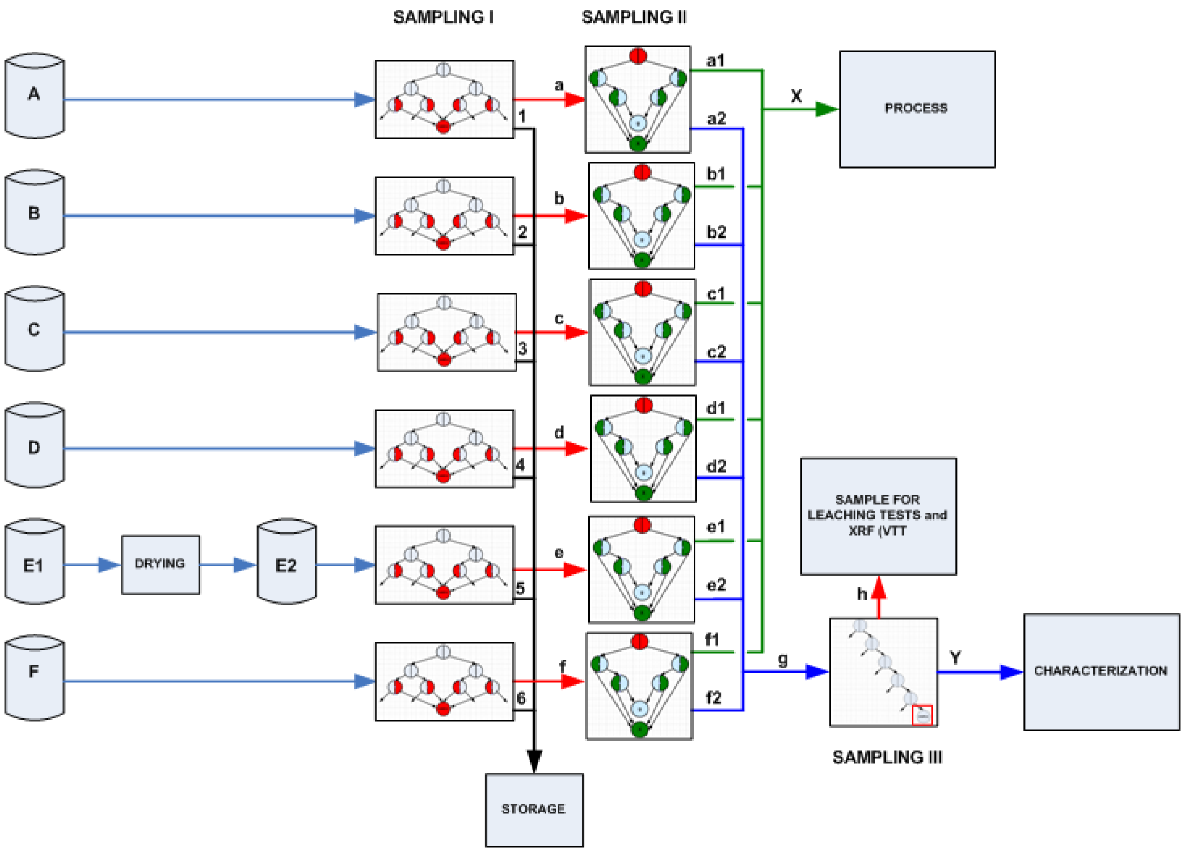


Figure 6-2 *Sampling procedure*

Table 6-1 *Description of sampling stages SAMPLING I and SAMPLING II*

SAMPLING STAGE	**DESCRIPTION**
SAMPLING I	Primary splitting stage of samples is shown in the Figure 2-1 as **SAMPLING I**, where each barrel (**A**, **B**, **C**, **D**, **E1** and **F**, each approximately 280kg of wet mass), was split in half (flows **a**, **b**, **c**, **d**, **e** and **f**). The other halves of the first sampling stage (samples 1-6) were put into storage.
SAMPLING II	The samples resulting from stage **SAMPLING I** in Figure 2-1, which are highlighted in blue (**a2**…**f2**), are combined to form sample **g** (~$^{1}/_{4}$ of total sample weight). The samples, highlighted in green (**a1**…**f1**) were combined to form sample **X** (~$^{3}/_{4}$ of total sample weight).
SAMPLING III	Sample **h** was taken from sample **g** by simple splitting and it was used for chemical analysis and leaching tests.

First part of **SAMPLING II** (added from **a1** to **f1**), sample **X**, was used for process for metals recovery. The rest of sample **g**, from here on referred to as sample **Y** was used for characterization of the feed. In order to determine the dry masses of samples **X** and **Y**, a sample from each of them was scooped to fill a three liters bucket. These samples were weighed and dried in a drying oven for 24 hours and weighed again to estimate the moisture content. It was assumed that the sample was homogeneously moist. After drying, the samples used for estimation of moisture content were returned to their original samples **X** and **Y**.

6.2 Particle Size Distribution

The characterization sample **Y** was screened three times into five size fractions x<2mm; 2≤x≤5mm; 5≤x≤10mm; 10≤x≤20mm and 20≤x≤40mm. The flow sheet of the screening process is presented in Figure 6-3.

As shown in Figure 6-3, the sample was screened with 10mm screen openings. In order to reach the best possible performance, material was screened using low capacity, long retention time, by diluting the feed and by spraying water on top of the screen so that fines would be washed from the surface of the coarse particles and the water bound agglomerates of bottom ash would break up. The underflow of the 10 mm screen was screened also three times with a 5mm screen size using the same procedure. The overflow of the10mm screen dried and screened dry with a 20mm screen.

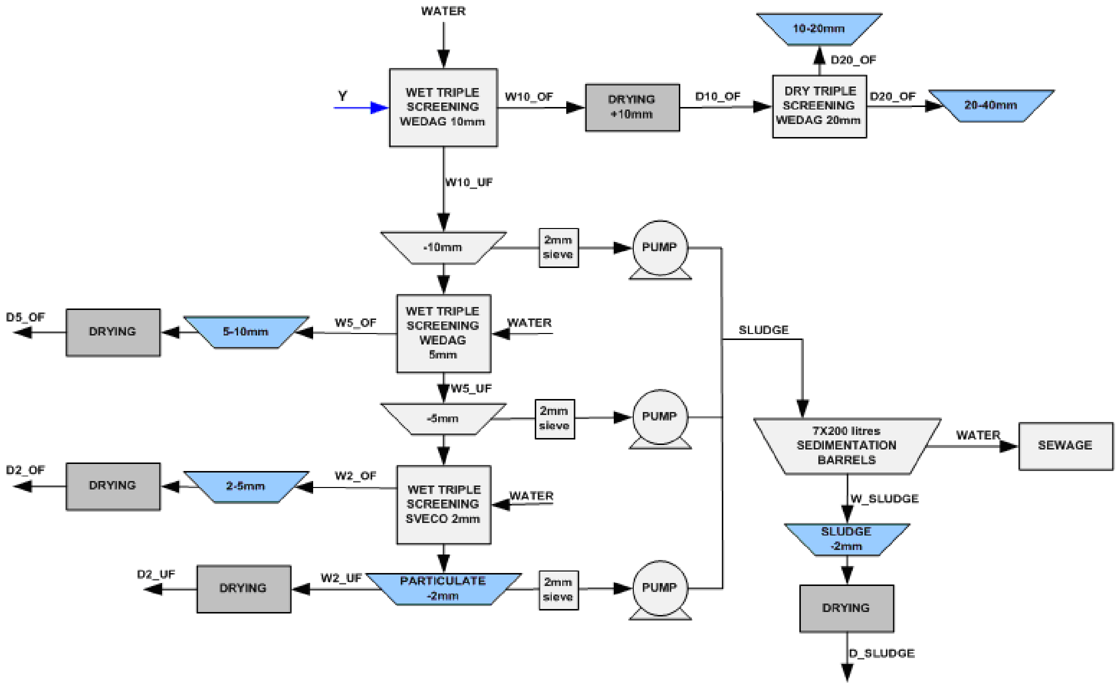


Figure 6-3 *Screening flow sheet and sampling procedure for composition analysis*

For screen sizes bigger than 5mm, the screening was performed using a vibrating inclined screen, Wedag MN 917/1 (Figure 6-4). The size of the screen was 500 by 160mm and it had capacity of 1 to 5m^3/h.

Figure 6-4 *Wedag MN 917/1 screen a) overview b) process c) washing*

Since plenty of water was used during the screening process, extra water was pumped out from the underflow buckets through a 2mm screen. Fine material, sludge, was left to settle for seven days in sedimentation barrels. After settling, clear water was drained from the barrels.

The underflow of the 5mm screen was screened using an inclined circular motion screen Sweco 800 LS 30 S 6666 (Figure 6-5) with a diameter of 80 cm and 2mm screen. As in the earlier screening stages, extra water was pumped through a 2mm screen into sedimentation barrels. All screening products were dried in oven for 48 hours at a temperature of 75 ˚C.

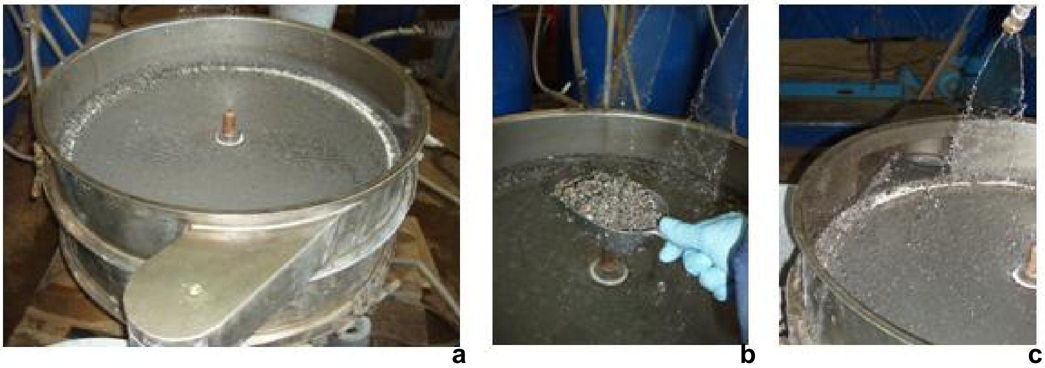


Figure 6-5 *Screening with Sweco 800 LS 30 S 6666 a) overview b) material feeding c) washing*

6.3 Composition Analysis of the Bottom Ash

The composition of the bottom ash sample was determined by handpicking and by chemical analysis of different particle size classes. The purpose of chemical analysis was to determine the concentrations of the important metals for recycling and the environmentally hazardous elements. Furthermore, leaching tests were done to test the leaching properties of the sample material.

6.3.1 Sampling and Sample Preparation

Each dried particle size class was first divided into two smaller samples by the splitter. Sampling methods of different size fractions for handpicking and chemical analysis and the sample codes used in these experiments and the sample masses are shown in Appendix III. One sample of each size fractions larger than 2mm was analyzed by handpicking.

The other sample, except for sample of sludge fraction was grinded by a disc mill. Also the handpicked nonmagnetic and magnetic agglomerates of size fraction 20-40mm were crushed for chemical analysis. After crushing the samples were first screened with a 1 mm screen in order to remove metal particles which the crusher would not comminute. The mass of removed metal particles was measured and classified by handpicking in different colored metals, red- copper containing metals, grey- non magnetic metals and magnetic metals. The ground and screened sample was divided into two 50g samples by a revolving 8-sample divider. The used method for chemical analysis were ICP and XRF, described in section 6.3.3.

6.3.2 Handpicking

Each sample was separately handpicked in order to determine their material composition. The handpicking was based on visual perceptions. Descriptions of the material categories used in handpicking are described on Table 6-2.

Table 6-2 *The categories of handpicking*

NAME OF THE CATEGORY	MATERIALS	DESCRIPTION
Grey-nonmagnetic	Aluminun, stainless steel, zinc	Gray-coloured nonmagnetic metal particles
Red-nonferrous	Copper, bronze, brass; copper-alloys	Red-coloured metal particles
Iron scrap	Iron and steel particles; iron-alloys	Magnetic metal particles
Nonmagnetic agglomerates	Non-magnetic metals, ceramics, glass, stones melt together. Most usual fusing material glass	Non-liberated "melt-together"-particles
Magnetic agglomerates	Magnetic metals, ceramics, glass, stones melt together. Most usual fusing material glass	Non-liberated "melt-together"-particles
Ceramics	Tiles and ceramic household goods, porcelain	
Glass	Glass household goods	
Stones and concrete	Stones and concrete	
Rest	Non-metallic and non magnetic particles	Combined when the particle were too small (-5mm) to identify different non-metallic materials from each other

First, a magnet was used to separate the magnetic particles from the mixture. The next step was to separate clearly metallic scrap from the magnetic agglomerates. Finally, the nonmagnetic part was handpicked particle by particle into different particle groups. The surface layer was removed with a file if the color of the metal particle was not recognizable because of the carbon- or oxide layer on the surface. After handpicking, the mass of all categories were measured and all categories were photographed.

The complete largest size fraction (20-40mm) was handpicked. Handpicking was the only applied composition analysis method, except for non-liberated nonmagnetic and magnetic agglomerates were ground and their composition was analyzed chemically.

6.3.3 Chemical Analysis

The purpose of the chemical analysis was to determine the concentration of valuable metal components like Al, Cu and Fe, and the environmentally hazardous elements such as Ba, Br, Cr, Cu, Mo, Pg, Sb, Se, Sn, Cl, F and SO_4. Also carbon concentration was analyzed of different fractions because presence of free carbon increases the leaching values of copper being and element of environmental concern.

For every fraction two parallel samples S1 and S2 were analyzed, each sample with X-ray fluorescence (XRF) analysis, with inductively coupled plasma (ICP) and the carbon concentration was analyzed with LECO CHN analyzer. The concentration of carbon was analyzed only for sample S2. Analyses were performed in the laboratory of Geological

Survey of Finland (GTK), Outokumpu. The description of the analysis methods is given in Table 6-3.

Table 6-3 *Description of the X-Ray Fluorescence (XRF) and Inductively Coupled Plasma (ICP) analysis methods*

ANALYSIS METHOD	**DESCRIPTION**
X-Ray Fluorescence (XRF) analysis	XRF is a tool for a qualitative identification of elements present in a material sample. The analytical system is based on specific emitted X-rays, characteristic to each individual element. These X-rays are detected by a detector and the element composition can be determined. With XRF it is possible to determine the concentration of fluor (F) and the elements heavier than fluor, noble gasses excluded
Inductively Coupled Plasma (ICP) analysis	Inductively Coupled Plasma (ICP) is an analytical technique used for the detection of trace metals in a liquid sample. Sample is first dissolved into acid. Elements emit characteristic wavelength specific light which can then be measured.
LECO CHN (Carbon, Nirogen and Hydrogen analysis, Leco-corporation)	LECO CHN is an instrument used to measure total carbon, hydrogen and nitrogen contents in solid and liquid samples.

6.3.4 Leaching Values

In order to determine the environmental quality of the bottom ash sample, a sample was sent to the Technical Research Centre of Finland (VTT), Espoo for leaching test and chemical analysis (XRF). The leaching test was CEN-analysis, described in Table 6-4.

Table 6-4 *Description of the CEN-leaching test*

ANALYSIS METHOD	**DESCRIPTION**
CEN (Commité Eurpéen de Normalisation)-leaching test	Two-stage batch leaching test performed according to CEN standard (EN 12457-3) that gives information at a liquid-solid ratio (L/S) of 2 l/kg. In the test the sample is shaken 6 hours with ion exchanged water so that L/S-ratio is 2 and the leached components are analyzed. The next stage is to shake the same material for 18 hours with L/S -ratio of 8. Cumulative L/S-ratio being 10.

6.4 Particle Shape and State of Liberation

The particle shape and the state of liberation of the materials were qualitatively determined by visual perceptions while handpicking. The purpose was to define most usual particle shapes and types of non-liberated particles of different material in each particle size class.

As described earlier, ICP and XRF analysis was carried out for the non-liberated particles of size class 20-40mm.

6.5 Material Density

The density of different handpicked material classes in individual particle size classes was determined. The purpose was to evaluate the suitability of separation methods based on specific weight of the particles. Determination of relative density of material is shown in Figure 6-6. The volume (V1) of the material was measured by immersing the handpicked material classes into graduated cylinder with water inside of known volume (V2) and by measuring the combined volume (V3). This way it was possible to determine the volume of material (V1) and to calculate the density of each material class within certain size class.

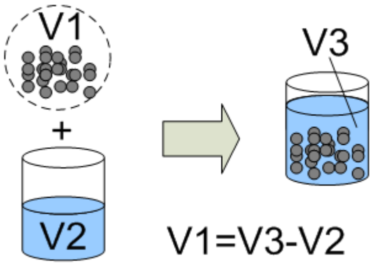


Figure 6-6 *Determination of relative density of handpicked material categories of different size*

7 RESULTS OF BOTTOM ASH CHARACTERIZATION

Before screening procedure the untreated bottom ash sample material was grey, damp, lumpy fine material with strong specific smell. Some lumps are formed by melting cooling process in the incineration furnace. Most lumpiness was due to high moisture content. The sintered lumps could not be broken down without strong mechanical force. The dried bottom ash was highly dusty with no strong smell. A closer look showed that besides fine, clay like material, bottom ash sample also contained recognizable items such as peaces of ceramic household goods, glass, metal particles, for instance metal wires, coins, molten metal droplets, steel scrap, tableware, bottle caps, tools etc.

7.1 Moisture Content of Bottom Ash Samples

The moisture contents with error estimates of the bottom ash sample of the barrel **E,** sample **X** and **Y** are shown in Table 7-1. After the drying procedure the material was assumed to be completely dry. However, this was not validated. The moisture of barrel E is assumed to be representative for all sample barrels.

Table 7-1 *Moisture content of the samples*

SAMPLE	Moisture content %	ERROR ESTIMATE%
BARREL E	20.05%	2.2%
SAMPLE X	14.63%	4.7%
SAMPLE Y	14.93%	4.7%

The masses of samples for process, characterization (**X** , combined mass of samples **h** and **Y)** and the stored sample are shown in Figure 7-1. The total wet mass of the sample delivered from Turku incineration plant was 1650 kg. The sample masses did not correspond the original mass of bottom ash sample. Sampling mass loss was 28kg. This is partly because the barrel **E1** was dried, water evaporated during sample procedure, also some material was lost. The accuracy of used scales also had some effect on the result. In addition if the combined mass of samples **X**, **h** and **Y**, would have been perfectly split, the combined mass should be equal to the stored sample. This is not true in this case. From samples **X**, **h** and **Y** there was additional water evaporation and material loss compared to stored sample, because of stage **SAMPLING II** and **III**.

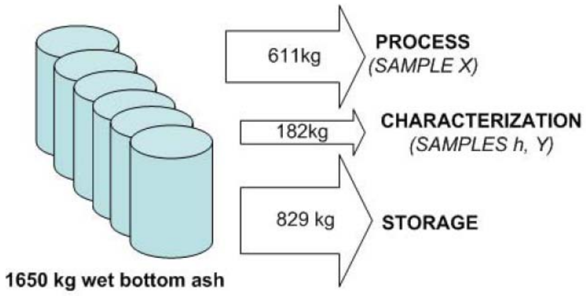


Figure 7-1 *Wet masses of final samples for bottom ash characterization and processing*

The masses of sampling procedure are shown in Appendix IV and the moisture contents in more detail in Appendix V. The moisture content estimation makes it possible to determine the dry weight of the sample for process and characterization feed. However, the moisture content values are not validated, but are assumed to be sufficiently accurate for estimation of dry content of feed material.

7.2 Particle Size Distribution

The bottom ash particles tend to block the 2mm screen deck of Wedag screen. Therefore, the screening technique was changed to circular motion screen for 2mm screen size. This Screening method worked better because of its self cleaning effect, which reduced the blocking.

The output of screening is shown in Figure 7-2, which presents the differential particle size distribution on the left and the cumulative particle size distribution of the bottom ash on right.

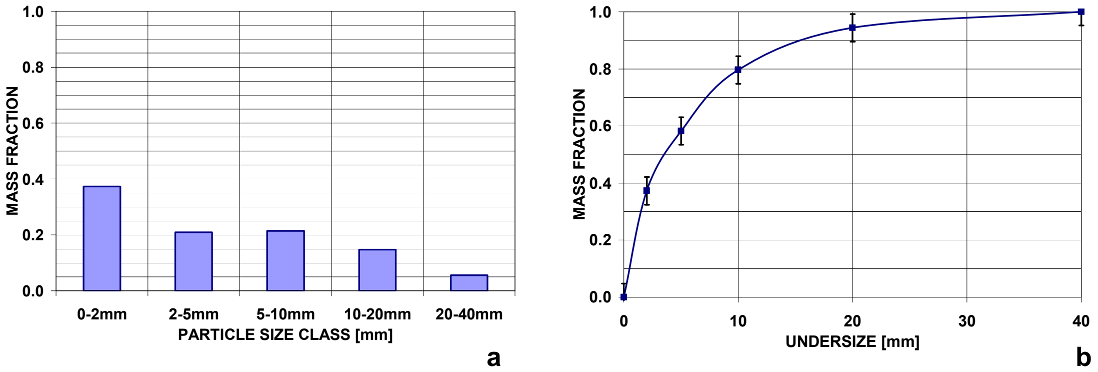


Figure 7-2 a) *Mass distribution of particle size classes, b) Cumulative particle distribution by screening undersize*

The graphs show that 37w-% of the bottom ash sample was smaller than 2 mm, from which the product of settling barrels (sludge) was 16w-%. 42w-% was larger than 5mm particles. This was the most important size fraction for this thesis concerning physical separation of metal particles. The masses of the screening process and the dry masses of different size fractions are shown in Appendix VI. The shown data is raw data. The mass balance of screening can be closed when taking the error margins under consideration. Dry feed mass for screening and summed dry screening products masses are within each others error margins. For this study, non-reconciled data was considered sufficiently reliable.

7.3 Composition

7.3.1 Chemical Analysis

As described in section 6.3.1 for pre-treatment of the samples before chemical analysis the larger than 0.5mm metal particles were sieved out from the crushed 2-5mm, 5-10 and 10-20mm samples before final sampling and chemical analysis. The This has effect on the results of the chemical analysis. The sieved metal product was further handpicked to grey nonmagnetic-, red nonferrous and magnetic metals. In 2-5mm size class around 2.9w-% of grey nonmagnetic, 0.7w-% of red nonferrous and 0.7w-% of magnetic metals were sieved out. In 5-10mm size class the corresponding masses were 3.6 w-%, 1.0w-% and 0.7w-% and in the 10-20mm fraction 2.2w-%, 1.3w-% and 1.5w-%. The masses of metals from sieving and the handpicked metal categories are shown in Appendix VII.

An average concentration of the two parallel samples is used in these results. There were no major differences in the concentrations of ICP and XRF results; the latter is discussed here. The sample masses for ICP and XRF for different particles size fractions are shown in Appendix VIII and the results of the analysis are shown in Appendix IX.

The characterization screening process produced two different products smaller than 2mm. These were the particles pumped with water to the settling barrels (0-2mm sludge) and the underflow of the 2mm screen (0-2mm granular). When dried, the product from the settling barrels (0-2mm sludge) was very fine structured powdery product and the underflow of 2mm screen (0-2mm granular) had a clearly larger, sandy structure. Both were analyzed separately to investigate if there was composition difference between them. The XRF results of selected elements are shown in Figure 7-3.

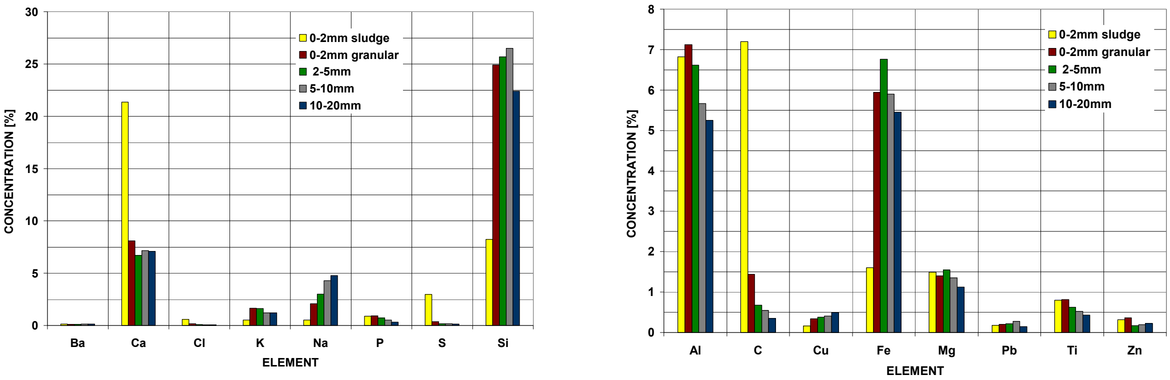


Figure 7-3 *Concentrations of selected elements in different particle size classes (XRF)*

Figure 7-3 shows that the major components of the bottom ash were Ca, Si, Al, Fe, all exceeding 5w-%, the most abundant being silica exceeding 20w-% of bottom ash. Carbon had high concentration (7.2w-%) in the sludge. In the case of carbon, the larger the particle size was, the lower was the carbon concentration. This is an important result from the point of view of environmental quality of bottom ash. High carbon concentration increases especially the leaching values of copper [1]. Consequently copper will end up in ground water after dumping or processing in asphalt. Other major components were Mg, K and Na.

Sulfur and Chlorine had the same tendency as carbon. Sulfur concentration in the sludge was 3w-% and in the larger size classes the concentration was much lower. In larger than 2mm particles the concentration was less than 0.18w-%. Concentration of chlorine in the sludge was the highest (0.59w-%), further decreasing to less than 0.09w-% in larger than 2mm particles. The high concentrations of Cl, P and S in the fines could be explained by high soot concentration in sludge. Soot particles are very porous and they work as an adsorbents, similar way as active coal does. Another possibility is that they end up to the fines with process water as dissolved anions (Cl^-, PO_4^{2-}, SO_3^{2-} and SO_4^{2-}). Ca dissolves the best in the cold water, which perhaps partly explains its high concentration in the sludge.

The concentration of Cu was lowest in the sludge (0.17w-%), increasing in larger size fractions. The Cu concentration was highest on 10-20mm particles (0.5w-%). The sludge also had the lowest Fe concentration (1.6w-%). In larger than 2mm particle classes the Fe concentration was between 5.5w-% and 6.75w-%. Concentration of zinc was highest in smaller than 2mm particles (0.32-0.36w-%). In larger than 2 mm particles the zinc concentration was 0.17-0.22w-%.

Aluminum concentration was highest on the 0-2mm granular fraction (7.1w-%) and the concentration declined in the larger particle size fractions, 10-20mm fraction consisting of 6.5w-% of aluminum. Also Ti concentration was the highest on 0-2mm fraction (0.8w-%) decreasing in larger particle size classes. Ti may be mostly in fines because it is already fine before incineration, mainly in pigments and some in household chemicals such as cosmetics and toothpaste.

Compared to their total occurrence, the light metals (Al, Mg, Ti) were more dominant in thesludge and 0-2mm granulate fraction. Reason for this might be that these lighter materials were easier dragged along by process water than heavies. It can also be assumed that Al and Mg are nearly completely present as fine oxide powder in the 0-2mm fraction, which gives the particles larger surface to mass ratio.

Figure 7-4 shows the mass flows of Fe, Cu, Al, Zn, C and Pb to the size classes within 0-20mm. Size class 20-40mm was excluded, because no chemical analysis was made on that fraction. The 2mm granulate class, being the largest size fraction in mass had largest massflow in al the shown elements. The sludge was 16w-% of the 0-2mm fraction. 63 w-% of iron, 66w-% of copper, 52w-% of aluminum and 44w-% of zinc was in larger than 2mm fraction. Also 62 w-% of lead was in larger than 2mm size fraction. Major part of coal (75w-%) was in smaller than 2mm fraction.

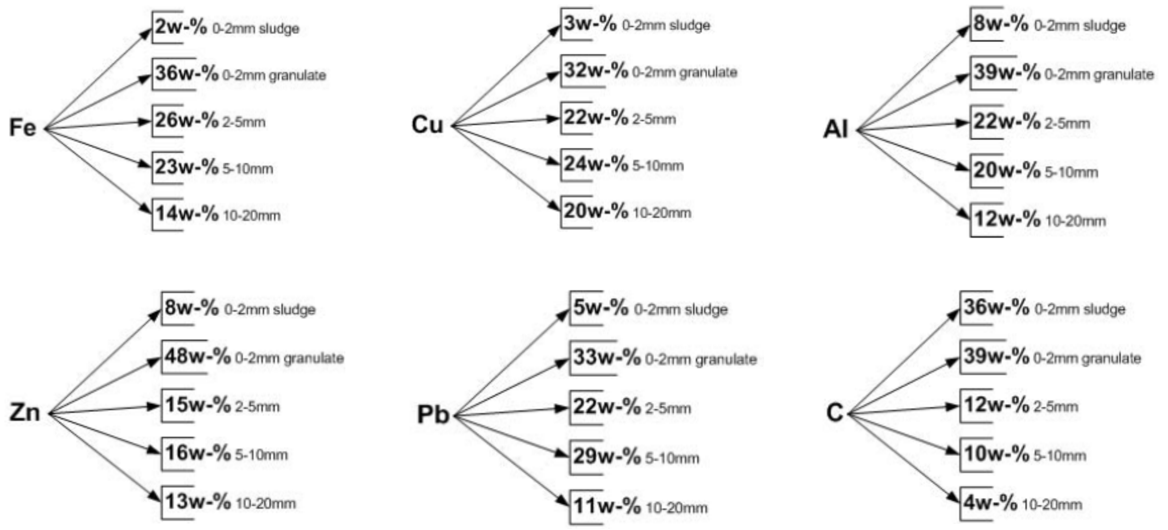


Figure 7-4 *Selected components massflows to size classes between 0-20mm (based on XRF analysis results)*

7.3.2 Environmental quality of Bottom Ash

7.3.2.1 Environmental Quality of Size Bottom Ash Size Fractions

The concentrations of many environmentally harmful elements in bottom ash exceeded the maximum allowed concentrations (MAC) of unpolluted soil (SAMASE-values, see Appendix X) in most size fractions. The values are regulated by the Finland's Environmental Administration (SYKE). The concentration of Ba, Cd, Cr, Cu, Pb, Sb, Sn and Zn exceeded the MAC value for polluted soil in most of the size classes.

The concentration of barium was twice as high as the MAC value in every particle size classes. Also the concentration of cadmium was twice the MAC value in smaller than 2mm particles and particle size class 2-5mm. For particle classes larger than 5mm the concentration of cadmium was below the limit. Also chrome concentration was lower in larger particle sizes, still it exceeding slightly the MAC value in all the classes.

Copper concentrations highly exceeded the MAC values in all the size classes; in the sludge it was five times higher, and in the other fractions it was more than eleven times higher than the MAC. Also the lead and antimony concentrations were more than four times too high in all the size classes. Tin concentration was more than thirty times too high in both classes smaller than 2mm and sixteen times too high in larger than 2mm particles. The concentration of zinc was the highest in smaller than 2mm particles and was two to five times higher than the MAC value in all the size classes.

7.3.2.2 Environmental Quality of Untreated Bottom Ash

Leaching test and XRF was carried out for a sample of untreated bottom ash. When compared to the SAMASE-values for polluted soil, the chemical composition of untreated bottom ash gave higher than MAC values for Ba, Cu, Sb, Sn and Zn to name the major hazardous constituents.

Comparing the leaching values of untreated bottom ash to the MAC leaching values for different types of landfills, the leaching values for chrome, copper, molybdenum, lead, antimony, selenium, chloride, and fluoride are over the MAC leaching values of typical landfill for inert waste, but they are lower than the MAC leaching values for landfills which do accept treated hazardous waste. The results of the leaching tests and the XRF and a summary of EU-MAC leaching qualifications for waste in different types of landfills are shown in Appendix XVI and the SAMASE-values are shown in Appendix X.

7.3.3 Handpicking

For all size classes larger than 2mm the material composition was determined by handpicking. The results of for handpicking and the masses from handpicking are shown in Figure 7-5. More details can be found in Appendix XI.

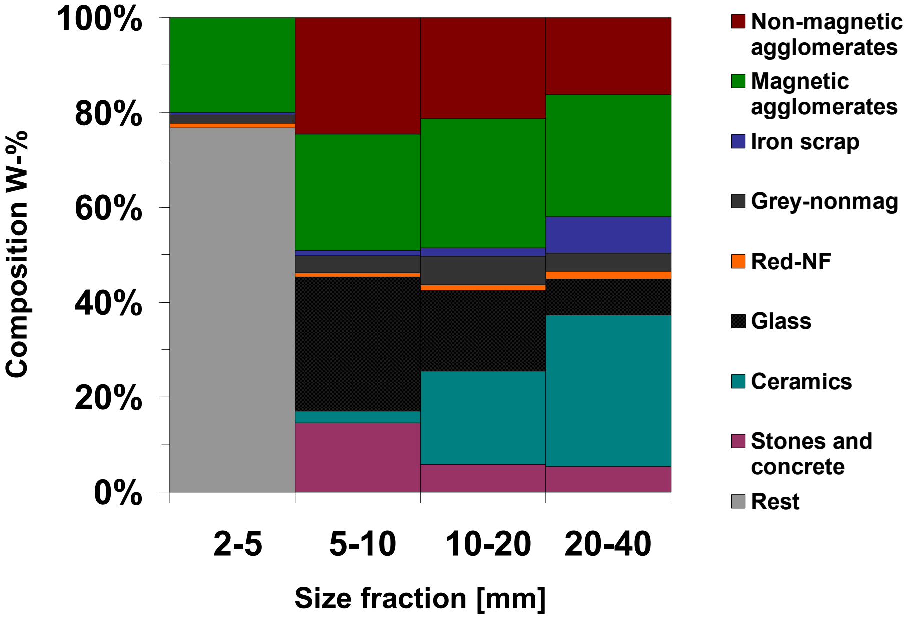


Figure 7-5 *Results of the handpicking*

The handpicking results (Figure 7-5) show that the concentrations of both magnetic and nonmagnetic agglomerates were high in every size class. 15-25w% of weight in all the size classes larger than 5mm were nonmagnetic agglomerates, 20-30w-% of size classes were magnetic agglomerates.

The amount of iron scrap was small compared to magnetic agglomerates fraction. In the small particle size classes the iron scrap particles concentration was lower than in the larger particle size classes. Concentration of iron scrap was the highest in particle size fraction 20-40mm, 7.8w-%. For 10-20mm size fraction the concentration was 1.8%, for 5-10mm 1.1w-%mm and for 2-5mm 0.4w-%. For the largest 20-40mm size fraction the handpicking results were close to the Fe concentrations of XRF-analysis, for the smaller fractions the handpicked concentration was much lower than in XRF-analysis. The reason for this might be that Fe is more dispersed in smaller size classes and was therefore more difficult to handpick than in larger size fractions.

The concentration of grey non-magnetic metals, from which the aluminum was the major element, was highest in size fraction 10-20mm, exceeding 6w-%. For size fractions 5-10mm and 20-40mm the concentration was lower, slightly more than 3.5w-%. The size fraction 2-5mm had the lowest grey nonferrous concentration, 1.9w-%. The handpicked value of 10-20mm of grey nonmagnetic metals (6.1w-%), was fairly close to the size fractions XRF-results aluminum concentration (5.2w-%). However, the handpicked concentrations of grey nonmagnetic metals for the 2-5mm (1.9w-%) and 5-10mm (3.5w-%) size fractions were quite different from the aluminum concentration of XRF-analysis results which were 6.6w-% and 5.6w-%, respectively. This can be explained by the inaccuracy of handpicking for smaller particle sizes, because the dispersed components and the alloys cannot be recognized visually and the large portion of the agglomerates was present in the samples. Ceramics also often contains aluminum oxides, which partly explains the higher concentration of Al in the chemical analysis.

The concentration of copper, consisting red nonferrous metal particles was 1w-% for 2-5mm fraction, 0.9w-% for 5-10mm fraction, 1.3w-% for 10-20mm fraction and 1.6 w-% for 20-40mm fraction. The handpicked nonmagnetic metals concentration (both red nonferrous and grey nonmagnetic metals included) was highest for the larger than 5mm size fractions. This result is important considering the metals separation from bottom ash. Eddy current separators, which is used for separating the nonmagnetic metals from nonmetals, works only for larger than 5mm particles. Pictures of handpicked particle classes are shown in Appendix XI.

For 2-5mm fraction XRF analysis gave 0.4w-% Cu concentration same for 5-10mm fraction. For 10-20mm the Cu concentration of XRF- analysis was 0.5w-%. The difference of two to three times higher concentration in handpicking can partly be explained by the inaccuracy of handpicking and by the copper alloys. Depending of the alloy, it can contain 55-90% of copper, most usual alloying elements being zinc and nickel for messing and tin for brass. Also one has to remember that that around 1w-% of red nonferrous metals was sieved out from the sample before the chemical analysis.

Figure 7-6 shows the massflows of metal particles into different size fractions. 90w-% of fairly well liberated iron scrap 76% of aluminum and 74% of copper particles were in the 10-40mm size fraction. This is an important result considering the eddy current separation process, which works the best for larger than 10mm particles.

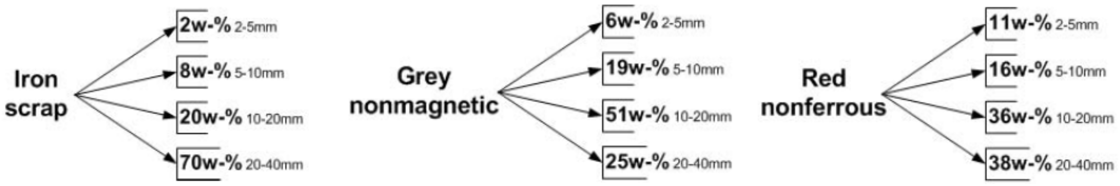


Figure 7-6 *Metal particles mass flows to size classes between 2-40mm (based on handpicking results)*

Glass tends to break down into small pieces and its concentration in 5-10mm was higher than in larger particle size classes. The tendency of the ceramics is the opposite, showing larger ceramics fraction for bigger sizes. However this is only true in handpickable ceramics. Ceramics, which are often Al_2SiO_5, break also into very fine dust. This gives in high concentrations of Al for fine fraction in the results of XRF analysis (Figure 7-3).

Almost 50w-% of handpicked size fractions was ceramics, glass, stones and concrete. All of these were most usually different kind of silicates in different crystal structures, often containing aluminum.

7.4 Shape, State of Liberation

The handpicking results showed that great part (40-50w-%) of the particle size classes larger than 5mm were non-liberated agglomerates. For the agglomerates of the largest size fraction, 20-40mm, the chemical composition was determined by ICP and XRF analysis. Figure 7-7 shows the XRF results for selected elements in magnetic and non-magnetic agglomerates of size class 20-40mm. The results of the ICP and XRF analysis are shown in Appendix XIII.

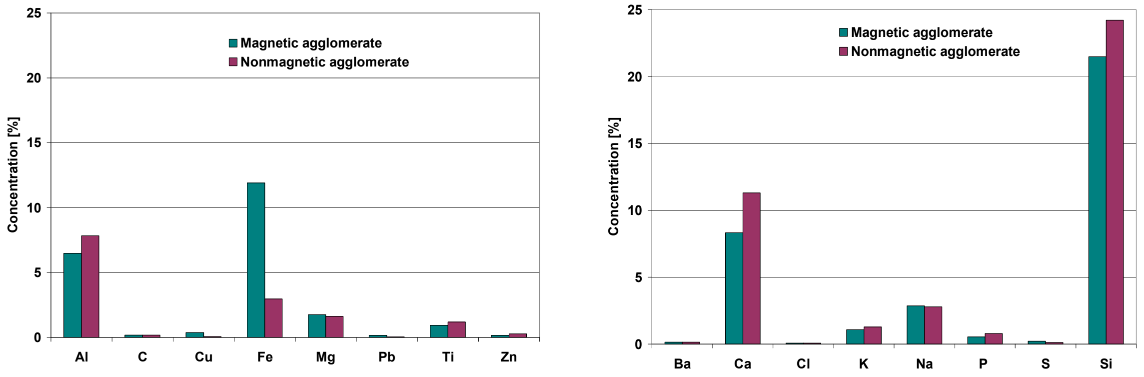


Figure 7-7 *Chemical composition of agglomerates in size class 20-40mm (XRF)*

Figure 7-7 shows that Al was concentrated more in the nonmagnetic agglomerates (7.8w-%), whereas in magnetic agglomerates the aluminum concentration is 6.5w-%. Cu and Fe were more concentrated in the magnetic agglomerate, with concentrations 0.39w-% and 11.9w-%, respectively. In non-magnetic agglomerate copper concentration was 0.08-w% and iron concentration 3.0w-%. In agglomerates calcium and silica were the major constituents, nonmagnetic agglomerates having 2.5w-% higher concentration for both of the constituents.

During the handpicking, all particle classes were photographed and the state of liberation, was visually analyzed. The focus was on metals liberation. Selections of representative photographs are shown in Appendix XI.

For particle class 0-2mm, the metal particles were relatively well-liberated. The only recognizable metal items were very small metal wires. The types of non-liberation were oxide layer on top of the wire and the different types of alloys. The non-metal particles in this size class were fine structured, sand-like mixtures of materials.

Particle size class 2-5mm contained more recognizable metal particles. Iron scrap particles for this size class were for example staples, nails, metal wires, assumed to be well-liberated except for alloying and oxidization on surface layer. This oxidation is not harmful if scrap is used as raw material for steel production. However, it does have effect on the price of sold scrap. Grey non-magnetic 2-5mm particles were mostly metal wires or molten metal droplets which had various shapes; flat-, elongated-, round-, pointy-, and/or porous particles. The metal particles were assumed to be well-liberated apart from oxidation and alloying elements. Red non-ferrous particles were for example wires, nails, copper droplets-All assumed to be well-liberated. 2-5mm non-metal particles were coarse structured granulate of ceramics, glass, stones, very non-liberated fused agglomerates, some magnetic with no visible metallic parts.

In class 5-10mm metallic iron scrap particles were nails, staples, metal wires, screws, flat, highly corroded iron scrap (e.g. parts of bottle caps), springs, metal turnings, buttons etc. The iron scrap was corroded but otherwise mostly well-liberated. Grey non-magnetic 5-10mm particles were metal droplets; metal wires, mostly well-liberated with various shapes. Red non-ferrous particles were wires, nails, different shapes of copper droplets, mostly well-liberated. Some metals had solidified together, e.g. solidified copper lump with steel nail and non-metals fused to metals, e.g. glass and Al. Nonmetal particles within this size class were stones, glass, porcelain and concrete. The agglomerates were coarse, stony, highly non-liberated, fused agglomerates, some magnetic. Most often the fusing material was glass and some metal particles were visible (e.g. metal wires, peaces of iron scrap, etc.)

In class 10-20mm iron scrap particles were recognizable steel objects, such as parts of bottle caps, metal wires, buttons, bolts, key chains, a watch-strap, etc. The scrap was mostly well-liberated except for oxidation and alloying. Grey non-magnetic particles in that size class were again of various shapes of metal droplets, metal wires, stainless steel objects, and springs. Red nonferrous metals were mostly wires, nails, bolts, coins, different shapes of copper droplets. Non-metal particles were stones, glass, porcelain and concrete. The state of liberation was fair with some non-liberation (e.g. glass and metal molten together, ferroconcrete...) Agglomerates were coarse, stony highly non-liberated, fused agglomerates, some of them magnetic. Most often the fusing material was glass and some visibly metallic parts.

In class 20-40mm iron scrap particles were various steel objects: batteries, nails, bottle caps, can lids. Other than corroded and alloys, these particles were mostly well-liberated. Possible non-liberation types are that metals have fused together (although no examples observed in sample), and some non-liberated articles like batteries. Other non-liberation found was mechanical connection (copper wire - steel screw). Grey nonmagnetic 20-40mm particles were among others stainless steel table ware, large molten porous metal particles, small containers, mostly well-liberated. Red non-ferrous particles were for example pieces of copper pipes, screws and copper wires. Most particles were visually determined well-liberated, although some metals found to be fused together and non-liberation by mechanical connection. The nonmetal particles were stones, glass, porcelain and concrete particles. Some non-liberation was found (e.g. glass and metal fused together, ferroconcrete particles). The 20-40mm agglomerates were coarse, stony, highly non-liberated fused together material, of which some were magnetic. Again, most often the attaching material was glass and some metallic parts were visible (e.g. metal wires, peaces of iron scrap). The table of liberation and shape analysis is shown in Appendix XIV.

Most of the aluminum particles found were fused. Aluminums melting point is 660 ˚C. Also some copper was also was found to be fused. The melting point of coppers is 1084 ˚C. Iron’s melting point was not reached during the incineration process for its melting point of is 1538 ˚C.

As mentioned earlier, the amount of larger than 5mm particles made up around 40% of the total weight of the bottom ash sample and the amount of agglomerates in the larger than

5mm size fraction was around 50% of the total weight, of which around half was magnetic particles. If the composition of the agglomerates was similar in all particle size classes, these magnetic particles, which also contained some copper and 6.5w-% of aluminum, could be refined with magnetic separation. The amount of agglomerates was roughly 20% of the total weight of the bottom ash sample and the amount of non-magnetic agglomerates 10w-%. These agglomerates contained iron scrap with bad quality, very little copper and some aluminum, all assumed to be bound in the agglomerates as very small metal particles. If these metals are needed to be separated and refined, a comminuting step should be included in bottom ash process.

7.5 Density Distribution

Figure 7-8 shows the densities of different handpicked material classes in different particle size classes. The results of density measurements are shown in Appendix XV.

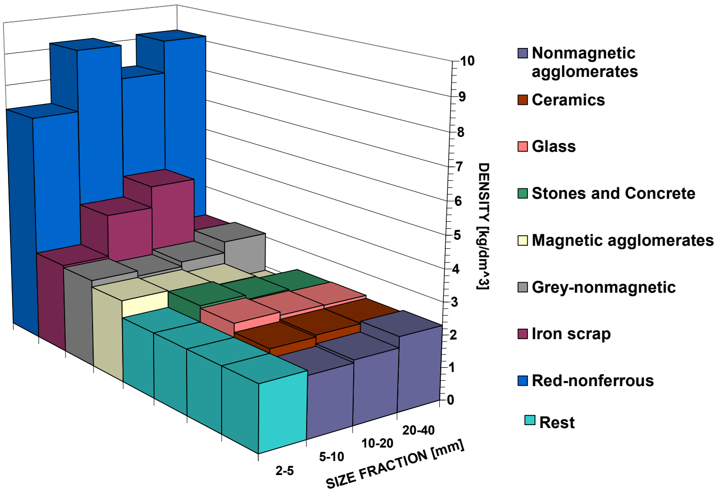


Figure 7-8 *Density distribution of material types in bottom ash*

The red-nonferrous material group mainly consists of copper, bronze and messing, having density of 8.96kg/dm^3, 8.7kg/dm^3 and 8.4kg/dm^3 respectively. In the density measurements the density of 2-5mm red nonferrous fraction was 7.21 kg/dm^3, 5-10mm 9.2 kg/dm^3, 10-20mm 8.10 kg/dm^3 and 20-40mm 9.15kg/dm^3. The densities of red nonferrous particles of different size were very close together and close to the real density of copper. There are deviations between the densities within the same material class. There can be several reasons for this. Factors effecting the materials density are for example the oxide layer on the surface of the particles, the possible air entrapped within the particle, the differences in the particle shape, the differences in number of particles in a sample, the error originating from the accuracy of used graduated cylinder and the scale, and the size of the sample. Most importantly, the density is an indicator for state of liberation. The state of liberation is the factor which determines the purity of material class and the salability of the metal product.

The density of aluminum is 2.7kg/dm^3 and the density of handpicked grey nonmagnetic particles was for size class 2-5mm 2.74 kg/dm^3, for 5-10mm 2.59 kg/dm^3, for 10-20mm 2.75 kg/dm^3 and for 20-40mm 3.12 kg/dm^3. The higher density of 20-10mm grey nonmagnetic particles can be explained by the fact that stainless steel was considered as a grey nonmagnetic material and the stainless steel particles were mostly only in the largest size fraction. Considering the error factors mentioned earlier, the values are very close together and to the density of aluminum and to each other.

On the basis of density distribution measurements it can be concluded that it is possible to separate copper from bottom ash by gravity separation, but for separation of aluminum, the density difference with nonmetallic particles is not sufficient.

7.5.1 Comments on the Reliability of the Data

The sample taken from bottom ash was a grab sample of six 200 liters barrels of bottom ash and it was not representative for the particular incineration plant. The results of this characterization just apply to the material investigated in this experimental work. The sampled material was damp, which made the particles stuck together, effecting on the splitting result, while splitting for dried sample **E1** worked better, since the sticking was reduced. However, for dry splitting plenty of dry, powdery particles were lost because of excessive dusting. The dried samples for dry content estimation were assumed to be completely dry, this was not validated.

As described in sections 6.3.1 and 7.3.1, for pre-treatment of the samples for chemical analysis the larger than 0.5mm metal particles were sieved out from the samples before final sampling and chemical analysis. This has some effect on the reliability of the chemical analysis results.

The chemical analysis was performed for two samples and the XRF and ICP results of the analysis on them did not have great deviation, which indicates that the sampling was somewhat reliable. Nevertheless, a third analysis is needed for error analysis. The error presented in the results is mass based error estimation derived from the sampling stages.

Lost mass on each sampling stage was within the error limits. The environmentally harmful elements mostly show very low concentration with high fundamental error. In order to reach more reliable results there is need to increase the number of analysis or the entire size fractions should be comminuted before the sampling procedure. In addition there is a need to look at the mineralogy of the bottom ash. This way it would be possible to further investigate which form the environmentally hazardous minerals are in bottom ash.

Also the screened size fractions of bottom ash were not analyzed by sieving in order to assess screening efficiency. The results are sufficiently reliable results for the purposes of this thesis. The acquired data can be interpreted as a generalization of characteristics and processing possibilities for MSWI. Characterization of MSWI bottom ashes from other MSWI plants and a more dynamic sampling method may improve the representative of characterization.

8 BOTTOM ASH PROCESSING

The bottom ash was screened with an inclined circular motion screen and after that processed with magnetic separation by a magnetic roll separator. Finally the separation of non-ferrous metals with an eddy current separator and a pneumatic shaking table was tested. The process flow sheet is shown in section 8.1, and the design of flowsheet is described in more detailed in results section 0. The processing techniques and the final process flow sheet are shown in section 8.2.5. The quality of products was determined by handpicking, chemical analysis and leaching tests.

8.1 Process Flowsheet

The flowsheet was designed by the author based on the results of characterization and established bottom ash processing. The experimental flowsheet design for was a three step separation (Figure 8-1), where 522kg (sample **X** dry weight) of MSWI bottom ash was wet screened into three fractions: +6.25, 1.18-6.25, and -1.18mm. The two largest size fractions were treated separately by the author in pilot plant of Geological Survey of Finland in Outokumpu. The fines (-1.18mm) were delivered for separate treatment to Salvor Oy, a soil cleansing company. The results of the fines treatment process are not included in this thesis.

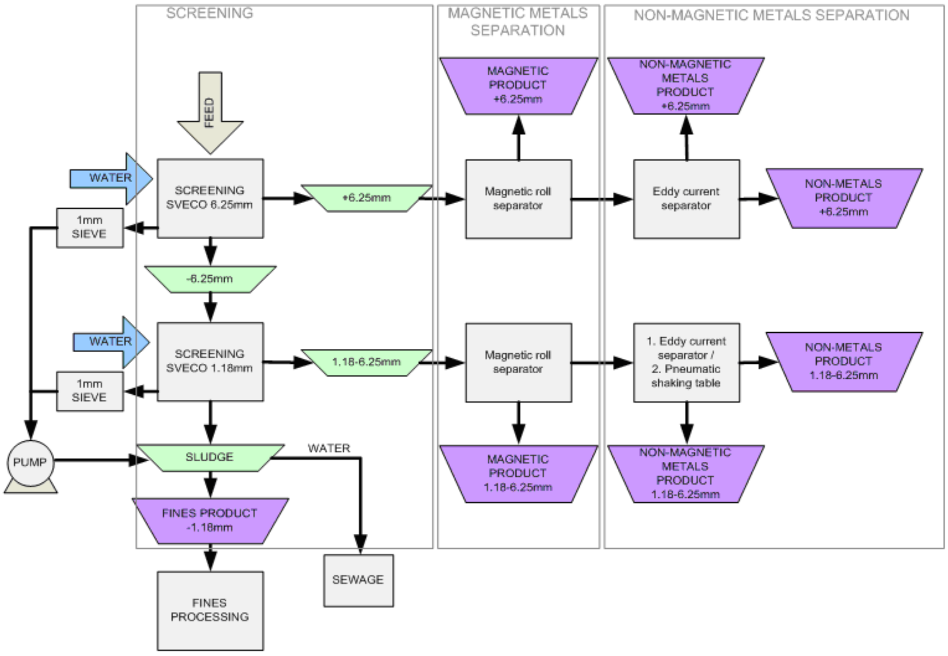


Figure 8-1 *Process flow sheet design*

The screened particle size classes, excluding the finest class, were processed using a magnetic separator in order to remove magnetic particles. The final step was to separate the non-ferrous metals (in addition to stainless steel). The largest size fraction was processed with a eddy current separator at Luleå University of Technology, Sweden for separation of the nonmagnetic metals from non metals. Besides the eddy current separator, also a pneumatic shaking table was tested for separating nonmagnetic metals from the 1.18-6.25mm size fraction.

8.2 Separation Methods

8.2.1 Screening

MSWI bottom ash was screened wet in two screening steps into three different size fractions; larger than 6.25mm (Coarse), 1.18-6.25mm (Medium) and smaller than 1.18mm (Fines). Screening was preformed with circular motion screen, Sweco XS60C888, 1,85 kW with a diameter of 1600mm (Figure 8-2).

Figure 8-2 *Sweco a) overview, b) feed of material and washing, c) top of the screen deck*

Possible parameters for the operation of screening process are feed rate, amplitude, direction of circular motion, screen size and pulp density of the feed. Screening was performed wet; water was added to the feed and water was sprayed on the top of the screen. Each screening step was performed twice.

The water was removed from the underflow in the same way as in the characterization screening (see section 6.2). Water and fines were pumped through a 1 mm screen to the sedimentation barrels.

After screening the weight of fractions were measured and two three liters samples were taken from each fraction. The samples were dried in the drying oven for 24 hours at 75 ˚C. The sludge was collected into ten sedimentation barrels. Before removing water from the barrels, after 3 days settling time, 5dl water samples were taken from each barrel and the samples were combined. The same was done again 7 days after the process and the samples were analyzed with ICP. After 7 days sedimentation extra water was removed and the fines were combined together into two 200 liters barrels. A 13 kg combined sample was taken from the fines slurry from both of the samples with a hose pump while constantly stirring the barrels. The sample was dried to estimate the solids content and the chemical composition analyzed with XRF and ICP. After sampling the sludge barrels were delivered to Salvor Oy for fines processing.

8.2.2 Magnetic Separation

A low intensity magnetic roll separator (Figure 8-3) was used for removing ferrous metal containing particles from the sample. The separator was constructed by the Geological Survey of Finland, Outokumpu (Table 8-1).

Table 8-1 *Details of the magnetic roll separator used for MSWI bottom ash processing*

SEPARATOR TYPE	Magnetic roll separator
MAGNETIC STRENGTH	0.2 Tesla at the surface of the drum
MAGNETIC SURFACE	30x16x250mm with 7 poles, around 150 degrees of magnetic surface.
PRODUCER	Build by Geological Survey of Finland, Outokumpu

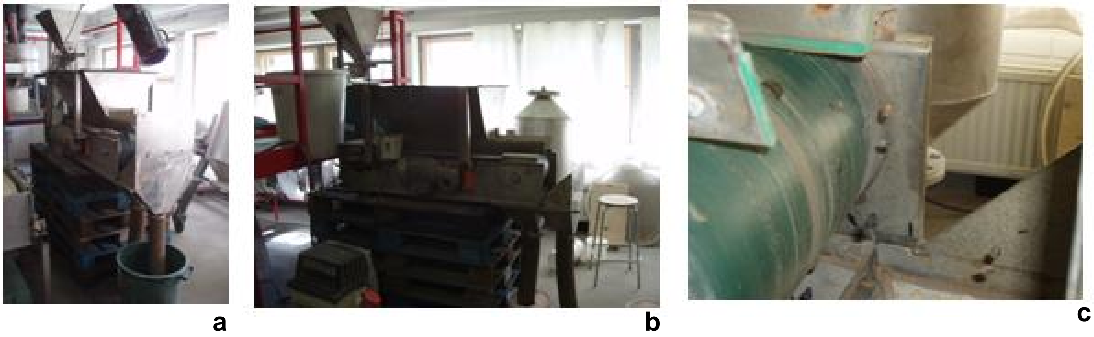


Figure 8-3 *Magnetic roll separator a) overview front, b) overview side, c) separation*

Possible parameters for the operation of the magnetic separator are feed rate, splitter position, position of the magnets, and belt speed. The material was fed to the belt by a shaker feeder. The peripheral speed of the drumwas adjusted with a frequency converter to the frequency of 40Hz, giving a belt speed of roughly 1 m/s.

Magnetic separation was performed three times as a pretreatment step for the eddy current separation. The bulk density of each magnetic product was measured and all the magnetic products were photographed. A combined sample for chemical analysis was taken by splitting each product of the three magnetic separations steps in half. The halves were combined together and the combination was split into smaller sample of around 4kg. The sampling procedure is shown in Appendix XVII. The sample was delivered to VTT for XRF analysis and leaching tests.

8.2.3 Eddy Current Separation

Eight samples were taken from Coarse and from Medium size fraction for the eddy current experiments. The sampling procedure is shown in Appendix XVII. The eddy current separation experiments were carried out with a rotating drum eddy current separator, BM 29.710/18 (Figure 8-4), described in the Table 8-2.

Table 8-2 *Details of the eddy current separator used for bottom ash processing*

SEPARATOR TYPE	Rotating drum eddy current separator BM 29.710/18
MAGNETIC STRENGTH	0.32 Tesla at the surface of the drum
MAGNETIC SURFACE	Diameter 300mm, 9 pairs of magnetic poles
PRODUCER	Bakker Magnetics, The Netherlands

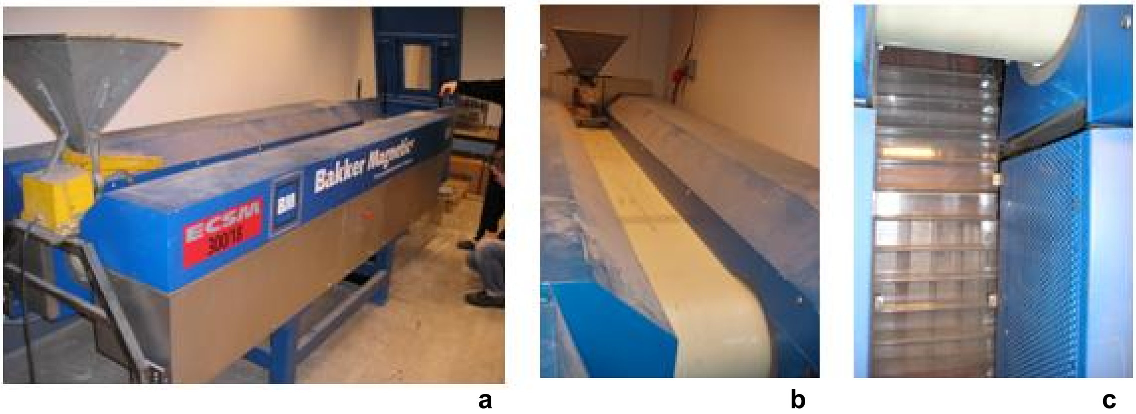


Figure 8-4 *Rotating drum eddy current separator, BM 29.710/18. a) overview I, b) overview II, c) product collectors*

The parameters for this eddy current separation are feed rate, belt speed, speed of the magnetic drum, direction of the magnetic drum rotation and splitter position. The test material was fed to the conveyor belt with the shaker feeder.

An array of collectors was placed in the front of the conveyor belt as shown in Figure 8-5. Collectors number 1 and 15 have dimensions of 710×510×105mm (length × width × height) and collectors from 2 to 14 had dimensions of 500×85×100mm. The collector no.15 was inclined. The right edge was positioned 14cm higher than the left edge. The direction of rotation for Coarse fraction was A (clockwise), and for Medium fraction it was B (counterclockwise).

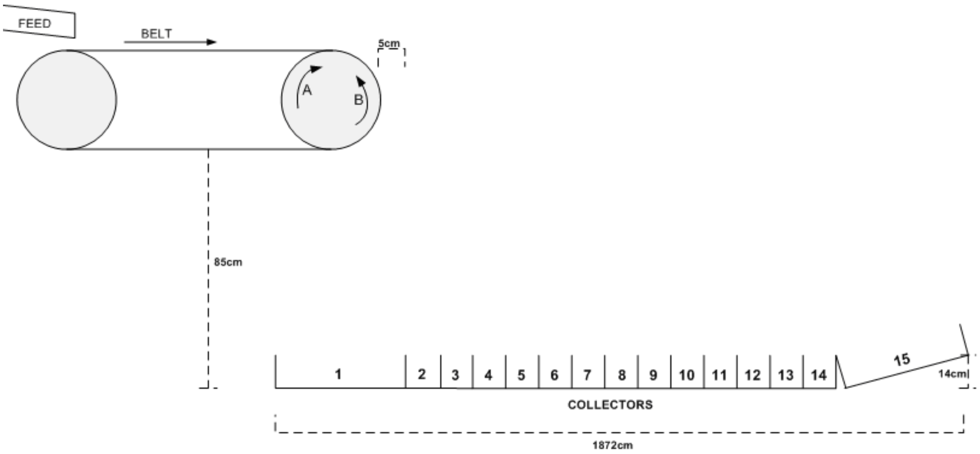


Figure 8-5 *Eddy current separators collectors (not to scale)*

Figure 8-6 shows a picture of the collector settings and the eddy current separators back wall, which is positioned approximately between collectors 12 and 13, the distance from the magnetic rotor was 1 meter and the distance from ground level was 45 cm.

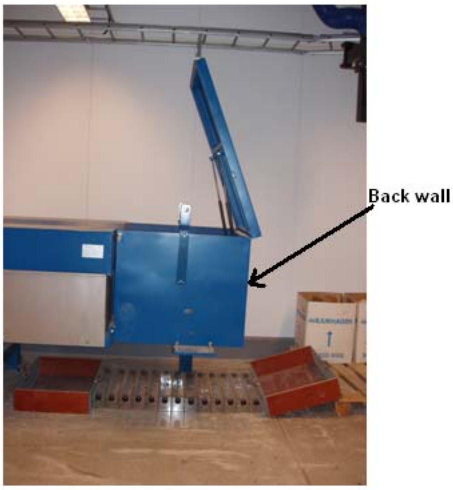


Figure 8-6 *Eddy current separator, collectors position and the location of separators back wall*

After separation, every collector was weighted and products were photographed. For the size fraction +6.25mm the quality of the products were analyzed by handpicking particles to nonmetallic-, grey nonmagnetic metal- and red nonmagnetic metal particles. Each handpicked class was photographed. One sample was chosen for further chemical analysis. The handpicked products of collectors which were categorized as non-metallic product (tailings) were combined. The sample was delivered for VTT for XRF analysis and leaching tests.

8.2.4 Pneumatic Shaking Table

The purpose of the pneumatic shaking table experiments was to assess technical feasibility for separation methods based on density differences for separating metal particles for Medium fraction.

The pneumatic shaking table used was produced by Kipp Kelly Ltd., MY-300 (Figure 8-7). Trapezium shaped table had side boards of 17 cm high. The openings of the steel screen deck were 0.7mm. The adjustable parameters effecting on separation performance are longitudinal were transversal angles of the table deck, drive axle eccentricity, number of strokes per minute, and airflow. Several different settings were used and the behavior of the test material and the performance of the separator were estimated visually.

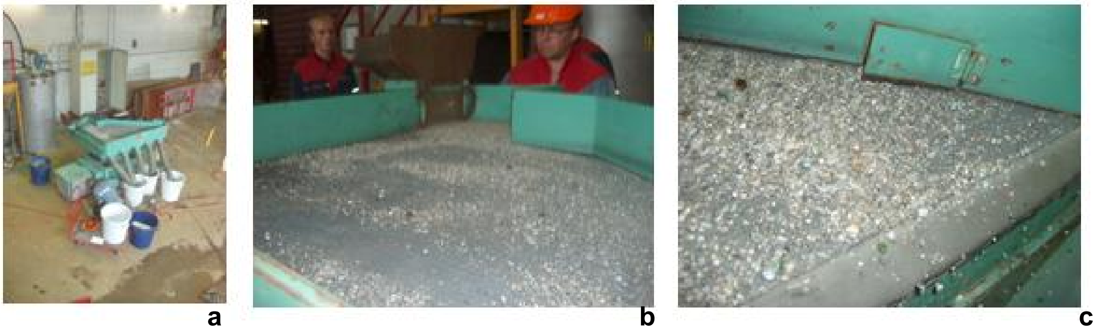


Figure 8-7 *Pneumatic shaking table, Kipp Kelly MY-300 a) overview I, b) overview II, c) splitter for concentrate*

8.2.5 The Modified Process Flowsheet and Sampling for Product Analysis

Figure 8-8 shows the resulting flow sheet for experiments and summary of the sampling of the products for quality tests. Difference to the original experimental flow sheet is the triple magnetic separation step. The reasoning for flowsheet design is described in the following chapter 9. Table 3-4 shows and overview of the sample codes and the used test methods.

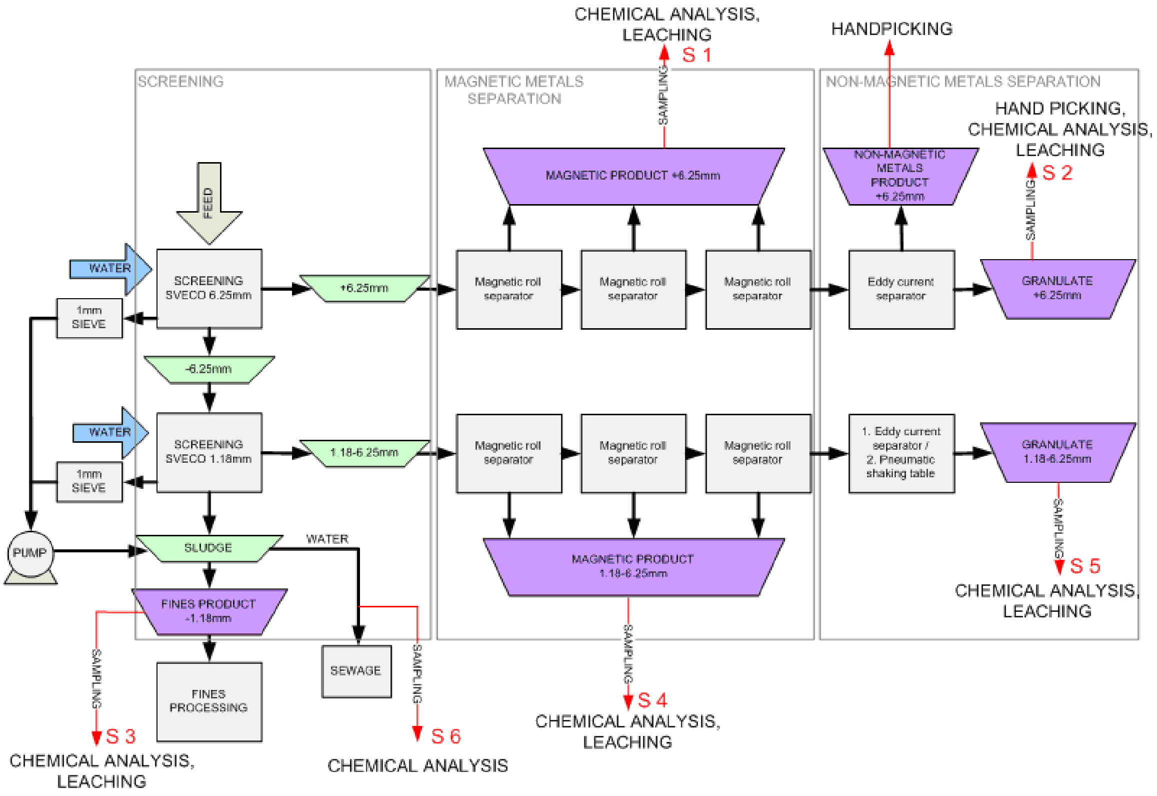


Figure 8-8 *Final process flow sheet and samples for quality tests of the products*

Table 8-3 *Summary of the process products, the samples taken from the products and the performed analysis methods*

PRODUCT	**SAMPLE**	**ANALYSIS METHOD**
COARSE MAGNETIC PRODUCT (+6.25mm)	**S1**	Chemical analysis (XRF), Leaching test
COARSE NONMAGNETIC METAL PRODUCT (+6.25mm)	Nonmagnetic metal products (**EC1_I**; **EC2_I**; **EC3_I**; **EC4_I**; **EC5_I**; **EC6_I**; **EC7_I**; **EC8_I**)	Handpicking
COARSE GRANULATE (+6.25mm)	Non-metallic products (**EC1_I**; **EC2_I**; **EC3_I**; **EC4_I**; **EC5_I**; **EC6_I**; **EC7_I**; **EC8_I**)	Handpicking
	S2 (=Non-metallic product **EC5_I**)	Chemical analysis (XRF), Leaching test
FINES PRODUCT (-1.18mm)	**S3**	Chemical analysis (XRF, ICP), Leaching test
MEDIUM MAGNETIC PRODUCT (1.18-6.25mm)	**S4**	Chemical analysis (XRF), Leaching test
MEDIUM GRANULATE (1.18-6.25mm)	**S5**	Chemical analysis (XRF), Leaching test
PROCESS WATER	**S6**	Chemical analysis (ICP)

9 RESULTS OF BOTTOM ASH PROCESSING

The processing flow sheet was determined on the bases of the literature survey. Another important factor affecting the process design was the results of the characterization and equipment availability in Geological Survey of Finland pilot plant in Outokumpu. However some modifications were made to the final flow sheet during the experiments, in order to reach the desired result.

Screening is a necessary pre-processing step for physical separation methods, because particle size is of great importance when it comes to mechanical separation. Wet screening was chosen based on the fact that bottom ash is damp, and in order to reach satisfactory screening efficiency the material was either needed to be dried or wet screened. When dried, bottom ash is extremely dusty causing problems in industrial hygiene. When using wet screening, the screening efficiency of fines increases and some soluble salts can possibly be washed out from the bottom ash granulates. The intention was also to investigate the effect of wet screening on the environmental quality of the process products and to compare it to the untreated bottom ash.

Magnetic separation is the best available technology for separation of ferrous metal. The purpose of magnetic separation was to remove magnetic particles from the bottom ash with high recovery, to avoid the damage to the eddy current separator.

Eddy current separator was chosen for separation of nonmagnetic metals, because according to characterization, aluminum is a major metal in bottom ash. Aluminum's density is very close to the density of nonmetallic material in bottom ash, and it is predicted that density separation would not work efficiently for that reason. Because eddy current separator was not expected to work for Medium sized particles, also a type of density separator, a pneumatic shaking table was tested for treatment of Medium fraction.

9.1 Results of Screening

The screen sizes were chosen based on the availability of the screen sizes and so that the screened size fractions would be close to the usual processing limits of the eddy current separator. Eddy current separation is the most used method in the recycling industry for separating metals from bottom ash. The inclined centrifugal screen was found best for screening of the bottom ash in the characterization stage (section 6.2). Therefore the method was also selected for the screening process.

The screening was carried out using a single deck. For adjustment of the screening process it was necessary to see the screening process performance on the deck. However, it is possible to screen with two screen decks at the same time, which reduces the energy and water consumption.

The aim was to increase the screening efficiency by keeping the transport of material slow, and the particle retention time long by setting the eccentric mass so that the screen was rotating anti-clockwise, vibrating against the product flow direction. This way the probability of undersize particles to enter into undersize product was increased. Screening was done at low feed rate while adding water to the feed and by spraying water on top of the screen to break the agglomerates and to wash the small particles from the surface of the large ones. Each screening step was performed twice in order to increase overall screening efficiency.

A problem with the 1.18mm screen deck was that the metal wires stuck to the screen deck (Figure 9-1). This causes blocking when screening large volumes of bottom ash. During characterization the 2mm screen deck was used. In this case there were much less metal wires entangled with the screen. With the screen deck of 2mm most of the metal wires reported to the underflow.

Figure 9-1 *Metal wires adhering to the Sweco 1.18 mm screen deck*

9.1.1 Mass Flows

Figure 9-2 *a* shows the screening flow sheet and Figure 9-2 *b* the dry mass fractions of different screening products. Table 9-1 shows the dry and wet masses of screened products. Fines product (Underflow 1.18mm) was sampled and the sample was dried to determine the dry mass and the chemical composition. The Medium product (Overflow 1.18mm) was also completely dried after it was noticed that for this fraction it was not possible to perform wet magnetic separation. The dry and wet masses of the screening products and the bulk densities are shown in Appendix XVIII.

The total mass of Fines sludge was 353.8 kg and with solids load of 46.5w-%, this gives 164.7 kg of solids in the Fines product. As shown in Figure 9-2 *b*, and in the Table 9-1, the dry masses of different size classes are very close to each other. The Coarse product was 34 w-% of the total product mass. The Fines and Medium product were both 33% fraction of the total dry weight of the products.

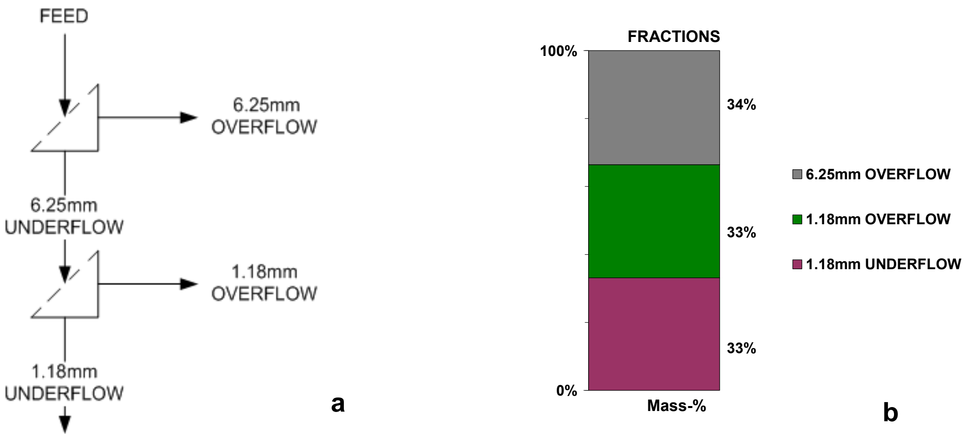


Figure 9-2 *a) Flow sheet of screening process, b) Relative dry masses of screening products*

Table 9-1 *Raw data of masses of screening products*

	Dry mass [kg]	ERROR EST. %
COARSE (6.25mm OVERFLOW)	**171.6**	0.26%
MEDIUM (1.18mm OVERFLOW)	**165.3**	0.27%
FINES (1.18mm UNDERFLOW)	**164.7**	0.18%
TOTAL PRODUCT MASS	**501.6**	0.42%
FEED MASS	**521.9**	4.72%

The total solids in feed was determined by measuring the moisture content of bottom ash feed sample for the process, and subtracting it from the wet feed weight, giving 521.9kg. The total output of the screening process was 501.6kg dry weight. Some losses, especially for fines occurred during the process. However, the feed and output masses of the screening process were equal within their error margins. The chemical composition and environmental quality of the products are discussed in section 9.6

Figure 9-3 shows the cumulative particle size distribution resulting from characterization and screening process, plotted in the same graph. The comparison shows that from screening products, the fraction of Medium product is larger and the Coarse product is smaller than in the characterization. However, the deviation is well within the characterization error range.

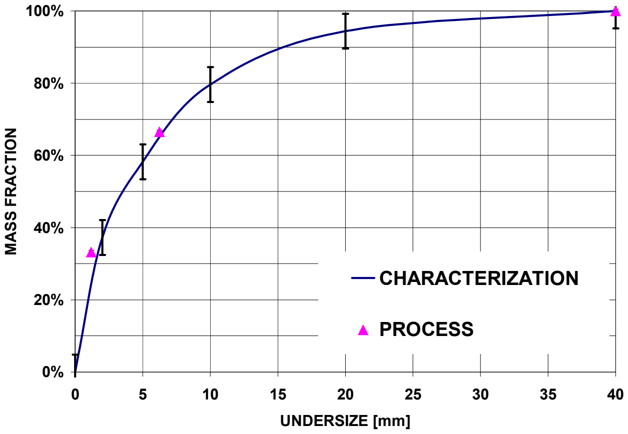


Figure 9-3 *Cumulative particle undersize distribution of bottom ash from characterization compared to the undersize distribution of screening process*

522kg of dry bottom ash was screened with approximately 2000 liters of water, the liquid-solid ratio was 3.8 and the sedimentation barrels contained a dry mass of 165kg of Fines product. The concentrations of analyzed elements in the process water are shown in Appendix XIX. The environmentally hazardous elements that were leached into the water during screening process were copper (0.14mg/l), chrome (0.03mg/l) and nickel (0.1mg/l). During the four days that elapsed between two samplings, the sample compositions did not change. pH of the samples were 8.5 and 8.6.

9.2 Results of Magnetic Separation

The initial idea was to treat the material damp, to avoid the drying step. However, as expected, the magnetic roll separator did not work for damp medium sized particles, and the material was dried after the screening.

The material was fed at low feed rate so that material formed a single particle layer on the conveyor belt. This provides the best possible separation efficiency and assures that all the magnetic particles are brought into strongest influence area of the magnetic field and that they are separated from nonmagnetic materials. The ideal splitter position was found by calibration runs, so that most nonmagnetic material was delivered to the nonmagnetic product.

During the test runs, it was noticed that the steel particles stuck to the belt at the end of the magnets, because there was no detaching mechanism (Figure 9-4). For this reason the magnets were adjusted so that the accumulation of magnetic material was below the belt as shown in Figure 9-6 *c*, so that weakly magnetic material did not bounce of into the nonmagnetic product bin by collision with magnetic material close to the splitter.

Figure 9-4 *Magnetic block formation on the belt of the magnetic roll separator*

Setting 2 was used during the entire process. The position adjustment of the magnets is shown in Figure 9-5 and the positions 6, 2 and 1 and the formation of block are shown in Figure 9-6.

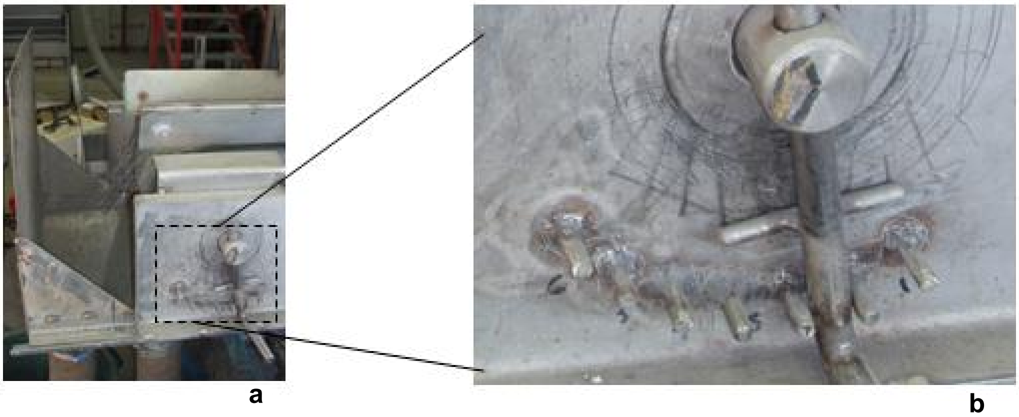


Figure 9-5 *The position adjustment of magnets a) control leveler of magnetic roll separator b) different setting positions (1-6)*

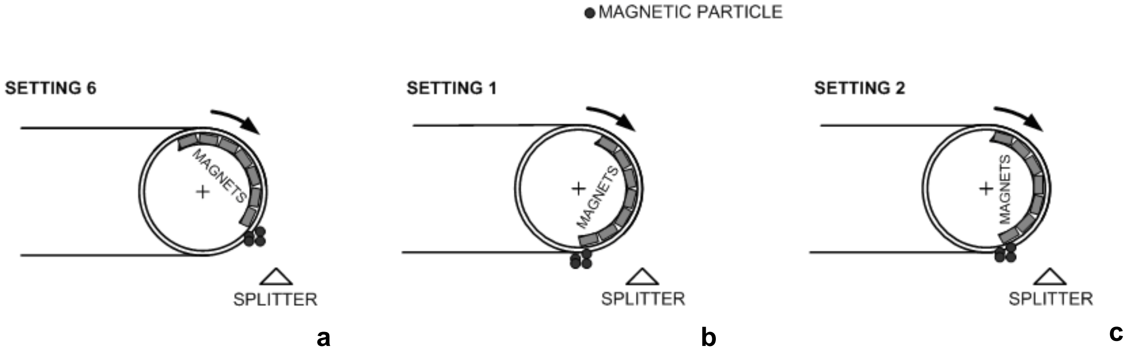


Figure 9-6 *Illustration of the positions of the magnets and formation of block in different settings a) setting 6, b) setting 1, c) setting 2*

The peripheral speed of magnetic drum was adjusted with a frequency converter to the frequency of 40Hz resulting in a belt speed of around 1 m/s. This speed was sufficiently low to allow for weakly magnetic particles to report to the magnetic product.

Both particle classes were first tested for wet magnetic separation, since they were wet after the screening step. For Coarse fraction separation worked fine when wet, the particles mass was large enough to separate from the wet belt. For Medium fraction drying was needed because in the wet separation all particles stuck to the conveyor belt (Figure 9-7). Before magnetic separation the size class Medium fraction was dried in a drying oven for 24 hours at 75 ˚C.

Figure 9-7 *Wet Medium fraction(1.18-6.25mm) particles stick to the conveyor belt*

9.2.1 Mass Flows

Magnetic separation was performed three times in order to assure that the quality of the feed for eddy current separation contained no magnetic particles. The flow sheets of magnetic separation is shown in Figure 8-8. The result was three magnetic products of different quality. Each product was weighed. The mass fractions of the separation products is shown in Figure 9-8 *a* and Figure 9-8 *b* for Coarse fraction and Medium fraction respectively. The total mass of Coarse magnetic product was altogether 22w-% and Medium magnetic product 20w-% of the mass of the feed. The masses and bulk densities of the products are shown in Appendix XX.

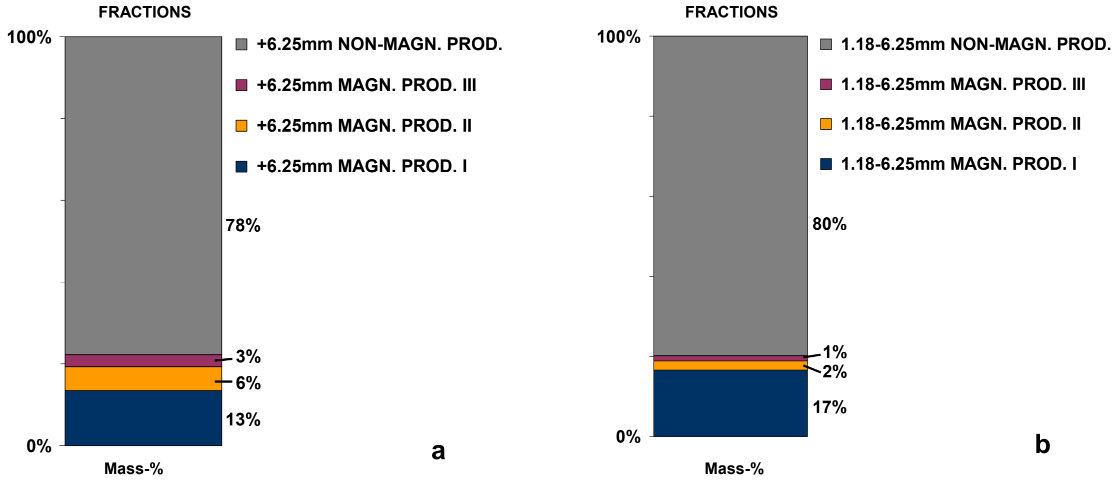


Figure 9-8 *Raw data of a) mass-% magnetic separation of Coarse products relative to feed b) Mass-% of magnetic separation Medium products relative to feed*

The product after the first magnetic separation contained mostly magnetic metal (steel) particles, the product after the third magnetic separation contained mainly magnetic agglomerates. The magnetic products with corresponding size were combined with each other and, a sample was taken for chemical analysis and leaching tests. The sample masses are shown in Appendix XXII.

The bulk densities of the products were rather low, 1.11-1.24 kg/dm^3 for Coarse magnetic product and 1.08 -1.44 kg/dm^3 for Medium and did not differ from bulk densities of the nonmagnetic products. The reason for this is that major part of magnetic products were mostly magnetic agglomerates.

9.2.2 Grade and Recovery of Magnetic Product

In order to calculate the grade and recovery of the magnetic products, the concentration of iron in the feed has to be known. However, the composition of the Coarse and Medium screening products were not analyzed. The total composition of the bottom ash for size fractions 0-2mm, 2-5mm, 5-10mm, 10-20mm and 20-40mm was known after characterization. These compositions needed to be converted to the concentrations of the Coarse and Medium size fractions, which were the feed material for magnetic separation. This was done by graphical interpolation, which is described in Appendix XXI. The resulting iron concentration for Medium fraction was 5.74w-%.

The flow sheet, shown in Figure 3-7, in section 8.2.5 shows that the compositions individual magnetic products were not analyzed, but all the magnetic products for each size class were combined, with no regard to their quality differences and the quality of the combined product was analyzed.

For Coarse fraction the iron concentration of the feed was 6.65w-% and the Fe-grade of the combined magnetic product 25.3w-%. For this magnetic product before the XRF-analysis 10w-% of steel scrap had to be sieved out from the sample and it was assumed that the XRF-analysis Fe-concentration, 17w-%, was representing 90w-% of the sample weight and remaining 10w-% was assumed 100w-% iron. The recovery for Coarse magnetic product was 86.7w-%. The grade of iron in the combined Medium product was 20w-%. The resulting recovery of combined magnetic Medium product was 70.6w-%. The grades and recoveries are shown in Figure 9-9. The data of the compositions of the magnetic products, and the grades and the recoveries are shown in Table 0-39, Appendix XXII.

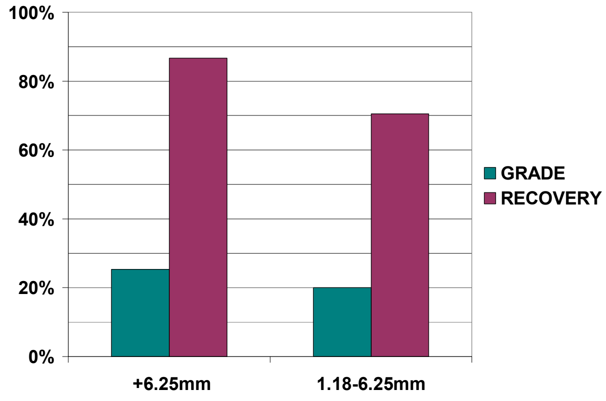


Figure 9-9 *Grades and recoveries for magnetic products*

The recoveries for iron were good. However the grades of the magnetic products were so low that it cannot be used as a feed material for steel production without further concentration steps. The magnetic products also had some copper in them; the Coarse product contained 0.39w-% copper and the Medium product 0.18 w-% copper. Copper is an unwanted element in steel production because it lowers the quality of steel. Copper dissolves into steel melt making it difficult to remove. The allowed amount of copper in the feed material depends on the quality of the steel to be produced. There is also more than 5w-% of aluminum in both of the magnetic products, which could be worth extracting, depending of its quality. To draw up grade-efficiency curves of magnetic separation process, each magnetic product need to be analyzed more closely.

9.3 Results of Eddy Current Separation

9.3.1 Process

During the eddy current runs the samples were fed on the conveyor belt as a single layer by a vibrating feeder. The sample masses are shown in Appendix XXI. For Coarse fraction eight runs were performed, twice for each setting combination. Two different belt speeds and magnetic rotor speeds were tested for both size fractions with different combinations twice. The experimental design is given in Table 9-2.

Table 9-2 *Tested parameters of the test runs with eddy current separator*

	COARSE 6.25-40mm			**MEDIM 1.18-6.25mm**		
RUN No.	**SAMPLE No.**	**ROTOR SPEED [rpm]**	**BELT SPEED [m/s]**	**SAMPLE No.**	**ROTOR SPEED [rpm]**	**BELT SPEED [m/s]**
1	**EC7_I**	3000	2	**EC7_II**	3000	2
2	**EC2_I**	2000	1	**EC2_II**	2000	1
3	**EC3_I**	3000	1	**EC3_II**	3000	1
4	**EC6_I**	2000	2	**EC6_II**	2000	2
5	**EC4_I**	3000	1	**EC4_II**	3000	1
6	**EC1_I**	2000	1	**EC1_II**	2000	1
7	**EC5_I**	3000	2	**EC5_II**	3000	2
8	**EC8_I**	2000	2	**EC8_II**	2000	2

The effect of the splitter position on concentration of nonmagnetic metals and non-metals were tested. After each run the collectors were weighed and their composition was analyzed by handpicking. The handpicked collector products were photographed, the photos are on the attached cd. The total sum of these products was assumed to be the composition of the feed.

An alternating magnetic field, imposed by the rotating magnetic drum induces eddy currents in the non-ferrous metal particles and they are thrown into different collectors depending on their magnetic properties, shape and size. Nonmetallic particles do not have these electrodynamic actions and the overall force transferred to them is smaller than to the non-ferrous metal particles. This way the separation takes place.

The purpose was to produce mixed metal concentrate with maximum grade and recovery, recovery being more important as this is assumed to be a pre-concentration (rougher) stage. Based on literature the clockwise rotation (A) (see Figure 8-5) of the eddy current's magnetic drum was chosen for 6.25mm particles treatment. This is because it is found more effective for separation of metals from large particles. For small particles counterclockwise (B) rotation was used because fine nonferrous metal particles can only be separated by eddy current separator in backward mode [63].

9.3.2 Eddy Current Separation Process for Coarse Particles

The composition of the feed for Coarse fraction was determined afterwards by summing of the weighed average of the handpicked compositions of different products. The total concentration for metals in feed for Coarse particles was 5.8w-% for grey nonmagnetic metals and 1.37w-% for red nonferrous metals. Comparing this with earlier interpolated concentration values (interpolation shown in Appendix XXI), which were based on handpicking in characterization stage, red nonferrous concentration is very close to the interpolated value 1.40%, interpolated grey nonmagnetic metals concentration (4.7%) being more than 1% lower.

Figure 9-10 shows the collector compositions, the mass distribution of the collectors and the cumulative grade-recovery curves of weighed average of two parallel runs with different splitter positions. The graphs on the left (a, c, e and g) show the composition of each collector and the relative mass distribution between of the collectors. Collector number one is placed nearest to the magnetic rotor (Figure 8-5). The graphs on the right (b, d, f, and h) show the corresponding cumulative red nonferrous, grey nonmagnetic and total metals grade-recovery curves. Each value is calculated by moving the splitter position from left to right (from position 1 to position 15); the metal product is collected to the right side of the splitter. For the first splitter position, where the recovery is unity, the splitter is placed on the left side of the first collector.

Every of three data points correspond to a specific splitter location, e.g. the last data point of each curve shows the data for splitter position 15. A number of these sets are indicated by green and orange markers in Figure 9-10 *b*, *d*, *f* and *h*. The handpicking results and the grades and recoveries of the eddy current runs for Coarse size fraction are shown in Appendix XX.

As shown in the Figure 9-10 *a*, *c, e* and *g*, with a belt speed of 1m/s and rotor speeds 2000 and 3000rpms, around 65% of the total mass is thrown in to the collector number 5. For belt speed 2m/s and magnetic rotor speeds of 2000 and 3000rpms, 70% of the total feed mass is collected in the collector no. 10. The grade-recovery curves on the right show that when positioning the splitter after the collector with largest product, there is a clear inflection point, with optimum recovery and after which the grade is at a stable plateau. These inflection points are indicated by a green marker with SP6 in grade recovery curves for a belt speed of 1m/s in Figure 9-10 *b* and *d* and SP11 for a belt speed of 2m/s in Figure 9-10 *f* and *h*.

At higher belt speed the contribution of belt speed to the total force affecting the particles is higher than at lower belt speed. At constant magnetic rotor speed and increasing the belt speed the particles motion the conveyor belt's effect to the total force than for a lower belt speed. In other words, the separation based on magnetic properties becomes less significant for higher belt speed. The metal grade is inversely proportional to the eddy current separators belt speed (see Figure 9-10 *b*, *d*, *f* and *h)* as was expected.

For constant belt speed the changing the magnets rotational speed will affect of magnetic induction to the particle impulse and the particles motion will be more strongly influenced by its magnetic susceptibility. Therefore, a metallic particle can carry a larger non-metallic part and still be recovered in the metal product. This results in an inverse relation between magnet rotational speed and metal product grade.

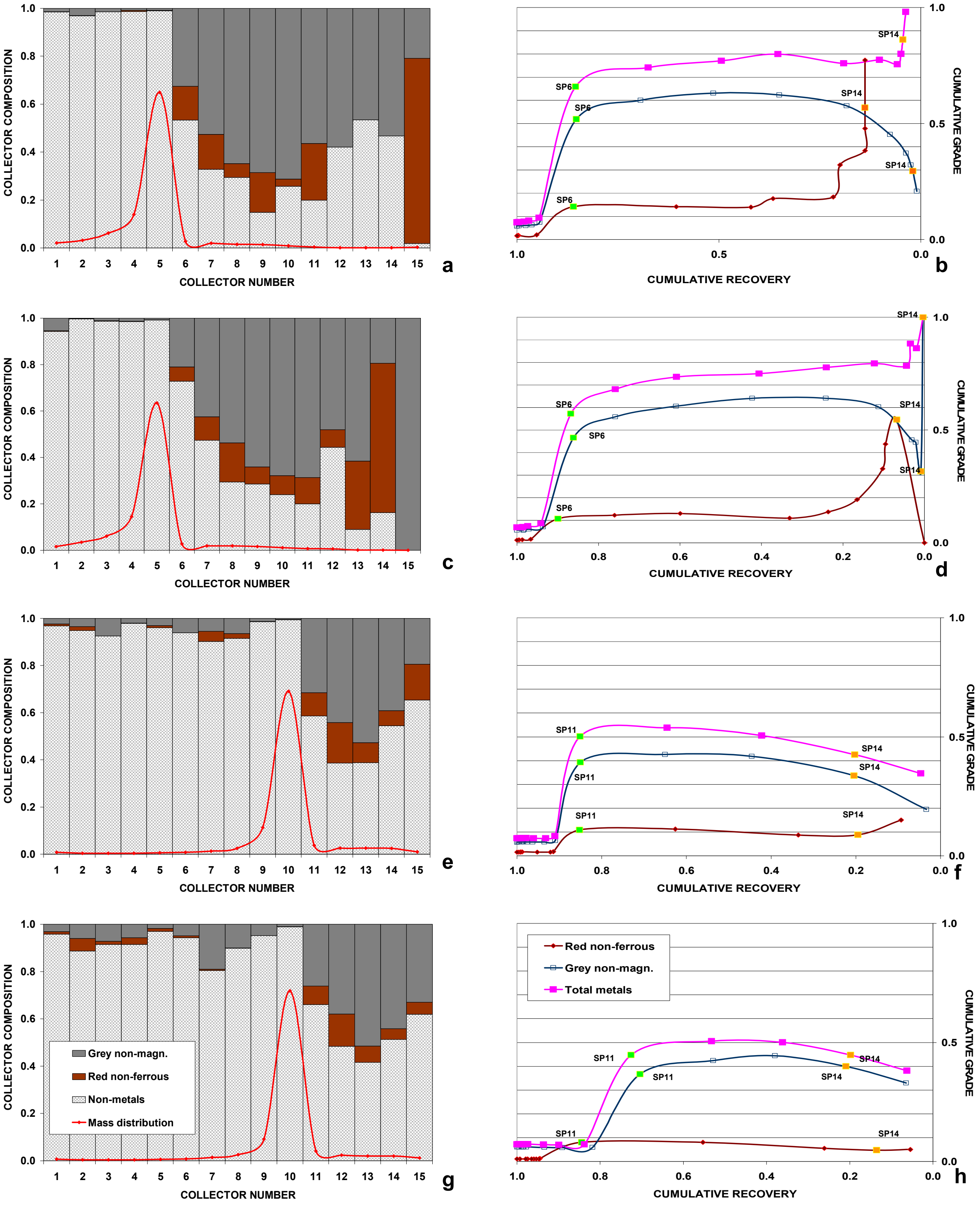


Figure 9-10 *a) Relative masses and compositions of collectors (1m/s, 2000rpm); b) Cumulative grade-recovery (1m/s, 2000rpm); c) Relative masses and compositions of collectors (1m/s, 3000rpm); d)Cumulative grade-recovery (1m/s, 3000rpm); e) Relative masses and compositions of collectors (2m/s, 2000rpm); f) Cumulative grade-recovery (2m/s, 2000rpm); g) Relative masses and compositions of collectors (2m/s, 3000rpm); h) Cumulative grade-recovery (2m/s, 3000rpm)*

The composition of metals in each eddy current sample of Coarse fraction of grey nonmagnetic particles varied between 5.17% and 6.35% and the concentration of red nonferrous particles between 1.07% and 1.74% of the sample's total mass. Figure 9-11 shows the grades and recoveries of the products within different settings. The composition of metals in each sample and the composition of metals in nonmagnetic Coarse fraction is shown in Appendix XXV.

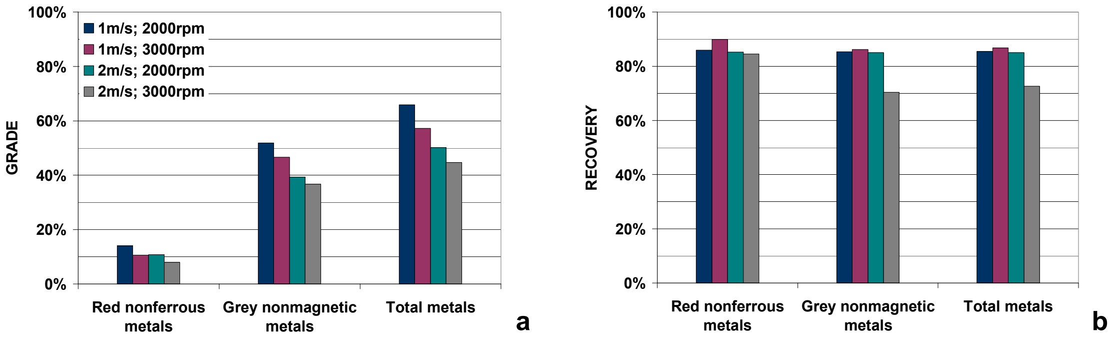


Figure 9-11 *a) grades- and b) recoveries of product with different test parameters*

Figure 9-11 *b* shows that the effect of parameters are not as clear for recovery as they are for the grade. The only clear difference is the effect of increasing the magnetic rotor speed from 2000rpms to 3000rpms when the belt speed is 1m/s. This increases the recovery of red non-ferrous from 85% to 90%. When taking the errors into account, there is basically no difference with the red nonferrous recoveries for the settings 1m/s 2000rpm and 2m/s 2000rpm. Nor can a difference be seen for grey nonmagnetic recoveries (~85%) for belt speed 1m/s with both of the magnetic rotor speeds and for belt speed 2m/s with magnetic rotor speed 2000rpms.

There was a steel wall around 1mm distance from the magnetic rotor (see Figure 8-4 *a* and Figure 8-6). The bottom of the wall was positioned 45cm from the ground level. The large metal particles bounced against the wall, when the sum of kinetic and magnetic forces was high. This affected metals recovery with the high belt speeds. Especially for the setting 2m/s, 3000rpm, this might be the major influence on the recovery of the metals. There was also bouncing of particles between different collectors, especially when particles hit the splitter between the collectors. This bouncing effect is higher for the settings of higher force, i.e. high belt and rotational speed.

From the point of view of environmental control, eddy current separation offers the possibility of high recovery of copper. Although grade is fairly low for such case, environmentally harmful copper can be removed from the MSWI bottom ash and can be recovered as copper scrap product. This dual gain is optimal for a belt speed of 1 m/s and a magnetic rotor speed of 3000rpm. Separation efficiency and environmental footprint of granular product can be controlled by a rougher-cleaner configuration of several eddy current separators, possibly combined with sink-float separation. However, the environmental quality assessment of the different products with different settings can only be compared by comparing leaching tests for all the Granular products.

If the goal is to sell the product after the first eddy current separation, the settings with best grade should be chosen, because of the better price of the product. Figure 9-12 shows the calculated Coarse products.The product masses are normalized to the total feed of 128.5kg, for every setting. Figure 9-12 shows the similarity of the products with setting combinations of 1m/s, 2000rpm, SP5; 1m/s, 3000rpm SP5 and 2m/s, 2000rpm, SP11. More detailed values are shown in Appendix XXV.

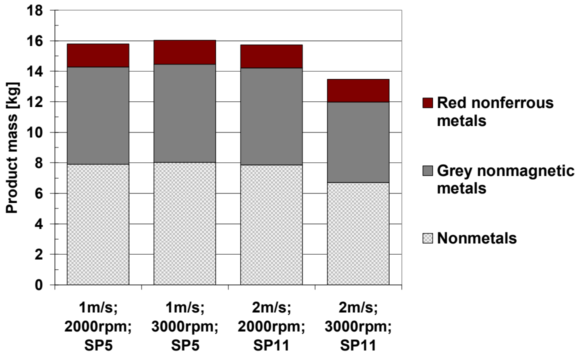


Figure 9-12 *Eddy current separation products for Coarse fraction with different process settings*

For verification of environmental quality of the granulate (the nonmetallic product) of the eddy current separation for particles larger than 6.25mm, the nonmetallic product of sample 4 was chosen for further composition analysis with XRF and for leaching tests. The environmental quality results are shown in section 9.6.

For testing the minimum particle size for eddy current separation it might have been more useful to use cut size 4mm instead of 6mm for screening, which would have given an opportunity to test how do metal particles close to 5mm behave in eddy current experiments. Also it would be interesting to make a visual investigation on the handpicked products, if there is a trend of size and shape of metallic particles which end up to the nonmetallic product.

9.3.3 Eddy Current Separation Process for Medium Particles

Only one run per setting combination (1m/s, 2000rpm; 1m/s, 3000rmp; 2m/s, 2000rpm and 1m/s, 3000rpm) was performed for Medium fraction. The repetition was considered unnecessary, because visual inspection of the products revealed unsatisfactory results. The grade of the metallic product was not acceptable because nonmetallic particles had the same trajectory as metallic particles. The result is supported by findings in literature study (section 3), that eddy current works the best for larger than 10mm particles and for smaller than 5mm particles traditional eddy current performs poorly [56] [1]. The main reason for this was the particles were too small for effective differences in particle trajectories.

The interpolated grey nonferrous metals concentration in Medium nonferrous separation feed was 3.14w-% and red nonferrous metals 0.89w-%.

The weight of every collector product was measured and the products were photographed. The photographs can be found in the cd attached. The product masses and fractions in different collectors is shown in Appendix XX.

9.4 Qualitative Survey with Pneumatic Shaking Table

Several settings were used and the behavior of the test material was and the performance was visually determined. The density diagram shows (see Figure 7-8), that with pneumatic shaking table it is possible to concentrate the copper particles. The separation copper did work in some extent, the copper containing particles (mainly peaces of copper wires) were mainly on the right side of the shaking table, where was the concentrate splitter (see Figure 8-7). The problem as the shape of the particles which did not allow them to enter into concentrate and they ended up into very low-grade copper product. The aluminum particles did not separate at all and immigrated to all the streams.

The pneumatic shaking table is not ideal device for producing copper concentrate, because of its low grade. However, it could be used as a pre-concentration step or for improving the environmental quality of the granulate product. According to the interpolation, the concentration of red nonferrous metal particles in feed was 0.9% (based on handpicking results) and 0.4% based on XRF results of copper. The copper concentration was so low, that it would not be economically feasible to use pneumatic shaking table for copper separation.

From the point of view of environmental control of products, XRF and leaching tests were made to investigate if the removal of copper is necessary. This was done by testing the environmental quality of the product of magnetic separation (Medium Granulate), The results of these tests are shown in section 9.6.

9.5 The Final Products in Bottom Ash Processing

Figure 9-13 shows the fractional dry masses of process products relative to the bottom ash feed. The values are raw data. Fines (Sludge) was the largest product with 32% fraction. Second largest products were the Medium (1.18-6.25mm) and Coarse (+6.25mm) Granulates both representing around one quarter of the product. The metal products were smaller, the magnetic products both were 7% of the total product mass and the nonmagnetic- (nonferrous) metal product was the smallest, 3% of the product mass.

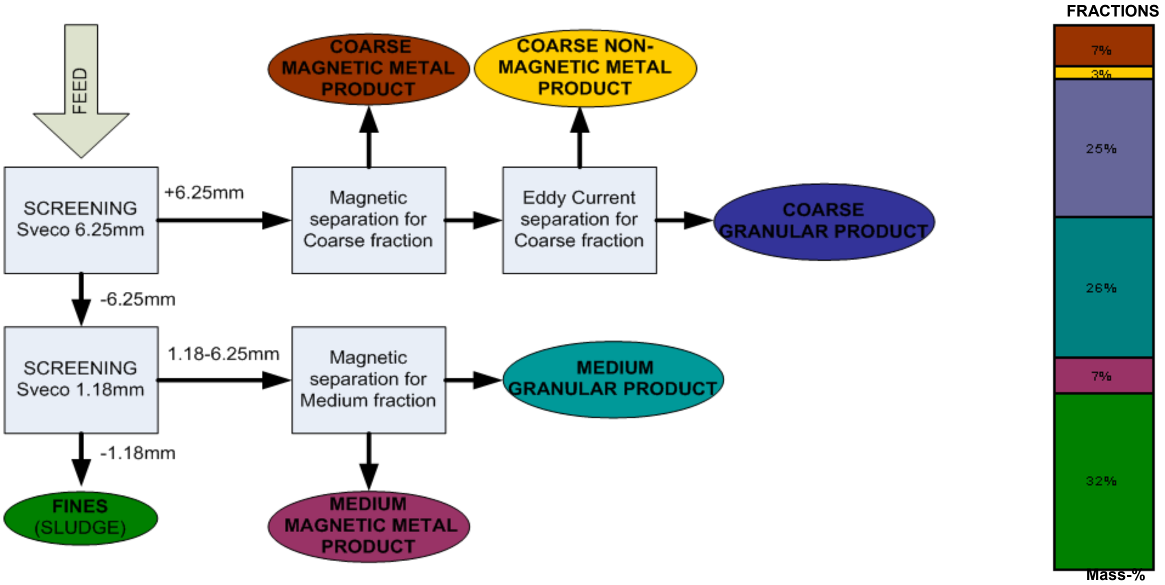


Figure 9-13 *Approximate fractional mass of products of the process relative to bottom ash feed*

Iron was recovered with good recovery, 87% for Coarse and 70% for Medium fraction (see Figure 9-9). The grade however was quite low, only 25% and 20%, respectively. According to the handpicking results for size fractions larger than 2mm, the concentration of total Coarse nonmagnetic metals (red nonferrous and grey nonmagnetic metals) is 5.6w-% for larger than 2mm particles. The Coarse nonmagnetic metal product with chosen process parameters was 3% of the total product mass with around 55% grade and 85% recovery. Even though the recovery for nonmagnetic metals recovery was good for the Coarse fraction, the total nonferrous recovery was quite poor; part of the nonmagnetic metals remained in the Granulate products because of the lacking nonferrous metals separation step for Medium fraction.

9.6 Environmental Quality of the Products

Figure 9-14 shows the concentrations of environmentally critical elements in the untreated bottom ash, the Granulate products and process Fines (Sludge) from bottom ash processing and the SAMASE-values (Appendix X). The results from the XRF measurements are shown in Appendix XX. Figure 9-14 shows that for nearly all the illustrated elements the concentration in Fines was the highest. This result indicates that bottom ash environmental quality can be improved by removing the finest fraction which contains largest concentrations of contaminants. In this case however, a treatment method for fines processing has to be developed in the future.

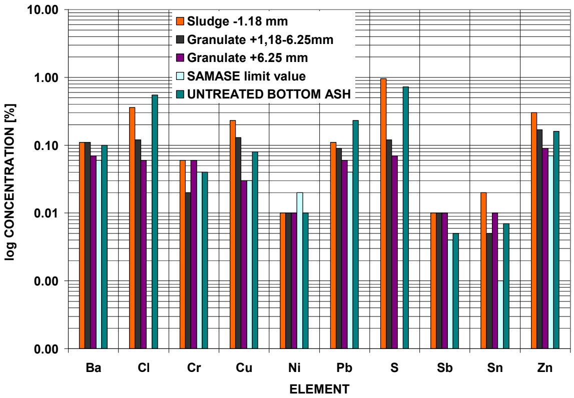


Figure 9-14 *Concentration of environmentally critical elements in the final products of bottom ash processing. All the values showing 0.01% are in reality <0.01%.*

Figure 9-14 shows that the contaminant concentrations in the Granulate products were higher than the SAMASE MAC values. The only exception nickel, where the concentrations were lower than the MAC value. Ni and Sb values for Sludge and for both of the Granulate products were <0.01%. No conclusions can be drawn from the Sb concentration, because of the inaccuracy of the XRF analysis. Figure 9-14shows that the concentrations of all the shown elements are lower for Coarse and Medium size fractions than for Fines and the overall contaminant concentration of Coarse Granulate was lower than the Medium Granulate for Ba, Cl, Cu, Pb, S and Zn in Figure 9-14. The difference in concentrations of Zn and Cu for different sized processed granulates can be partly explained by the lacking nonferrous separation step for Medium Granulate. The contaminant concentration in Medium Granulate was lower than in Coarse Granulate only for Cr and Sn. Also the characterization results of the concentration of Cr and Sn were higher in small particle size classes than in large particle size classes (see Figure 7-3).

The concentration of carbon (2.47w-%) was analyzed only from the Fines. The value is lower than the value obtained in the characterization (7%). Sludge in characterization step only included the fine particles pumped with the process water through 2mm screen to the sedimentation barrels. This way it was much finer than Fines from the process, which included all the material pumped to the sedimentation barrels and the underflow of 1.18mm screen. This carbon may consist of unburned incineration fuel and carbonate feed compounds. Because small particles have a larger specific surface area, and contained major part of carbon, particles in Fines may be responsible for a considerable fraction of heavy metal and salt release.

In order to use the bottom ash as raw material, e.g. for road construction, the contaminant concentrations should be within the MACs for non-polluted soil. The maximum allowed concentrations are, and most of contaminants in the products occurred in very low concentrations. Therefore it is difficult to decide the usability of the products without more profound testing.

Figure 9-15 shows the concentrations of contaminants in magnetic products and the same size granulates. The results show that magnetic separation step can improve environmental quality of the product, by removing some environmentally hazardous elements such as Cu, Cr and Zn from the granulate. However one must remember that the magnetic product is only a small fraction of the size class. The overall concentration of fraction per element does not necessarily change significantly by separating the magnetic particles. The effect of magnetic separation might be important in the case of Cu, Zn, Pb, Cr, Ni and Si because it removes from bottom ash magnetic particles such as batteries.

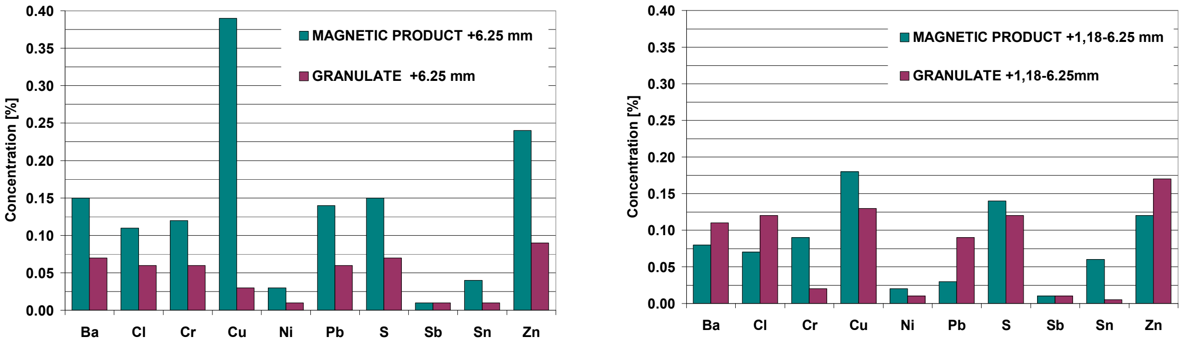


Figure 9-15 *Concentration of environmentally harmful elements in different sized magnetic products compared to same sized granulates a) Coarse particles b) Medium particles*

The environmental quality of bottom ash products mainly depends on its leaching values. For the environmental impact evaluation, leaching tests are required before conclusions can be made.

The results of the leaching tests on the process products are shown in Appendix XX and the acceptable MACs for different types of landfills is in European Union are shown in

Appendix XVI. Figure 9-16 shows the maximum leaching values (with liquid/solid ratio 10:1) of the untreated bottom ash and nonmetallic products of the bottom ash processing and compares them to the acceptable level of contaminants for landfill for inert waste.

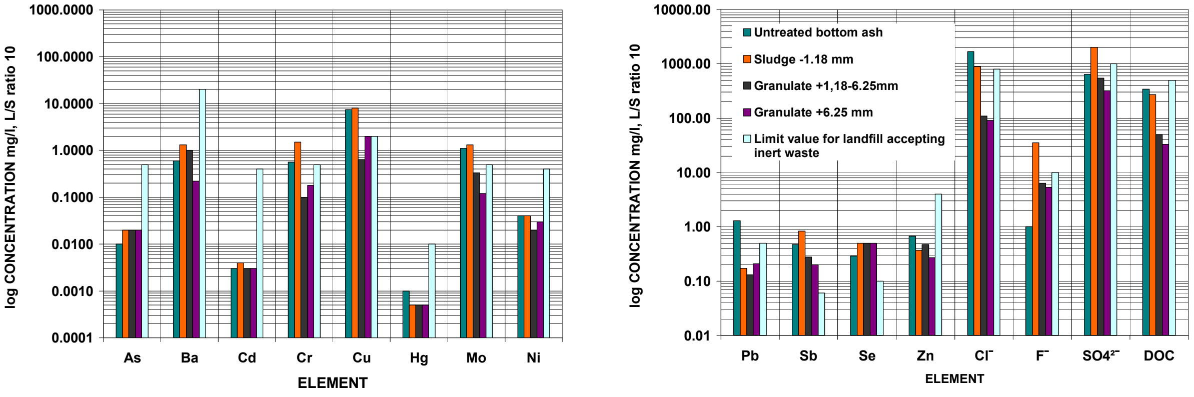


Figure 9-16 *Comparison of leaching values of selected elements in untreated bottom ash and treated fines and granulate bottom ash products to the MAC leaching values to which standard landfill accepts for waste*

The leaching values of As, Ba, Cd, Hg, Ni, Zn and dissolved organic carbon (DOC) were lower for all the process products as well as it was for the untreated bottom ash, than the acceptable value for a landfill accepting only inert waste. The DOC and nickel values were lower for coarse granulates than for Fines and untreated bottom ash. The leaching values for Cr were above the MAC for Fines and for untreated bottom ash, while the leaching values of Granulate products were lower than the MAC value. Same effect can be seen in the case of Cu, Mo and Cl^-. Leaching values of copper for Coarse Granulate was at the MAC of acceptable value and higher than the leaching value of Medium Granulate, which well below of the MAC value. This was the case even though the XRF results for Medium Granulate showed higher copper concentration than for Coarse Granulate. Based on this result, the nonferrous metals separation step is not necessary for the Medium fraction in order to reach acceptable leaching values for copper.

The leaching values of lead for untreated bottom ash was higher than the MAC, but for the process products the concentrations were lower than the MAC. The separation of metals might have had a positive effect on the quality. The leaching values of antimony were higher than the MAC in all the cases, in fact the leaching value of antimony in Fines was so high that it is classified as hazardous waste. The leaching values of antimony for granulates was lower than for the untreated bottom ash and Fines. Also the leaching values of selenium were too high in all the cases. The fluoride and SO_4^{2-} leaching values were too high for Fines, the values for granulates being lower than the MAC value.

10 CONCLUSIONS AND RECOMMENDATIONS

In this thesis suitable processing methods were studied for metals recovery from MSWI bottom ash. A literature survey has been done to investigate existing data on bottom ash properties and processing methods. The result is an overview on the composition and variations of MSWI bottom ash, the factors influencing the bottom ash quality and the usual processing practices. The literature study revealed that MSWI bottom ash is extremely inhomogeneous and generalizations of bottom ash composition are hard to make; many time and place dependent variables affect its quality.

In the experiments the bottom ash sample was first characterized. The designed experimental process flowsheet was based on the literature study and the bottom ash characterization. The MSWI bottom ash sample was processed according to the designed flowsheet; first wet screened, the magnetic particles were separated by magnetic separation and lastly the nonmagnetic material was processed using eddy current separation. After processing the qualities of the products were assessed.

The characterization consisted of analysis of sample material for particle size- and density, particle shape, composition analysis of valuable metal and contaminant content by chemical analysis and by handpicking the bottom ash particles into different material classes, and an overview of the state of liberation of the particles.

According to literature MSWI bottom ash contains a large fraction of very small (<2mm) particles that constitute the major part of environmentally harmful elements. The characterization supported the findings, 37w-% of bottom ash was smaller than 2mm, potentially containing highest concentrations of carbon, sulfur, chloride and zinc and having the largest massflows of many environmentally harmful elements. These were, in addition to the above mentioned elements, copper, lead and barium.

As for the characterization, handpicking was important with regard to the mechanical processing of bottom ash, because it gave a good overview of bulk properties and the distribution of mechanically separable metals in different particle size classes. The handpicked nonmagnetic metals concentration (both red nonferrous and grey nonmagnetic metals) was the highest for fractions larger than 5mm. According to the handpicking results, 90w-% of fairly well liberated iron scrap, 76w-% of “grey nonmagnetic metal” and 74w-% of “red nonferrous metal” particles were in the 10-40mm size fraction. This is an important result considering the traditional eddy current separation process, which works the best for particles larger than 10mm, and has an economic minimum for processing of 5mm. The literature study showed that 7-10w-% of bottom ash is scrap metals. The results from the handpicking were similar, however showing that scrap metal concentration is dependents on the size fraction. Total amount of scrap metals in the 20-40mm was 13% and decreasing when going to smaller size fractions. In the 2-5mm size fraction, there is 3w-% of scrap metals

The handpicking results showed that a great part (40-50w-%) of the particle size classes larger than 5mm were non-liberated agglomerates. The amount of agglomerates was smaller than the value introduced in literature survey (up to 85w-%). The amount of iron scrap was small compared to the magnetic agglomerates fraction. Literature showed high concentrations for iron scrap (4-15w-%). Assumingly most of the iron scrap was removed among other large metal scrap particles when screening it with 40mm screen, which was done before the bottom ash sample was taken. There were some metals in the agglomerates, but a comminution step should be included in the process flowsheet only if there is a way to separate small metallic particles from the bulk. For other than agglomerates the concentration of liberated metallic particles was fairly good in bottom ash. Other types of non-liberation found from bottom ash were thermal fusion and mechanic attachment of metals. A substantial part of copper and nearly all aluminum was molten and the sample had no recognizable non-combusted material particles. This shows that either the unburnt material is larger than 40mm, which was removed before sampling for experiments, or the burning process in Turku incineration plant is efficient. The amount of non-incinerated material found in literature survey was 1-5% of bottom ash weight.

Based on the results of density measurements it can be concluded that it is possible to separate copper from bottom ash by gravity separation. However, for separation of aluminum from the bottom ash, the density difference with nonmetallic particles is not sufficient.

The characterization step was important because it showed it is possible to predict how ash would behave in the processing methods and the material flows of different elements to the various products. The attained data can be interpreted as a generalization of characteristics and processing possibilities for MSWI bottom ash.

The process developed included wet screening of the bottom ash into three particle size classes: +6.25mm (Coarse), 0.18-6.25mm (Medium) and sludge of 0-0.18mm (Fines). Wet screening was chosen for environmental and work hygienic reasons; bottom ash is very dusty when dried. In the literature, wet screening proved an efficient way for washing the small fraction to the underflow and made it possible to wash out some soluble salts. This was supported by the results of this study. One of the challenges in bottom ash screening is the presence of metal wires, which can cause screen blocking and reduce screening efficiency.

In addition to the waste water problem, another problem with wet processing was that Medium particles cannot be treated damp in magnetic separation, which was predicted, based on the literature study. Therefore the Medium screening product needed to be dried.

Figure 10-1 shows the massflows of different products after processing. The fines product, which was 32w-% of the total product dry mass, was delivered for treatebility tests to Salvor Oy and the Coarse and Medium products were processed with magnetic and eddy current separators and the performance of the processes were assessed.

As shown in Figure 10-1, both of the magnetic products, the fraction of Coarse and Medium Magnetic products were 7w-% of total solid output. From the Coarse fraction 87% of iron was recovered at a grade of 25% and from the Medium fraction 71% of iron was recovered at a grade of 20%. The quality of the magnetic product was poor; the bulk density was low and it contained some copper, lowering the steel scrap's quality.

Bottom ash was challenging material for eddy current separation. Only around 40w-% of bottom ash is the suitable particle size range for eddy current separation (>5mm), and the shape range of nonmagnetic metal particles in bottom ash is very wide. The amount of coarse nonmagnetic metal product was 3w-% of total dry output. For particles larger than 6.25mm also the recovery of nonferrous metals was possible by traditional eddy current separation. Considering the heterogeneity in shape and size, the reached metals recovery was good (85% for Grey nonmagnetic metals and 90% for red nonferrous metals) with mixed metal grade of around 55%.

Even though the recovery for nonmagnetic metals was good for the Coarse fraction, the total nonferrous recovery was not as good. A part of the nonmagnetic metals remained in the Granulate products (tailings from eddy current separation) because the tested nonferrous metals separation steps (eddy current separator and pneumatic shaking table) for Medium fraction did not work, as was expected based on the literature.

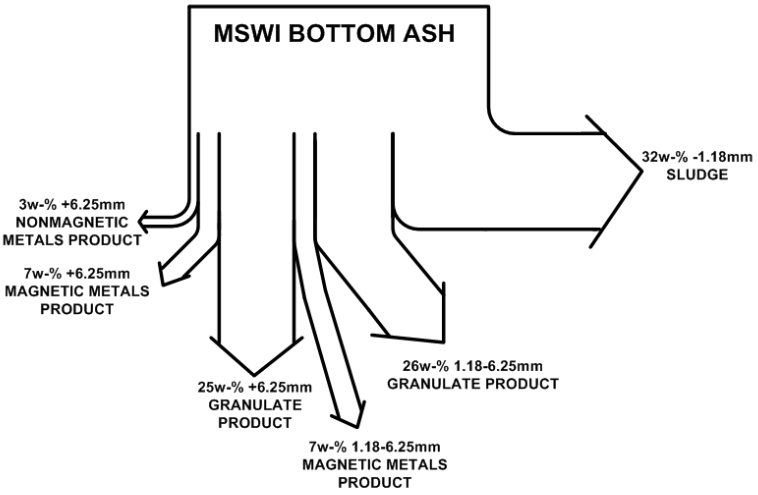


Figure 10-1 *Mass flows of bottom ash processing, expressed in dry mass-% of total solid output*

Figure 10-1 shows that the total amount of granulate products (Coarse and Medium) was 51w-% of total dry output. For untreated bottom ash, the obtained leaching values of many elements (Cr, Cu, Mo, Pb, Sb, Se, Cl^-) exceeded the MAC values of landfill accepting inert waste. After processing the leaching values for the Granulate products was over the MAC for inert waste landfills only for Se and Sb. In the Fines, the leaching value of antimony was so high that it can only be placed into landfills accepting hazardous waste.

Because leaching value of copper in the Medium Granulate product (26w-% of the total output) was below the MAC for inert landfills, the nonferrous metals separation step was found unnecessary for the Medium fraction in order to reach acceptable leaching values for copper. The Coarse Granulate product (25w-%) showed a higher leaching value for copper even though the red-nonferrous metal particles were separated with good recovery and its copper concentration (XRF) was lower than for Medium Granulate.

Based on the leaching results, the process improved the quality of bottom ash by concentrating the SAMASE listed elements to the Fines products and this way decreasing the volume of waste with unacceptable leaching values and by recovering some metals. Because small particles have a larger specific surface area and contain the major part of carbon, fine particles are responsible for a considerable fraction of heavy metal and salt release. The results indicate that the environmental quality of MSWI bottom ash can be improved by removal of the finest fraction by wet screening, for this fraction contains the largest concentrations of contaminants. The result is supported by the findings from the literature.

In order to use the bottom ash granulate products as raw material for the civil engineering industry there should be first made MAC leaching values of SAMASE-listed elements especially for building materials, before bottom ash processing can be optimized to meet those requirements. In Finland this kind of values do not exist yet, unlike in countries, where waste has been incinerated for a longer period of time (e.g. Denmark, The Netherlands).

The more complicated the treatment process and the cleaner the product it produces, the higher the use of resources per unit mass of MSWI bottom ash. From the point of view of the recycling material market, high resource use result in high price of cleaned product will constrain material recycling. Also, it is not easy to further improve the quality to a higher level after a certain level has been reached. Figure 10-2 shows the relationship between input and output quality of treatment. For an increase in recycling rate the use of resources per ton of treated bottom ash increase unequivalently faster. However, recycling of metals from waste may give indirect savings and environmental benefits, which may not appear on the short term. An example of this may be the reduction of the use of primary resources and energy in secondary aluminum production.

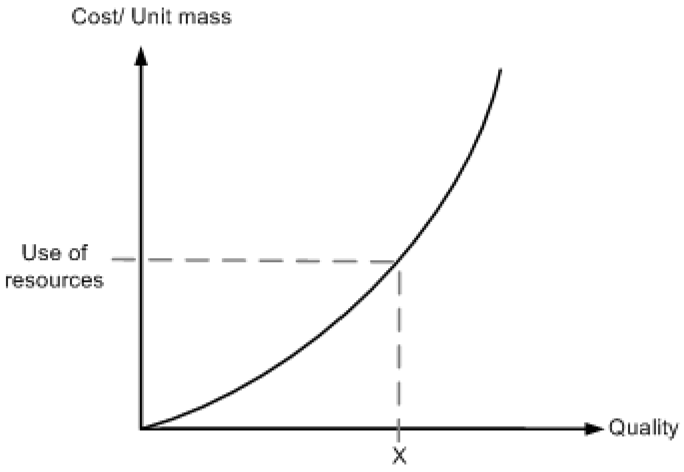


Figure 10-2 *Relationship between quality improvement and costs input (processing and investment) per unit mass of product (where X is e.g. environmental quality and/or metals grade-recovery)*

The concentrations of most contaminants in the products occurred in very low concentrations. The MAC values are very low as well and often a greater accuracy of the data is needed to verify true toxicity of the sample. Therefore it is difficult to decide the usability of the products without more extensive testing and well planned sampling. It should be understood that these results only apply reliably to the material investigated in these experiments.

The process flowsheet used can be applied as a pre-concentration step for recovery of metals from MSWI bottom ash. The metal products need to be further processed in order to reach the quality requirements for raw material for metallurgical processing. Larger scale pilot plant tests are needed for more reliable evaluation of feasibility of bottom ash treatment and processing. Also, wet eddy current separation could be tested for nonmagnetic metals separation from the Medium fraction. Furthermore, the metal product needs a thorough metallurgical quality assessment. The chemical analysis results call for mineralogical study of MSWI bottom ash to evaluate compound structure and chemical activity, for both metals recycling and environmental point of view. Most importantly, although wet processing shows its advantages, feasibility studies on waste water management and fines treatment need to be considered.

If the waste management strategy in Finland develops towards incineration of waste, there will be a need for establishing a practice for management of its residues, bottom ash being the largest waste stream. The process described in this thesis is one possible treatment option for bottom ash among many processing possibilities. To summarize the benefits from this type of wet processing and metals separation are good recovery of metals, effective Fines removal and producing Granulate products with improved leaching properties when compared to untreated bottom ash.

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APPENDICES

Appendix I

Table 0-1 *Bottom ash particle size distribution from literature*

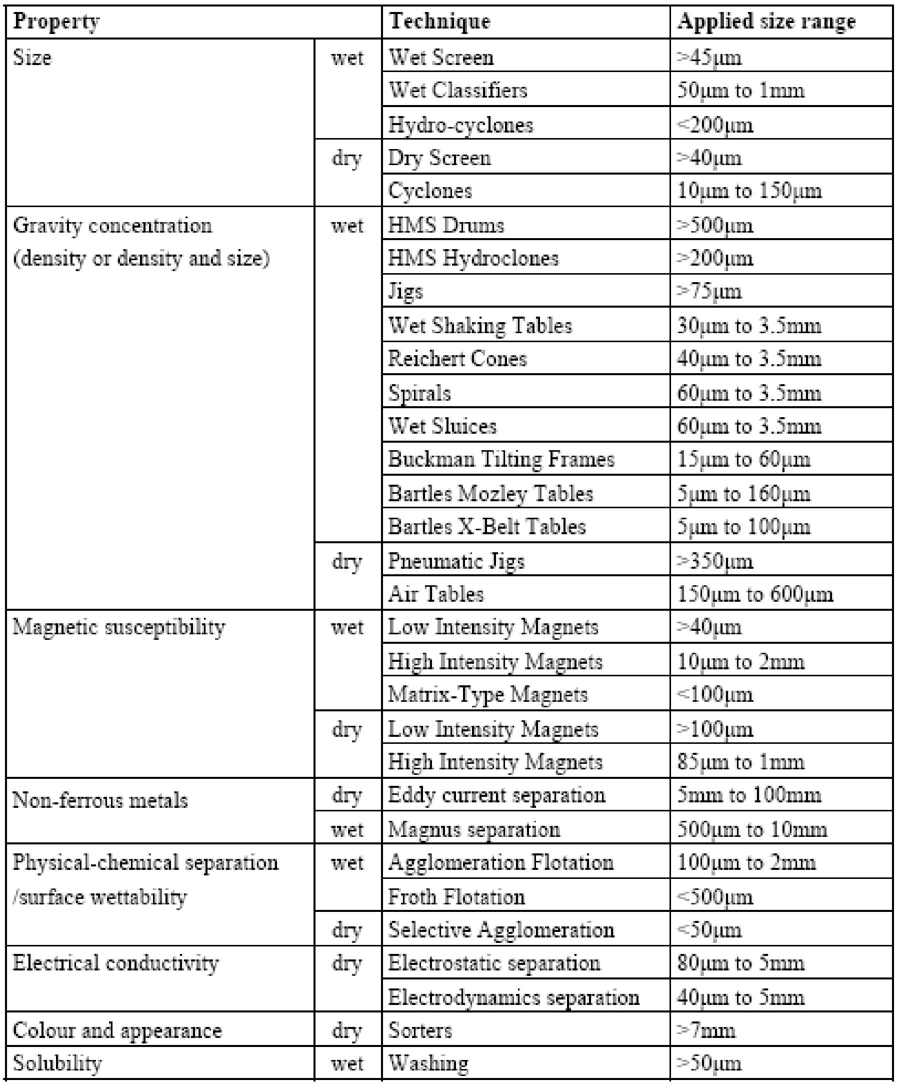
R. Forteza et al. [32]			H.-M. Lo et al. [33]		J.M. Chimenos et al. [9]		
Top size (mm)	Accumulated w-%		Top size (mm)	Accumulated w-%	Top size (mm)	a	b
	max	min		average		average	average
0.075	5	2	**0.3**	3.28	**0.5**	14	18
0.09	7	3	**0.6**	4.26	**1.5**	27	32
0.5	18	9	**1.18**	14.76	**3**	49	53
1	24	12	**2**	35.92	**5**	63	68
2.5	41	27	**5**	68.8	**10.5**	83	92
5	66	50	**20**	96.4	**20.5**	98	99
8	90	77	**63**	100	**40**	100	100
10	95	85					
12.5	98	92					
40	100	100					

Table 0-2 *Concentration of elements in bottom ash*

	CONCENTRATION (%)	
Element	**min**	**max**
Ag	0.00003	0.00369
Al	2.19000	7.28000
As	0.00001	0.01890
B	0.00380	0.05100
Ba	0.04000	0.30000
Br	0.00014	0.01502
C	1.00000	6.00000
Ca	0.03700	12.30000
Cd	0.00003	0.00705
Cl	0.08000	0.41900
Co	0.00060	0.03500
Cr	0.00230	0.31700
Cs	0.00010	0.00020
Cu	0.01900	0.82400
Fe	0.02000	0.11000
Fe	0.41200	15.00000
Hg	0.00000	0.00078
K	0.07500	1.60000
Mg	0.04000	2.60000
Mn	0.00830	0.24000
Mo	0.00025	0.02760
N	0.01100	0.09000
Na	0.28700	4.20000
Ni	0.00070	0.42800
O	40.00000	50.00000
P	0.14000	0.64000
Pb	0.00980	1.37000
S	0.10000	0.50000
Sb	0.00100	0.04300
Se	0.00001	0.00100
Si	9.10000	30.80000
Sn	0.00020	0.03800
Sr	0.00850	0.10000
Ti	0.26000	0.95000
Zn	0.06130	0.77700
Reference	**A.J. Chandler et al. [35]**	

Appendix II

Table 0-3 *Applied size ranges of common separation techniques [1]*



Property		Technique	Applied size range
Size	wet	Wet Screen	>45μm
		Wet Classifiers	50μm to 1mm
		Hydro-cyclones	<200μm
	dry	Dry Screen	>40μm
		Cyclones	10μm to 150μm
Gravity concentration (density or density and size)	wet	HMS Drums	>500μm
		HMS Hydroclones	>200μm
		Jigs	>75μm
		Wet Shaking Tables	30μm to 3.5mm
		Reichert Cones	40μm to 3.5mm
		Spirals	60μm to 3.5mm
		Wet Sluices	60μm to 3.5mm
		Buckman Tilting Frames	15μm to 60μm
		Bartles Mozley Tables	5μm to 160μm
		Bartles X-Belt Tables	5μm to 100μm
	dry	Pneumatic Jigs	>350μm
		Air Tables	150μm to 600μm
Magnetic susceptibility	wet	Low Intensity Magnets	>40μm
		High Intensity Magnets	10μm to 2mm
		Matrix-Type Magnets	<100μm
	dry	Low Intensity Magnets	>100μm
		High Intensity Magnets	85μm to 1mm
Non-ferrous metals	dry	Eddy current separation	5mm to 100mm
	wet	Magnus separation	500μm to 10mm
Physical-chemical separation /surface wettability	wet	Agglomeration Flotation	100μm to 2mm
		Froth Flotation	<500μm
	dry	Selective Agglomeration	<50μm
Electrical conductivity	dry	Electrostatic separation	80μm to 5mm
		Electrodynamics separation	40μm to 5mm
Colour and appearance	dry	Sorters	>7mm
Solubility	wet	Washing	>50μm

Appendix III

Sampling: Composition analysis

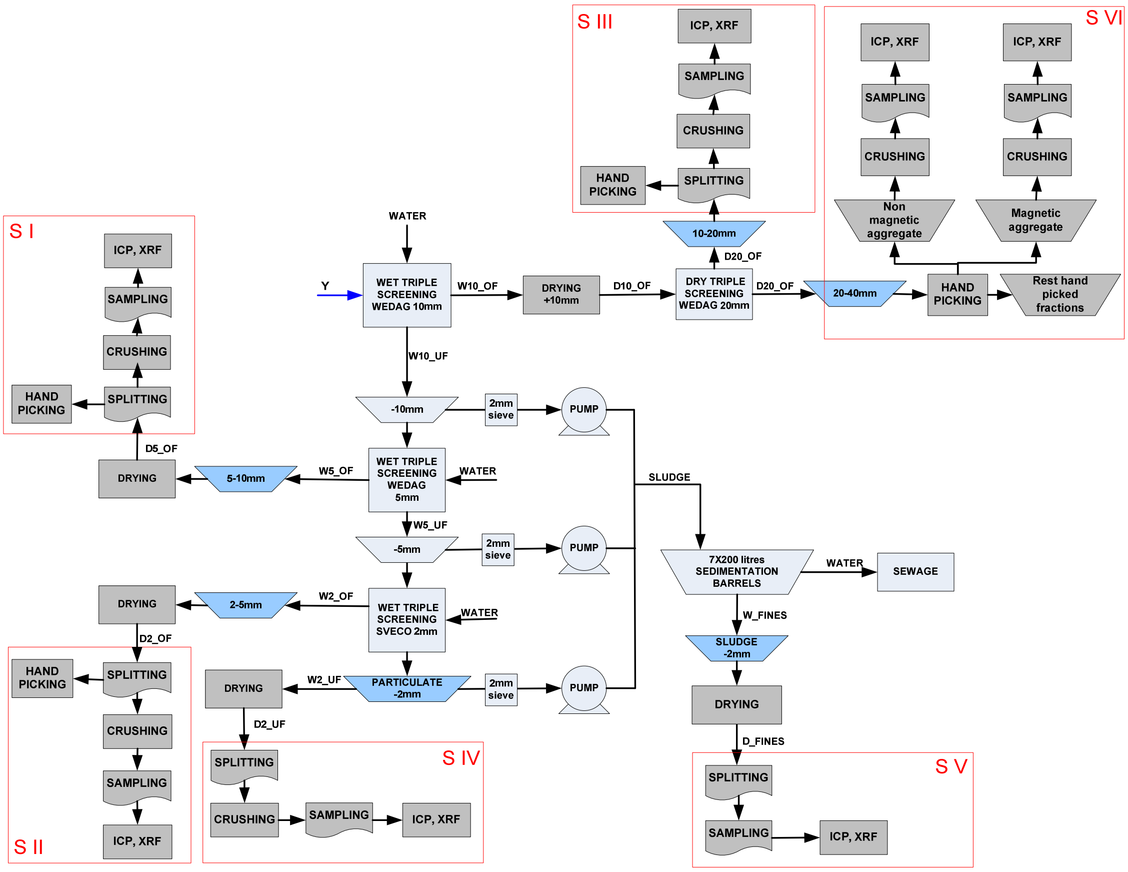


Figure 0-1 *S I: 5-10mm, S II: 2-5mm, S III:10-20mm, S IV: 0-2mm particulate, S V: 0-2mm sludge, S VI: 20-40mm*

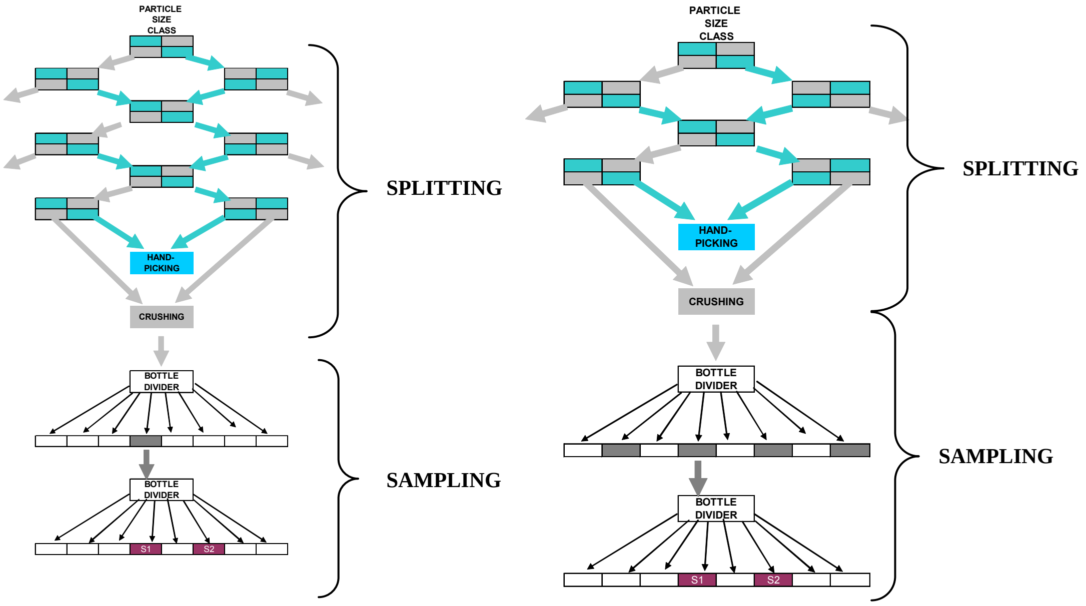


Figure 0-2 *Sampling procedure of size fractions for chemical analysis a) cases S I and S II (2-5mm and 5-10mm) b)case S III*

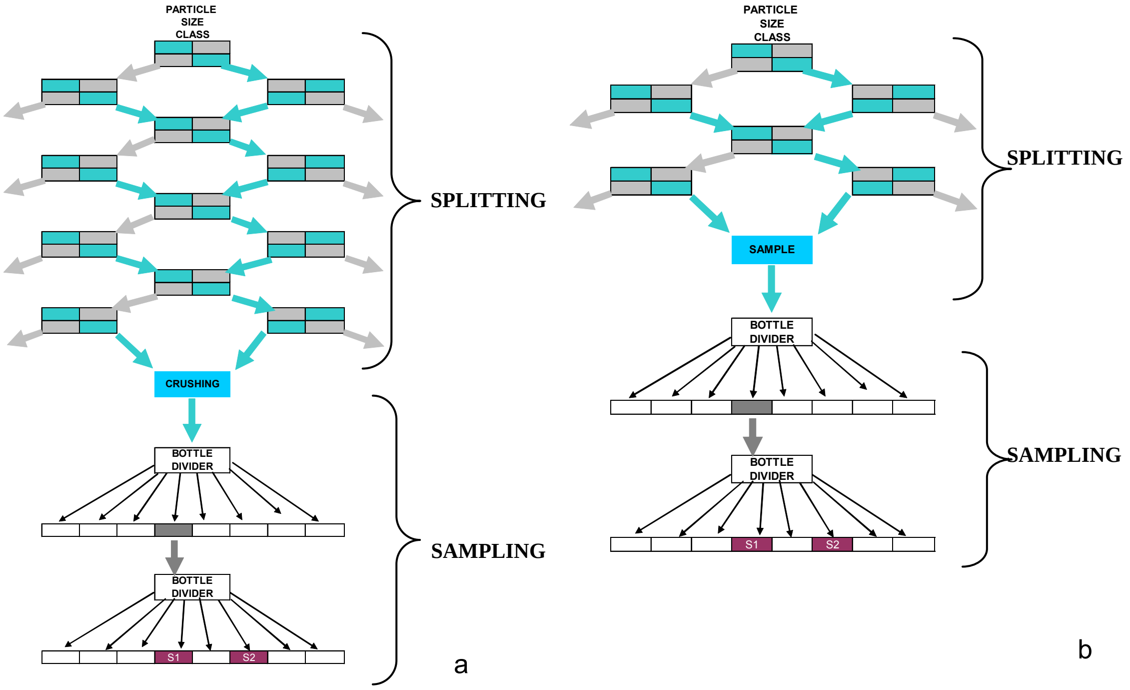


Figure 0-3 *Sampling procedure 0-2mm particulate size fraction, a) case S IV, b) case S V*

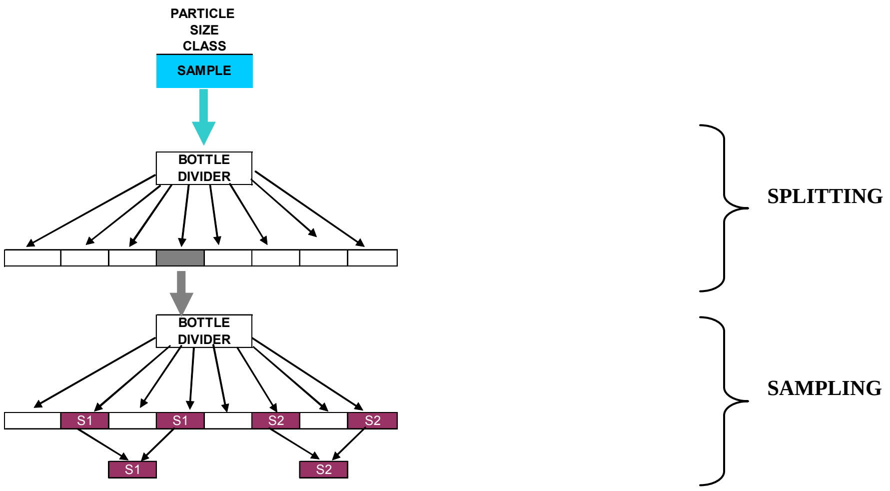


Figure 0-4 *Sampling for chemical analysis of 20-40mm magnetic agglomegate, case S VI*

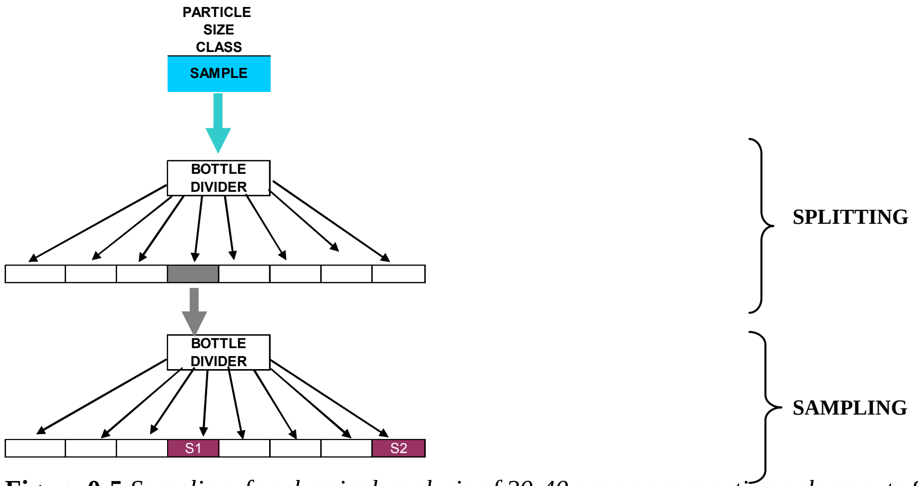


Figure 0-5 *Sampling for chemical analysis of 20-40mm non-magnetic agglomegate S VI*

Appendix IV

Sampling masses for characterization and process (Flowsheet: Error! Reference source not found.)

Table 0-4 *Raw data of masses of sampling [kg]*

SAMPLE	SAMPLE MASS		RELATIVE ERROR *	ERROR ESTIMATE σ**
A	262	kg	0.76%	0.76%
B	288	kg	0.69%	0.69%
C	284	kg	0.70%	0.70%
D	302	kg	0.66%	0.66%
E1	280	kg	0.71%	0.71%
E2	224.45	kg	0.02%	0.71%
F	286	kg	0.70%	0.70%
A+B+C+D+E1+F	1702	kg	4.24%	1.73%
a	131.85	kg	0.04%	0.76%
1	128.50	kg	0.04%	0.76%
b	136.00	kg	0.04%	0.70%
2	149.20	kg	0.03%	0.70%
c	133.90	kg	0.04%	0.71%
3	145.10	kg	0.03%	0.71%
d	144.10	kg	0.03%	0.66%
4	150.65	kg	0.03%	0.66%
e	112.80	kg	0.04%	0.72%
5	110.95	kg	0.05%	0.72%
f	140.30	kg	0.04%	0.70%
6	144.60	kg	0.03%	0.70%
a1	104.45	kg	0.05%	0.77%
b1	104.10	kg	0.05%	0.70%
c1	101.15	kg	0.05%	0.71%
d1	109.95	kg	0.05%	0.66%
e1	85.85	kg	0.06%	0.72%
f1	105.85	kg	0.05%	0.70%
a2	28.45	kg	0.18%	0.78%
b2	30.95	kg	0.16%	0.71%
c2	32.30	kg	0.15%	0.72%
d2	33.85	kg	0.15%	0.68%
e2	26.75	kg	0.19%	0.74%
f2	31.80	kg	0.16%	0.72%
g	184.10	kg	0.03%	1.78%
h	3.85	kg	1.30%	2.20%
X	611.35	kg	0.01%	1.74%
Y	182.10	kg	0.03%	1.77%
X+h+Y+Storage	1626.30	kg	1.55%	13.32%

*Relative error is calculated from accuracy of used scale at the time

** ERROR ESTIMATE is calculated with: $\sigma = \sqrt{\sum_{n=1}^{N} \sigma^2}$, according to the flow sheet of the sampling procedure, shown in Figure 1

Appendix V

Estimation of moisture content of bottom ash (barrel E), the process sample X and the characterization sample Y

Table 0-5 *Moisture content measurements of barrel E*

MEASURED VALUE	BARREL E
Volume before drying [dm^3]	210
Relative error %	0.95%
Mass before drying [kg]	280
Relative error %	0.71%
Volume after drying [dm^3]	209
Relative error %	1.33%
Mass after drying [kg]	223.85
Relative error %	1.22%
Wet bulk density[kg/dm^3]	1.33
ERROR ESTIMATE%***	1.19%
Dry bulk density [kg/dm^3]	1.07
ERROR ESTIMATE%	1.81%
Moisture content %	**20.05%**
ERROR ESTIMATE%	2.17%

Table 0-6 *Estimation of sample bulk densities and moisture content of samples X and Y*

MEASURED VALUE	SAMPLE E	SAMPLE X			SAMPLE Y		
		1	2	average	1	2	average
Volume before drying [dm^3]*	210	3	3	3	3	3	3
Relative error %	0.95%	3.33%	3.33%		3.33%	3.33%	
Mass before drying [kg]**	280	3.753	3.501	3.627	3.628	3.717	3.673
Relative error %	0.71%	0.03%	0.03%		0.03%	0.03%	
Volume after drying [dm^3]	209	3	3	3	3	3	3
Relative error %	1.33%	3.33%	3.33%		3.33%	3.33%	
Mass after drying [kg]	223.85	3.205	2.988	3.097	3.098	3.150	3.124
Relative error %	1.22%	0.03%	0.03%		0.03%	0.03%	
Wet bulk density[kg/dm^3]	1.33	1.25	1.17	1.21	1.21	1.24	1.22
ERROR EST.%***	1.19%	3.33%	3.33%		3.33%	3.33%	
Dry bulk density [kg/dm^3]	1.07	1.07	1.00	1.03	1.03	1.05	1.04
ERROR EST.%	1.81%	3.33%	3.33%		3.33%	3.33%	
Moisture content %	**20.05%**	14.60%	14.65%	**14.63%**	14.61%	15.25%	**14.93%**
ERROR EST.%	2.17%	4.71%	4.71%		4.71%	4.71%	

*Volume was measured by filling 3 liters bucket with water. Used error was the accuracy of the scale which was: 2903g water could be fit in the 3000ml bucket=1/30

** Used error is the accuracy of the scale (2kg)

***The dr:ied ash was emptied into 5 barrels, each weighted separately and marked to the point ash filled the barrel and after removing the ash from barrels, the weight of same volume of water was measured. Used error is the accuracy of the scale (0.1kg)

**** The ERROR ESTIMATE was calculated cumulatively with $\sigma = \sqrt{\sum_{n=1}^{N} \sigma^2}$, where the relative errors of sample masses and bulk densities were used.

Appendix VI

Characterization: screening flow sheet and masses

Table 0-7 *Measured masses of characterization screening*

SAMPLE	SAMPLE MASS		RELATIVE ERROR	ERROR ESTIMATE σ*
W_Y	182.1	kg	1.00%	0.41%
W10_OF	33.6	kg	0.15%	4.79%
D10_OF	30.5	kg	0.16%	4.79%
D20_OF	22.0	kg	0.23%	4.80%
D20_UF	8.4	kg	0.60%	4.83%
W5_OF	36.9	kg	0.14%	4.79%
D5_OF	32.0	kg	0.16%	4.79%
W2_OF	42.5	kg	0.12%	4.79%
D2_OF	31.35	kg	0.16%	4.79%
W2_UF	56.27	kg	0.09%	4.79%
D2_UF	46.54	kg	0.11%	4.79%
SLUDGE	1418	kg	6.92%	4.79%
W_SLUDGE	17.4	kg	0.29%	4.80%
D_SLUDGE	9.1	kg	0.55%	4.83%

*The ERROR ESTIMATE was calculated cumulatively with $\sigma = \sqrt{\sum_{n=1}^{N} \sigma^2}$ according to the flow sheet in The relative errors of sample masses due to applied scale accuracy were used.

Results of characterization: particle size distribution

Table 0-8 *Dry masses and mass fractions of different size classes*

SIZE FRACTION	SAMPLE CODE	DRY MASS [kg]	ERROR ESTIMATE %	MASS FRACTION %	ERROR ESTIMATE %
0-2mm	D2_UF+D_SLUDGE	55.64	4.83%	37.24%	11.78%
2-5mm	D2_OF	31.35	4.79%	20.99%	11.76%
5-10mm	D5_OF	32.00	4.79%	21.42%	11.76%
10-20mm	D10_OF	22.00	4.80%	14.73%	11.76%
20-40mm	D20_OF	8.40	4.80%	5.62%	11.76%
TOTAL		149.39	10.74%		

Appendix VII

Material screened out from each grinded size fraction sample before sampling from chemical analysis

Table 0-1 *Material screened out with 0.5 mm screen from each grinded size fraction before splitting for chemical analysis*

SIZE FRACTION	**2-5 mm**			
SAMPLE MASS	**3888 g**			
	CLASS	**m [g]**	**ERROR EST. %**	**w-%**
	Grey nonmagn.	114.0	0.09%	2.93%
	Red nonferrous	27.8	0.36%	0.72%
	Magnetic	27.9	0.36%	0.72%
	TOTAL	169.7	0.52%	4.36%

SIZE FRACTION	**5-10mm**			
SAMPLE MASS	**3912 g**			
	CLASS	**m [g]**	**ERROR EST. %**	**w-%**
	Grey nonmagn.	140.1	0.07%	3.58%
	Red nonferrous	41.1	0.24%	1.05%
	Magnetic	29.0	0.34%	0.74%
	Total	210.2	0.43%	5.37%

SIZE FRACTION	**10-20 mm**			
SAMPLE MASS	**5326 g**			
	CLASS	**m [g]**	**ERROR EST. %**	**w-%**
	Non magn.	116.4	0.09%	2.19%
	Red nonferrous	67.3	0.15%	1.26%
	Magnetic	81.2	0.12%	1.52%
	Total	264.9	0.21%	4.97%

SIZE FRACTION				
SAMPLE MASS	**2163 g**			
	CLASS	**m [g]**	**ERROR EST.**	**w-%**
	Grey nonmagn.	12.3	0.81%	0.57%

SIZE FRACTION				
SAMPLE MASS	**1365 g**			
	CLASS	**m [g]**	**ERROR EST. %**	**w-%**
	Grey nonmagn.	5.2	1.92%	0.38%

Appendix VIII

Characterization: samples for chemical analysis

Table 0-2*Sample masses for chemical analysis of 5-10mm size fraction (S I)*

S I (5-10mm)	mass [g]	fraction [%]
ORIGINAL MASS	32000.00	100.00%
HANDPICKING	1730.10	5.41%
CRUSHING	3912.00	12.23%
S1	62.05	1.59%
S2	59.22	1.51%

Table 0-3 *Sample masses for chemical analysis of 0-2mm sludge size fraction (S V)*

S V (0-2mm sludge)	mass [g]	fraction [%]
ORIGINAL MASS	9100.00	100.00%
SAMPLE	2185.00	24.01%
S1	34.37	1.57%
S2	35.09	1.61%

Table 0-4 *Sample masses for chemical analysis of 2-5mm size fraction* (SII)

S II (2-5mm)	mass [g]	fraction [%]
ORIGINAL MASS	31350.00	100.00%
HANDPICKING	1025.20	3.27%
CRUSHING	3888.00	12.40%
S1	60.20	1.55%
S2	61.99	1.59%

Notice: Sample for handpicking was further split half (mass in this table) according to procedure described in

Table 0-5 *Sample masses for chemical analysis of 10-20mm size fraction (S III)*

S III (10-20mm)	mass [g]	fraction [%]
ORIGINAL MASS	8400.00	100.00%
HANDPICKING	3072.20	36.57%
CRUSHING	5326.00	63.40%
S1	36.89	0.69%
S2	34.11	0.64%

Table 0-6 *Sample masses for chemical analysis of -2mm particulate size fraction (S IV)*

S IV (0-2mm particulate)	mass [g]	fraction [%]
ORIGINAL MASS	46536.00	100.00%
CRUSHING	3213.00	6.90%
S1	50.60	1.57%
S2	49.47	1.54%

Table 0-7 *Sample masses for chemical analysis of 20-40mm magnetic agglomerate size fraction (S VI)*

S VI (20-40mm magnetic agglomerate)	mass [g]	fraction [%]
ORIGINAL MASS	2163	100.00%
SPLITTING	268.11	12.40%
S1	35.12	1.62%
S2	34.83	1.61%

Table 0-8 *Sample masses for chemical analysis of 20-40mm non- magnetic agglomerate size fraction (S VI)*

S VI (20-40mm magnetic agglomerate)	mass [g]	fraction [%]
ORIGINAL MASS	1365	100.00%
SPLITTING	173.80	12.73%
S1	41.28	3.02%
S2	40.65	2.98%

Table 0-9 *Samples for chemical analysis*

	mass [g]	
SAMPLES FOR CHEMICAL ANALYSIS	S1	S2
S I (5-10mm)	62.05	59.22
S II (2-5mm)	60.20	61.99
S III (10-20mm)	36.89	34.11
S IV (-2mm particulate)	50.60	49.47
S V (-2mm sludge)	34.37	35.09
S VI (20-40mm magnetic agglomerate)	35.12	34.83
S VI (20-40mm non-magnetic agglomerate)	41.28	40.65

Appendix IX

XRF and ICP results of the characterization: chemical composition of particle size 2-20mm

Table 0-10 *XRF and ICP results. Chemical composition of 0-2mm sludge.*

0-2mm	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
SLUDGE	**1**	**2**	**AVERAGE**	**[±p%]**	**1**	**2**	**AVERAGE**	**[±p%]**	**XRF-ICP [p%]**
Ag	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0002	0.0002	0.0002
Al	6.8700	6.7741	6.8221	0.0479	6.3300	6.3100	6.3200	0.0100	0.5021
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0106	0.0053	0.0053	0.0053
Ba	0.1360	0.1300	0.1330	0.0030	0.1090	0.1030	0.1060	0.0030	0.0270
Bi	0.0030	0.0030	0.0030	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	7.2000	7.2000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	21.6000	21.1000	21.3500	0.2500	20.1000	21.5000	20.8000	0.7000	0.5500
Cd	N.A.	N.A.	N.A.	N.A.	0.0016	0.0024	0.0020	0.0004	N.A.
Ce	0.0040	0.0040	0.0040	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.5900	0.5800	0.5850	0.0050	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0100	0.0130	0.0115	0.0015	0.0056	0.0051	0.0053	0.0003	0.0062
Cr	0.0180	0.0900	0.0540	0.0360	0.0759	0.0794	0.0777	0.0018	0.0237
Cs	0.0000	0.0010	0.0005	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.1650	0.1650	0.1650	0.0000	0.1640	0.1510	0.1575	0.0065	0.0075
Fe	1.6100	1.5900	1.6000	0.0100	1.5000	1.5700	1.5350	0.0350	0.0650
Ga	0.0018	0.0017	0.0018	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
K	0.6200	0.4010	0.5105	0.1095	0.8860	0.9130	0.8995	0.0135	0.3890
Li	N.A.	N.A.	N.A.	N.A.	0.0068	0.0064	0.0066	0.0002	N.A.
La	0.0040	0.0060	0.0050	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.5100	1.4800	1.4950	0.0150	1.5000	1.5000	1.5000	0.0000	0.0050
Mn	0.0940	0.0970	0.0955	0.0015	0.0962	0.1080	0.1021	0.0059	0.0066
Mo	0.0006	0.0002	0.0004	0.0002	0.0020	0.0020	0.0020	0.0000	0.0016
Na	0.5900	0.4599	0.5250	0.0650	0.5480	0.5120	0.5300	0.0180	0.0050
Nb	0.0025	0.0027	0.0026	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0110	0.0100	0.0105	0.0005	0.0096	0.0055	0.0076	0.0020	0.0029
P	0.7300	1.0616	0.8958	0.1658	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.1790	0.1760	0.1775	0.0015	0.1640	0.1560	0.1600	0.0040	0.0175
Rb	0.0010	0.0001	0.0006	0.0004	N.A.	N.A.	N.A.	N.A.	N.A.
S	3.0600	2.9200	2.9900	0.0700	2.1300	2.2000	2.1650	0.0350	0.8250
Sb	0.0250	0.0260	0.0255	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Si	8.2900	8.2100	8.2500	0.0400	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0350	0.0350	0.0350	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0380	0.0098	0.0239	0.0141	0.0290	0.0291	0.0291	0.0000	0.0052
Ta	0.0010	0.0020	0.0015	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.8100	0.7900	0.8000	0.0100	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0071	0.0069	0.0070	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0010	0.0010	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0011	0.0010	0.0011	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.3180	0.3150	0.3165	0.0015	0.3290	0.3330	0.3310	0.0020	0.0145
Zr	0.0180	0.0196	0.0188	0.0008	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

0-2mm	CONCENTRATION XRF [%]			DEVIATION
SLUDGE	**S1**	**S2**	**AVERAGE**	**[±p%]**
SiO2	17.7000	17.6000	0.0000	0.0500
TiO2	2.3500	1.3200	6.8221	0.5150
Al2O3	13.0000	12.8000	0.0000	0.1000
Cr2O3	0.1320	0.1320	0.1330	0.0000
V2O3	0.0100	0.0100	0.0030	0.0000
FeO	2.0500	2.0400	7.2000	0.0050
MnO	0.1210	0.1250	21.3500	0.0020
MgO	2.5000	2.4600	0.0000	0.0200
CaO	30.2000	29.6000	0.0040	0.3000
Rb2O	0.0011	0.0011	0.5850	0.0000
SrO	0.0450	0.0440	0.0115	0.0005
BaO	0.1520	0.1460	0.0540	0.0030
Na2O	0.7900	0.7800	0.0005	0.0050
K2O	0.7500	0.7300	0.1650	0.0100
ZrO2	0.0240	0.0230	1.6000	0.0005
P2O2	1.6600	1.6100	0.0018	0.0250
CO2	0.0000	26.4000	0.5105	13.2000
OxSumm	71.4851	95.8211	0.0000	12.1680

Table 0-11 *XRF and ICP results Chemical composition of 0-2mm particulate.*

0-2mm	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
PARTICULATE	S1	S2	AVERAGE	[±p%]	S1	S2	AVERAGE	[±p%]	XRF-ICP [p%]
Ag	0.0000	0.0000	0.0000	0.0000	0.0006	0.0005	0.0006	0.0000	0.0006
Al	7.1500	7.0916	7.1208	0.0292	6.6000	6.9600	6.7800	0.1800	0.3408
As	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
Ba	0.1270	0.1280	0.1275	0.0005	0.1240	0.1260	0.1250	0.0010	0.0025
Bi	0.0040	0.0030	0.0035	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	1.4400	1.4400	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	8.1700	8.0300	8.1000	0.0700	8.5000	8.4300	8.4650	0.0350	0.3650
Cd	N.A.	N.A.	N.A.	N.A.	0.0006	0.0039	0.0022	0.0016	N.A.
Ce	0.0060	0.0050	0.0055	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.1920	0.1640	0.1780	0.0140	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0030	0.0140	0.0085	0.0055	0.0065	0.0078	0.0071	0.0007	0.0014
Cr	0.0500	0.0490	0.0495	0.0005	0.8440	0.0391	0.4416	0.4025	0.3921
Cs	0.0040	0.0030	0.0035	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.3660	0.3160	0.3410	0.0250	0.2350	0.9660	0.6005	0.3655	0.2595
Fe	6.0500	5.8400	5.9450	0.1050	9.3100	5.9700	7.6400	1.6700	1.6950
Ga	0.0019	0.0013	0.0016	0.0003	N.A.	N.A.	N.A.	N.A.	N.A.
K	2.0100	1.3073	1.6587	0.3513	2.4000	2.6300	2.5150	0.1150	0.8563
Li	N.A.	N.A.	N.A.	N.A.	0.0076	0.0066	0.0071	0.0005	N.A.
La	0.0040	0.0060	0.0050	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.4200	1.3800	1.4000	0.0200	1.4400	1.4100	1.4250	0.0150	0.0250
Mn	0.0980	0.0920	0.0950	0.0030	0.1650	0.0882	0.1266	0.0384	0.0316
Mo	0.0000	0.0000	0.0000	0.0000	0.1090	0.0000	0.0545	0.0545	0.0545
Na	2.3200	1.8161	2.0680	0.2520	2.1800	2.4800	2.3300	0.1500	0.2620
Nb	0.0023	0.0020	0.0022	0.0002	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0160	0.0140	0.0150	0.0010	0.5920	0.0071	0.2996	0.2924	0.2846
P	0.7500	1.0879	0.9190	0.1690	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.2380	0.1630	0.2005	0.0375	0.1250	0.1050	0.1150	0.0100	0.0855
Rb	0.0062	0.0008	0.0035	0.0027	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.3820	0.3680	0.3750	0.0070	0.2830	0.2640	0.2735	0.0095	0.1015
Sb	0.0210	0.0180	0.0195	0.0015	N.A.	N.A.	N.A.	N.A.	N.A.
Si	25.0000	24.8000	24.9000	0.1000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0370	0.0310	0.0340	0.0030	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0290	0.0075	0.0183	0.0107	0.0298	0.0310	0.0304	0.0006	0.0121
Ta	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.8200	0.8100	0.8150	0.0050	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0096	0.0093	0.0095	0.0002	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0000	0.0010	0.0005	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0005	0.0007	0.0006	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.3320	0.3900	0.3610	0.0290	0.3060	0.2940	0.3000	0.0060	0.0610
Zr	0.0210	0.0221	0.0216	0.0006	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

0-2mm	CONCENTRATION XRF [%]			DEVIATION
PARTICULATE	S1	S2	AVERAGE	[±p%]
SiO2	53.4000	53.0000	53.2000	0.2000
TiO2	1.3800	1.3500	1.3650	0.0150
Al2O3	13.5000	13.4000	13.4500	0.0500
Cr2O3	0.0730	0.0710	0.0720	0.0010
V2O3	0.0140	0.0140	0.0140	0.0000
FeO	7.7900	7.5100	7.6500	0.1400
MnO	0.1260	0.1180	0.1220	0.0040
MgO	2.3500	2.2800	2.3150	0.0350
CaO	11.4000	11.2000	11.3000	0.1000
Rb2O	0.0068	0.0069	0.0069	0.0001
SrO	0.0340	0.0340	0.0340	0.0000
BaO	0.1420	0.1430	0.1425	0.0005
Na2O	3.1200	3.0800	3.1000	0.0200
K2O	2.4200	2.3800	2.4000	0.0200
ZrO2	0.0028	0.0260	0.0144	0.0116
P2O2	1.7200	1.6500	1.6850	0.0350
CO2	0.0000	5.2800	2.6400	2.6400
OxSumm	97.4786	101.5429	99.5108	2.0322

Table 0-12 *XRF and ICP results Chemical composition of 2-5mm partcles.*

2-5mm	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
	1	2	AVERAGE	[±p%]	1	2	AVERAGE	[±p%]	XRF-ICP [p%]
Ag	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Al	5.5100	5.8215	5.6657	0.1557	6.6400	6.5400	6.5900	0.0500	0.9243
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ba	0.1370	0.1300	0.1335	0.0035	0.0990	0.0946	0.0968	0.0022	0.0367
Bi	0.0030	0.0040	0.0035	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	0.5500	0.5500	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	7.2500	7.1000	7.1750	0.0750	7.2100	6.9400	7.0750	0.1350	0.1000
Cd	N.A.	N.A.	N.A.	N.A.	0.0007	0.0013	0.0010	0.0003	N.A.
Ce	0.0060	0.0070	0.0065	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.0690	0.0710	0.0700	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0030	0.0210	0.0120	0.0090	0.0044	0.0095	0.0069	0.0026	0.0051
Cr	0.0470	0.0440	0.0455	0.0015	0.0272	0.0382	0.0327	0.0055	0.0128
Cs	0.0020	0.0030	0.0025	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.3050	0.5100	0.4075	0.1025	0.2310	0.1590	0.1950	0.0360	0.2125
Fe	6.1600	5.6400	5.9000	0.2600	7.8500	5.7800	6.8150	1.0350	0.9150
Ga	0.0016	0.0014	0.0015	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
K	1.4700	0.9723	1.2211	0.2489	2.3600	2.5200	2.4400	0.0800	1.2189
Li	N.A.	N.A.	N.A.	N.A.	0.0068	0.0078	0.0073	0.0005	N.A.
La	0.0040	0.0040	0.0040	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.3500	1.3600	1.3550	0.0050	1.6500	1.8100	1.7300	0.0800	0.3750
Mn	0.0730	0.0680	0.0705	0.0025	0.0272	0.0602	0.0437	0.0165	0.0268
Mo	0.0087	0.0001	0.0044	0.0043	0.0000	0.0000	0.0000	0.0000	0.0044
Na	4.8000	3.7442	4.2721	0.5279	3.1700	3.7000	3.4350	0.2650	0.8371
Nb	0.0017	0.0013	0.0015	0.0002	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0130	0.0130	0.0130	0.0000	0.0100	0.0040	0.0070	0.0030	0.0060
P	0.4150	0.6264	0.5207	0.1057	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.2650	0.2860	0.2755	0.0105	0.2290	0.1190	0.1740	0.0550	0.1015
Rb	0.0045	0.0005	0.0025	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.1850	0.1810	0.1830	0.0020	0.1480	0.1200	0.1340	0.0140	0.0490
Sb	0.0170	0.0160	0.0165	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Si	26.6000	26.4000	26.5000	0.1000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0170	0.0160	0.0165	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0410	0.0106	0.0258	0.0152	0.0287	0.0335	0.0311	0.0024	0.0053
Ta	0.0010	0.0000	0.0005	0.0005	N.A.	N.A.	0.0000	0.0000	0.0000
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.5300	0.5100	0.5200	0.0100	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0067	0.0069	0.0068	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0000	0.0005	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0008	0.0018	0.0013	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.1680	0.2140	0.1910	0.0230	0.2240	0.1370	0.1805	0.0435	0.0105
Zr	0.0230	0.0255	0.0243	0.0013	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

2-5mm	CONCENTRATION XRF [%]			DEVIATION
	S1	S2	AVERAGE	[±p%]
SiO2	55.1000	54.7000	54.9000	0.2000
TiO2	1.0500	1.0100	1.0300	0.0200
Al2O3	12.5000	12.5000	12.5000	0.0000
Cr2O3	0.0710	0.0590	0.0650	0.0060
V2O3	0.0130	0.0120	0.0125	0.0005
FeO	8.8300	8.5700	8.7000	0.1300
MnO	0.1070	0.0980	0.1025	0.0045
MgO	2.5600	2.5800	2.5700	0.0100
CaO	9.3600	9.4100	9.3850	0.0250
Rb2O	0.0068	0.0067	0.0068	0.0000
SrO	0.0370	0.0420	0.0395	0.0025
BaO	0.1570	0.1310	0.1440	0.0130
Na2O	4.5600	4.4700	4.5150	0.0450
K2O	2.3800	2.2900	2.3350	0.0450
ZrO2	0.0290	0.0250	0.0270	0.0020
P2O2	1.2800	1.3000	1.2900	0.0100
CO2	0.0000	2.4900	1.2450	1.2450
OxSumm	98.0408	99.6937	98.8673	0.8264

Table 0-13 *XRF and ICP results Chemical composition of 5-10mm particles.*

5-10mm	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
	1	2	AVERAGE	[±p%]	1	2	AVERAGE	[±p%]	XRF-ICP [p%]
Ag	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001	0.9890	0.0001
Al	5.5100	5.8215	5.6657	0.1557	5.7300	5.3300	5.5300	0.0362	0.1357
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Ba	0.1370	0.1300	0.1335	0.0035	0.1750	0.1270	0.1510	0.1589	0.0175
Bi	0.0030	0.0040	0.0035	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	0.5500	0.5500	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	7.2500	7.1000	7.1750	0.0750	7.5400	8.2100	7.8750	0.0425	0.7000
Cd	N.A.	N.A.	N.A.	N.A.	0.0006	0.0002	0.0004	0.4398	N.A.
Ce	0.0060	0.0070	0.0065	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.0690	0.0710	0.0700	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0030	0.0210	0.0120	0.0090	0.0042	0.0042	0.0042	0.0036	0.0078
Cr	0.0470	0.0440	0.0455	0.0015	0.0440	0.0338	0.0389	0.1311	0.0066
Cs	0.0020	0.0030	0.0025	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.3050	0.5100	0.4075	0.1025	1.5300	0.1630	0.8465	0.8074	0.4390
Fe	6.1600	5.6400	5.9000	0.2600	6.7400	5.4700	6.1050	0.1040	0.2050
Ga	0.0016	0.0014	0.0015	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
K	1.4700	0.9723	1.2211	0.2489	1.8300	1.7900	1.8100	0.0110	0.5889
Li	N.A.	N.A.	N.A.	N.A.	0.0068	0.0066	0.0067	0.0171	N.A.
La	0.0040	0.0040	0.0040	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.3500	1.3600	1.3550	0.0050	1.4700	1.4700	1.4700	0.0000	0.1150
Mn	0.0730	0.0680	0.0705	0.0025	0.0440	0.0670	0.0555	0.2072	0.0150
Mo	0.0087	0.0001	0.0044	0.0043	0.0000	0.0000	0.0000	1.0000	0.0044
Na	4.8000	3.7442	4.2721	0.5279	4.8000	4.9700	4.8850	0.0174	0.6129
Nb	0.0017	0.0013	0.0015	0.0002	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0130	0.0130	0.0130	0.0000	0.0112	0.0085	0.0098	0.1394	0.0032
P	0.4150	0.6264	0.5207	0.1057	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.2650	0.2860	0.2755	0.0105	0.5490	0.1750	0.3620	0.5166	0.0865
Rb	0.0045	0.0005	0.0025	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.1850	0.1810	0.1830	0.0020	0.1180	0.1330	0.1255	0.0598	0.0575
Sb	0.0170	0.0160	0.0165	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Si	26.6000	26.4000	26.5000	0.1000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0170	0.0160	0.0165	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0410	0.0106	0.0258	0.0152	0.0433	0.0467	0.0450	0.0378	0.0192
Ta	0.0010	0.0000	0.0005	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.5300	0.5100	0.5200	0.0100	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0067	0.0069	0.0068	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0000	0.0005	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0008	0.0018	0.0013	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.1680	0.2140	0.1910	0.0230	0.1580	0.1410	0.1495	0.0569	0.0415
Zr	0.0230	0.0255	0.0243	0.0013	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

5-10mm	CONCENTRATION XRF [%]			DEVIATION
	S1	S2	AVERAGE	[±p%]
SiO2	56.8000	56.6000	56.7000	0.1000
TiO2	0.8800	0.8600	0.8700	0.0100
Al2O3	10.4000	11.0000	10.7000	0.3000
Cr2O3	0.0690	0.0650	0.0670	0.0020
V2O3	0.0099	0.0100	0.0100	0.0000
FeO	7.9200	7.2600	7.5900	0.3300
MnO	0.0950	0.0870	0.0910	0.0040
MgO	2.2400	2.2500	2.2450	0.0050
CaO	10.2000	9.9400	10.0700	0.1300
Rb2O	0.0049	0.0038	0.0044	0.0006
SrO	0.0480	0.0480	0.0480	0.0000
BaO	0.1530	0.1450	0.1490	0.0040
Na2O	6.4700	6.3500	6.4100	0.0600
K2O	1.7700	1.7700	1.7700	0.0000
ZrO2	0.0310	0.0300	0.0305	0.0005
P2O2	0.9500	0.9500	0.9500	0.0000
CO2	0.0000	2.0200	1.0100	1.0100
OxSumm	98.0408	99.3888	98.7148	0.6740

Table 0-14 *XRF and ICP results. Chemical composition of 10-20mm particles.*

10-20mm	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
	1	2	AVERAGE	[±p%]	1	2	AVERAGE	[±p%]	XRF-ICP [p%]
Ag	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0001	0.0001
Al	5.1500	5.3452	5.2476	0.0976	5.2000	4.8600	5.0300	0.1700	0.2176
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ba	0.1460	0.1470	0.1465	0.0005	0.1490	0.1420	0.1455	0.0035	0.0010
Bi	0.0030	0.0030	0.0030	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	0.3500	0.3500	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	7.1100	7.0600	7.0850	0.0250	7.8000	7.7000	7.7500	0.0500	0.6650
Cd	N.A.	N.A.	N.A.	N.A.	0.0004	0.0002	0.0003	0.0001	N.A.
Ce	0.0050	0.0050	0.0050	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.0660	0.0640	0.0650	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0140	0.0180	0.0160	0.0020	0.0067	0.0052	0.0059	0.0008	0.0101
Cr	0.0430	0.0420	0.0425	0.0005	0.0364	0.0413	0.0389	0.0025	0.0036
Cs	0.0030	0.0020	0.0025	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.4040	0.5800	0.4920	0.0880	0.4930	0.4690	0.4810	0.0120	0.0110
Fe	5.4700	5.4400	5.4550	0.0150	7.5600	5.7100	6.6350	0.9250	1.1800
Ga	0.0008	0.0007	0.0008	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
K	1.2200	0.0000	0.6100	0.6100	1.5900	1.5900	1.5900	0.0000	0.9800
Li	N.A.	N.A.	N.A.	N.A.	0.0079	0.0073	0.0076	0.0003	N.A.
La	0.0020	0.0020	0.0020	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.1200	1.1300	1.1250	0.0050	1.2400	1.1900	1.2150	0.0250	0.0900
Mn	0.1690	0.1590	0.1640	0.0050	0.1730	0.1690	0.1710	0.0020	0.0070
Mo	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Na	5.3300	4.2218	4.7759	0.5541	5.5400	5.6200	5.5800	0.0400	0.8041
Nb	0.0016	0.0011	0.0014	0.0003	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0110	0.0120	0.0115	0.0005	0.0125	0.0052	0.0089	0.0037	0.0027
P	0.2540	0.3692	0.3116	0.0576	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.1490	0.1510	0.1500	0.0010	0.1410	0.1550	0.1480	0.0070	0.0020
Rb	0.0047	0.0006	0.0027	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.1550	0.1340	0.1445	0.0105	0.0875	0.1200	0.1038	0.0163	0.0408
Sb	0.0150	0.0150	0.0150	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Si	17.5000	27.3000	22.4000	4.9000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0160	0.0170	0.0165	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0340	0.0089	0.0214	0.0126	0.0382	0.0397	0.0390	0.0008	0.0175
Ta	0.0000	0.0020	0.0010	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.4330	0.4300	0.4315	0.0015	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0050	0.0049	0.0050	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0010	0.0010	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0012	0.0010	0.0011	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.1840	0.2630	0.2235	0.0395	0.3350	0.1930	0.2640	0.0710	0.0405
Zr	0.0460	0.0493	0.0477	0.0017	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

10-20mm	CONCENTRATION XRF [%]			DEVIATION
	S1	S2	AVERAGE	[±p%]
SiO2	58.9000	58.3000	58.6000	0.3000
TiO2	0.7200	0.7200	0.7200	0.0000
Al2O3	9.9200	10.1000	10.0100	0.0900
Cr2O3	0.0620	0.0610	0.0615	0.0005
V2O3	0.0081	0.0072	0.0077	0.0005
FeO	7.0300	6.9900	7.0100	0.0200
MnO	0.2180	0.2050	0.2115	0.0065
MgO	1.8500	1.8800	1.8650	0.0150
CaO	9.9500	9.8800	9.9150	0.0350
Rb2O	0.0051	0.0051	0.0051	0.0000
SrO	0.0400	0.0400	0.0400	0.0000
BaO	0.1630	0.1650	0.1640	0.0010
Na2O	7.1900	7.1600	7.1750	0.0150
K2O	1.4800	1.4300	1.4550	0.0250
ZrO2	0.0630	0.0580	0.0605	0.0025
P2O2	0.5800	0.5600	0.5700	0.0100
CO2	0.0000	1.2800	0.6400	0.6400
OxSumm	98.1792	98.8413	98.5103	0.3311

Appendix X

SAMASE-values, Concentration of environmentally harmful elements in MSWI bottom ash size fractions

Table 0-15 *Reference values for polluted soil (SAMASE-values, Finnish Ministry of Environment [65])*

SAMASE-values [%]

	Soil concentration	**Reference concentration in soil**	**Limit-value in soil**
As	0.00050	0.00100	0.00500
B	0.00300	0.00050	0.00500
Ba	0.05000	0.06000	0.06000
Be	0.00030	0.00010	0.00100
Br	0.00100	0.00500	0.03000
Cd	0.00003	0.00005	0.00100
Co	0.00100	0.00500	0.02000
Cr	0.00800	0.01000	0.04000
Cu	0.00250	0.01000	0.03000
F	0.04000	0.02000	0.20000
Hg	0.00001	0.00002	0.00050
Mo	0.00012	0.00050	0.02000
Ni	0.00200	0.00600	0.02000
Pb	0.00170	0.00600	0.04000
S-	-	0.00002	0.00002
Sb	0.00005	0.00050	0.00400
Se	0.00003	0.00010	0.00100
Sn	0.00040	0.00500	0.00100
Tl	0.00005	0.00005	0.00100
U	0.00027	0.00500	0.05000
V	0.00900	0.00500	0.05000
Zn	0.00700	0.01500	0.07000

Table 0-16 *Concentration of environmentally harmful elements in MSWI bottom ash size fractions, the values which exceeds the MAC (Maximum allowed concentration) value of polluted soil (SAMASE-values, Finnish Ministry of Environment) are highlighted with grey*

concentration of environmentally harmful elements in BOTTOM ASH size fractions [%]

	0-2mm sludge		**0-2mm particulate**		**2-5mm**		**5-10mm**		**10-20mm**	
	XRF	**ICP**	**XRF**	**ICP**	**XRF**	**ICP**	**XRF**	**ICP**	**XRF**	**ICP**
As	0.00000	0.00530	0.00000	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
B	-	-	-	-	-	-	-	-	-	-
Ba	0.13300	0.10600	0.12750	0.12500	0.13350	0.09680	0.13350	0.15100	0.14650	0.14550
Be	-	-	-	-	-	-	-	-	-	-
Br	-	-	-	-	-	-	-	-	-	-
Cd	-	0.00196	-	0.00223	-	0.00101	-	0.00038	-	0.00029
Co	0.01150	0.00532	0.00850	0.00713	0.01200	0.00694	0.01200	0.00418	0.01600	0.00593
Cr	0.05400	0.07765	0.04950	0.44155	0.04550	0.03270	0.04550	0.03890	0.04250	0.03885
Cu	0.16500	0.15750	0.34100	0.60050	0.40750	0.19500	0.40750	0.84650	0.38550	0.39600
F	-	-	-	-	-	-	-	-	-	-
Hg	-	-	-	-	-	-	-	-	-	-
Mo	0.00040	0.00199	0.00000	0.05450	0.00440	0.00000	0.00440	0.00430	0.00000	0.00000
Ni	0.01050	0.00756	0.01500	0.29956	0.01300	0.00697	0.01300	0.00983	0.01150	0.00885
Pb	0.17750	0.16000	0.20050	0.11500	0.27550	0.17400	0.27550	0.36200	0.15000	0.14800
S-	-	-	-	-	-	-	-	-	-	-
Sb	0.02550	-	0.01950	-	0.01650	-	0.01650	-	0.14450	-
Se	-	-	-	-	-	-	-	-	-	-
Sn	0.03500	-	0.03400	-	0.01650	-	0.01650	-	0.01650	-
Tl	-	-	-	-	-	-	-	-	-	-
U	0.00000	-	0.00000	-	0.00000	-	0.00000	-	0.00000	
V	0.00700	-	0.00945	-	0.00680	-	0.00680	-	0.00495	
Zn	0.31650	0.33100	0.36100	0.30000	0.19100	0.18050	0.19100	0.14950	0.22350	0.26400

Appendix XI

Results of characterization: handpicking

Table 0-17 *Samples for handpicking*

HANDPICKING SAMPLES	mass [g]
S I (5-10mm)	1730.1
S II (2-5mm)	1025.2
S III (10-20mm)	3072.2
S VI (20-40mm)	8419.3

Table 0-18 *Results of the handpicking*

		Grey non-mag.	Red Non-ferr.	Iron scrap	Non-magn. agglomerates	Magn. agglomerates	Ceramics	Glass	Stones and concrete	Rest	TOTAL
2-5mm	**mass [g]**	19.2	10.1	4.5	-	204	-	-	-	787.4	1025.2
	ERROR EST. %	0.52%	0.99%	2.22%	-	0.05%	-	-	-	0.01%	2.49%
	Concentration %	**1.87%**	**0.99%**	**0.44%**	**-**	**19.90%**	**-**	**-**	**-**	**76.80%**	100.00%
	ERROR EST. %	2.54%	2.68%	3.34%	-	2.49%	-	-	-	2.49%	3.52%
5-10mm	**mass [g]**	62.2	14.7	19.1	425.2	423.8	43.2	489.6	252.3	-	1730.1
	ERROR EST. %	0.16%	0.68%	0.52%	0.02%	0.02%	0.23%	0.02%	0.04%	-	0.91%
	Concentration %	**3.60%**	**0.85%**	**1.10%**	**24.58%**	**24.50%**	**2.50%**	**28.30%**	**14.58%**	-	100.00%
	ERROR EST. %	0.92%	1.13%	1.05%	0.91%	0.91%	0.93%	0.91%	0.91%	0.91%	1.28%
10-20mm	**mass [g]**	247.5	48.6	72.7	866.6	1115.9	805.6	693.1	238.5	-	4088.5
	ERROR EST. %	0.04%	0.21%	0.14%	0.01%	0.01%	0.01%	0.01%	0.04%	-	0.26%
	Concentration %	**6.05%**	**1.19%**	**1.78%**	**21.20%**	**27.29%**	**19.70%**	**16.95%**	**5.83%**	-	100.00%
	ERROR EST. %	0.26%	0.33%	0.29%	0.26%	0.26%	0.26%	0.26%	0.26%	0.26%	0.36%
20-40mm	**mass [g]**	317.8	137.3	653.4	1365	2163	2693.4	641.9	447.5	-	8419.3
	ERROR EST. %	0.03%	0.07%	0.02%	0.01%	0.00%	0.00%	0.02%	0.02%	-	0.09%
	Concentration %	**3.77%**	**1.63%**	**7.76%**	**16.21%**	**25.69%**	**31.99%**	**7.62%**	**5.32%**	-	100.00%
	ERROR EST. %	0.09%	0.11%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.12%

Appendix XII

Results of characterization: particle shapes and liberation, pictures of the handpicked size fractions

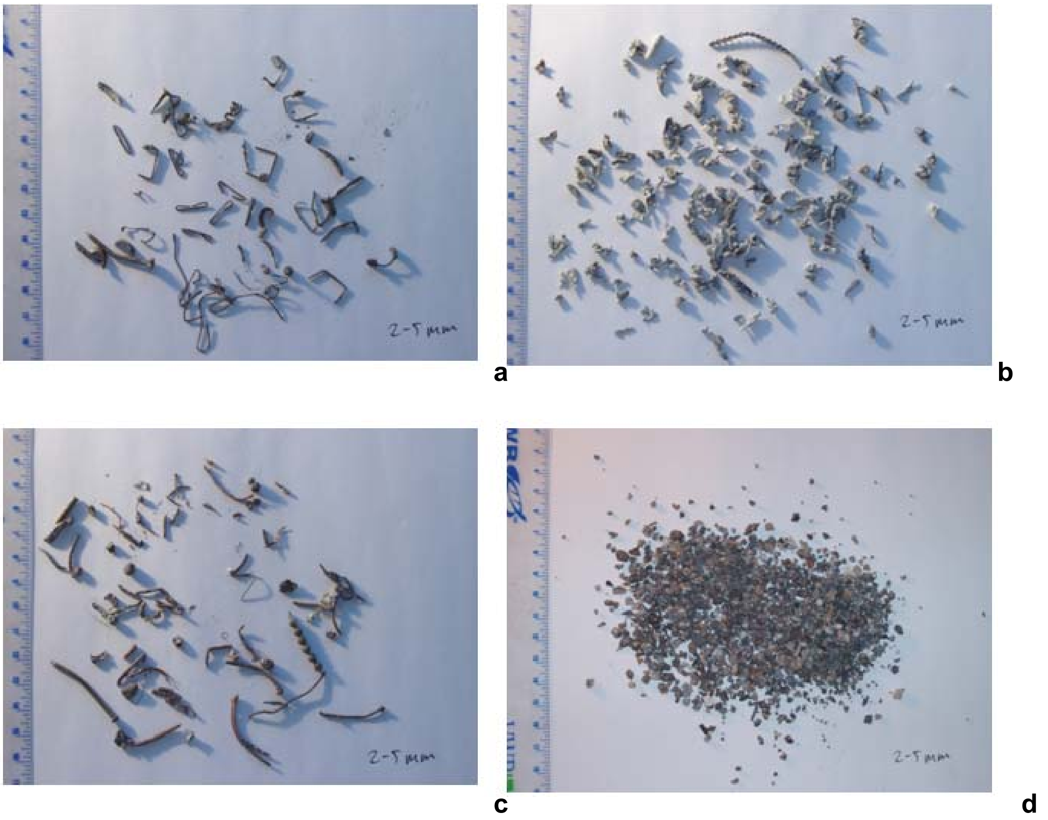
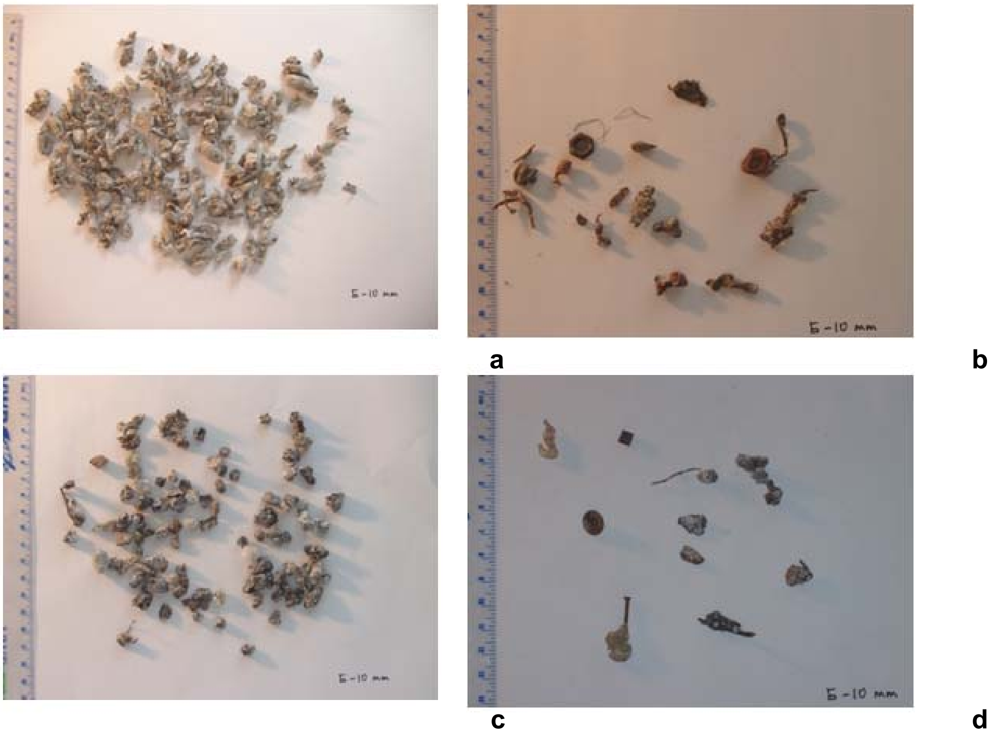


Figure 0-1 *Photographs of handpicked fractions of 2-5mm particle size class a) steel particles, b) grey nonmagnetic metal particles, c) red nonferrous metal particles, d) rest*



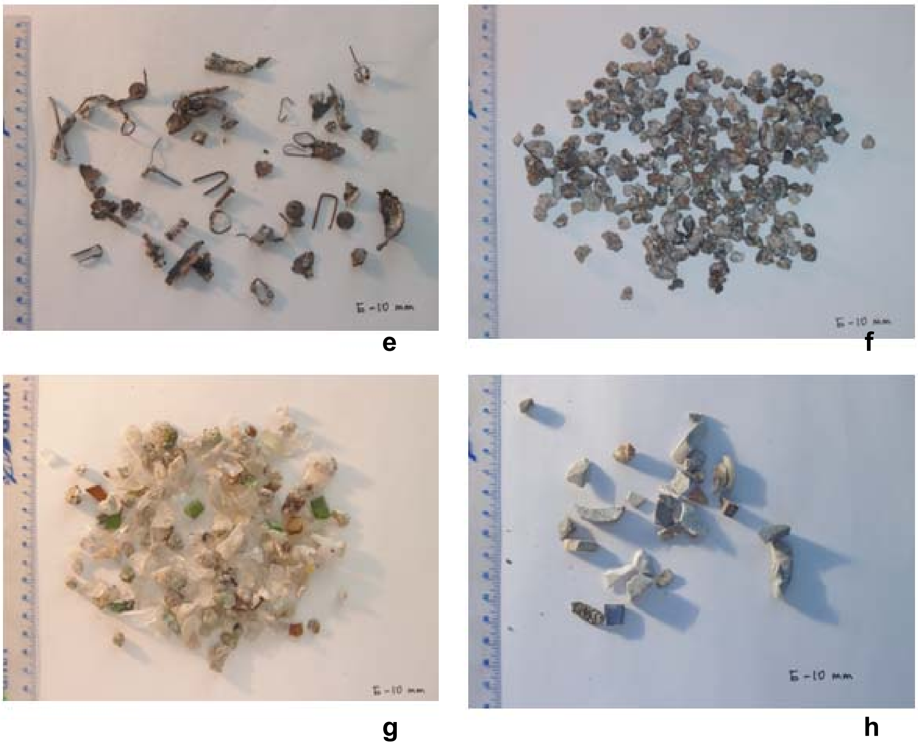


Figure 0-2 *Photographs of handpicked fractions of 5-10mm particle size class a) grey nonmagnetic metal particles b) red nonferrous metal particles c) magnetic agglomerates , d) examples of non-liberated particles, e) steel scrap, f) nonmagnetic agglomerates, g) glass, h) ceramics*

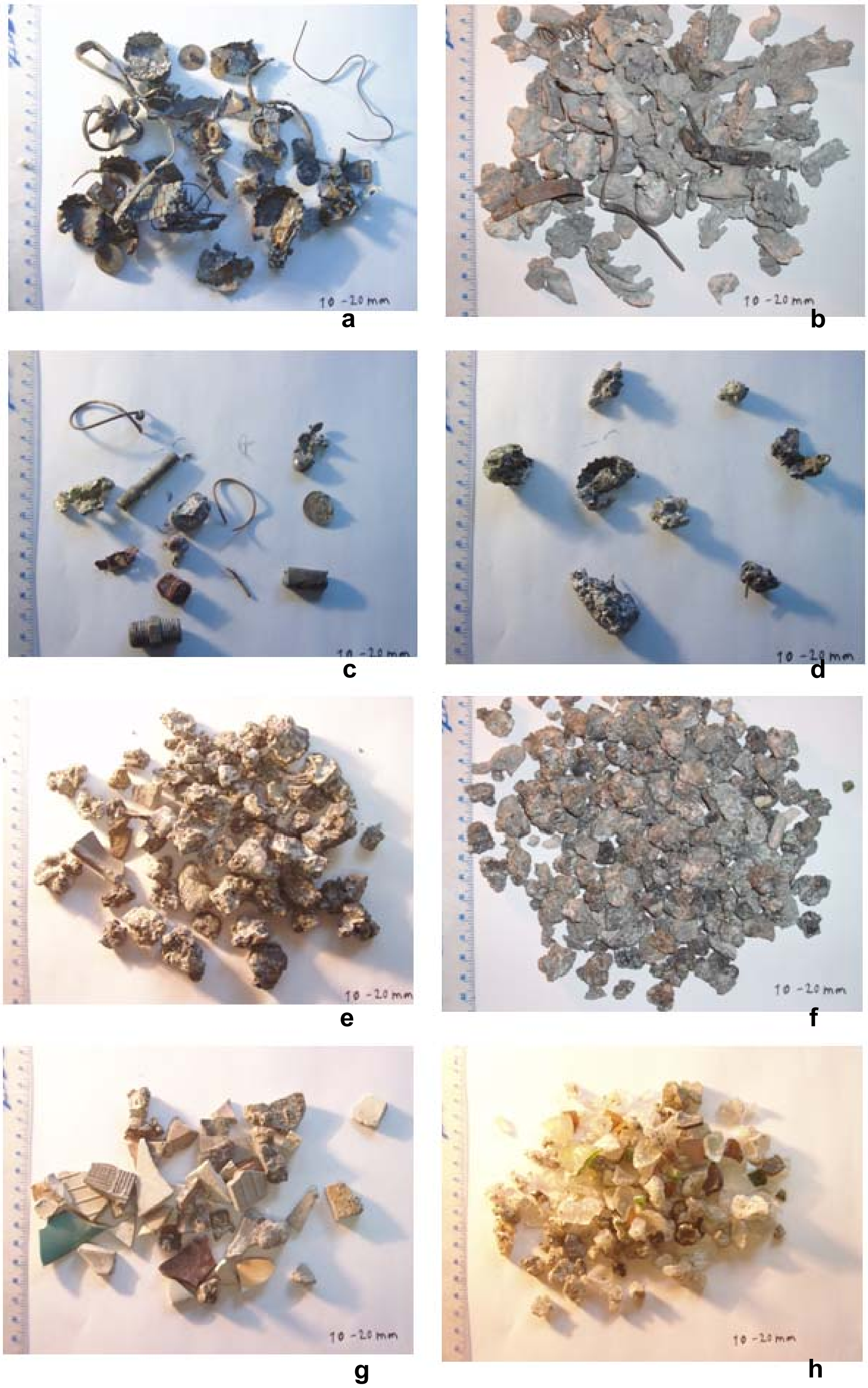


Figure 0-3 *Photographs of handpicked fractions of 10-20mm particle size class a) steel scrap, b) grey nonmagnetic metal particles c) red nonferrous metal particles d) examples of non-liberated particles, e) magnetic agglomerates , f) nonmagnetic agglomerates, g) ceramics, h) glass*

Figure 0-4 *Photographs of handpicked fractions of 20-30mm particle size class a) steel scrap, b)steel scrap, c) red nonferrous metal particles, d) stainless steel e) grey nonmagnetic metal particles f) grey nonmagnetic metal particles, g) magnetic agglomerates , h) nonmagnetic agglomerates*

Appendix XIII

ICP and XRF results of characterization: Chemical composition of 20-40mm agglomerates

Table 0-19 *XRF and ICP results. Chemical composition of 20-40mm magnetic agglomerate particles.*

MAGNETIC AGGLOMERATE	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
20-40mm	**1**	**2**	**AVERAGE**	**[±p%]**	**1**	**2**	**AVERAGE**	**[±p%]**	**XRF-ICP [p%]**
Ag	0.0020	0.0030	0.0025	0.0005	0.0000	0.0005	0.0002	0.0002	0.0023
Al	6.3700	6.5624	6.4662	0.0962	8.7500	6.2200	7.4850	1.2650	1.0188
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ba	0.1440	0.1560	0.1500	0.0060	0.1510	0.1500	0.1505	0.0005	0.0005
Bi	0.0030	0.0030	0.0030	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	0.1800	0.1800	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	8.3400	8.3200	8.3300	0.0100	8.9600	9.4800	9.2200	0.2600	0.8900
Cd	N.A.	N.A.	N.A.	N.A.	0.0000	0.0000	0.0000	0.0000	N.A.
Ce	0.0060	0.0020	0.0040	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.0720	0.0730	0.0725	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0160	0.0210	0.0185	0.0025	0.0070	0.0084	0.0077	0.0007	0.0108
Cr	0.1410	0.1360	0.1385	0.0025	0.1310	0.1490	0.1400	0.0090	0.0015
Cs	0.0040	0.0010	0.0025	0.0015	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.4070	0.3640	0.3855	0.0215	0.4710	0.3210	0.3960	0.0750	0.0105
Fe	12.1000	11.7000	11.9000	0.2000	13.3000	13.0000	13.1500	0.1500	1.2500
Ga	0.0011	0.0012	0.0012	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
K	1.2900	0.8624	1.0762	0.2138	1.6100	1.7300	1.6700	0.0600	0.5938
Li	N.A.	N.A.	N.A.	N.A.	0.0078	0.0072	0.0075	0.0003	N.A.
La	0.0050	0.0040	0.0045	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.7700	1.7700	1.7700	0.0000	1.8900	1.8700	1.8800	0.0100	0.1100
Mn	0.1100	0.1120	0.1110	0.0010	0.1340	0.1210	0.1275	0.0065	0.0165
Mo	0.0019	0.0015	0.0017	0.0002	0.0000	0.0000	0.0000	0.0000	0.0017
Na	3.1800	2.5354	2.8577	0.3223	2.9000	3.0400	2.9700	0.0700	0.1123
Nb	0.0010	0.0010	0.0010	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0270	0.0220	0.0245	0.0025	0.0265	0.0161	0.0213	0.0052	0.0032
P	0.4180	0.6330	0.5255	0.1075	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.1760	0.1610	0.1685	0.0075	0.2000	0.1440	0.1720	0.0280	0.0035
Rb	0.0047	0.0007	0.0027	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.2030	0.1990	0.2010	0.0020	0.1440	0.1720	0.1580	0.0140	0.0430
Sb	0.0170	0.0170	0.0170	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Si	21.5000	21.5000	21.5000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0190	0.0190	0.0190	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0220	0.0058	0.0139	0.0081	0.0246	0.0249	0.0248	0.0001	0.0109
Ta	0.0030	0.0020	0.0025	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0000	0.0002	0.0001	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	0.9500	0.9400	0.9450	0.0050	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0090	0.0100	0.0095	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0010	0.0010	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0015	0.0014	0.0015	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.1620	0.1530	0.1575	0.0045	0.2110	0.1950	0.2030	0.0080	0.0455
Zr	0.0390	0.0459	0.0425	0.0035	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

MAGNETIC AGGLOMERATE	CONCENTRATION XRF [%]			DEVIATION
20-40mm	**S1**	**S2**	**AVERAGE**	**[±p%]**
SiO2	46.0000	46.0000	46.0000	0.0000
TiO2	1.5900	1.5700	1.5800	0.0100
Al2O3	12.0000	12.4000	12.2000	0.2000
Cr2O3	0.2070	0.1990	0.2030	0.0040
V2O3	0.0130	0.0150	0.0140	0.0010
FeO	15.5000	15.1000	15.3000	0.2000
MnO	0.1420	0.1450	0.1435	0.0015
MgO	2.9300	2.9400	2.9350	0.0050
CaO	11.7000	11.6000	11.6500	0.0500
Rb2O	0.0051	0.0058	0.0055	0.0004
SrO	0.0270	0.0260	0.0265	0.0005
BaO	0.1730	0.1740	0.1735	0.0005
Na2O	4.2900	4.3000	4.2950	0.0050
K2O	1.5500	1.5700	1.5600	0.0100
ZrO2	0.0530	0.0540	0.0535	0.0005
P2O2	0.9600	0.9600	0.9600	0.0000
CO2	0.0000	0.6600	0.3300	0.3300
OxSumm	97.1401	97.7188	97.4295	0.2893

Table 0-20 *XRF and ICP results. Chemical composition of 20-40mm non-magnetic agglomerate particles.*

NON-MAGNETIC AGGLOMERATE	CONCENTRATION XRF [%]			DEVIATION	CONCENTRATION ICP [%]			DEVIATION	CONCENTRATION DIFFERENCE
20-40mm	1	2	AVERAGE	[±p%]	1	2	AVERAGE	[±p%]	XRF-ICP [p%]
Ag	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0001	0.0001
Al	7.8300	7.8300	7.8300	0.0000	7.5700	7.6700	7.6200	0.0500	0.2100
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ba	0.1440	0.1430	0.1435	0.0005	0.1320	0.1330	0.1325	0.0005	0.0110
Bi	0.0030	0.0030	0.0030	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
C	N.A.	0.1900	0.1900	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ca	11.3000	11.3000	11.3000	0.0000	10.9000	12.1000	11.5000	0.6000	0.2000
Cd	N.A.	N.A.	N.A.	N.A.	0.0004	0.0009	0.0006	0.0002	N.A.
Ce	0.0060	0.0060	0.0060	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Cl	0.0680	0.0640	0.0660	0.0020	N.A.	N.A.	N.A.	N.A.	N.A.
Co	0.0100	0.0200	0.0150	0.0050	0.0047	0.0070	0.0058	0.0012	0.0092
Cr	0.0530	0.0520	0.0525	0.0005	0.0331	0.0385	0.0358	0.0027	0.0167
Cs	0.0030	0.0050	0.0040	0.0010	N.A.	N.A.	N.A.	N.A.	N.A.
Cu	0.0790	0.0830	0.0810	0.0020	0.0777	0.0839	0.0808	0.0031	0.0002
Fe	2.9600	2.9500	2.9550	0.0050	3.0700	3.1900	3.1300	0.0600	0.1750
Ga	0.0019	0.0022	0.0021	0.0002	N.A.	N.A.	N.A.	N.A.	N.A.
K	1.5300	1.0107	1.2704	0.2596	1.6400	1.9600	1.8000	0.1600	0.5296
Li	N.A.	N.A.	N.A.	N.A.	0.0066	0.0070	0.0068	0.0002	N.A.
La	0.0060	0.0030	0.0045	0.0015	N.A.	N.A.	N.A.	N.A.	N.A.
Mg	1.6100	1.6200	1.6150	0.0050	1.6500	1.7400	1.6950	0.0450	0.0800
Mn	0.1030	0.1000	0.1015	0.0015	0.0331	0.1030	0.0681	0.0350	0.0335
Mo	0.0002	0.0004	0.0003	0.0001	0.0000	0.0007	0.0003	0.0003	0.0000
Na	3.1200	2.4706	2.7953	0.3247	3.0700	3.2900	3.1800	0.1100	0.3847
Nb	0.0035	0.0022	0.0029	0.0007	N.A.	N.A.	N.A.	N.A.	N.A.
Ni	0.0120	0.0120	0.0120	0.0000	0.0082	0.0081	0.0082	0.0001	0.0039
P	0.6400	0.9627	0.8013	0.1613	N.A.	N.A.	N.A.	N.A.	N.A.
Pb	0.0450	0.0460	0.0455	0.0005	0.0425	0.0382	0.0404	0.0022	0.0052
Rb	0.0043	0.0004	0.0024	0.0019	N.A.	N.A.	N.A.	N.A.	N.A.
S	0.1160	0.1100	0.1130	0.0030	0.0330	0.0971	0.0651	0.0321	0.0480
Sb	0.0220	0.0220	0.0220	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Si	24.2000	24.2000	24.2000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Sn	0.0130	0.0140	0.0135	0.0005	N.A.	N.A.	N.A.	N.A.	N.A.
Sr	0.0320	0.0084	0.0202	0.0118	0.0301	0.0318	0.0310	0.0009	0.0107
Ta	0.0000	0.0030	0.0015	0.0015	N.A.	N.A.	N.A.	N.A.	N.A.
Te	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Th	0.0002	0.0002	0.0002	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Ti	1.2100	1.2000	1.2050	0.0050	N.A.	N.A.	N.A.	N.A.	N.A.
U	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
V	0.0120	0.0120	0.0120	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
W	0.0010	0.0010	0.0010	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.
Y	0.0013	0.0014	0.0014	0.0001	N.A.	N.A.	N.A.	N.A.	N.A.
Zn	0.2770	0.2750	0.2760	0.0010	0.2940	0.3090	0.3015	0.0075	0.0255
Zr	0.0460	0.0527	0.0494	0.0034	N.A.	N.A.	N.A.	N.A.	N.A.
LOI	0.0000	0.0000	0.0000	0.0000	N.A.	N.A.	N.A.	N.A.	N.A.

NON-MAGNETIC AGGLOMERATE	CONCENTRATION XRF [%]			DEVIATION
20-40mm	S1	S2	AVERAGE	[±p%]
SiO2	51.8000	51.7000	51.7500	0.0500
TiO2	2.0100	2.0100	2.0100	0.0000
Al2O3	14.8000	14.8000	14.8000	0.0000
Cr2O3	0.0770	0.0760	0.0765	0.0005
V2O3	0.0170	0.0180	0.0175	0.0005
FeO	3.8100	3.8000	3.8050	0.0050
MnO	0.1330	0.1290	0.1310	0.0020
MgO	2.6700	2.6800	2.6750	0.0050
CaO	15.8000	15.8000	15.8000	0.0000
Rb2O	0.0047	0.0035	0.0041	0.0006
SrO	0.0380	0.0380	0.0380	0.0000
BaO	0.1610	0.1600	0.1605	0.0005
Na2O	4.2000	4.1900	4.1950	0.0050
K2O	1.8400	1.8400	1.8400	0.0000
ZrO2	0.0620	0.0620	0.0620	0.0000
P2O2	1.4800	1.4600	1.4700	0.0100
CO2	0.0000	0.7000	0.3500	0.3500
OxSumm	98.9027	99.4665	99.1846	0.2819

Appendix XIV

Results of characterization: particle shapes and liberation

Table 0-21 *Examples of particle shapes and the types of non-liberated particles in different particle classes*

SIZE CLASS	PARTICLE CLASS	EXAMPLES OF PARTICLE SHAPES		STATE OF LIBERATION
0-2mm	**Metal particles**	Metal wires		Well-liberated
	Non-metal particles	Fine structured sand		Assumption: well-liberated
2-5mm	**Metal particles**	**Iron scrap:**	Staples; nails; metal wires	Well-liberated
		Grey non-magnetic:	Various shapes flat-/, elongated-/, round-/, pointy-/, porous, molten and again solidified metal droplets; metal wires	Well-liberated
		Red non-ferrous	Wires; nails; molten and again solidified copper droplets	Well-liberated
	Non-metal particles	Coarse structured gravel		Well-liberated
	Agglomerates	Coarse structured gravel		Highly ill-liberated, melt together agglomerates, some magnetic. No visibly metallic parts
5-10mm	**Metal particles**	**Iron scrap:**	Nails, staples; metal wires; screws; flat, highly corroded iron scrap (e.g. parts of bottle caps); springs; metal turning scrap; buttons	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
		Grey non-magnetic:	Various shapes flat-/, elongated-/, round-/, pointy-/, porous, molten and again solidified metal droplets; metal wires	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
		Red non-ferrous	Wires; nails; different shapes of molten and again solidified copper droplets	Mostly well-liberated, possible that metals have solidified together (e.g. copper lump with steel nai
	Non-metal particles	Stones, glass, porcelain, concrete		Mostly well-liberated. Some ill-liberation (e.g.Glass and metal molten together, ferroconcrete..)
	Agglomerates	Coarse, stony,		Highly ill-liberated, melt together agglomerates, some magnetic. It is possible to see that most ofte attaching material is glass. Some visibly metallic parts (e.g. metal wires , peaces of iron scrap,
10-20mm	**Metal particles**	**Iron scrap:**	Various steel articles; parts of bottle caps; metal wires; buttons; bolts; key chains; watch-strap	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
		Grey non-magnetic:	Various shapes molten and again solidified metal droplets; metal wires; stainless steel articles; springs	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
		Red non-ferrous	Wires; nails; bolts; coins; different shapes of molten and again solidified copper droplets	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
	Non-metal particles	Stones, glass, porcelain, concrete		Mostly well-liberated. Some ill-liberation (e.g.Glass and metal molten together, ferroconcrete..)
	Agglomerates	Coarse, stony		Highly ill-liberated, melt together agglomerates, some magnetic. Most often the attaching material Some visibly metallic parts (e.g. metal wires , peaces of iron scrap,
20-40mm	**Metal particles**	**Iron scrap:**	Various steel articles: batteries, nails, bottle caps, can lids	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample), liberated articles like batteries. Ill-liberated by mechanical connection (copper wire - steel screw)
		Grey non-magnetic:	**Stainles steel table ware, large molten porous metal particles, containers,**	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample)
		Red non-ferrous	**Peaces of copper pipes, nuts, copperwires**	Mostly well-liberated, possible that metals have solidified together (no examples seen in sample), liberated by mechanical connection (copper wire - steel screw)
	Non-metal particles	Stones, glass, porcelain, concrete		Mostly well-liberated. Some ill-liberation (e.g.Glass and metal molten together, ferroconcrete..)
	Agglomerates	Coarse, stony		Highly ill-liberated, melt together agglomerates, some magnetic. Most often the attaching material Some visible metallic parts (e.g. metal wires , peaces of iron scrap,

Appendix XV

Material density distribution

Table 0-22 *Densities of different handpicked size fractions of different size particles*

Size fraction	**20-40mm**							
Particle class	**Nonmagnetic agglomerates**	**Magnetic agglomerates**	**Grey-nonmagnetic**	**Iron scrap**	**Red-nonferrous**	**Glass**	**Stones and Concrete**	**Ceramics**
Mass [g]	1365	2163	317.8	653.4	137.3	641.9	447.5	904.6
Volume [ml]	594	1162	102	217	15	276	194	406
Density [kg/dm^3]	2.30	1.86	3.12	3.01	9.15	2.33	2.31	2.23

Size fraction	**10-20mm**							
	Nonmagnetic agglomerates	**Magnetic agglomerates**	**Grey-nonmagnetic**	**Iron scrap**	**Red-nonferrous**	**Glass**	**Stones and Concrete**	**Ceramics**
Mass [g]	866.6	1115.9	247.5	72.7	48.6	693.1	238.5	805.6
Volume [ml]	442	466	90	15	6	295	100	362
Density [kg/dm^3]	1.96	2.39	2.75	4.85	8.10	2.35	2.39	2.23

Size fraction	**5-10mm**							
	Nonmagnetic agglomerates	**Magnetic agglomerates**	**Grey-nonmagnetic**	**Iron scrap**	**Red-nonferrous**	**Glass**	**Stones and Concrete**	**Ceramics**
Mass [g]	425.2	423.8	62.2	19.1	14.7	489.6	252.3	43.2
Volume [ml]	226	170	24	4.6	1.6	200	100	20
Density [kg/dm^3]	1.88	2.49	2.59	4.15	9.19	2.45	2.52	2.16

Size fraction	**2-5mm**				
	Rest	**Magnetic agglomerates**	**Grey-nonmagnetic**	**Iron scrap**	**Red-nonferrous**
Mass [g]	787.4	204	19.2	4.5	10.1
Volume [ml]	390	80	7	1.6	1.4
Density [kg/dm^3]	2.02	2.55	2.74	2.81	7.21

Appendix XVI

Composition and leaching values of untreated bottom ash

Table 0-23 *XRF results for untreated bottom ash*

UNTREATED BOTTOM ASH	
Element	**%**
Al	6.5000
Ba	0.1000
Ca	8.8000
Cl	0.5500
Cr	0.0400
Cu	0.0800
Fe	4.4000
K	1.8000
Mg	1.5000
Mn	0.0800
Na	3.5000
Ni	0.0100
P	0.7600
Pb	0.2300
Rb	0.0080
S	0.7200
Sb	0.0050
Si	21.0000
Sn	0.0070
Sr	0.0400
Ti	0.5500
Zn	0.1600
Zr	0.0200

Table 0-24 *Leaching values of untreated bottom ash, values which exceeds the limit values of regular MSW landfill are highlighted with grey*

UNTREATED BOTTOM ASH		
Sample	**h**	
L/S ratio		
	2	**10**
pH	11.5	11.4
Element	**leaching values mg/kg**	
As	0.01	0.01
Ba	0.14	0.6
Cd	0.002	0.003
Cr	0.32	0.56
Cu	6.2	7.4
Hg	<0.0002	<0.001
Mo	0.87	1.1
Ni	0.03	0.04
Pb	0.28	1.3
Sb	0.12	0.47
Se	<0.10	0.29
Zn	0.24	0.67
Cl-	1360	1681
F-	86	84*
SO_4^{2-}	280	639
DOC	280	341

Table 0-25 *Summary of EU-landfill qualifications for municipal solid waste [64]*

landfill for permanent waste	**landfill for municipal solid waste, which receives also treated hazardous waste**	**landfill for hazardous waste**
	limit leaching values [mg/kg] L/S ratio 10	
0.5	2	25
20	100	300
0.4	1	5
0.5	10	70
2	50	100
0.01	0.2	2
0.5	10	30
0.4	10	40
0.5	10	50
0.06	0.7	5
0.1	0.5	7
4	50	200
800	15000	25000
10	150	500
1000	20000	50000
500	800	1000

Appendix XVII

Sampling of magnetic products

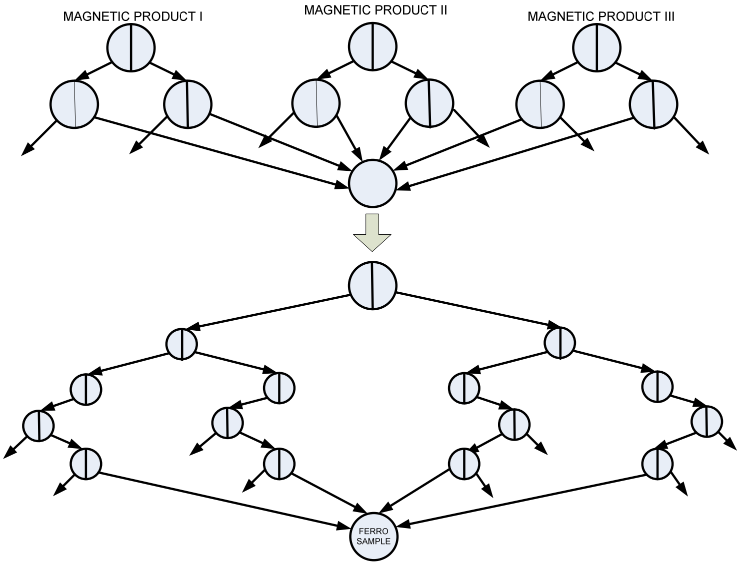


Figure 0-5*Sampling of magnetic product for quality analysis*

Sampling for eddy current process

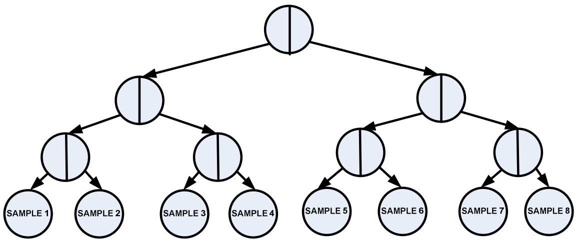


Figure 0-6 *Sampling procedure of size class +6.25mm for eddy current measurements*

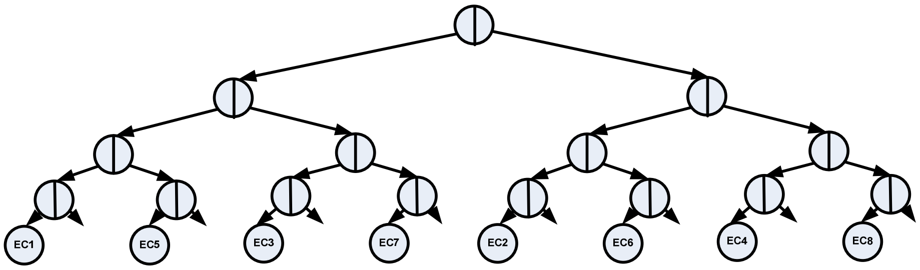


Figure 0-7 *Sampling procedure of size class 1.18-6.25mm for eddy current measurements*

Appendix XVIII
Water content measurement of screening products

Table 0-26 *Water content determination for screening products of bottom ash processing*

	6.25mm OVERFLOW			1.18mm OVERFLOW			1.18mm UNDERFLOW	
	sample 1	sample 2	total 6.25mm overflow	sample 1	sample 2	total 1.18mm overflow	sample 1	total 1.18mm underflow
Wet volume [dm^3]	**3**	**3**	**-**	**3**	**3**	**-**	**-**	**245.4**
STDEV %	3.33%	3.33%	-	3.33%	3.33%	-	-	4.07%
Wet mass [kg]	**3.65**	**3.725**	**171.3**	**3.986**	**3.65**	**208.8**	**13.800**	**353.8**
STDEV %	0.03%	0.03%	0.12%	0.03%	0.03%	0.96%	0.07%	0.06%
Wet bulk density [kg/dm^3]	**1.22**	**1.24**	**-**	**1.33**	**1.22**	**-**	**-**	**1.44**
STDEV %	3.33%	3.33%	-	3.33%	3.33%	-	-	4.08%
Dry volume [dm^3]	**3**	**3**	**-**	**3**	**3**	**-**	**-**	**-**
STDEV %	3.33%	3.33%	-	3.33%	3.33%	-	-	-
Dry mass [kg]	**3.546**	**3.622**	**166.5***	**2.973**	**2.909**	**165.3**	**6.423**	**164.7***
STDEV %	0.03%	0.03%	0.12%	0.03%	0.03%	0.27%	0.16%	0.18%
Dry bulk density [kg/dm^3]	**1.18**	**1.21**	**-**	**0.99**	**0.97**	**-**	**-**	**-**
STDEV %	3.33%	3.33%	-	3.33%	3.33%	-	-	-
Water content [%]	**2.85%**	**2.77%**	**2.81%**	**25.41%**	**20.30%**	**20.83%**	**53.46%**	**53.46%**
STDEV %	0.04%	0.04%	0.17%	0.04%	0.04%	1.00%	0.17%	0.26%

* not measured; calculated with the value of water content measurements

Table 0-27 *Product masses of bottom ash screening process*

	Wet mass [kg]	ERROR EST. %	Dry mass [kg]	ERROR EST. %	Concentration %	ERROR EST. %
6.25mm OVERFLOW	176.2	0.11%	171.6	0.26%	34.21%	0.49%
1.18mm OVERFLOW	241.9	0.12%	165.3	0.27%	32.96%	0.50%
1.18mm UNDERFLOW	353.8	0.06%	164.7	0.18%	32.83%	0.45%
TOTAL	771.9	0.18%	501.6	0.42%	100.00%	0.59%
FEED	611.4	0.12%	521.9	4.72%		

Table 0-28 *Sampling of underflow of 1.18mm screen in bottom ash screening process*

		ERROR EST. %
Underflow 1.18mm wet mass [kg]	353.8	0.06%
Sample wet mass [kg]	13.8	0.07%
Sample dry mass [kg]	6.4	0.16%
Water content %	53.46%	0.17%
Underflow 1.18mm dry mass [kg]	164.7	0.18%

Appendix XIX

Chemical composition of process water after screening.

Table 0-29 *Chemical composition results of the screening water sample 1 taken 3 days after the process, sample 2 taken 7 days after process.*

	[mg/l]	
	SAMPLING 1	SAMPLING 2
pH	8.5	8.6
Ag	<0.1	<0.1
Al	10.6	6.81
As	<0.1	<0.1
Ba	<0.1	<0.1
Ca	19.2	30.4
Cd	<0.1	<0.1
Co	<0.1	<0.1
Cr	<0.1	0.03
Cu	0.1	0.14
Fe	0.06	0.12
K	14.5	21.2
Li	<0.1	<0.1
Mg	1.61	1.3
Mn	<0.1	<0.1
Na	30.2	53
Ni	<0.1	0.1
Pb	<0.1	<0.1
S	11.6	17.7
Sr	0.12	0.12
Zn	<0.1	<0.1

Appendix XX

Results of Magnetic separation process

Table 0-30 *Bulk densities of magnetic products*

	Sample volume [dm³]	ERROR EST. %	**Sample mass [kg]**	ERROR EST. %	**Bulk density [kg/dm³]**	ERROR EST. %
+6.25mm MAGN. PROD. I	3	3.33%	3.720	0.03%	1.24	3.33%
+6.25mm MAGN. PROD. II	3	3.33%	3.577	0.03%	1.19	3.33%
+6.25mm MAGN. PROD. III	3	3.33%	3.329	0.03%	1.11	3.33%
+6.25mm NON-MAGN. PROD.	10	5.50%	10.377	0.01%	1.04	5.50%
Coarse MAGN. PROD. I	3	3.33%	4.315	0.02%	1.44	3.33%
Coarse MAGN. PROD. II	3	3.33%	3.228	0.03%	1.08	3.33%
Coarse MAGN. PROD. III	0.8	6.25%	0.896	0.11%	1.12	6.25%
Coarse NON-MAGN. PROD.	3	3.33%	3.344	0.03%	1.11	3.33%

Table 0-31 *Magnetic separation +6.25mm*

	Dry mass [kg]	ERROR EST. %	**Concentration %**	ERROR EST. %
+6.25mm MAGN. PROD. I	23.0	0.22%	13.48%	0.32%
+6.25mm MAGN. PROD. II	10.0	0.50%	5.84%	0.55%
+6.25mm MAGN. PROD. III	5.1	0.99%	2.97%	1.02%
+6.25mm NON-MAGN. PROD.	132.3	0.08%	77.71%	0.25%
TOTAL	170.3	0.23%	100.00%	0.33%
+6.25mm MAGN. PROD. TOT.	38.0	0.47%	22.29%	1.16%
FEED (6.25mm OVERFLOW)	166.5	0.27%		

Table 0-32 *Product masses of magnetic separation +6.25mm*

	Dry mass [kg]	ERROR EST. %	**Concentration %**	ERROR EST. %
Coarse MAGN. PROD. I	27.4	0.18%	16.58%	0.30%
Coarse MAGN. PROD. II	3.9	1.30%	2.33%	1.32%
Coarse MAGN. PROD. III	2.2	2.33%	1.30%	2.34%
Coarse NON-MAGN. PROD.	131.9	0.08%	79.79%	0.35%
TOTAL	165.3	0.35%	100.00%	0.42%
Coarse MAGN. PROD. TOT.	33.4	0.75%	20.21%	2.69%
FEED (Coarse OVERFLOW)	165.3	0.27%		

Appendix XXI

Interpolation of composition of bottom ash processing screening products

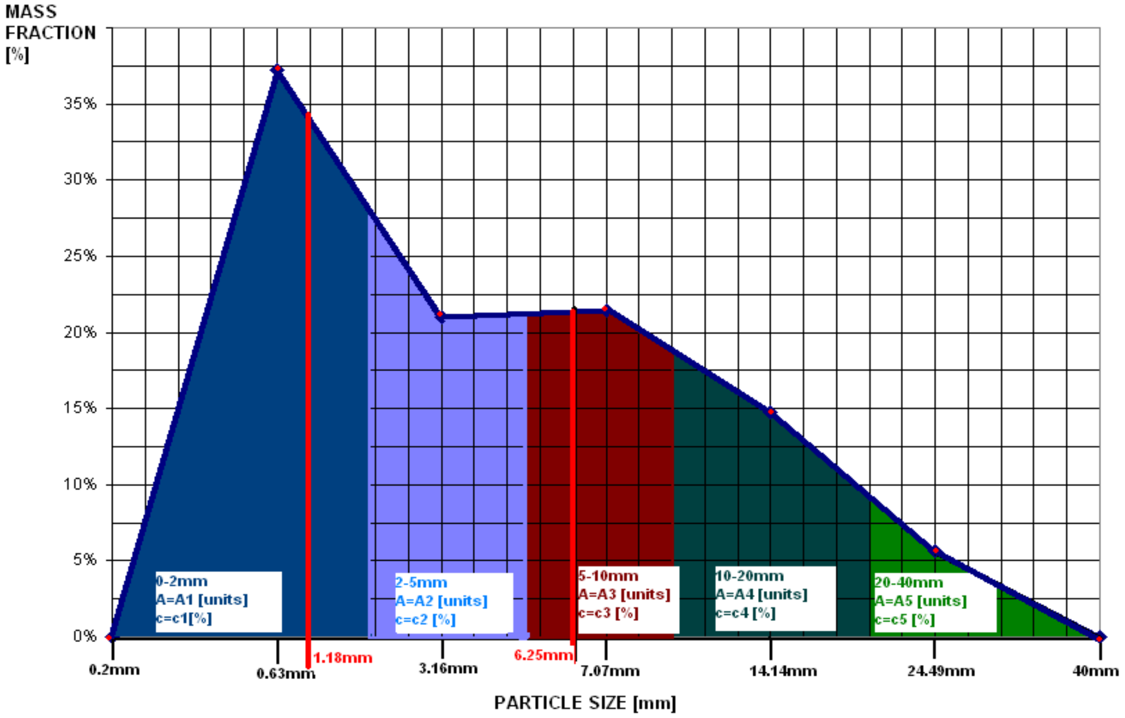


Figure 0-8 *Areas for interpolation of the concentrations of size classes Coarse and +6.25mm feed for magnetic separation*

Example: Calculating the total concentration:

$$c_{TOT} = (A1*c1 + A2*c2 + A3*c3 + A4*c4 + A5*c5)/(A1+A2+A3+A4+A5)$$

Table 0-33 *Interpolation of particle size classes*

	PARTICLE SIZE CLASS							
	0-2mm	2-5mm	5-10mm	10-20mm	20-40mm	0-40mm	1.18-2mm	5-6.25mm
Geometric mean of particle size	0.63	3.16	7.07	14.14	24.49			
measured w-%	37.24%	20.99%	21.42%	14.73%	5.62%	100.00%	-	-
Interpolated AREA [units]	76	45	38	34	12	205	22	18
interpolated w-%	37.07%	21.95%	18.54%	16.59%	5.85%	100.00%	10.73%	8.78%
measured Fe-% in feed	5.23%	5.90%	5.90%	5.46%	11.30%[1]			

[1] Concentration of Fe is a combination of Handpicking and chemical analysis:

Table 0-34 *Calculation of the Fe-concentration in size fraction 20-40mm*

	HANDPICKING	Fe-%
Maggnetic agglomerates	25.69%	11.90%
Non-magnetic agglomerates	16.21%	2.96%
Iron scrap	7.76%	100.00%
REST	50.34%	0%
TOTAL 20-40mm	100.00%	11.30%

Table 0-35 *Interpolated composition of screening products (feed for magnetic separation)*

	PARTICLE SIZE CLASS		
	0-1.18mm	**Coarse**	**+6.25mm**
measured mass [kg]	164.67	165.30	166.49
AREA [units]	54	85	66
Interpolated feed w-%	26.34%	41.46%	67.80%
Interpolated Fe-% in feed	5.23%	5.73%	6.65%
Interpolated mass of Fe [kg] in feed	8.98	9.47	10.95

Table 0-36 *Interpolated Copper concentration in MAgentic separation feed and nonferrous separation feed (calculated with handpickedred nonferrous metals concentrations); Cu%=rednonferrous concentration*

	PARTICLE SIZE CLASS	
INTERPOLATER FEED COMPOSITION	**Coarse**	**+6.25mm**
measured magnetic separation feed [kg]	165.30	166.49
AREA [units]	85	66
Interpolated magnetic separation feed w-%	41.46%	67.80%
Interpolated Cu-% in Magnetic separation feed	0.74%	1.17%
Interpolated mass Cu [kg] in magnetic separation feed	1.23	1.94
Magnetic product [kg]	33.40	37.95
Copper concentration in magnetic product[%]	0.18%	0.39%
Copper mass in magnetic product [kg]	0.06	0.15
Interpolated mass Cu [kg] in NF-separation feed	1.17	1.79
Interpolated Cu concentration [%] in NF-separation feed	0.89%	1.40%

Table 0-37 *Interpolated Copper concentration in Magnetic separation feed and nonferrous separation feed (calculated XRF-copper concentrations from characterization); Cu%=copper concentration*

	PARTICLE SIZE CLASS	
INTERPOLATER FEED COMPOSITION	**Coarse**	**+6.25mm**
measured magnetic separation feed [kg]	165.30	166.49
AREA [units]	85	66
Interpolated magnetic separation feed w-%	41.46%	67.80%
Interpolated Cu-% in Magnetic separation feed	0.36%	0.64%
Interpolated mass Cu [kg] in magnetic separation feed	0.60	1.07
Magnetic product [kg]	33.40	37.95
Copper concentration in magnetic product[%]	0.18%	0.39%
Copper mass in magnetic product [kg]	0.06	0.15
Interpolated mass Cu [kg] in NF-separation feed	0.54	0.92
Interpolated Cu concentration [%] in NF-separation feed	0.41%	0.72%

Table 0-38 *Interpolated Aluminum concentration in Magentic separation feed and nonferrous separation feed (calculated with handpickedred metals concentrations); Al%=grey nonmagnetic concentration*

	PARTICLE SIZE CLASS	
INTERPOLATER FEED COMPOSITION	**Coarse**	**+6.25mm**
measured magnetic separation feed [kg]	165.30	166.49
AREA [units]	85	66
Interpolated magnetic separation feed w-%	41.46%	67.80%
Interpolated Al-% in Magnetic separation feed	3.60%	4.89%
Interpolated mass Al [kg] in magnetic separation feed	5.94	8.15
Magnetic product [kg]	33.40	37.95
Al concentration in magnetic product[%]	5.40%	5.70%
Al mass in magnetic product [kg]	1.80	2.16
Interpolated mass Al [kg] in NF-separation feed	4.14	5.99
Interpolated Al concentration [%] in NF-separation feed	3.14%	4.66%

Appendix XXII

Composition of magnetic product and results of XRF

Figure 0-9 *Masses of magnetic product samples for quality analysis*

	Coarse	+6.25mm
FERROUS SAMPLE MASS [g]	**3892**	**4122**

Table 0-39 *Composition of magnetic products*

	MAGENTIC PRODUCT	
	+6.25mm	**Coarse**
Element	**concentration [%]**	
Al	5.7	5.4
Ba	0.15	0.08
Ca	6.2	5.4
Cl	0.11	0.07
Cr	0.12	0.09
Cu	0.39	0.18
Fe	17.00*	20
K	1.3	1.4
Mg	1	1.3
Mn	0.16	0.15
Na	3.5	3.5
Ni	0.03	0.02
P	0.31	0.46
Pb	0.14	0.03
Rb	0	0
S	0.15	0.14
Sb	0	0
Si	18	17
Sn	0.04	0.06
Sr	0.03	0.02
Ti	0.55	0.56
Zn	0.24	0.12
Zr	0.02	0.01

*10% of total sample weight of steel scrap was sieved out before the magnetic separation

Table 0-40 *Calculation of grades of magnetic products and recoveries of magnetic separation. Fe-concentration of feed is interpolated*

	FEED			**MAGNETIC PRODUCT**				
	m [kg]	**ERROR EST.%**	**Fe-%**	**mass [kg]**	**ERROR EST.%**	**Fe-%**	**GRADE**	**RECOVERY**
1.18-6.25mm	165.30	0.27%	5.73%	33.4	0.75%	20.00%	20.00%	70.55%
+6.25mm	166.49	0.27%	6.65%	37.95	0.47%	25.30%	25.30%	86.69%

Appendix XXIII

Sample masses for eddy current separation process

Table 0-41 *Sample masses of size class +6.25mm for eddy current measurements*

Samples: +6.25mm **Sample No.**	**mass [kg]**	**ERROR EST. %**
EC1_I	13.1	0.38%
EC2_I	13.35	0.37%
EC3_I	13.85	0.36%
EC4_I	15.35	0.33%
EC5_I	14.8	0.34%
EC6_I	16.75	0.30%
EC7_I	15.05	0.33%
EC8_I	13.4	0.37%

Table 0-42 *Sample masses of size class Coarse for eddy current measurements*

Samples: Coarse **Sample No.**	**mass [kg]**	**ERROR EST.%**
EC1_II	7.6	0.66%
EC2_II	7.45	0.67%
EC3_II	8.1	0.62%
EC4_II	8.05	0.62%
EC5_II	9	0.56%
EC6_II	8.55	0.58%
EC7_II	8.5	0.59%
EC8_II	8.05	0.62%

Appendix XXIV

Results of eddy current separation for size fraction +6.25mm

Table 0-43 *Handpicking results for products of eddy current run EC1_I (1m/s, 2000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	281	0.36%	Grey non-magn.	5.3	1.89%	766.3	0.39%
			Red non-ferrous	0.8	0.00%	182.5	0.40%
			Non-metals	270.7	0.04%	12148.4	0.07%
			TOTAL	276.8	0.26%	13097.2	0.13%
2	465	0.22%	Grey non-magn.	11.2	0.89%	761.0	0.36%
			Red non-ferrous	0.4	0.00%	181.7	0.41%
			Non-metals	448.8	0.02%	11877.7	0.08%
			TOTAL	460.4	0.14%	12820.4	0.12%
3	802	0.12%	Grey non-magn.	16.6	0.60%	749.8	0.35%
			Red non-ferrous	0.0	0.00%	181.3	0.41%
			Non-metals	770.0	0.01%	11428.9	0.08%
			TOTAL	786.6	0.09%	12360.0	0.12%
4	1975	0.05%	Grey non-magn.	3.3	3.03%	733.2	0.34%
			Red non-ferrous	17.7	0.00%	181.3	0.41%
			Non-metals	1953.7	0.01%	10658.9	0.08%
			TOTAL	1974.7	0.12%	11573.4	0.13%
5	8532	0.01%	Grey non-magn.	75.4	0.13%	729.9	0.27%
			Red non-ferrous	11.3	0.00%	163.6	0.43%
			Non-metals	8340.6	0.00%	8705.2	0.09%
			TOTAL	8427.3	0.01%	9598.7	0.13%
6	352	0.28%	Grey non-magn.	120.1	0.08%	654.5	0.28%
			Red non-ferrous	63.0	0.00%	152.3	0.44%
			Non-metals	164.3	0.06%	364.6	0.43%
			TOTAL	347.4	0.06%	1171.4	0.36%
7	274	0.37%	Grey non-magn.	142.6	0.07%	534.4	0.31%
			Red non-ferrous	44.6	0.00%	89.3	0.58%
			Non-metals	82.7	0.12%	200.3	0.58%
			TOTAL	269.9	0.08%	824.0	0.43%
8	197	0.51%	Grey non-magn.	127.0	0.08%	391.8	0.36%
			Red non-ferrous	17.1	0.00%	44.7	0.82%
			Non-metals	47.1	0.21%	117.6	0.75%
			TOTAL	191.2	0.12%	554.1	0.52%
9	163	0.61%	Grey non-magn.	135.8	0.07%	264.8	0.44%
			Red non-ferrous	0.0	0.00%	27.6	1.04%
			Non-metals	23.2	0.43%	70.5	0.95%
			TOTAL	159.0	0.18%	362.9	0.63%
10	101	0.99%	Grey non-magn.	68.5	0.15%	129.0	0.62%
			Red non-ferrous	3.9	2.56%	27.6	1.04%
			Non-metals	24.4	0.41%	47.3	1.12%
			TOTAL	96.8	0.57%	203.9	0.83%
11	71.6	1.40%	Grey non-magn.	30.6	0.33%	60.5	0.90%
			Red non-ferrous	23.7	0.42%	23.7	0.42%
			Non-metals	13.1	0.76%	22.9	1.55%
			TOTAL	67.4	0.47%	107.1	1.00%
12	19.9	5.03%	Grey non-magn.	13.2	0.76%	29.9	1.23%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	3.2	3.13%	9.8	2.20%
			TOTAL	16.4	1.54%	39.7	1.53%
13	13	7.69%	Grey non-magn.	3.3	3.03%	16.7	1.50%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	6.2	1.61%	6.6	1.56%
			TOTAL	9.5	2.21%	23.3	1.52%
14	0	0.00%	Grey non-magn.	0.0	0.00%	13.4	0.75%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	0.0	0.00%	0.4	0.00%
			TOTAL	0.0	0.00%	13.8	0.74%
15	17.3	5.78%	Grey non-magn.	13.4	0.75%	13.4	0.75%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	0.4	0.00%	0.4	0.00%
			TOTAL	13.8	0.74%	13.8	0.74%

Table 0-44 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC1_I (1m/s, 2000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY DETERMINATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	1.91%	1.91%	0.69%	5.07%	100.00%	0.00%	5.85%	0.41%
	Red non-ferrous	0.29%	0.26%	0.44%	2.34%	100.00%	0.00%	1.39%	0.42%
	Non-metals	97.80%	0.27%	2.23%	0.49%	100.00%	0.00%	92.76%	0.15%
	TOTAL								
2	Grey non-magn.	2.43%	0.90%	1.46%	2.96%	99.31%	5.07%	5.94%	0.38%
	Red non-ferrous	0.09%	0.14%	0.22%	1.91%	99.56%	2.34%	1.42%	0.42%
	Non-metals	97.48%	0.14%	3.69%	0.30%	97.77%	0.49%	92.65%	0.15%
	TOTAL								
3	Grey non-magn.	2.11%	0.61%	2.17%	2.14%	97.85%	2.96%	6.07%	0.37%
	Red non-ferrous	0.00%	0.09%	0.00%	1.91%	99.34%	1.91%	1.47%	0.42%
	Non-metals	97.89%	0.09%	6.34%	0.21%	94.08%	0.30%	92.47%	0.15%
	TOTAL								
4	Grey non-magn.	0.17%	3.03%	0.43%	2.23%	95.68%	2.14%	6.34%	0.36%
	Red non-ferrous	0.90%	0.12%	9.70%	1.21%	99.34%	1.91%	1.57%	0.42%
	Non-metals	98.94%	0.12%	16.08%	0.73%	87.74%	0.21%	92.10%	0.15%
	TOTAL								
5	Grey non-magn.	0.89%	0.13%	9.84%	0.77%	95.25%	2.23%	7.60%	0.30%
	Red non-ferrous	0.13%	0.01%	6.19%	0.00%	89.64%	1.21%	1.70%	0.45%
	Non-metals	98.97%	0.01%	68.66%	0.01%	71.66%	0.73%	90.69%	0.15%
	TOTAL								
6	Grey non-magn.	34.57%	0.11%	15.67%	0.45%	85.41%	0.77%	55.87%	0.46%
	Red non-ferrous	18.13%	0.06%	34.52%	0.00%	83.45%	0.00%	13.00%	0.57%
	Non-metals	47.29%	0.09%	1.35%	0.01%	3.00%	0.01%	31.13%	0.56%
	TOTAL								
7	Grey non-magn.	52.83%	0.11%	18.61%	0.39%	69.74%	0.45%	64.85%	0.53%
	Red non-ferrous	16.52%	0.08%	24.44%	0.00%	48.93%	0.00%	10.84%	0.72%
	Non-metals	30.64%	0.15%	0.68%	0.01%	1.65%	0.01%	24.31%	0.72%
	TOTAL								
8	Grey non-magn.	66.42%	0.15%	16.57%	0.35%	51.13%	0.39%	70.71%	0.63%
	Red non-ferrous	8.94%	0.12%	9.37%	0.00%	24.49%	0.00%	8.07%	0.97%
	Non-metals	24.63%	0.25%	0.39%	0.02%	0.97%	0.01%	21.22%	0.91%
	TOTAL								
9	Grey non-magn.	85.41%	0.19%	17.72%	0.25%	34.56%	0.35%	72.97%	0.77%
	Red non-ferrous	0.00%	0.18%	0.00%	0.00%	15.12%	0.00%	7.61%	1.22%
	Non-metals	14.59%	0.47%	0.19%	0.03%	0.58%	0.02%	19.43%	1.14%
	TOTAL								
10	Grey non-magn.	70.76%	0.59%	8.94%	0.31%	16.83%	0.25%	63.27%	1.03%
	Red non-ferrous	4.03%	2.63%	2.14%	0.40%	15.12%	0.00%	13.54%	1.33%
	Non-metals	25.21%	0.70%	0.20%	0.03%	0.39%	0.03%	23.20%	1.39%
	TOTAL								
11	Grey non-magn.	45.40%	0.58%	3.99%	0.31%	7.90%	0.31%	56.49%	1.35%
	Red non-ferrous	35.16%	0.63%	12.99%	0.40%	12.99%	0.40%	22.13%	1.09%
	Non-metals	19.44%	0.90%	0.11%	0.04%	0.19%	0.03%	21.38%	1.85%
	TOTAL								
12	Grey non-magn.	80.49%	1.72%	1.72%	0.33%	3.90%	0.31%	75.31%	1.96%
	Red non-ferrous	0.00%	1.54%	0.00%	0.40%	0.00%	0.40%	0.00%	1.53%
	Non-metals	19.51%	3.48%	0.03%	0.06%	0.08%	0.04%	24.69%	2.68%
	TOTAL								
13	Grey non-magn.	34.74%	3.75%	0.43%	0.38%	2.18%	0.33%	71.67%	2.14%
	Red non-ferrous	0.00%	2.21%	0.00%	0.20%	0.00%	0.40%	0.00%	1.52%
	Non-metals	65.26%	2.74%	0.05%	0.29%	0.05%	0.06%	28.33%	2.18%
	TOTAL								
14	Grey non-magn.	0.00%	0.00%	0.00%	0.38%	1.75%	0.38%	97.10%	1.05%
	Red non-ferrous	0.00%	0.00%	0.00%	0.40%	0.00%	0.20%	0.00%	0.74%
	Non-metals	0.00%	0.00%	0.00%	0.07%	0.00%	0.29%	2.90%	0.74%
	TOTAL								
15	Grey non-magn.	97.10%	1.05%	1.75%	0.39%	1.75%	0.38%	97.10%	1.05%
	Red non-ferrous	0.00%	0.74%	0.00%	0.16%	0.00%	0.40%	0.00%	0.74%
	Non-metals	2.90%	0.74%	0.00%	0.07%	0.00%	0.07%	2.90%	0.74%
	TOTAL								

Table 0-45 *Handpicking results for products of eddy current run EC2_I (1m/s, 2000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	265.4	0.38%	Grey non-magn.	2.1	4.76%	765.6	0.49%
			Red non-ferrous	0.0	0.00%	230.9	2.28%
			Non-metals	262.9	0.04%	12289.3	0.12%
			TOTAL	265.0	0.04%	13285.8	0.05%
2	382.8	0.26%	Grey non-magn.	14.1	0.71%	763.5	0.42%
			Red non-ferrous	0.1	100.00%	230.9	2.28%
			Non-metals	368.6	0.03%	12026.4	0.12%
			TOTAL	382.8	0.03%	13020.8	0.05%
3	842	0.12%	Grey non-magn.	6.7	1.49%	749.4	0.41%
			Red non-ferrous	0.0	0.00%	230.8	0.93%
			Non-metals	834.9	0.01%	11657.8	0.12%
			TOTAL	841.6	0.01%	12638.0	0.05%
4	1743.2	0.06%	Grey non-magn.	26.4	0.38%	742.7	0.39%
			Red non-ferrous	1.2	8.33%	230.8	0.93%
			Non-metals	1712.2	0.01%	10822.9	0.12%
			TOTAL	1739.8	0.01%	11796.4	0.05%
5	8711.1	0.01%	Grey non-magn.	63.9	0.16%	716.3	0.39%
			Red non-ferrous	26.5	0.38%	229.6	0.71%
			Non-metals	8616.0	0.00%	9110.7	0.13%
			TOTAL	8706.4	0.00%	10056.6	0.05%
6	402.1	0.25%	Grey non-magn.	124.1	0.08%	652.4	0.41%
			Red non-ferrous	42.1	0.24%	203.1	0.74%
			Non-metals	236.2	0.04%	494.7	0.58%
			TOTAL	402.4	0.02%	1350.2	0.15%
7	255	0.39%	Grey non-magn.	133.4	0.07%	528.3	0.45%
			Red non-ferrous	32.0	0.31%	161.0	0.83%
			Non-metals	89.8	0.11%	258.5	0.80%
			TOTAL	255.2	0.04%	947.8	0.17%
8	195.1	0.51%	Grey non-magn.	123.3	0.08%	394.9	0.52%
			Red non-ferrous	5.3	1.89%	129.0	0.91%
			Non-metals	66.5	0.15%	168.7	0.99%
			TOTAL	195.1	0.05%	692.6	0.20%
9	212.3	0.47%	Grey non-magn.	119.0	0.08%	271.6	0.62%
			Red non-ferrous	61.6	0.16%	123.7	0.84%
			Non-metals	31.9	0.31%	102.2	1.26%
			TOTAL	212.5	0.05%	497.5	0.23%
10	133.5	0.75%	Grey non-magn.	96.7	0.10%	152.6	0.83%
			Red non-ferrous	3.1	3.23%	62.1	1.18%
			Non-metals	35.2	0.28%	70.3	1.51%
			TOTAL	135.0	0.07%	285.0	0.31%
11	39.2	2.55%	Grey non-magn.	30.3	0.33%	55.9	1.36%
			Red non-ferrous	1.9	5.26%	59.0	0.96%
			Non-metals	8.5	1.18%	35.1	2.11%
			TOTAL	40.7	0.25%	150.0	0.42%
12	12.5	8.00%	Grey non-magn.	4.0	2.50%	25.6	1.98%
			Red non-ferrous	0.0	0.00%	57.1	0.18%
			Non-metals	9.3	1.08%	26.6	2.34%
			TOTAL	13.3	0.75%	109.3	0.47%
13	8.4	11.90%	Grey non-magn.	5.4	1.85%	21.6	1.87%
			Red non-ferrous	0.0	0.00%	57.1	0.18%
			Non-metals	3.8	2.63%	17.3	2.79%
			TOTAL	9.2	1.09%	96.0	0.41%
14	25.8	3.88%	Grey non-magn.	14.2	0.70%	16.2	1.88%
			Red non-ferrous	0.0	0.00%	57.1	0.18%
			Non-metals	12.5	0.80%	13.5	2.83%
			TOTAL	26.7	0.37%	86.8	0.25%
15	58	1.72%	Grey non-magn.	2.0	5.00%	2.0	5.00%
			Red non-ferrous	57.1	0.18%	57.1	0.00%
			Non-metals	1.0	10.00%	1.0	0.00%
			TOTAL	60.1	0.17%	60.1	0.17%

Table 0-46 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC2_I (1m/s, 2000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	0.79%	4.76%	0.27%	10.46%	100.00%	0.00%	5.76%	0.49%
	Red non-ferrous	0.00%	0.04%	0.00%	0.00%	100.00%	0.00%	1.74%	2.28%
	Non-metals	99.21%	0.05%	2.14%	0.79%	100.00%	0.00%	92.50%	0.13%
	TOTAL								
2	Grey non-magn.	3.68%	0.71%	1.84%	3.82%	99.73%	10.46%	5.86%	0.42%
	Red non-ferrous	0.03%	0.00%	0.04%	147.24%	100.00%	29.59%	1.77%	2.28%
	Non-metals	96.29%	0.04%	3.00%	0.51%	97.86%	0.79%	92.36%	0.13%
	TOTAL								
3	Grey non-magn.	0.80%	1.49%	0.88%	3.32%	97.88%	3.82%	5.93%	0.42%
	Red non-ferrous	0.00%	0.01%	0.04%	147.24%	99.96%	29.59%	1.83%	0.93%
	Non-metals	99.20%	0.02%	6.79%	0.34%	94.86%	0.51%	92.24%	0.13%
	TOTAL								
4	Grey non-magn.	1.52%	0.38%	3.45%	2.28%	97.01%	3.32%	6.30%	0.39%
	Red non-ferrous	0.07%	8.33%	0.52%	29.59%	99.96%	29.59%	1.96%	0.93%
	Non-metals	98.41%	0.01%	13.93%	0.96%	88.07%	0.34%	91.75%	0.13%
	TOTAL								
5	Grey non-magn.	0.73%	0.16%	8.35%	0.81%	93.56%	2.28%	7.12%	0.39%
	Red non-ferrous	0.30%	0.38%	11.48%	6.25%	99.44%	29.59%	2.28%	0.71%
	Non-metals	98.96%	0.00%	70.11%	0.01%	74.14%	0.96%	90.59%	0.15%
	TOTAL								
6	Grey non-magn.	30.84%	0.08%	16.21%	0.35%	85.21%	0.81%	48.32%	0.43%
	Red non-ferrous	10.46%	0.24%	18.23%	3.95%	87.96%	6.25%	15.04%	0.76%
	Non-metals	58.70%	0.05%	1.92%	0.01%	4.03%	0.01%	36.64%	0.60%
	TOTAL								
7	Grey non-magn.	52.27%	0.08%	17.42%	0.43%	69.00%	0.35%	55.74%	0.48%
	Red non-ferrous	12.54%	0.31%	13.86%	9.95%	69.73%	3.95%	16.99%	0.85%
	Non-metals	35.19%	0.12%	0.73%	0.01%	2.10%	0.01%	27.27%	0.82%
	TOTAL								
8	Grey non-magn.	63.20%	0.10%	16.11%	0.36%	51.58%	0.43%	57.02%	0.56%
	Red non-ferrous	2.72%	1.89%	2.30%	3.22%	55.87%	9.95%	18.63%	0.93%
	Non-metals	34.09%	0.16%	0.54%	0.02%	1.37%	0.01%	24.36%	1.01%
	TOTAL								
9	Grey non-magn.	56.00%	0.10%	15.54%	0.35%	35.48%	0.36%	54.59%	0.67%
	Red non-ferrous	28.99%	0.17%	26.68%	2.48%	53.57%	3.22%	24.86%	0.88%
	Non-metals	15.01%	0.32%	0.26%	0.02%	0.83%	0.02%	20.54%	1.28%
	TOTAL								
10	Grey non-magn.	71.63%	0.13%	12.63%	0.33%	19.93%	0.35%	53.54%	0.88%
	Red non-ferrous	2.30%	3.23%	1.34%	2.58%	26.89%	2.48%	21.79%	1.22%
	Non-metals	26.07%	0.29%	0.29%	0.03%	0.57%	0.02%	24.67%	1.54%
	TOTAL								
11	Grey non-magn.	74.45%	0.41%	3.96%	0.33%	7.30%	0.33%	37.27%	1.43%
	Red non-ferrous	4.67%	5.27%	0.82%	2.62%	25.55%	2.58%	39.33%	1.05%
	Non-metals	20.88%	1.20%	0.07%	0.04%	0.29%	0.03%	23.40%	2.15%
	TOTAL								
12	Grey non-magn.	30.08%	2.61%	0.52%	0.38%	3.34%	0.33%	23.42%	2.04%
	Red non-ferrous	0.00%	0.75%	0.00%	2.62%	24.73%	2.62%	52.24%	0.50%
	Non-metals	69.92%	1.31%	0.08%	0.05%	0.22%	0.04%	24.34%	2.38%
	TOTAL								
13	Grey non-magn.	58.70%	2.15%	0.71%	0.41%	2.82%	0.38%	22.50%	1.92%
	Red non-ferrous	0.00%	1.09%	0.00%	1.29%	24.73%	2.62%	59.48%	0.45%
	Non-metals	41.30%	2.85%	0.03%	0.28%	0.14%	0.05%	18.02%	2.82%
	TOTAL								
14	Grey non-magn.	53.18%	0.80%	1.85%	0.42%	2.12%	0.41%	18.66%	1.89%
	Red non-ferrous	0.00%	0.37%	0.00%	2.62%	24.73%	1.29%	65.78%	0.30%
	Non-metals	46.82%	0.88%	0.10%	0.07%	0.11%	0.28%	15.55%	2.84%
	TOTAL								
15	Grey non-magn.	3.33%	5.00%	0.26%	0.49%	0.26%	0.42%	3.33%	5.00%
	Red non-ferrous	95.01%	0.24%	24.73%	2.25%	24.73%	2.62%	95.01%	0.17%
	Non-metals	1.66%	10.00%	0.01%	0.12%	0.01%	0.07%	1.66%	0.17%
	TOTAL								

Table 0-47 *Weighted average of the handpicking results for products of eddy current runs EC1_I and EC2_I (1m/s, 2000rpm)*

EDDY CURRENT PRODUCTS					EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	MASS FRACTION %	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	273.3	0.62%	2.06%	0.79%	Grey non-magn.	3.7	0.45%	765.9	0.44%
					Red non-ferrous	0.4	0.45%	206.7	0.45%
					Non-metals	266.8	0.44%	12218.9	0.38%
					TOTAL	270.9	0.44%	13191.6	0.38%
2	423.6	0.61%	3.19%	0.78%	Grey non-magn.	12.7	0.45%	762.3	0.44%
					Red non-ferrous	0.2	0.49%	206.3	0.45%
					Non-metals	408.7	0.44%	11952.1	0.37%
					TOTAL	421.6	0.44%	12920.7	0.38%
3	821.9	0.60%	6.19%	0.77%	Grey non-magn.	11.6	0.45%	749.6	0.44%
					Red non-ferrous	0.0	0.45%	206.1	0.45%
					Non-metals	802.5	0.43%	11543.5	0.37%
					TOTAL	814.1	0.43%	12499.1	0.38%
4	1859.0	0.56%	14.00%	0.74%	Grey non-magn.	14.9	0.45%	738.0	0.44%
					Red non-ferrous	9.4	0.45%	206.1	0.45%
					Non-metals	1832.8	0.42%	10741.0	0.37%
					TOTAL	1857.1	0.42%	11685.0	0.37%
5	8621.6	0.42%	64.95%	0.64%	Grey non-magn.	69.6	0.45%	723.1	0.44%
					Red non-ferrous	18.9	0.45%	196.6	0.45%
					Non-metals	8478.4	0.35%	8908.1	0.35%
					TOTAL	8567.0	0.35%	9827.9	0.36%
6	376.8	0.62%	2.84%	0.78%	Grey non-magn.	122.1	0.44%	653.4	0.44%
					Red non-ferrous	52.5	0.45%	177.7	0.45%
					Non-metals	200.3	0.44%	429.7	0.44%
					TOTAL	374.9	0.44%	1260.9	0.44%
7	264.4	0.62%	1.99%	0.79%	Grey non-magn.	138.0	0.44%	531.3	0.44%
					Red non-ferrous	38.3	0.45%	125.2	0.45%
					Non-metals	86.3	0.45%	229.4	0.45%
					TOTAL	262.5	0.44%	886.0	0.44%
8	195.8	0.63%	1.48%	0.79%	Grey non-magn.	125.1	0.44%	393.4	0.45%
					Red non-ferrous	11.2	0.45%	86.9	0.45%
					Non-metals	56.8	0.45%	143.2	0.45%
					TOTAL	193.2	0.44%	623.4	0.44%
9	187.7	0.63%	1.41%	0.79%	Grey non-magn.	127.4	0.44%	268.2	0.45%
					Red non-ferrous	30.8	0.45%	75.7	0.45%
					Non-metals	27.6	0.45%	86.4	0.45%
					TOTAL	185.8	0.44%	430.3	0.45%
10	117.2	0.64%	0.88%	0.80%	Grey non-magn.	82.6	0.45%	140.8	0.45%
					Red non-ferrous	3.5	0.45%	44.9	0.45%
					Non-metals	29.8	0.45%	58.8	0.45%
					TOTAL	115.9	0.45%	244.5	0.45%
11	55.4	0.65%	0.42%	0.81%	Grey non-magn.	30.4	0.45%	58.2	0.45%
					Red non-ferrous	12.8	0.45%	41.4	0.45%
					Non-metals	10.8	0.45%	29.0	0.45%
					TOTAL	54.0	0.45%	128.6	0.45%
12	16.2	0.70%	0.12%	0.85%	Grey non-magn.	8.6	0.45%	27.7	0.45%
					Red non-ferrous	0.0	0.45%	28.6	0.45%
					Non-metals	6.3	0.45%	18.2	0.45%
					TOTAL	14.8	0.45%	74.5	0.45%
13	10.7	0.74%	0.08%	0.88%	Grey non-magn.	4.4	0.45%	19.2	0.45%
					Red non-ferrous	0.0	0.45%	28.6	0.45%
					Non-metals	5.0	0.45%	12.0	0.45%
					TOTAL	9.3	0.45%	59.7	0.45%
14	12.9	0.65%	0.10%	0.81%	Grey non-magn.	7.1	0.45%	14.8	0.45%
					Red non-ferrous	0.0	0.45%	28.6	0.45%
					Non-metals	6.3	0.45%	7.0	0.45%
					TOTAL	13.4	0.45%	50.3	0.45%
15	37.7	0.67%	0.28%	0.83%	Grey non-magn.	7.7	0.45%	7.7	0.45%
					Red non-ferrous	28.6	0.45%	28.6	0.00%
					Non-metals	0.7	0.45%	0.7	0.00%
					TOTAL	37.0	0.45%	37.0	0.45%

Table 0-48 *Weighted average of EC1_I and EC2_I grades and recoveries of eddy current metal product when moving splitter position from left to right (1m/s, 2000rpm)*

	EDDY CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	1.37%	0.63%	0.48%	0.62%	100.00%	0.00%	5.81%	0.58%
	Red non-ferrous	0.15%	0.63%	0.19%	0.61%	100.00%	0.00%	1.57%	0.59%
	Non-metals	98.49%	0.63%	2.18%	0.61%	100.00%	0.00%	92.63%	0.53%
	TOTAL								
2	Grey non-magn.	3.00%	0.63%	1.65%	0.61%	99.52%	6.06%	5.90%	0.58%
	Red non-ferrous	0.06%	0.66%	0.12%	0.64%	99.81%	10.08%	1.60%	0.59%
	Non-metals	96.94%	0.62%	3.34%	0.61%	97.82%	2.57%	92.50%	0.53%
	TOTAL					0.00%	0.00%		
3	Grey non-magn.	1.43%	0.62%	1.52%	0.61%	97.87%	2.91%	6.00%	0.58%
	Red non-ferrous	0.00%	0.62%	0.00%	0.61%	99.69%	7.91%	1.65%	0.58%
	Non-metals	98.57%	0.61%	6.57%	0.60%	94.47%	1.65%	92.35%	0.53%
	TOTAL								
4	Grey non-magn.	0.80%	0.61%	1.94%	0.61%	96.35%	2.24%	6.32%	0.58%
	Red non-ferrous	0.51%	0.62%	4.57%	0.62%	99.69%	7.91%	1.76%	0.58%
	Non-metals	98.69%	0.59%	15.00%	0.59%	87.90%	1.16%	91.92%	0.52%
	TOTAL								
5	Grey non-magn.	0.81%	0.57%	9.09%	0.61%	94.40%	1.83%	7.36%	0.57%
	Red non-ferrous	0.22%	0.57%	9.15%	0.61%	95.12%	1.95%	2.00%	0.57%
	Non-metals	98.97%	0.49%	69.39%	0.55%	72.90%	0.91%	90.64%	0.51%
	TOTAL								
6	Grey non-magn.	32.57%	0.63%	15.94%	0.61%	85.31%	0.45%	51.82%	0.63%
	Red non-ferrous	14.01%	0.63%	25.42%	0.61%	85.97%	0.45%	14.10%	0.63%
	Non-metals	53.42%	0.62%	1.64%	0.61%	3.52%	0.37%	34.08%	0.63%
	TOTAL								
7	Grey non-magn.	52.56%	0.63%	18.02%	0.61%	69.37%	0.44%	59.97%	0.63%
	Red non-ferrous	14.59%	0.63%	18.52%	0.61%	60.56%	0.45%	14.13%	0.63%
	Non-metals	32.85%	0.63%	0.71%	0.61%	1.88%	0.37%	25.90%	0.63%
	TOTAL								
8	Grey non-magn.	64.79%	0.63%	16.34%	0.61%	51.35%	0.44%	63.10%	0.63%
	Red non-ferrous	5.80%	0.63%	5.42%	0.61%	42.03%	0.45%	13.94%	0.63%
	Non-metals	29.41%	0.63%	0.46%	0.61%	1.17%	0.37%	22.97%	0.63%
	TOTAL								
9	Grey non-magn.	68.57%	0.63%	16.63%	0.61%	35.02%	0.44%	62.33%	0.63%
	Red non-ferrous	16.59%	0.63%	14.91%	0.61%	36.62%	0.45%	17.59%	0.63%
	Non-metals	14.83%	0.63%	0.23%	0.61%	0.71%	0.36%	20.07%	0.63%
	TOTAL								
10	Grey non-magn.	71.27%	0.63%	10.79%	0.61%	18.38%	0.44%	57.59%	0.63%
	Red non-ferrous	3.02%	0.63%	1.69%	0.61%	21.70%	0.43%	18.35%	0.63%
	Non-metals	25.71%	0.63%	0.24%	0.61%	0.48%	0.34%	24.05%	0.63%
	TOTAL								
11	Grey non-magn.	56.35%	0.63%	3.98%	0.61%	7.60%	0.42%	45.27%	0.63%
	Red non-ferrous	23.67%	0.63%	6.19%	0.61%	20.01%	0.42%	32.17%	0.63%
	Non-metals	19.98%	0.63%	0.09%	0.61%	0.24%	0.24%	22.56%	0.63%
	TOTAL								
12	Grey non-magn.	57.89%	0.63%	1.12%	0.61%	3.62%	0.41%	37.23%	0.63%
	Red non-ferrous	0.00%	0.63%	0.00%	0.61%	13.82%	0.38%	38.34%	0.63%
	Non-metals	42.11%	0.63%	0.05%	0.61%	0.15%	0.37%	24.43%	0.63%
	TOTAL								
13	Grey non-magn.	46.54%	0.63%	0.57%	0.61%	2.50%	0.40%	32.09%	0.63%
	Red non-ferrous	0.00%	0.63%	0.00%	0.61%	13.82%	0.40%	47.88%	0.63%
	Non-metals	53.46%	0.63%	0.04%	0.61%	0.10%	0.37%	20.03%	0.63%
	TOTAL								
14	Grey non-magn.	53.18%	0.63%	0.93%	0.61%	1.93%	0.41%	29.41%	0.63%
	Red non-ferrous	0.00%	0.63%	0.00%	0.61%	13.82%	0.21%	56.77%	0.63%
	Non-metals	46.82%	0.63%	0.05%	0.61%	0.06%	1.50%	13.82%	0.63%
	TOTAL								
15	Grey non-magn.	20.81%	0.63%	1.00%	0.61%	1.00%	0.41%	20.81%	0.63%
	Red non-ferrous	77.29%	0.63%	13.82%	0.61%	13.82%	0.41%	77.29%	0.45%
	Non-metals	1.89%	0.63%	0.01%	0.62%	0.01%	0.37%	1.89%	0.45%
	TOTAL								

Table 0-49 *Handpicking results for products of eddy current run EC3_I (1m/s, 3000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	202.6	0.49%	Grey non-magn.	24.1	0.41%	840.1	0.45%
			Red non-ferrous	0.0	0.00%	155.7	1.44%
			Non-metals	178.2	0.06%	12852.5	0.09%
			TOTAL	202.3	0.05%	13848.3	0.05%
2	617.7	0.16%	Grey non-magn.	1.2	8.33%	816.0	0.45%
			Red non-ferrous	0.0	0.00%	155.7	1.44%
			Non-metals	616.4	0.02%	12674.3	0.09%
			TOTAL	617.6	0.02%	13646.0	0.05%
3	848.2	0.12%	Grey non-magn.	8.1	1.23%	814.8	0.32%
			Red non-ferrous	0.7	14.29%	155.7	1.44%
			Non-metals	838.6	0.01%	12057.9	0.09%
			TOTAL	847.4	0.01%	13028.4	0.05%
4	2020	0.05%	Grey non-magn.	35.0	0.29%	806.7	0.30%
			Red non-ferrous	4.3	2.33%	155.0	1.08%
			Non-metals	1978.4	0.01%	11219.3	0.09%
			TOTAL	2017.7	0.00%	12181.0	0.05%
5	8832	0.01%	Grey non-magn.	77.3	0.13%	771.7	0.30%
			Red non-ferrous	11.3	0.88%	150.7	1.02%
			Non-metals	8737.4	0.00%	9240.9	0.10%
			TOTAL	8826.0	0.00%	10163.3	0.06%
6	344.6	0.29%	Grey non-magn.	77.0	0.13%	694.4	0.31%
			Red non-ferrous	29.9	0.33%	139.4	1.03%
			Non-metals	237.0	0.04%	503.5	0.44%
			TOTAL	343.9	0.03%	1337.3	0.16%
7	227.7	0.44%	Grey non-magn.	127.3	0.08%	617.4	0.33%
			Red non-ferrous	16.1	0.62%	109.5	1.15%
			Non-metals	85.0	0.12%	266.5	0.60%
			TOTAL	228.4	0.04%	993.4	0.19%
8	249.4	0.40%	Grey non-magn.	151.6	0.07%	490.1	0.37%
			Red non-ferrous	18.9	0.53%	93.4	1.22%
			Non-metals	78.0	0.13%	181.5	0.73%
			TOTAL	248.5	0.04%	765.0	0.21%
9	220.7	0.45%	Grey non-magn.	162.9	0.06%	338.5	0.44%
			Red non-ferrous	16.4	0.61%	74.5	1.34%
			Non-metals	41.1	0.24%	103.5	0.96%
			TOTAL	220.4	0.05%	516.5	0.26%
10	136.5	0.73%	Grey non-magn.	94.9	0.11%	175.6	0.60%
			Red non-ferrous	16.5	0.61%	58.1	1.48%
			Non-metals	25.6	0.39%	62.4	1.21%
			TOTAL	137.0	0.07%	296.1	0.34%
11	71.4	1.40%	Grey non-magn.	39.6	0.25%	80.7	0.88%
			Red non-ferrous	15.5	0.65%	41.6	1.71%
			Non-metals	15.9	0.63%	36.8	1.55%
			TOTAL	71.0	0.14%	159.1	0.45%
12	29.4	3.40%	Grey non-magn.	16.9	0.59%	41.1	1.21%
			Red non-ferrous	0.9	11.11%	26.1	2.10%
			Non-metals	15.6	0.64%	20.9	1.98%
			TOTAL	33.4	0.30%	88.1	0.60%
13	19	5.26%	Grey non-magn.	15.6	0.64%	24.2	1.50%
			Red non-ferrous	0.0	0.00%	25.2	0.40%
			Non-metals	2.7	3.70%	5.3	3.77%
			TOTAL	18.3	0.55%	54.7	0.72%
14	31.4	3.18%	Grey non-magn.	3.5	2.86%	8.6	2.37%
			Red non-ferrous	25.2	0.40%	25.2	0.40%
			Non-metals	2.6	3.85%	2.6	3.85%
			TOTAL	31.3	0.32%	36.4	0.79%
15	5	20.00%	Grey non-magn.	5.1	1.96%	5.1	1.96%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	0.0	0.00%	0.0	0.00%
			TOTAL	5.1	1.96%	5.1	1.96%

Table 0-50 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC3_I (1m/s, 3000rpm)*

	EDDY CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	11.91%	0.42%	2.87%	2.69%	100.00%	0.00%	6.07%	0.45%
	Red non-ferrous	0.00%	0.05%	0.00%	0.00%	100.00%	0.00%	1.12%	1.44%
	Non-metals	88.09%	0.07%	1.39%	0.73%	100.00%	0.00%	92.81%	0.10%
	TOTAL								
2	Grey non-magn.	0.19%	8.33%	0.14%	3.19%	97.13%	2.69%	5.98%	0.46%
	Red non-ferrous	0.00%	0.02%	0.00%	0.00%	100.00%	0.00%	1.14%	1.44%
	Non-metals	99.81%	0.02%	4.80%	0.35%	98.61%	0.73%	92.88%	0.10%
	TOTAL								
3	Grey non-magn.	0.96%	1.23%	0.96%	2.84%	96.99%	3.19%	6.25%	0.33%
	Red non-ferrous	0.08%	14.29%	0.45%	25.64%	100.00%	0.00%	1.20%	1.44%
	Non-metals	98.96%	0.02%	6.52%	0.24%	93.82%	0.35%	92.55%	0.10%
	TOTAL								
4	Grey non-magn.	1.73%	0.29%	4.17%	2.00%	96.02%	2.84%	6.62%	0.30%
	Red non-ferrous	0.21%	2.33%	2.76%	6.29%	99.55%	25.64%	1.27%	1.08%
	Non-metals	98.05%	0.01%	15.39%	0.85%	87.29%	0.24%	92.10%	0.11%
	TOTAL								
5	Grey non-magn.	0.88%	0.13%	9.20%	0.84%	91.86%	2.00%	7.59%	0.30%
	Red non-ferrous	0.13%	0.88%	7.26%	3.28%	96.79%	6.29%	1.48%	1.02%
	Non-metals	99.00%	0.00%	67.98%	0.01%	71.90%	0.85%	90.92%	0.12%
	TOTAL								
6	Grey non-magn.	22.39%	0.13%	9.17%	0.67%	82.66%	0.84%	51.93%	0.35%
	Red non-ferrous	8.69%	0.34%	19.20%	1.96%	89.53%	3.28%	10.42%	1.04%
	Non-metals	68.92%	0.05%	1.84%	0.01%	3.92%	0.01%	37.65%	0.47%
	TOTAL								
7	Grey non-magn.	55.74%	0.09%	15.15%	0.29%	73.49%	0.67%	62.15%	0.38%
	Red non-ferrous	7.05%	0.62%	10.34%	1.72%	70.33%	1.96%	11.02%	1.17%
	Non-metals	37.22%	0.13%	0.66%	0.01%	2.07%	0.01%	26.83%	0.63%
	TOTAL								
8	Grey non-magn.	61.01%	0.08%	18.05%	0.43%	58.34%	0.29%	64.07%	0.42%
	Red non-ferrous	7.61%	0.53%	12.14%	0.97%	59.99%	1.72%	12.21%	1.24%
	Non-metals	31.39%	0.13%	0.61%	0.02%	1.41%	0.01%	23.73%	0.76%
	TOTAL								
9	Grey non-magn.	73.91%	0.08%	19.39%	0.40%	40.29%	0.43%	65.54%	0.51%
	Red non-ferrous	7.44%	0.61%	10.53%	1.33%	47.85%	0.97%	14.42%	1.36%
	Non-metals	18.65%	0.25%	0.32%	0.02%	0.81%	0.02%	20.04%	0.99%
	TOTAL								
10	Grey non-magn.	69.27%	0.13%	11.30%	0.38%	20.90%	0.40%	59.30%	0.69%
	Red non-ferrous	12.04%	0.61%	10.60%	1.30%	37.32%	1.33%	19.62%	1.52%
	Non-metals	18.69%	0.40%	0.20%	0.03%	0.49%	0.02%	21.07%	1.26%
	TOTAL								
11	Grey non-magn.	55.77%	0.29%	4.71%	0.37%	9.61%	0.38%	50.72%	0.99%
	Red non-ferrous	21.83%	0.66%	9.96%	1.26%	26.72%	1.30%	26.15%	1.77%
	Non-metals	22.39%	0.64%	0.12%	0.04%	0.29%	0.03%	23.13%	1.61%
	TOTAL								
12	Grey non-magn.	50.60%	0.66%	2.01%	0.38%	4.89%	0.37%	46.65%	1.35%
	Red non-ferrous	2.69%	11.12%	0.58%	1.55%	16.76%	1.26%	29.63%	2.18%
	Non-metals	46.71%	0.71%	0.12%	0.04%	0.16%	0.04%	23.72%	2.07%
	TOTAL								
13	Grey non-magn.	85.25%	0.84%	1.86%	0.38%	2.88%	0.38%	44.24%	1.67%
	Red non-ferrous	0.00%	0.55%	0.00%	0.62%	16.18%	1.55%	46.07%	0.82%
	Non-metals	14.75%	3.74%	0.02%	0.26%	0.04%	0.04%	9.69%	3.84%
	TOTAL								
14	Grey non-magn.	11.18%	2.87%	0.42%	0.43%	1.02%	0.38%	23.63%	2.50%
	Red non-ferrous	80.51%	0.51%	16.18%	1.43%	16.18%	0.62%	69.23%	0.89%
	Non-metals	8.31%	3.86%	0.02%	0.09%	0.02%	0.26%	7.14%	3.93%
	TOTAL								
15	Grey non-magn.	100.00%	2.77%	0.61%	0.45%	0.61%	0.43%	100.00%	2.77%
	Red non-ferrous	0.00%	1.96%	0.00%	1.43%	0.00%	1.43%	0.00%	1.96%
	Non-metals	0.00%	1.96%	0.00%	0.09%	0.00%	0.09%	0.00%	1.96%
	TOTAL								

Table 0-51 *Handpicking results for products of eddy current run EC4_I (1m/s, 3000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	255.6	0.39%	Grey non-magn.	1.7	5.88%	785.3	0.58%
			Red non-ferrous	1.6	6.25%	196.2	2.54%
			Non-metals	252.4	0.04%	14208.3	0.14%
			TOTAL	255.7	0.04%	15189.8	0.10%
2	417.9	0.24%	Grey non-magn.	1.3	7.69%	783.6	0.51%
			Red non-ferrous	0.1	100.00%	194.6	2.49%
			Non-metals	415.5	0.02%	13955.9	0.14%
			TOTAL	416.9	0.02%	14934.1	0.10%
3	934.5	0.11%	Grey non-magn.	11.9	0.84%	782.3	0.40%
			Red non-ferrous	2.0	5.00%	194.5	1.03%
			Non-metals	918.2	0.01%	13540.4	0.15%
			TOTAL	932.1	0.01%	14517.2	0.10%
4	2229	0.04%	Grey non-magn.	22.1	0.45%	770.4	0.39%
			Red non-ferrous	3.0	3.33%	192.5	0.90%
			Non-metals	2201.2	0.00%	12622.2	0.15%
			TOTAL	2226.3	0.00%	13585.1	0.10%
5	9721	0.01%	Grey non-magn.	45.9	0.22%	748.3	0.39%
			Red non-ferrous	12.5	0.80%	189.5	0.80%
			Non-metals	9656.6	0.00%	10421.0	0.17%
			TOTAL	9715.0	0.00%	11358.8	0.11%
6	445.5	0.22%	Grey non-magn.	89.0	0.11%	702.4	0.40%
			Red non-ferrous	19.7	0.51%	177.0	0.80%
			Non-metals	336.9	0.03%	764.4	0.62%
			TOTAL	445.6	0.02%	1643.8	0.30%
7	332.6	0.30%	Grey non-magn.	114.3	0.09%	613.4	0.42%
			Red non-ferrous	39.7	0.25%	157.3	0.83%
			Non-metals	178.8	0.06%	427.5	0.82%
			TOTAL	332.8	0.03%	1198.2	0.35%
8	313.9	0.32%	Grey non-magn.	152.5	0.07%	499.1	0.46%
			Red non-ferrous	73.5	0.14%	117.6	0.95%
			Non-metals	87.9	0.11%	248.7	1.08%
			TOTAL	313.9	0.03%	865.4	0.41%
9	236.2	0.42%	Grey non-magn.	132.0	0.08%	346.6	0.56%
			Red non-ferrous	17.1	0.58%	44.1	1.54%
			Non-metals	87.5	0.11%	160.8	1.34%
			TOTAL	236.6	0.04%	551.5	0.51%
10	168.7	0.59%	Grey non-magn.	112.8	0.09%	214.6	0.70%
			Red non-ferrous	9.0	1.11%	27.0	1.91%
			Non-metals	47.0	0.21%	73.3	1.98%
			TOTAL	168.8	0.06%	314.9	0.67%
11	119.1	0.84%	Grey non-magn.	91.0	0.11%	101.8	1.02%
			Red non-ferrous	7.1	1.41%	18.0	2.20%
			Non-metals	22.5	0.44%	26.3	3.29%
			TOTAL	120.6	0.08%	146.1	0.99%
12	145.1	0.69%	Grey non-magn.	0.0	0.00%	10.8	3.11%
			Red non-ferrous	1.6	6.25%	10.9	2.59%
			Non-metals	0.0	0.00%	3.8	8.57%
			TOTAL	1.6	6.25%	25.5	2.36%
13	15.5	6.45%	Grey non-magn.	5.4	1.85%	10.8	3.11%
			Red non-ferrous	9.3	1.08%	9.3	1.08%
			Non-metals	0.4	25.00%	3.8	8.57%
			TOTAL	15.1	0.66%	23.9	1.82%
14	7.4	13.51%	Grey non-magn.	3.7	2.70%	5.4	3.99%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	3.4	2.94%	3.4	2.94%
			TOTAL	7.1	1.41%	8.8	2.88%
15	1.7	58.82%	Grey non-magn.	1.7	5.88%	1.7	5.88%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	0.0	0.00%	0.0	0.00%
			TOTAL	1.7	5.88%	1.7	5.88%

Table 0-52 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC4_I (1m/s, 3000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	0.66%	5.88%	0.22%	13.69%	100.00%	0.00%	5.17%	0.58%
	Red non-ferrous	0.63%	6.25%	0.82%	28.71%	100.00%	0.00%	1.29%	2.54%
	Non-metals	98.71%	0.06%	1.78%	1.07%	100.00%	0.00%	93.54%	0.17%
	TOTAL								
2	Grey non-magn.	0.31%	7.69%	0.17%	11.48%	99.78%	13.69%	5.25%	0.52%
	Red non-ferrous	0.02%	100.00%	0.05%	36.93%	99.18%	28.71%	1.30%	2.49%
	Non-metals	99.66%	0.03%	2.92%	0.66%	98.22%	1.07%	93.45%	0.17%
	TOTAL								
3	Grey non-magn.	1.28%	0.84%	1.52%	5.21%	99.62%	11.48%	5.39%	0.41%
	Red non-ferrous	0.21%	5.00%	1.02%	25.30%	99.13%	36.93%	1.34%	1.03%
	Non-metals	98.51%	0.02%	6.46%	0.43%	95.30%	0.66%	93.27%	0.18%
	TOTAL								
4	Grey non-magn.	0.99%	0.45%	2.81%	3.32%	98.10%	5.21%	5.67%	0.40%
	Red non-ferrous	0.13%	3.33%	1.53%	13.44%	98.11%	25.30%	1.42%	0.90%
	Non-metals	98.87%	0.01%	15.49%	1.11%	88.84%	0.43%	92.91%	0.18%
	TOTAL								
5	Grey non-magn.	0.47%	0.22%	5.84%	1.35%	95.29%	3.32%	6.59%	0.40%
	Red non-ferrous	0.13%	0.80%	6.37%	7.75%	96.59%	13.44%	1.67%	0.81%
	Non-metals	99.40%	0.00%	67.96%	0.01%	73.34%	1.11%	91.74%	0.20%
	TOTAL								
6	Grey non-magn.	19.97%	0.11%	11.33%	0.74%	89.44%	1.35%	42.73%	0.49%
	Red non-ferrous	4.42%	0.51%	10.04%	5.31%	90.21%	7.75%	10.77%	0.85%
	Non-metals	75.61%	0.04%	2.37%	0.01%	5.38%	0.01%	46.50%	0.68%
	TOTAL								
7	Grey non-magn.	34.34%	0.09%	14.55%	0.53%	78.11%	0.74%	51.19%	0.55%
	Red non-ferrous	11.93%	0.25%	20.23%	11.37%	80.17%	5.31%	13.13%	0.90%
	Non-metals	53.73%	0.06%	1.26%	0.01%	3.01%	0.01%	35.68%	0.89%
	TOTAL								
8	Grey non-magn.	48.58%	0.07%	19.42%	0.58%	63.56%	0.53%	57.67%	0.62%
	Red non-ferrous	23.42%	0.14%	37.46%	2.71%	59.94%	11.37%	13.59%	1.03%
	Non-metals	28.00%	0.12%	0.62%	0.01%	1.75%	0.01%	28.74%	1.15%
	TOTAL								
9	Grey non-magn.	55.79%	0.09%	16.81%	0.51%	44.14%	0.58%	62.85%	0.75%
	Red non-ferrous	7.23%	0.59%	8.72%	2.59%	22.48%	2.71%	8.00%	1.62%
	Non-metals	36.98%	0.12%	0.62%	0.02%	1.13%	0.01%	29.16%	1.43%
	TOTAL								
10	Grey non-magn.	66.82%	0.11%	14.36%	0.47%	27.33%	0.51%	68.15%	0.98%
	Red non-ferrous	5.33%	1.11%	4.59%	2.56%	13.76%	2.59%	8.57%	2.03%
	Non-metals	27.84%	0.22%	0.33%	0.02%	0.52%	0.02%	23.28%	2.09%
	TOTAL								
11	Grey non-magn.	75.46%	0.14%	11.59%	0.45%	12.96%	0.47%	69.68%	1.42%
	Red non-ferrous	5.89%	1.41%	3.62%	2.53%	9.17%	2.56%	12.32%	2.41%
	Non-metals	18.66%	0.45%	0.16%	0.03%	0.19%	0.02%	18.00%	3.43%
	TOTAL					0.00%	0.00%		
12	Grey non-magn.	0.00%	6.25%	0.00%	0.45%	1.38%	0.45%	42.35%	3.90%
	Red non-ferrous	100.00%	8.84%	0.82%	2.59%	5.56%	2.53%	42.75%	3.51%
	Non-metals	0.00%	6.25%	0.00%	0.03%	0.03%	0.03%	14.90%	8.89%
	TOTAL								
13	Grey non-magn.	35.76%	1.97%	0.69%	0.47%	1.38%	0.45%	45.19%	3.60%
	Red non-ferrous	61.59%	1.26%	4.74%	1.27%	4.74%	2.59%	38.91%	2.12%
	Non-metals	2.65%	25.01%	0.00%	0.58%	0.03%	0.03%	15.90%	8.77%
	TOTAL								
14	Grey non-magn.	52.11%	3.05%	0.47%	0.51%	0.69%	0.47%	61.36%	4.92%
	Red non-ferrous	0.00%	1.41%	0.00%	2.54%	0.00%	1.27%	0.00%	2.88%
	Non-metals	47.89%	3.26%	0.02%	0.14%	0.02%	0.58%	38.64%	4.12%
	TOTAL								
15	Grey non-magn.	100.00%	8.32%	0.22%	0.58%	0.22%	0.51%	100.00%	8.32%
	Red non-ferrous	0.00%	5.88%	0.00%	2.53%	0.00%	2.54%	0.00%	5.88%
	Non-metals	0.00%	5.88%	0.00%	0.14%	0.00%	0.14%	0.00%	5.88%
	TOTAL								

Table 0-53 *Weighted average of the handpicking results for products of eddy current runs EC3_I and EC4_I (1m/s, 3000rpm)*

EDDY CURRENT PRODUCTS					EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	MASS FRACTION %	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	230.5	0.87%	1.57%	1.10%	Grey non-magn.	12.3	0.64%	811.3	0.63%
					Red non-ferrous	0.8	0.64%	177.0	0.64%
					Non-metals	217.2	0.63%	13564.9	0.54%
					TOTAL	230.4	0.63%	14553.2	0.54%
2	512.7	0.85%	3.50%	1.09%	Grey non-magn.	1.3	0.64%	799.0	0.63%
					Red non-ferrous	0.1	0.66%	176.1	0.64%
					Non-metals	510.8	0.62%	13347.8	0.53%
					TOTAL	512.1	0.62%	14322.9	0.54%
3	893.5	0.83%	6.10%	1.07%	Grey non-magn.	10.1	0.64%	797.7	0.63%
					Red non-ferrous	1.4	0.64%	176.1	0.64%
					Non-metals	880.4	0.62%	12836.9	0.53%
					TOTAL	891.9	0.62%	13810.7	0.54%
4	2129.7	0.78%	14.55%	1.03%	Grey non-magn.	28.2	0.64%	787.6	0.63%
					Red non-ferrous	3.6	0.64%	174.7	0.64%
					Non-metals	2095.5	0.59%	11956.5	0.52%
					TOTAL	2127.3	0.59%	12918.8	0.53%
5	9298.7	0.59%	63.53%	0.90%	Grey non-magn.	60.8	0.63%	759.4	0.63%
					Red non-ferrous	11.9	0.64%	171.1	0.64%
					Non-metals	9220.4	0.50%	9861.0	0.51%
					TOTAL	9293.1	0.50%	10791.5	0.52%
6	397.6	0.86%	2.72%	1.09%	Grey non-magn.	83.3	0.63%	698.6	0.63%
					Red non-ferrous	24.5	0.64%	159.2	0.64%
					Non-metals	289.5	0.63%	640.6	0.63%
					TOTAL	397.3	0.63%	1498.4	0.63%
7	282.8	0.86%	1.93%	1.10%	Grey non-magn.	120.5	0.63%	615.3	0.63%
					Red non-ferrous	28.5	0.64%	134.6	0.64%
					Non-metals	134.3	0.63%	351.1	0.63%
					TOTAL	283.3	0.63%	1101.0	0.63%
8	283.3	0.86%	1.94%	1.10%	Grey non-magn.	152.1	0.63%	494.8	0.63%
					Red non-ferrous	47.6	0.64%	106.1	0.64%
					Non-metals	83.2	0.63%	216.8	0.63%
					TOTAL	282.9	0.63%	817.8	0.63%
9	228.8	0.87%	1.56%	1.10%	Grey non-magn.	146.7	0.63%	342.8	0.63%
					Red non-ferrous	16.8	0.64%	58.5	0.64%
					Non-metals	65.5	0.63%	133.6	0.64%
					TOTAL	228.9	0.63%	534.9	0.63%
10	153.4	0.87%	1.05%	1.11%	Grey non-magn.	104.3	0.63%	196.1	0.63%
					Red non-ferrous	12.6	0.64%	41.8	0.64%
					Non-metals	36.8	0.64%	68.1	0.64%
					TOTAL	153.7	0.63%	306.0	0.63%
11	96.5	0.88%	0.66%	1.11%	Grey non-magn.	66.6	0.63%	91.8	0.64%
					Red non-ferrous	11.1	0.64%	29.2	0.64%
					Non-metals	19.4	0.64%	31.3	0.64%
					TOTAL	97.1	0.63%	152.3	0.63%
12	90.2	0.89%	0.62%	1.12%	Grey non-magn.	8.0	0.64%	25.2	0.64%
					Red non-ferrous	1.3	0.64%	18.1	0.64%
					Non-metals	7.4	0.64%	11.9	0.64%
					TOTAL	16.7	0.64%	55.2	0.64%
13	17.2	0.92%	0.12%	1.14%	Grey non-magn.	10.2	0.64%	17.2	0.64%
					Red non-ferrous	4.9	0.64%	16.8	0.64%
					Non-metals	1.5	0.64%	4.5	0.64%
					TOTAL	16.6	0.64%	38.5	0.64%
14	18.8	0.94%	0.13%	1.16%	Grey non-magn.	3.6	0.64%	6.9	0.64%
					Red non-ferrous	12.0	0.64%	12.0	0.64%
					Non-metals	3.0	0.64%	3.0	0.64%
					TOTAL	18.6	0.64%	21.9	0.64%
15	3.3	1.13%	0.02%	1.32%	Grey non-magn.	3.3	0.64%	3.3	0.64%
					Red non-ferrous	0.0	0.64%	0.0	0.00%
					Non-metals	0.0	0.64%	0.0	0.00%
					TOTAL	3.3	0.64%	3.3	0.64%

Table 0-54 *Weighted average of EC3_I and EC4_I grades and recoveries of eddy current metal product when moving splitter position from left to right (1m/s, 3000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	5.35%	0.90%	1.52%	4.84%	100.00%	0.00%	5.57%	0.83%
	Red non-ferrous	0.36%	0.90%	0.48%	9.24%	100.00%	0.00%	1.22%	0.84%
	Non-metals	94.28%	0.89%	1.60%	4.28%	100.00%	0.00%	93.21%	0.76%
	TOTAL								
2	Grey non-magn.	0.24%	0.89%	0.15%	4.62%	98.48%	4.62%	5.58%	0.83%
	Red non-ferrous	0.01%	0.91%	0.03%	8.97%	99.52%	8.97%	1.23%	0.83%
	Non-metals	99.75%	0.88%	3.77%	2.40%	98.40%	2.40%	93.19%	0.76%
	TOTAL					0.00%			
3	Grey non-magn.	1.13%	0.89%	1.24%	3.52%	98.33%	3.52%	5.78%	0.83%
	Red non-ferrous	0.16%	0.89%	0.78%	5.64%	99.50%	5.64%	1.28%	0.83%
	Non-metals	98.71%	0.87%	6.49%	1.68%	94.63%	1.68%	92.95%	0.76%
	TOTAL					0.00%			
4	Grey non-magn.	1.33%	0.87%	3.48%	2.42%	97.08%	2.42%	6.10%	0.83%
	Red non-ferrous	0.17%	0.87%	2.04%	3.30%	98.71%	3.30%	1.35%	0.83%
	Non-metals	98.50%	0.84%	15.45%	1.28%	88.14%	1.28%	92.55%	0.75%
	TOTAL					0.00%			
5	Grey non-magn.	0.65%	0.81%	7.49%	0.64%	93.60%	0.64%	7.04%	0.82%
	Red non-ferrous	0.13%	0.81%	6.74%	0.64%	96.67%	0.64%	1.59%	0.82%
	Non-metals	99.22%	0.70%	67.97%	0.53%	72.69%	0.53%	91.38%	0.73%
	TOTAL					0.00%			
6	Grey non-magn.	20.97%	0.89%	10.27%	0.61%	86.11%	0.61%	46.62%	0.89%
	Red non-ferrous	6.18%	0.89%	13.87%	0.63%	89.93%	0.63%	10.62%	0.89%
	Non-metals	72.86%	0.89%	2.13%	0.53%	4.72%	0.53%	42.75%	0.89%
	TOTAL					0.00%			
7	Grey non-magn.	42.53%	0.89%	14.85%	0.63%	75.84%	0.63%	55.88%	0.89%
	Red non-ferrous	10.06%	0.89%	16.10%	0.64%	76.06%	0.64%	12.23%	0.90%
	Non-metals	47.41%	0.89%	0.99%	0.52%	2.59%	0.52%	31.89%	0.89%
	TOTAL					0.00%			
8	Grey non-magn.	53.76%	0.89%	18.74%	0.63%	60.99%	0.63%	60.51%	0.89%
	Red non-ferrous	16.82%	0.89%	26.89%	0.63%	59.96%	0.63%	12.98%	0.90%
	Non-metals	29.41%	0.89%	0.61%	0.51%	1.60%	0.51%	26.51%	0.90%
	TOTAL					0.00%			
9	Grey non-magn.	64.07%	0.89%	18.08%	0.62%	42.25%	0.62%	64.08%	0.90%
	Red non-ferrous	7.32%	0.90%	9.47%	0.63%	33.07%	0.63%	10.94%	0.90%
	Non-metals	28.61%	0.89%	0.48%	0.48%	0.98%	0.48%	24.98%	0.90%
	TOTAL					0.00%			
10	Grey non-magn.	67.86%	0.90%	12.86%	0.61%	24.17%	0.61%	64.09%	0.90%
	Red non-ferrous	8.17%	0.90%	7.10%	0.61%	23.59%	0.61%	13.65%	0.90%
	Non-metals	23.97%	0.90%	0.27%	0.34%	0.50%	0.34%	22.27%	0.90%
	TOTAL					0.00%			
11	Grey non-magn.	68.62%	0.90%	8.21%	0.60%	11.31%	0.60%	60.28%	0.90%
	Red non-ferrous	11.42%	0.90%	6.26%	0.58%	16.50%	0.58%	19.18%	0.90%
	Non-metals	19.95%	0.90%	0.14%	0.53%	0.23%	0.53%	20.54%	0.90%
	TOTAL					0.00%			
12	Grey non-magn.	48.05%	0.90%	0.99%	0.58%	3.10%	0.58%	45.61%	0.90%
	Red non-ferrous	7.60%	0.90%	0.72%	0.58%	10.23%	0.58%	32.81%	0.90%
	Non-metals	44.35%	0.90%	0.05%	0.53%	0.09%	0.53%	21.58%	0.90%
	TOTAL					0.00%			
13	Grey non-magn.	61.62%	0.90%	1.26%	0.57%	2.11%	0.57%	44.55%	0.90%
	Red non-ferrous	29.41%	0.90%	2.76%	0.24%	9.52%	0.24%	43.74%	0.90%
	Non-metals	8.97%	0.90%	0.01%	2.19%	0.03%	2.19%	11.71%	0.90%
	TOTAL					0.00%			
14	Grey non-magn.	19.40%	0.90%	0.44%	0.57%	0.85%	0.57%	31.60%	0.90%
	Red non-ferrous	64.35%	0.90%	6.76%	0.60%	6.76%	0.60%	54.61%	0.90%
	Non-metals	16.25%	0.90%	0.02%	0.53%	0.02%	0.53%	13.79%	0.90%
	TOTAL					0.00%			
15	Grey non-magn.	100.00%	0.90%	0.41%	0.59%	0.41%	0.59%	100.00%	0.90%
	Red non-ferrous	0.00%	0.90%	0.00%	0.61%	0.00%	0.61%	0.00%	0.64%
	Non-metals	0.00%	0.90%	0.00%	0.54%	0.00%	0.54%	0.00%	0.64%
	TOTAL								

Table 0-55 *Handpicking results for products of eddy current run EC5_I (2m/s, 2000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	112.6	0.89%	Grey non-magn.	1.6	6.25%	911.0	0.64%
			Red non-ferrous	0.2	50.00%	246.5	2.09%
			Non-metals	110.8	0.09%	13576.2	0.03%
			TOTAL	112.6	0.09%	14733.7	0.03%
2	52.8	1.89%	Grey non-magn.	1.4	7.14%	909.4	0.59%
			Red non-ferrous	0.0	0.00%	246.3	1.53%
			Non-metals	49.6	0.20%	13465.4	0.03%
			TOTAL	51.0	0.20%	14621.1	0.03%
3	53.9	1.86%	Grey non-magn.	1.4	7.14%	908.0	0.52%
			Red non-ferrous	0.0	0.00%	246.3	1.53%
			Non-metals	52.5	0.19%	13415.8	0.03%
			TOTAL	53.9	0.19%	14570.1	0.02%
4	52.9	1.89%	Grey non-magn.	1.3	7.69%	906.6	0.44%
			Red non-ferrous	0.2	50.00%	246.3	1.53%
			Non-metals	51.4	0.19%	13363.3	0.02%
			TOTAL	52.9	0.19%	14516.2	0.02%
5	106.9	0.94%	Grey non-magn.	1.8	5.56%	905.3	0.33%
			Red non-ferrous	1.9	5.26%	246.1	0.57%
			Non-metals	105.2	0.10%	13311.9	0.02%
			TOTAL	108.9	0.09%	14463.3	0.02%
6	114.3	0.87%	Grey non-magn.	9.9	1.01%	903.5	0.21%
			Red non-ferrous	0.0	0.00%	244.2	0.33%
			Non-metals	102.7	0.10%	13206.7	0.02%
			TOTAL	112.6	0.09%	14354.4	0.02%
7	215.8	0.46%	Grey non-magn.	16.1	0.62%	893.6	0.18%
			Red non-ferrous	18.1	0.55%	244.2	0.33%
			Non-metals	181.2	0.06%	13104.0	0.02%
			TOTAL	215.4	0.05%	14241.8	0.01%
8	392.1	0.26%	Grey non-magn.	10.5	0.95%	877.5	0.17%
			Red non-ferrous	16.8	0.60%	226.1	0.30%
			Non-metals	364.2	0.03%	12922.8	0.02%
			TOTAL	391.5	0.03%	14026.4	0.01%
9	1743	0.06%	Grey non-magn.	11.7	0.85%	867.0	0.13%
			Red non-ferrous	0.0	0.00%	209.3	0.27%
			Non-metals	1729.1	0.01%	12558.6	0.02%
			TOTAL	1740.8	0.01%	13634.9	0.01%
10	10067	0.01%	Grey non-magn.	53.8	0.19%	855.3	0.09%
			Red non-ferrous	18.4	0.54%	209.3	0.27%
			Non-metals	9986.9	0.00%	10829.5	0.02%
			TOTAL	10059.1	0.00%	11894.1	0.01%
11	541.9	0.18%	Grey non-magn.	180.6	0.06%	801.5	0.07%
			Red non-ferrous	78.0	0.13%	190.9	0.22%
			Non-metals	283.6	0.04%	842.6	0.06%
			TOTAL	542.2	0.02%	1835.0	0.03%
12	251.6	0.40%	Grey non-magn.	128.2	0.08%	620.9	0.08%
			Red non-ferrous	28.8	0.35%	112.9	0.27%
			Non-metals	111.5	0.09%	559.0	0.07%
			TOTAL	268.5	0.04%	1292.8	0.03%
13	482	0.21%	Grey non-magn.	276.2	0.04%	492.7	0.08%
			Red non-ferrous	42.0	0.24%	84.1	0.24%
			Non-metals	164.1	0.06%	447.5	0.07%
			TOTAL	482.3	0.02%	1024.3	0.03%
14	387.1	0.26%	Grey non-magn.	169.6	0.06%	216.5	0.11%
			Red non-ferrous	42.1	0.24%	42.1	0.24%
			Non-metals	175.5	0.06%	283.4	0.07%
			TOTAL	387.2	0.03%	542.0	0.04%
15	155.5	0.64%	Grey non-magn.	46.9	0.21%	46.9	0.21%
			Red non-ferrous	0.0	0.00%	0.0	0.00%
			Non-metals	107.9	0.09%	107.9	0.09%
			TOTAL	154.8	0.06%	154.8	0.06%

Table 0-56 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC5_I (2m/s, 2000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	1.42%	6.25%	0.18%	16.57%	100.00%	0.00%	6.18%	0.65%
	Red non-ferrous	0.18%	50.00%	0.08%	88.70%	100.00%	0.00%	1.67%	2.09%
	Non-metals	98.40%	0.13%	0.82%	0.35%	100.00%	0.00%	92.14%	0.04%
	TOTAL								
2	Grey non-magn.	2.75%	7.15%	0.15%	13.05%	99.82%	16.57%	6.22%	0.59%
	Red non-ferrous	0.00%	0.20%	0.00%	88.70%	99.92%	88.70%	1.68%	1.53%
	Non-metals	97.25%	0.28%	0.37%	0.31%	99.18%	0.35%	92.10%	0.04%
	TOTAL								
3	Grey non-magn.	2.60%	7.15%	0.15%	11.50%	99.67%	13.05%	6.23%	0.52%
	Red non-ferrous	0.00%	0.19%	0.00%	88.70%	99.92%	88.70%	1.69%	1.53%
	Non-metals	97.40%	0.27%	0.39%	0.29%	98.82%	0.31%	92.08%	0.04%
	TOTAL								
4	Grey non-magn.	2.46%	7.69%	0.14%	10.75%	99.52%	11.50%	6.25%	0.44%
	Red non-ferrous	0.38%	50.00%	0.08%	52.49%	99.92%	88.70%	1.70%	1.53%
	Non-metals	97.16%	0.27%	0.38%	4.61%	98.43%	0.29%	92.06%	0.03%
	TOTAL								
5	Grey non-magn.	1.65%	5.56%	0.20%	6.71%	99.37%	10.75%	6.26%	0.33%
	Red non-ferrous	1.74%	5.26%	0.77%	21.39%	99.84%	52.49%	1.70%	0.57%
	Non-metals	96.60%	0.13%	0.77%	0.14%	98.05%	4.61%	92.04%	0.03%
	TOTAL								
6	Grey non-magn.	8.79%	1.01%	1.09%	4.07%	99.18%	6.71%	6.29%	0.21%
	Red non-ferrous	0.00%	0.09%	0.00%	28.00%	99.07%	21.39%	1.70%	0.33%
	Non-metals	91.21%	0.13%	0.76%	0.13%	97.28%	0.14%	92.00%	0.03%
	TOTAL								
7	Grey non-magn.	7.47%	0.62%	1.77%	2.92%	98.09%	4.07%	6.27%	0.19%
	Red non-ferrous	8.40%	0.55%	7.34%	7.20%	99.07%	28.00%	1.71%	0.33%
	Non-metals	84.12%	0.07%	1.33%	0.11%	96.52%	0.13%	92.01%	0.02%
	TOTAL								
8	Grey non-magn.	2.68%	0.95%	1.15%	2.59%	96.32%	2.92%	6.26%	0.17%
	Red non-ferrous	4.29%	0.60%	6.82%	5.35%	91.72%	7.20%	1.61%	0.30%
	Non-metals	93.03%	0.04%	2.68%	0.09%	95.19%	0.11%	92.13%	0.02%
	TOTAL								
9	Grey non-magn.	0.67%	0.85%	1.28%	2.32%	95.17%	2.59%	6.36%	0.13%
	Red non-ferrous	0.00%	0.01%	0.00%	6.98%	84.91%	5.35%	1.54%	0.27%
	Non-metals	99.33%	0.01%	12.74%	0.05%	92.50%	0.09%	92.11%	0.02%
	TOTAL								
10	Grey non-magn.	0.53%	0.19%	5.91%	1.71%	93.89%	2.32%	7.19%	0.09%
	Red non-ferrous	0.18%	0.54%	7.46%	4.28%	84.91%	6.98%	1.76%	0.27%
	Non-metals	99.28%	0.00%	73.56%	0.03%	79.77%	0.05%	91.05%	0.02%
	TOTAL								
11	Grey non-magn.	33.31%	0.06%	19.82%	1.12%	87.98%	1.71%	43.68%	0.08%
	Red non-ferrous	14.39%	0.13%	31.64%	2.83%	77.44%	4.28%	10.40%	0.23%
	Non-metals	52.31%	0.04%	2.09%	0.03%	6.21%	0.03%	45.92%	0.07%
	TOTAL					0.00%	0.00%		
12	Grey non-magn.	47.75%	0.09%	14.07%	0.94%	68.16%	1.12%	48.03%	0.09%
	Red non-ferrous	10.73%	0.35%	11.68%	2.57%	45.80%	2.83%	8.73%	0.27%
	Non-metals	41.53%	0.10%	0.82%	0.03%	4.12%	0.03%	43.24%	0.08%
	TOTAL								
13	Grey non-magn.	57.27%	0.04%	30.32%	0.73%	54.08%	0.94%	48.10%	0.09%
	Red non-ferrous	8.71%	0.24%	17.04%	1.11%	34.12%	2.57%	8.21%	0.24%
	Non-metals	34.02%	0.06%	1.21%	0.13%	3.30%	0.03%	43.69%	0.08%
	TOTAL								
14	Grey non-magn.	43.80%	0.06%	18.62%	0.65%	23.77%	0.73%	39.94%	0.12%
	Red non-ferrous	10.87%	0.24%	17.08%	2.09%	17.08%	1.11%	7.77%	0.24%
	Non-metals	45.33%	0.06%	1.29%	0.03%	2.09%	0.13%	52.29%	0.08%
	TOTAL								
15	Grey non-magn.	30.30%	0.22%	5.15%	0.64%	5.15%	0.65%	30.30%	0.22%
	Red non-ferrous	0.00%	0.06%	0.00%	2.09%	0.00%	2.09%	0.00%	0.06%
	Non-metals	69.70%	0.11%	0.79%	0.03%	0.79%	0.03%	69.70%	0.11%
	TOTAL								

Table 0-57 *Handpicking results for products of eddy current run EC6_I (2m/s, 2000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	134.3	0.74%	Grey non-magn.	4.1	2.44%	908.3	0.50%
			Red non-ferrous	1.7	5.88%	254.1	1.03%
			Non-metals	129.1	0.08%	15555.0	0.03%
			TOTAL	134.9	0.07%	16717.4	0.02%
2	63.7	1.57%	Grey non-magn.	2.6	3.85%	904.2	0.47%
			Red non-ferrous	1.8	5.56%	252.4	0.92%
			Non-metals	60.1	0.17%	15425.9	0.03%
			TOTAL	64.5	0.16%	16582.5	0.02%
3	63.7	1.57%	Grey non-magn.	7.1	1.41%	901.6	0.43%
			Red non-ferrous	0.0	0.00%	250.6	0.79%
			Non-metals	57.0	0.18%	15365.8	0.02%
			TOTAL	64.1	0.16%	16518.0	0.02%
4	71.3	1.40%	Grey non-magn.	1.2	8.33%	894.5	0.41%
			Red non-ferrous	0.0	0.00%	250.6	0.79%
			Non-metals	70.5	0.14%	15308.8	0.02%
			TOTAL	71.7	0.14%	16453.9	0.02%
5	95.8	1.04%	Grey non-magn.	4.4	2.27%	893.3	0.28%
			Red non-ferrous	0.0	0.00%	250.6	0.79%
			Non-metals	91.6	0.11%	15238.3	0.02%
			TOTAL	96.0	0.10%	16382.2	0.02%
6	150.9	0.66%	Grey non-magn.	6.6	1.52%	888.9	0.22%
			Red non-ferrous	0.0	0.00%	250.6	0.79%
			Non-metals	144.5	0.07%	15146.7	0.02%
			TOTAL	151.1	0.07%	16286.2	0.01%
7	203.4	0.49%	Grey non-magn.	7.3	1.37%	882.3	0.18%
			Red non-ferrous	1.0	10.00%	250.6	0.79%
			Non-metals	195.0	0.05%	15002.2	0.02%
			TOTAL	203.3	0.05%	16135.1	0.01%
8	394.3	0.25%	Grey non-magn.	38.6	0.26%	875.0	0.14%
			Red non-ferrous	0.0	0.00%	249.6	0.48%
			Non-metals	355.5	0.03%	14807.2	0.01%
			TOTAL	394.1	0.03%	15931.8	0.01%
9	1827.5	0.05%	Grey non-magn.	33.5	0.30%	836.4	0.13%
			Red non-ferrous	3.2	3.13%	249.6	0.48%
			Non-metals	1788.8	0.01%	14451.7	0.01%
			TOTAL	1825.5	0.01%	15537.7	0.01%
10	11634	0.01%	Grey non-magn.	54.1	0.18%	802.9	0.11%
			Red non-ferrous	12.9	0.78%	246.4	0.33%
			Non-metals	11561.9	0.00%	12662.9	0.01%
			TOTAL	11628.9	0.00%	13712.2	0.01%
11	605.5	0.17%	Grey non-magn.	182.5	0.05%	748.8	0.11%
			Red non-ferrous	37.9	0.26%	233.5	0.28%
			Non-metals	384.8	0.03%	1101.0	0.05%
			TOTAL	605.2	0.02%	2083.3	0.03%
12	558.1	0.18%	Grey non-magn.	238.1	0.04%	566.3	0.12%
			Red non-ferrous	111.3	0.09%	195.6	0.28%
			Non-metals	208.4	0.05%	716.2	0.06%
			TOTAL	557.8	0.02%	1478.1	0.03%
13	358.7	0.28%	Grey non-magn.	169.4	0.06%	328.2	0.15%
			Red non-ferrous	29.5	0.34%	84.3	0.42%
			Non-metals	159.4	0.06%	507.8	0.06%
			TOTAL	358.3	0.03%	920.3	0.04%
14	407	0.25%	Grey non-magn.	143.2	0.07%	158.8	0.21%
			Red non-ferrous	10.8	0.93%	54.8	0.46%
			Non-metals	252.6	0.04%	348.4	0.06%
			TOTAL	406.6	0.02%	562.0	0.04%
15	155.7	0.64%	Grey non-magn.	15.6	0.64%	15.6	0.64%
			Red non-ferrous	44.0	0.23%	44.0	0.23%
			Non-metals	95.8	0.10%	95.8	0.10%
			TOTAL	155.4	0.06%	155.4	0.06%

Table 0-58 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC6_I (2m/s, 2000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	3.04%	2.44%	0.45%	7.82%	100.00%	0.00%	5.43%	0.50%
	Red non-ferrous	1.26%	5.88%	0.67%	13.78%	100.00%	0.00%	1.52%	1.03%
	Non-metals	95.70%	0.11%	0.83%	0.30%	100.00%	0.00%	93.05%	0.04%
	TOTAL								
2	Grey non-magn.	4.03%	3.85%	0.29%	6.57%	99.55%	7.82%	5.45%	0.48%
	Red non-ferrous	2.79%	5.56%	0.71%	10.40%	99.33%	13.78%	1.52%	0.92%
	Non-metals	93.18%	0.23%	0.39%	0.27%	99.17%	0.30%	93.03%	0.03%
	TOTAL								
3	Grey non-magn.	11.08%	1.42%	0.78%	4.69%	99.26%	6.57%	5.46%	0.43%
	Red non-ferrous	0.00%	0.16%	0.00%	10.40%	98.62%	10.40%	1.52%	0.79%
	Non-metals	88.92%	0.23%	0.37%	0.25%	98.78%	0.27%	93.02%	0.03%
	TOTAL								
4	Grey non-magn.	1.67%	8.33%	0.13%	5.08%	98.48%	4.69%	5.44%	0.41%
	Red non-ferrous	0.00%	0.14%	0.00%	7.12%	98.62%	10.40%	1.52%	0.79%
	Non-metals	98.33%	0.20%	0.45%	3.50%	98.42%	0.25%	93.04%	0.03%
	TOTAL								
5	Grey non-magn.	4.58%	2.28%	0.48%	3.07%	98.35%	5.08%	5.45%	0.28%
	Red non-ferrous	0.00%	0.10%	0.00%	5.72%	98.62%	7.12%	1.53%	0.79%
	Non-metals	95.42%	0.15%	0.59%	0.13%	97.96%	3.50%	93.02%	0.02%
	TOTAL								
6	Grey non-magn.	4.37%	1.52%	0.73%	2.59%	97.86%	3.07%	5.46%	0.23%
	Red non-ferrous	0.00%	0.07%	0.00%	4.06%	98.62%	5.72%	1.54%	0.79%
	Non-metals	95.63%	0.10%	0.93%	0.11%	97.38%	0.13%	93.00%	0.02%
	TOTAL								
7	Grey non-magn.	3.59%	1.37%	0.80%	2.29%	97.14%	2.59%	5.47%	0.18%
	Red non-ferrous	0.49%	10.00%	0.39%	5.97%	98.62%	4.06%	1.55%	0.79%
	Non-metals	95.92%	0.07%	1.25%	0.09%	96.45%	0.11%	92.98%	0.02%
	TOTAL								
8	Grey non-magn.	9.79%	0.26%	4.25%	1.67%	96.33%	2.29%	5.49%	0.14%
	Red non-ferrous	0.00%	0.03%	0.00%	6.90%	98.23%	5.97%	1.57%	0.48%
	Non-metals	90.21%	0.04%	2.29%	0.08%	95.19%	0.09%	92.94%	0.02%
	TOTAL								
9	Grey non-magn.	1.84%	0.30%	3.69%	1.15%	92.08%	1.67%	5.38%	0.13%
	Red non-ferrous	0.18%	3.13%	1.26%	5.65%	98.23%	6.90%	1.61%	0.48%
	Non-metals	97.99%	0.01%	11.50%	0.05%	92.91%	0.08%	93.01%	0.02%
	TOTAL								
10	Grey non-magn.	0.47%	0.18%	5.96%	1.11%	88.40%	1.15%	5.86%	0.11%
	Red non-ferrous	0.11%	0.78%	5.08%	3.51%	96.97%	5.65%	1.80%	0.33%
	Non-metals	99.42%	0.00%	74.33%	0.02%	81.41%	0.05%	92.35%	0.02%
	TOTAL								
11	Grey non-magn.	30.16%	0.06%	20.09%	0.77%	82.44%	1.11%	35.94%	0.11%
	Red non-ferrous	6.26%	0.26%	14.92%	2.09%	91.89%	3.51%	11.21%	0.28%
	Non-metals	63.58%	0.03%	2.47%	0.02%	7.08%	0.02%	52.85%	0.06%
	TOTAL								
12	Grey non-magn.	42.69%	0.05%	26.21%	0.60%	62.35%	0.77%	38.31%	0.12%
	Red non-ferrous	19.95%	0.09%	43.80%	0.99%	76.98%	2.09%	13.23%	0.29%
	Non-metals	37.36%	0.05%	1.34%	0.02%	4.60%	0.02%	48.45%	0.07%
	TOTAL								
13	Grey non-magn.	47.28%	0.07%	18.65%	0.54%	36.13%	0.60%	35.66%	0.16%
	Red non-ferrous	8.23%	0.34%	11.61%	0.55%	33.18%	0.99%	9.16%	0.42%
	Non-metals	44.49%	0.07%	1.02%	0.13%	3.26%	0.02%	55.18%	0.07%
	TOTAL								
14	Grey non-magn.	35.22%	0.07%	15.77%	0.49%	17.48%	0.54%	28.26%	0.22%
	Red non-ferrous	2.66%	0.93%	4.25%	1.07%	21.57%	0.55%	9.75%	0.46%
	Non-metals	62.12%	0.05%	1.62%	0.03%	2.24%	0.13%	61.99%	0.08%
	TOTAL								
15	Grey non-magn.	10.04%	0.64%	1.72%	0.50%	1.72%	0.49%	10.04%	0.64%
	Red non-ferrous	28.31%	0.24%	17.32%	1.02%	17.32%	1.07%	28.31%	0.24%
	Non-metals	61.65%	0.12%	0.62%	0.03%	0.62%	0.03%	61.65%	0.12%
	TOTAL								

Table 0-59 *Weighted average of the handpicking results for products of eddy current runs EC5_I and EC6_I (2m/s, 2000rpm)*

EDDY CURRENT PRODUCTS					EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	MASS FRACTION %	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	124.1	0.26%	0.79%	0.30%	Grey non-magn.	2.9	0.26%	909.6	0.25%
					Red non-ferrous	1.0	0.29%	250.5	0.25%
					Non-metals	120.5	0.25%	14628.3	0.21%
					TOTAL	124.5	0.25%	15788.4	0.21%
2	58.6	0.27%	0.37%	0.31%	Grey non-magn.	2.0	0.26%	906.6	0.25%
					Red non-ferrous	1.0	0.26%	249.5	0.25%
					Non-metals	55.2	0.25%	14507.8	0.21%
					TOTAL	58.2	0.25%	15664.0	0.21%
3	59.1	0.27%	0.37%	0.31%	Grey non-magn.	4.4	0.26%	904.6	0.25%
					Red non-ferrous	0.0	0.25%	248.6	0.25%
					Non-metals	54.9	0.25%	14452.6	0.21%
					TOTAL	59.3	0.25%	15605.8	0.21%
4	62.7	0.27%	0.40%	0.31%	Grey non-magn.	1.2	0.26%	900.2	0.25%
					Red non-ferrous	0.1	0.28%	248.6	0.25%
					Non-metals	61.6	0.25%	14397.7	0.21%
					TOTAL	62.9	0.25%	15546.5	0.21%
5	101.0	0.26%	0.64%	0.30%	Grey non-magn.	3.2	0.26%	898.9	0.25%
					Red non-ferrous	0.9	0.26%	248.5	0.25%
					Non-metals	98.0	0.25%	14336.2	0.21%
					TOTAL	102.0	0.25%	15483.6	0.21%
6	133.8	0.26%	0.85%	0.30%	Grey non-magn.	8.1	0.25%	895.7	0.25%
					Red non-ferrous	0.0	0.25%	247.6	0.25%
					Non-metals	124.9	0.25%	14238.2	0.21%
					TOTAL	133.1	0.25%	15381.5	0.21%
7	209.2	0.26%	1.32%	0.29%	Grey non-magn.	11.4	0.25%	887.6	0.25%
					Red non-ferrous	9.0	0.26%	247.6	0.25%
					Non-metals	188.5	0.25%	14113.3	0.21%
					TOTAL	209.0	0.25%	15248.5	0.21%
8	393.3	0.25%	2.49%	0.29%	Grey non-magn.	25.4	0.25%	876.2	0.25%
					Red non-ferrous	7.9	0.25%	238.6	0.25%
					Non-metals	359.6	0.25%	13924.7	0.21%
					TOTAL	392.9	0.25%	15039.5	0.21%
9	1787.7	0.24%	11.32%	0.28%	Grey non-magn.	23.3	0.25%	850.7	0.25%
					Red non-ferrous	1.7	0.25%	230.7	0.25%
					Non-metals	1760.8	0.24%	13565.2	0.21%
					TOTAL	1785.8	0.24%	14646.6	0.21%
10	10900.2	0.19%	69.03%	0.24%	Grey non-magn.	54.0	0.25%	827.4	0.25%
					Red non-ferrous	15.5	0.25%	229.0	0.25%
					Non-metals	10824.3	0.19%	11804.3	0.20%
					TOTAL	10893.8	0.19%	12860.8	0.20%
11	575.7	0.25%	3.65%	0.29%	Grey non-magn.	181.6	0.25%	773.5	0.25%
					Red non-ferrous	56.7	0.25%	213.6	0.25%
					Non-metals	337.4	0.25%	980.0	0.25%
					TOTAL	575.7	0.25%	1967.0	0.25%
12	414.6	0.25%	2.63%	0.29%	Grey non-magn.	186.6	0.25%	591.9	0.25%
					Red non-ferrous	72.7	0.25%	156.9	0.25%
					Non-metals	163.0	0.25%	642.6	0.25%
					TOTAL	422.3	0.25%	1391.3	0.25%
13	416.4	0.25%	2.64%	0.29%	Grey non-magn.	219.4	0.25%	405.2	0.25%
					Red non-ferrous	35.4	0.25%	84.2	0.25%
					Non-metals	161.6	0.25%	479.6	0.25%
					TOTAL	416.4	0.25%	969.0	0.25%
14	397.7	0.25%	2.52%	0.29%	Grey non-magn.	155.6	0.25%	185.8	0.25%
					Red non-ferrous	25.5	0.25%	48.9	0.25%
					Non-metals	216.5	0.25%	318.0	0.25%
					TOTAL	397.5	0.25%	552.6	0.25%
15	155.6	0.26%	0.99%	0.29%	Grey non-magn.	30.3	0.25%	30.3	0.25%
					Red non-ferrous	23.4	0.25%	23.4	0.25%
					Non-metals	101.5	0.25%	101.5	0.25%
					TOTAL	155.1	0.25%	155.1	0.25%

Table 0-60 *Weighted average of EC5_I and EC6_I grades and recoveries of eddy current metal product when moving splitter position from left to right (2m/s, 2000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	2.35%	0.36%	0.32%	4.31%	100.00%	0.00%	5.76%	0.33%
	Red non-ferrous	0.80%	0.38%	0.40%	3.90%	100.00%	0.00%	1.59%	0.33%
	Non-metals	96.84%	0.36%	0.82%	1.40%	100.00%	0.00%	92.65%	0.30%
	TOTAL								
2	Grey non-magn.	3.50%	0.36%	0.22%	3.31%	99.68%	3.31%	5.79%	0.33%
	Red non-ferrous	1.65%	0.36%	0.38%	2.79%	99.60%	2.79%	1.59%	0.33%
	Non-metals	94.85%	0.36%	0.38%	1.17%	99.18%	1.17%	92.62%	0.30%
	TOTAL								
3	Grey non-magn.	7.47%	0.36%	0.49%	2.42%	99.45%	2.42%	5.80%	0.33%
	Red non-ferrous	0.00%	0.36%	0.00%	2.79%	99.22%	2.79%	1.59%	0.33%
	Non-metals	92.53%	0.36%	0.38%	1.03%	98.80%	1.03%	92.61%	0.30%
	TOTAL								
4	Grey non-magn.	1.98%	0.36%	0.14%	2.27%	98.97%	2.27%	5.79%	0.33%
	Red non-ferrous	0.15%	0.38%	0.04%	2.71%	99.22%	2.71%	1.60%	0.33%
	Non-metals	97.87%	0.36%	0.42%	1.75%	98.42%	1.75%	92.61%	0.30%
	TOTAL								
5	Grey non-magn.	3.12%	0.36%	0.35%	0.26%	98.83%	0.26%	5.81%	0.33%
	Red non-ferrous	0.87%	0.36%	0.36%	0.27%	99.18%	0.27%	1.60%	0.33%
	Non-metals	96.01%	0.36%	0.67%	0.25%	98.00%	0.25%	92.59%	0.30%
	TOTAL								
6	Grey non-magn.	6.12%	0.36%	0.90%	0.24%	98.48%	0.24%	5.82%	0.33%
	Red non-ferrous	0.00%	0.36%	0.00%	0.21%	98.83%	0.21%	1.61%	0.33%
	Non-metals	93.88%	0.36%	0.85%	0.22%	97.33%	0.22%	92.57%	0.30%
	TOTAL								
7	Grey non-magn.	5.47%	0.36%	1.26%	0.25%	97.58%	0.25%	5.82%	0.33%
	Red non-ferrous	4.31%	0.36%	3.60%	0.25%	98.83%	0.25%	1.62%	0.33%
	Non-metals	90.22%	0.36%	1.29%	0.24%	96.48%	0.24%	92.56%	0.30%
	TOTAL								
8	Grey non-magn.	6.48%	0.36%	2.80%	0.24%	96.33%	0.24%	5.83%	0.33%
	Red non-ferrous	2.00%	0.36%	3.14%	0.26%	95.23%	0.26%	1.59%	0.33%
	Non-metals	91.52%	0.35%	2.46%	0.24%	95.19%	0.24%	92.59%	0.29%
	TOTAL								
9	Grey non-magn.	1.30%	0.35%	2.56%	0.25%	93.53%	0.25%	5.81%	0.33%
	Red non-ferrous	0.10%	0.35%	0.68%	0.26%	92.09%	0.26%	1.58%	0.33%
	Non-metals	98.60%	0.34%	12.04%	0.24%	92.73%	0.24%	92.62%	0.29%
	TOTAL								
10	Grey non-magn.	0.50%	0.32%	5.93%	0.25%	90.97%	0.25%	6.43%	0.32%
	Red non-ferrous	0.14%	0.32%	6.18%	0.25%	91.41%	0.25%	1.78%	0.32%
	Non-metals	99.36%	0.28%	74.00%	0.20%	80.69%	0.20%	91.79%	0.29%
	TOTAL								
11	Grey non-magn.	31.55%	0.35%	19.97%	0.25%	85.04%	0.25%	39.32%	0.35%
	Red non-ferrous	9.85%	0.35%	22.62%	0.25%	85.24%	0.25%	10.86%	0.36%
	Non-metals	58.61%	0.35%	2.31%	0.21%	6.70%	0.21%	49.82%	0.35%
	TOTAL								
12	Grey non-magn.	44.19%	0.35%	20.52%	0.25%	65.07%	0.25%	42.54%	0.35%
	Red non-ferrous	17.21%	0.36%	29.00%	0.25%	62.61%	0.25%	11.27%	0.36%
	Non-metals	38.60%	0.35%	1.11%	0.21%	4.39%	0.21%	46.19%	0.35%
	TOTAL								
13	Grey non-magn.	52.70%	0.35%	24.12%	0.25%	44.55%	0.25%	41.82%	0.35%
	Red non-ferrous	8.49%	0.36%	14.11%	0.12%	33.61%	0.12%	8.69%	0.36%
	Non-metals	38.81%	0.35%	1.10%	1.01%	3.28%	1.01%	49.49%	0.35%
	TOTAL								
14	Grey non-magn.	39.13%	0.35%	17.10%	0.25%	20.43%	0.25%	33.62%	0.36%
	Red non-ferrous	6.40%	0.36%	10.16%	0.25%	19.50%	0.25%	8.84%	0.36%
	Non-metals	54.46%	0.35%	1.48%	0.19%	2.17%	0.19%	57.54%	0.35%
	TOTAL								
15	Grey non-magn.	19.51%	0.36%	3.33%	0.24%	3.33%	0.24%	19.51%	0.36%
	Red non-ferrous	15.08%	0.36%	9.34%	0.25%	9.34%	0.25%	15.08%	0.36%
	Non-metals	65.41%	0.36%	0.69%	0.13%	0.69%	0.13%	65.41%	0.36%
	TOTAL								

Table 0-61 *Handpicking results for products of eddy current run EC7_I (2m/s, 3000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	100.8	0.99%	Grey non-magn.	2.2	4.55%	906.4	0.66%
			Red non-ferrous	0.3	33.33%	167.0	3.98%
			Non-metals	97.6	0.10%	13205.8	0.03%
			TOTAL	100.1	0.10%	14279.2	0.03%
2	51.9	1.93%	Grey non-magn.	2.4	4.17%	904.2	0.63%
			Red non-ferrous	0.3	33.33%	166.7	3.72%
			Non-metals	28.8	0.35%	13108.2	0.03%
			TOTAL	31.5	0.32%	14179.1	0.03%
3	57.6	1.74%	Grey non-magn.	2.5	4.00%	901.8	0.59%
			Red non-ferrous	1.3	7.69%	166.4	3.45%
			Non-metals	54.8	0.18%	13079.4	0.03%
			TOTAL	58.6	0.17%	14147.6	0.02%
4	56.4	1.77%	Grey non-magn.	1.0	10.00%	899.3	0.55%
			Red non-ferrous	0.6	16.67%	165.1	3.39%
			Non-metals	56.4	0.18%	13024.6	0.03%
			TOTAL	58.0	0.17%	14089.0	0.02%
5	77.9	1.28%	Grey non-magn.	0.7	14.29%	898.3	0.44%
			Red non-ferrous	1.7	5.88%	164.5	3.25%
			Non-metals	71.1	0.14%	12968.2	0.02%
			TOTAL	73.5	0.14%	14031.0	0.02%
6	118.7	0.84%	Grey non-magn.	5.4	1.85%	897.6	0.18%
			Red non-ferrous	0.2	50.00%	162.8	3.21%
			Non-metals	114.7	0.09%	12897.1	0.02%
			TOTAL	120.3	0.08%	13957.5	0.02%
7	203.9	0.49%	Grey non-magn.	56.7	0.18%	892.2	0.11%
			Red non-ferrous	0.0	0.00%	162.6	2.69%
			Non-metals	147.4	0.07%	12782.4	0.02%
			TOTAL	204.1	0.05%	13837.2	0.01%
8	431.5	0.23%	Grey non-magn.	39.7	0.25%	835.5	0.11%
			Red non-ferrous	0.7	14.29%	162.6	2.69%
			Non-metals	391.7	0.03%	12635.0	0.02%
			TOTAL	432.1	0.02%	13633.1	0.01%
9	1180.6	0.08%	Grey non-magn.	72.2	0.14%	795.8	0.10%
			Red non-ferrous	0.1	100.00%	161.9	2.53%
			Non-metals	1106.9	0.01%	12243.3	0.02%
			TOTAL	1179.2	0.01%	13201.0	0.01%
10	10278.1	0.01%	Grey non-magn.	83.4	0.12%	723.6	0.09%
			Red non-ferrous	18.9	0.53%	161.8	0.46%
			Non-metals	10164.8	0.00%	11136.4	0.02%
			TOTAL	10267.1	0.00%	12021.8	0.01%
11	690.6	0.14%	Grey non-magn.	179.7	0.06%	640.2	0.09%
			Red non-ferrous	46.2	0.22%	142.9	0.45%
			Non-metals	464.1	0.02%	971.6	0.06%
			TOTAL	690.0	0.01%	1754.7	0.03%
12	360.1	0.28%	Grey non-magn.	133.3	0.08%	460.5	0.09%
			Red non-ferrous	56.6	0.18%	96.7	0.52%
			Non-metals	169.6	0.06%	507.5	0.08%
			TOTAL	359.5	0.03%	1064.7	0.04%
13	255.4	0.39%	Grey non-magn.	152.1	0.07%	327.2	0.10%
			Red non-ferrous	19.2	0.52%	40.1	0.78%
			Non-metals	85.6	0.12%	337.9	0.09%
			TOTAL	256.9	0.04%	705.2	0.04%
14	289.3	0.35%	Grey non-magn.	122.7	0.08%	175.1	0.12%
			Red non-ferrous	9.8	1.02%	20.9	0.96%
			Non-metals	158.0	0.06%	252.3	0.08%
			TOTAL	290.5	0.03%	448.3	0.05%
15	157.3	0.64%	Grey non-magn.	52.4	0.19%	52.4	0.19%
			Red non-ferrous	11.1	0.90%	11.1	0.90%
			Non-metals	94.3	0.11%	94.3	0.11%
			TOTAL	157.8	0.06%	157.8	0.06%

Table 0-62 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC7_I (2m/s, 3000rpm)*

	EDDY CURRENT CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	2.20%	4.55%	0.24%	14.21%	100.00%	0.00%	6.35%	0.67%
	Red non-ferrous	0.30%	33.33%	0.18%	99.56%	100.00%	0.00%	1.17%	3.98%
	Non-metals	97.50%	0.14%	0.74%	0.41%	100.00%	0.00%	92.48%	0.04%
	TOTAL								
2	Grey non-magn.	7.62%	4.18%	0.26%	10.28%	99.76%	14.21%	6.38%	0.63%
	Red non-ferrous	0.95%	33.33%	0.18%	74.24%	99.82%	99.56%	1.18%	3.72%
	Non-metals	91.43%	0.47%	0.22%	0.39%	99.26%	0.41%	92.45%	0.04%
	TOTAL								
3	Grey non-magn.	4.27%	4.00%	0.28%	8.61%	99.49%	10.28%	6.37%	0.59%
	Red non-ferrous	2.22%	7.69%	0.78%	42.20%	99.64%	74.24%	1.18%	3.45%
	Non-metals	93.52%	0.25%	0.41%	0.34%	99.04%	0.39%	92.45%	0.04%
	TOTAL								
4	Grey non-magn.	1.72%	10.00%	0.11%	8.79%	99.22%	8.61%	6.38%	0.55%
	Red non-ferrous	1.03%	16.67%	0.36%	19.84%	98.86%	42.20%	1.17%	3.39%
	Non-metals	97.24%	0.25%	0.43%	4.95%	98.63%	0.34%	92.45%	0.03%
	TOTAL								
5	Grey non-magn.	0.95%	14.29%	0.08%	6.48%	99.11%	8.79%	6.40%	0.44%
	Red non-ferrous	2.31%	5.88%	1.02%	15.19%	98.50%	19.84%	1.17%	3.25%
	Non-metals	96.73%	0.20%	0.54%	0.18%	98.20%	4.95%	92.43%	0.03%
	TOTAL								
6	Grey non-magn.	4.49%	1.85%	0.60%	4.92%	99.03%	6.48%	6.43%	0.18%
	Red non-ferrous	0.17%	50.00%	0.12%	18.50%	97.49%	15.19%	1.17%	3.21%
	Non-metals	95.34%	0.12%	0.87%	0.15%	97.66%	0.18%	92.40%	0.03%
	TOTAL								
7	Grey non-magn.	27.78%	0.18%	6.26%	2.22%	98.43%	4.92%	6.45%	0.11%
	Red non-ferrous	0.00%	0.05%	0.00%	18.50%	97.37%	18.50%	1.18%	2.69%
	Non-metals	72.22%	0.08%	1.12%	0.12%	96.79%	0.15%	92.38%	0.02%
	TOTAL								
8	Grey non-magn.	9.19%	0.25%	4.38%	1.79%	92.18%	2.22%	6.13%	0.11%
	Red non-ferrous	0.16%	14.29%	0.42%	17.37%	97.37%	18.50%	1.19%	2.69%
	Non-metals	90.65%	0.03%	2.97%	0.10%	95.68%	0.12%	92.68%	0.02%
	TOTAL								
9	Grey non-magn.	6.12%	0.14%	7.97%	1.29%	87.80%	1.79%	6.03%	0.10%
	Red non-ferrous	0.01%	100.00%	0.06%	21.89%	96.95%	17.37%	1.23%	2.53%
	Non-metals	93.87%	0.01%	8.38%	0.07%	92.71%	0.10%	92.75%	0.02%
	TOTAL								
10	Grey non-magn.	0.81%	0.12%	9.20%	1.03%	79.83%	1.29%	6.02%	0.09%
	Red non-ferrous	0.18%	0.53%	11.32%	10.31%	96.89%	21.89%	1.35%	0.46%
	Non-metals	99.00%	0.00%	76.97%	0.03%	84.33%	0.07%	92.64%	0.02%
	TOTAL								
11	Grey non-magn.	26.04%	0.06%	19.83%	0.92%	70.63%	1.03%	36.48%	0.09%
	Red non-ferrous	6.70%	0.22%	27.66%	6.92%	85.57%	10.31%	8.14%	0.45%
	Non-metals	67.26%	0.03%	3.51%	0.03%	7.36%	0.03%	55.37%	0.07%
	TOTAL								
12	Grey non-magn.	37.08%	0.08%	14.71%	0.83%	50.81%	0.92%	43.25%	0.10%
	Red non-ferrous	15.74%	0.18%	33.89%	4.54%	57.90%	6.92%	9.08%	0.52%
	Non-metals	47.18%	0.07%	1.28%	0.03%	3.84%	0.03%	47.67%	0.09%
	TOTAL								
13	Grey non-magn.	59.21%	0.08%	16.78%	0.73%	36.10%	0.83%	46.40%	0.11%
	Red non-ferrous	7.47%	0.52%	11.50%	1.68%	24.01%	4.54%	5.69%	0.78%
	Non-metals	33.32%	0.12%	0.65%	0.14%	2.56%	0.03%	47.92%	0.10%
	TOTAL								
14	Grey non-magn.	42.24%	0.09%	13.54%	0.68%	19.32%	0.73%	39.06%	0.13%
	Red non-ferrous	3.37%	1.02%	5.87%	8.64%	12.51%	1.68%	4.66%	0.96%
	Non-metals	54.39%	0.07%	1.20%	0.03%	1.91%	0.14%	56.28%	0.09%
	TOTAL								
15	Grey non-magn.	33.21%	0.20%	5.78%	0.66%	5.78%	0.68%	33.21%	0.20%
	Red non-ferrous	7.03%	0.90%	6.65%	3.98%	6.65%	8.64%	7.03%	0.90%
	Non-metals	59.76%	0.12%	0.71%	0.03%	0.71%	0.03%	59.76%	0.12%
	TOTAL								

Table 0-63 *Handpicking results for products of eddy current run EC8_I (2m/s, 3000rpm)*

EDDY CURRENT PRODUCTS			EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	85.6	1.17%	Grey non-magn.	3.5	2.86%	771.8	0.50%
			Red non-ferrous	1.8	5.56%	138.9	1.42%
			Non-metals	75.0	0.13%	12382.9	0.04%
			TOTAL	80.3	0.12%	13293.6	0.03%
2	59.8	1.67%	Grey non-magn.	2.6	3.85%	768.3	0.46%
			Red non-ferrous	4.2	2.38%	137.1	1.28%
			Non-metals	45.0	0.22%	12307.9	0.03%
			TOTAL	51.8	0.19%	13213.3	0.03%
3	49.5	2.02%	Grey non-magn.	4.8	2.08%	765.7	0.40%
			Red non-ferrous	0.0	0.00%	132.9	1.22%
			Non-metals	36.5	0.27%	12262.9	0.03%
			TOTAL	41.3	0.24%	13161.5	0.03%
4	43.4	2.30%	Grey non-magn.	5.0	2.00%	760.9	0.37%
			Red non-ferrous	2.3	4.35%	132.9	1.22%
			Non-metals	36.9	0.27%	12226.4	0.03%
			TOTAL	44.2	0.23%	13120.2	0.02%
5	83.5	1.20%	Grey non-magn.	2.1	4.76%	755.9	0.33%
			Red non-ferrous	0.0	0.00%	130.6	1.09%
			Non-metals	75.9	0.13%	12189.5	0.02%
			TOTAL	78.0	0.13%	13076.0	0.02%
6	113.9	0.88%	Grey non-magn.	5.8	1.72%	753.8	0.22%
			Red non-ferrous	1.7	5.88%	130.6	1.09%
			Non-metals	98.0	0.10%	12113.6	0.02%
			TOTAL	105.5	0.09%	12998.0	0.02%
7	187.4	0.53%	Grey non-magn.	15.0	0.67%	748.0	0.15%
			Red non-ferrous	1.9	5.26%	128.9	0.87%
			Non-metals	162.2	0.06%	12015.6	0.02%
			TOTAL	179.1	0.06%	12892.5	0.01%
8	294.4	0.34%	Grey non-magn.	32.6	0.31%	733.0	0.12%
			Red non-ferrous	0.0	0.00%	127.0	0.59%
			Non-metals	253.5	0.04%	11853.4	0.02%
			TOTAL	286.1	0.03%	12713.4	0.01%
9	1352.7	0.07%	Grey non-magn.	49.2	0.20%	700.4	0.11%
			Red non-ferrous	0.0	0.00%	127.0	0.59%
			Non-metals	1300.0	0.01%	11599.9	0.02%
			TOTAL	1349.2	0.01%	12427.3	0.01%
10	9624	0.01%	Grey non-magn.	109.8	0.09%	651.2	0.10%
			Red non-ferrous	11.6	0.86%	127.0	0.59%
			Non-metals	9492.3	0.00%	10299.9	0.02%
			TOTAL	9613.7	0.00%	11078.1	0.01%
11	441.4	0.23%	Grey non-magn.	113.7	0.09%	541.4	0.10%
			Red non-ferrous	43.2	0.23%	115.4	0.56%
			Non-metals	276.7	0.04%	807.6	0.07%
			TOTAL	433.6	0.02%	1464.4	0.04%
12	301.3	0.33%	Grey non-magn.	115.7	0.09%	427.7	0.10%
			Red non-ferrous	32.2	0.31%	72.2	0.68%
			Non-metals	148.4	0.07%	530.9	0.08%
			TOTAL	296.3	0.03%	1030.8	0.04%
13	310.5	0.32%	Grey non-magn.	135.2	0.07%	312.0	0.10%
			Red non-ferrous	19.4	0.52%	40.0	0.87%
			Non-metals	149.4	0.07%	382.5	0.08%
			TOTAL	304.0	0.03%	734.5	0.04%
14	259.9	0.38%	Grey non-magn.	120.7	0.08%	176.8	0.12%
			Red non-ferrous	15.2	0.66%	20.6	1.10%
			Non-metals	123.7	0.08%	233.1	0.09%
			TOTAL	259.6	0.04%	430.5	0.05%
15	175.1	0.57%	Grey non-magn.	56.1	0.18%	56.1	0.18%
			Red non-ferrous	5.4	1.85%	5.4	1.85%
			Non-metals	109.4	0.09%	109.4	0.09%
			TOTAL	170.9	0.06%	170.9	0.06%

Table 0-64 *Determination of grade and recovery of eddy current metal product when moving splitter position from left to right EC8_I (2m/s, 3000rpm)*

	EDDY CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	4.36%	2.86%	0.45%	7.90%	100.00%	0.00%	5.81%	0.50%
	Red non-ferrous	2.24%	5.56%	1.30%	13.45%	100.00%	0.00%	1.04%	1.42%
	Non-metals	93.40%	0.18%	0.61%	0.48%	100.00%	0.00%	93.15%	0.05%
	TOTAL								
2	Grey non-magn.	5.02%	3.85%	0.34%	6.49%	99.55%	7.90%	5.81%	0.46%
	Red non-ferrous	8.11%	2.39%	3.02%	7.63%	98.70%	13.45%	1.04%	1.28%
	Non-metals	86.87%	0.29%	0.36%	0.40%	99.39%	0.48%	93.15%	0.05%
	TOTAL								
3	Grey non-magn.	11.62%	2.10%	0.62%	5.05%	99.21%	6.49%	5.82%	0.40%
	Red non-ferrous	0.00%	0.24%	0.00%	7.63%	95.68%	7.63%	1.01%	1.22%
	Non-metals	88.38%	0.37%	0.29%	0.38%	99.03%	0.40%	93.17%	0.04%
	TOTAL								
4	Grey non-magn.	11.31%	2.01%	0.65%	4.33%	98.59%	5.05%	5.80%	0.37%
	Red non-ferrous	5.20%	4.35%	1.66%	4.35%	95.68%	7.63%	1.01%	1.22%
	Non-metals	83.48%	0.35%	0.30%	3.97%	98.74%	0.38%	93.19%	0.04%
	TOTAL								
5	Grey non-magn.	2.69%	4.76%	0.27%	2.94%	97.94%	4.33%	5.78%	0.33%
	Red non-ferrous	0.00%	0.13%	0.00%	3.85%	94.02%	4.35%	1.00%	1.09%
	Non-metals	97.31%	0.18%	0.61%	0.20%	98.44%	3.97%	93.22%	0.03%
	TOTAL								
6	Grey non-magn.	5.50%	1.73%	0.75%	2.46%	97.67%	2.94%	5.80%	0.22%
	Red non-ferrous	1.61%	5.88%	1.22%	3.58%	94.02%	3.85%	1.00%	1.09%
	Non-metals	92.89%	0.14%	0.79%	0.17%	97.83%	0.20%	93.20%	0.03%
	TOTAL								
7	Grey non-magn.	8.38%	0.67%	1.94%	1.91%	96.92%	2.46%	5.80%	0.15%
	Red non-ferrous	1.06%	5.26%	1.37%	4.21%	92.80%	3.58%	1.00%	0.87%
	Non-metals	90.56%	0.08%	1.31%	0.14%	97.03%	0.17%	93.20%	0.02%
	TOTAL								
8	Grey non-magn.	11.39%	0.31%	4.22%	1.50%	94.97%	1.91%	5.77%	0.12%
	Red non-ferrous	0.00%	0.03%	0.00%	4.44%	91.43%	4.21%	1.00%	0.59%
	Non-metals	88.61%	0.05%	2.05%	0.11%	95.72%	0.14%	93.24%	0.02%
	TOTAL								
9	Grey non-magn.	3.65%	0.20%	6.37%	1.17%	90.75%	1.50%	5.64%	0.11%
	Red non-ferrous	0.00%	0.01%	0.00%	4.01%	91.43%	4.44%	1.02%	0.59%
	Non-metals	96.35%	0.01%	10.50%	0.07%	93.68%	0.11%	93.34%	0.02%
	TOTAL								
10	Grey non-magn.	1.14%	0.09%	14.23%	0.78%	84.37%	1.17%	5.88%	0.10%
	Red non-ferrous	0.12%	0.86%	8.35%	3.22%	91.43%	4.01%	1.15%	0.59%
	Non-metals	98.74%	0.00%	76.66%	0.03%	83.18%	0.07%	92.98%	0.02%
	TOTAL								
11	Grey non-magn.	26.22%	0.09%	14.73%	0.70%	70.15%	0.78%	36.97%	0.10%
	Red non-ferrous	9.96%	0.23%	31.10%	1.68%	83.08%	3.22%	7.88%	0.56%
	Non-metals	63.81%	0.04%	2.23%	0.03%	6.52%	0.03%	55.15%	0.07%
	TOTAL								
12	Grey non-magn.	39.05%	0.09%	14.99%	0.63%	55.42%	0.70%	41.49%	0.11%
	Red non-ferrous	10.87%	0.31%	23.18%	1.41%	51.98%	1.68%	7.00%	0.68%
	Non-metals	50.08%	0.08%	1.20%	0.03%	4.29%	0.03%	51.50%	0.09%
	TOTAL								
13	Grey non-magn.	44.47%	0.08%	17.52%	0.56%	40.42%	0.63%	42.48%	0.11%
	Red non-ferrous	6.38%	0.52%	13.97%	0.58%	28.80%	1.41%	5.45%	0.87%
	Non-metals	49.14%	0.07%	1.21%	0.16%	3.09%	0.03%	52.08%	0.09%
	TOTAL								
14	Grey non-magn.	46.49%	0.09%	15.64%	0.51%	22.91%	0.56%	41.07%	0.13%
	Red non-ferrous	5.86%	0.66%	10.94%	1.40%	14.83%	0.58%	4.79%	1.10%
	Non-metals	47.65%	0.09%	1.00%	0.03%	1.88%	0.16%	54.15%	0.10%
	TOTAL								
15	Grey non-magn.	32.83%	0.19%	7.27%	0.50%	7.27%	0.51%	32.83%	0.19%
	Red non-ferrous	3.16%	1.85%	3.89%	1.39%	3.89%	1.40%	3.16%	1.85%
	Non-metals	64.01%	0.11%	0.88%	0.04%	0.88%	0.03%	64.01%	0.11%
	TOTAL								

Table 0-65 *Weighted average of the handpicking results for products of eddy current runs EC7_I and EC8_I (2m/s, 3000rpm)*

EDDY CURRENT PRODUCTS					EDDY CURRENT PRODUCTS HANDPICKING				
COLLECTOR NO.	m [g]	ERROR EST.%	MASS FRACTION %	ERROR EST.%	PRODUCT	MASS [g]	ERROR EST.%	CUMUL. MASS [g]	ERROR EST.%
1	93.5	0.30%	0.67%	0.34%	Grey non-magn.	2.8	0.29%	841.4	0.29%
					Red non-ferrous	1.0	0.31%	153.4	0.29%
					Non-metals	86.7	0.29%	12808.1	0.24%
					TOTAL	90.5	0.29%	13802.9	0.24%
2	55.7	0.31%	0.40%	0.35%	Grey non-magn.	2.5	0.29%	838.5	0.29%
					Red non-ferrous	2.2	0.31%	152.4	0.29%
					Non-metals	36.6	0.29%	12721.5	0.24%
					TOTAL	41.3	0.29%	13712.4	0.24%
3	53.7	0.31%	0.39%	0.35%	Grey non-magn.	3.6	0.29%	836.0	0.29%
					Red non-ferrous	0.7	0.29%	150.2	0.29%
					Non-metals	46.0	0.29%	12684.8	0.24%
					TOTAL	50.2	0.29%	13671.1	0.24%
4	50.1	0.31%	0.36%	0.35%	Grey non-magn.	2.9	0.30%	832.4	0.29%
					Red non-ferrous	1.4	0.30%	149.5	0.29%
					Non-metals	47.0	0.29%	12638.9	0.24%
					TOTAL	51.3	0.29%	13620.8	0.24%
5	80.6	0.30%	0.58%	0.34%	Grey non-magn.	1.4	0.30%	829.5	0.29%
					Red non-ferrous	0.9	0.29%	148.1	0.29%
					Non-metals	73.4	0.29%	12591.9	0.24%
					TOTAL	75.7	0.29%	13569.5	0.24%
6	116.4	0.30%	0.84%	0.34%	Grey non-magn.	5.6	0.29%	828.1	0.29%
					Red non-ferrous	0.9	0.32%	147.2	0.29%
					Non-metals	106.6	0.29%	12518.5	0.24%
					TOTAL	113.1	0.29%	13493.8	0.24%
7	195.9	0.29%	1.41%	0.33%	Grey non-magn.	36.5	0.29%	822.5	0.29%
					Red non-ferrous	0.9	0.29%	146.3	0.29%
					Non-metals	154.6	0.29%	12411.8	0.24%
					TOTAL	192.0	0.29%	13380.7	0.24%
8	365.2	0.29%	2.63%	0.33%	Grey non-magn.	36.3	0.29%	786.0	0.29%
					Red non-ferrous	0.4	0.30%	145.4	0.29%
					Non-metals	324.9	0.29%	12257.3	0.23%
					TOTAL	361.5	0.29%	13188.7	0.24%
9	1263.8	0.28%	9.12%	0.32%	Grey non-magn.	61.1	0.29%	749.7	0.29%
					Red non-ferrous	0.1	0.35%	145.0	0.29%
					Non-metals	1200.2	0.28%	11932.4	0.23%
					TOTAL	1261.4	0.28%	12827.1	0.24%
10	9962.0	0.22%	71.87%	0.27%	Grey non-magn.	96.2	0.29%	688.6	0.29%
					Red non-ferrous	15.4	0.29%	145.0	0.29%
					Non-metals	9839.8	0.22%	10732.2	0.23%
					TOTAL	9951.3	0.22%	11565.8	0.23%
11	570.2	0.29%	4.11%	0.32%	Grey non-magn.	147.8	0.29%	592.5	0.29%
					Red non-ferrous	44.8	0.29%	129.6	0.29%
					Non-metals	373.5	0.29%	892.3	0.29%
					TOTAL	566.1	0.28%	1614.4	0.29%
12	331.7	0.29%	2.39%	0.33%	Grey non-magn.	124.8	0.29%	444.6	0.29%
					Red non-ferrous	44.8	0.29%	84.9	0.29%
					Non-metals	159.4	0.29%	518.8	0.29%
					TOTAL	329.0	0.29%	1048.3	0.29%
13	282.0	0.29%	2.03%	0.33%	Grey non-magn.	143.9	0.29%	319.9	0.29%
					Red non-ferrous	19.3	0.29%	40.1	0.29%
					Non-metals	116.4	0.29%	359.5	0.29%
					TOTAL	279.7	0.29%	719.4	0.29%
14	275.1	0.29%	1.98%	0.33%	Grey non-magn.	121.7	0.29%	175.9	0.29%
					Red non-ferrous	12.4	0.29%	20.8	0.29%
					Non-metals	141.4	0.29%	243.0	0.29%
					TOTAL	275.6	0.29%	439.7	0.29%
15	165.9	0.29%	1.20%	0.33%	Grey non-magn.	54.2	0.29%	54.2	0.29%
					Red non-ferrous	8.3	0.29%	8.3	0.29%
					Non-metals	101.6	0.29%	101.6	0.29%
					TOTAL	164.1	0.29%	164.1	0.29%

Table 0-66 *Weighted average of EC7_I and EC8_I grades and recoveries of eddy current metal product when moving splitter position from left to right (2m/s, 3000rpm)*

	EDDY CURRENT GRADE AND RECOVERY ESTIMATION								
COLLECTOR NO.	PRODUCT	GRADE OF COLLECTOR	ERROR EST.%	FRACTION OF TOTAL PRODUCT	ERROR EST. %	CUMUL. RECOVERY	ERROR EST.%	CUMUL. GRADE	ERROR EST.%
1	Grey non-magn.	3.12%	0.41%	0.34%	0.40%	100.00%	0.00%	6.10%	0.38%
	Red non-ferrous	1.13%	0.43%	0.67%	0.41%	100.00%	0.00%	1.11%	0.38%
	Non-metals	95.74%	0.41%	0.68%	0.40%	100.00%	0.00%	92.79%	0.34%
	TOTAL								
2	Grey non-magn.	6.04%	0.41%	0.30%	0.40%	99.66%	3.42%	6.12%	0.37%
	Red non-ferrous	5.29%	0.42%	1.42%	0.41%	99.33%	1.93%	1.11%	0.38%
	Non-metals	88.67%	0.41%	0.29%	0.40%	99.32%	1.42%	92.77%	0.34%
	TOTAL					0.00%			
3	Grey non-magn.	7.19%	0.41%	0.43%	0.40%	99.37%	2.65%	6.12%	0.37%
	Red non-ferrous	1.34%	0.41%	0.44%	0.40%	97.91%	1.76%	1.10%	0.38%
	Non-metals	91.47%	0.41%	0.36%	0.40%	99.04%	1.22%	92.79%	0.34%
	TOTAL					0.00%			
4	Grey non-magn.	5.71%	0.41%	0.35%	0.40%	98.94%	2.30%	6.11%	0.37%
	Red non-ferrous	2.77%	0.42%	0.93%	0.41%	97.47%	1.49%	1.10%	0.38%
	Non-metals	91.52%	0.41%	0.37%	0.40%	98.68%	2.11%	92.79%	0.34%
	TOTAL					0.00%			
5	Grey non-magn.	1.82%	0.42%	0.16%	0.41%	98.59%	0.30%	6.11%	0.37%
	Red non-ferrous	1.16%	0.41%	0.57%	0.40%	96.54%	0.30%	1.09%	0.38%
	Non-metals	97.02%	0.41%	0.57%	0.40%	98.31%	0.29%	92.80%	0.34%
	TOTAL					0.00%			
6	Grey non-magn.	4.94%	0.41%	0.66%	0.40%	98.43%	0.27%	6.14%	0.37%
	Red non-ferrous	0.82%	0.43%	0.60%	0.42%	95.97%	0.28%	1.09%	0.38%
	Non-metals	94.24%	0.41%	0.83%	0.40%	97.74%	0.26%	92.77%	0.34%
	TOTAL					0.00%			
7	Grey non-magn.	19.03%	0.41%	4.34%	0.40%	97.76%	0.28%	6.15%	0.37%
	Red non-ferrous	0.48%	0.41%	0.60%	0.40%	95.37%	0.26%	1.09%	0.37%
	Non-metals	80.49%	0.41%	1.21%	0.40%	96.91%	0.28%	92.76%	0.33%
	TOTAL					0.00%			
8	Grey non-magn.	10.03%	0.41%	4.31%	0.40%	93.42%	0.28%	5.96%	0.37%
	Red non-ferrous	0.10%	0.41%	0.24%	0.40%	94.77%	0.29%	1.10%	0.37%
	Non-metals	89.87%	0.40%	2.54%	0.39%	95.70%	0.28%	92.94%	0.33%
	TOTAL					0.00%			
9	Grey non-magn.	4.84%	0.40%	7.26%	0.40%	89.11%	0.29%	5.84%	0.37%
	Red non-ferrous	0.00%	0.44%	0.03%	0.44%	94.53%	0.28%	1.13%	0.37%
	Non-metals	95.15%	0.39%	9.37%	0.39%	93.16%	0.28%	93.02%	0.33%
	TOTAL					0.00%			
10	Grey non-magn.	0.97%	0.36%	11.43%	0.40%	81.85%	0.29%	5.95%	0.37%
	Red non-ferrous	0.15%	0.36%	10.02%	0.40%	94.50%	0.29%	1.25%	0.37%
	Non-metals	98.88%	0.31%	76.82%	0.35%	83.79%	0.23%	92.79%	0.32%
	TOTAL					0.00%			
11	Grey non-magn.	26.11%	0.40%	17.57%	0.40%	70.42%	0.29%	36.70%	0.41%
	Red non-ferrous	7.91%	0.41%	29.17%	0.40%	84.48%	0.29%	8.03%	0.41%
	Non-metals	65.99%	0.40%	2.92%	0.39%	6.97%	0.23%	55.27%	0.40%
	TOTAL					0.00%			
12	Grey non-magn.	37.94%	0.41%	14.83%	0.40%	52.85%	0.28%	42.42%	0.41%
	Red non-ferrous	13.62%	0.41%	29.21%	0.40%	55.31%	0.29%	8.09%	0.41%
	Non-metals	48.44%	0.41%	1.24%	0.40%	4.05%	0.23%	49.49%	0.41%
	TOTAL					0.00%			
13	Grey non-magn.	51.47%	0.41%	17.11%	0.40%	38.02%	0.28%	44.46%	0.41%
	Red non-ferrous	6.90%	0.41%	12.58%	0.40%	26.11%	0.12%	5.57%	0.41%
	Non-metals	41.63%	0.41%	0.91%	0.40%	2.81%	1.06%	49.97%	0.41%
	TOTAL					0.00%			
14	Grey non-magn.	44.18%	0.41%	14.47%	0.40%	20.91%	0.28%	40.01%	0.41%
	Red non-ferrous	4.50%	0.41%	8.09%	0.40%	13.53%	0.29%	4.72%	0.41%
	Non-metals	51.32%	0.41%	1.10%	0.40%	1.90%	0.22%	55.27%	0.41%
	TOTAL					0.00%			
15	Grey non-magn.	33.02%	0.41%	6.44%	0.40%	6.44%	0.27%	33.02%	0.41%
	Red non-ferrous	5.08%	0.41%	5.44%	0.40%	5.44%	0.28%	5.08%	0.41%
	Non-metals	61.90%	0.41%	0.79%	0.40%	0.79%	0.14%	61.90%	0.41%
	TOTAL								

Appendix XXV

Concentration of metals in different +6.25mm eddy current samples and in total +6.25mm fraction

Table 0-67 *concentration of metals in eddy current +6.25mm samples*

TOTAL CONCENTRATION IN SAMPLE

SAMPLE		Grey non-magn.	Red non-ferrous	Non-metals	TOTAL mass [g]
EC1_I	mass [g]	766.3	182.5	12148.4	13097.2
	ERROR EST.%	0.39%	0.16%	0.07%	
	concentration [%]	**5.85%**	**1.39%**	**92.76%**	
	ERROR EST.%	0.41%	0.20%	0.14%	
EC2_I	mass [g]	765.6	230.9	12289.3	13285.8
	ERROR EST.%	0.49%	2.25%	0.12%	
	concentration [%]	**5.76%**	**1.74%**	**92.50%**	
	ERROR EST.%	0.49%	2.25%	0.12%	
EC3_I	mass [g]	840.1	155.7	12852.5	13848.3
	ERROR EST.%	0.45%	1.43%	0.09%	
	concentration [%]	**6.07%**	**1.12%**	**92.81%**	
	ERROR EST.%	0.45%	1.43%	0.10%	
EC4_I	mass [g]	785.3	196.2	14208.3	15189.8
	ERROR EST.%	0.58%	2.53%	0.14%	
	concentration [%]	**5.17%**	**1.29%**	**93.54%**	
	ERROR EST.%	0.58%	2.53%	0.17%	
EC5_I	mass [g]	911	246.5	13576.2	14733.7
	ERROR EST.%	0.64%	2.09%	0.03%	
	concentration [%]	**6.18%**	**1.67%**	**92.14%**	
	ERROR EST.%	0.64%	2.09%	0.04%	
EC6_I	mass [g]	908.3	254.1	15555	16717.4
	ERROR EST.%	0.50%	1.02%	0.03%	
	concentration [%]	**5.43%**	**1.52%**	**93.05%**	
	ERROR EST.%	0.50%	1.02%	0.04%	
EC7_I	mass [g]	906.4	167	13205.8	14279.2
	ERROR EST.%	0.66%	3.98%	0.03%	
	concentration [%]	**6.35%**	**1.17%**	**92.48%**	
	ERROR EST.%	0.66%	3.98%	0.04%	
EC8_I	mass [g]	771.8	138.9	12382.9	13293.6
	ERROR EST.%	0.50%	1.39%	0.04%	
	concentration [%]	**5.81%**	**1.04%**	**93.15%**	
	ERROR EST.%	0.50%	1.39%	0.05%	

Table 0-68 *Concentration of metals in +6.25mm nonmagnetic fraction (handpicking)*

	Concentration [%]	ERROR EST.%	Mass [kg]	ERROR EST.%
Total feed	100.00%	0.00%	128.54	1.27%
Total red nonferrous metals	1.37%	1.45%	1.77	1.93%
Total grey nonmagnetic metals	5.81%	1.32%	7.47	1.83%
Total metals	7.19%	1.96%	9.24	2.33%

Table 0-69 *Grade of the Coarse products of eddy current separation with different process settings*

Belt speed [m/s]; Rotor speed [rpm]	1m/s; 2000rpm; SP5	ERROR ESTIMATE %	1m/s; 3000rpm; SP5	ERROR ESTIMATE %	2m/s; 2000rpm; SP11	ERROR ESTIMATE %	2m/s; 3000rpm; SP11	ERROR ESTIMATE %
Red nonferrous metals grade [%]	14.10%	0.63%	10.62%	0.89%	10.86%	0.36%	8.03%	0.41%
Grey nonmagnetic metals grade [%]	51.82%	0.63%	46.62%	0.89%	39.32%	0.35%	36.70%	0.41%
Total metals grade [%]	65.92%	0.89%	57.25%	1.26%	50.18%	0.50%	44.73%	0.57%
Red nonferrous metals recovery [%]	85.97%	0.45%	89.93%	0.63%	85.24%	0.25%	84.48%	0.29%
Grey nonmagnetic metalsrecovery [%]	85.31%	0.45%	86.11%	0.61%	85.04%	0.25%	70.42%	0.29%
Total metals recovery [%]	85.45%	0.63%	86.79%	0.88%	85.08%	0.36%	72.59%	0.41%
Fraction of feed in the product [%]	9.60%	0.85%	10.74%	1.18%	12.41%	0.29%	11.72%	0.33%
Mass of product [kg]	12.34	1.53%	13.80	1.73%	15.96	1.30%	15.07	1.31%
Mass of red nonferrous metals in product [kg]	1.52	1.98%	1.59	2.02%	1.50	1.94%	1.49	1.95%
Mass of grey nonmagnetic metals in product [	6.38	1.94%	6.44	2.03%	6.36	1.87%	5.26	1.88%
Mass of metals in product [kg]	7.90	2.48%	8.02	2.62%	7.86	2.35%	6.71	2.36%

Appendix XXVI

Results of eddy current separation for Medium (1.18-6.25mm) particles

Table 0-70 *Masses of different collectors products when processing Medium bottom ash fraction with eddy current*

	1m/s; 2000rpm		1m/s; 3000rpm		2m/s; 2000rpm		2m/s; 3000rpm	
COLLECTOR	Mass [kg]	Mass [%]	Mass [kg]	Mass [%]	Mass [kg]	Mass [%]	Mass [kg]	Mass [%]
1	228.1	3.20%	150	1.99%	375.5	4.87%	361.7	4.89%
2	487.4	6.85%	503.1	6.67%	157	2.04%	158.3	2.14%
3	754.5	10.60%	820.2	10.88%	105	1.36%	203.2	2.75%
4	1610.1	22.62%	1756.3	23.30%	77.9	1.01%	82.5	1.12%
5	3500.3	49.17%	3719.2	49.33%	96.6	1.25%	88.8	1.20%
6	240.8	3.38%	248.4	3.29%	130.4	1.69%	130.3	1.76%
7	130.1	1.83%	146.3	1.94%	183.9	2.39%	203.4	2.75%
8	82.4	1.16%	92.9	1.23%	473.7	6.15%	531.5	7.19%
9	44.2	0.62%	53.4	0.71%	2200.8	28.57%	2267.5	30.68%
10	23.8	0.33%	26.3	0.35%	3380.9	43.89%	2878.5	38.94%
11	11.7	0.16%	14.8	0.20%	162.6	2.11%	138.6	1.88%
12	3.8	0.05%	4.8	0.06%	99.4	1.29%	103.9	1.41%
13	0	0.00%	2.2	0.03%	81.4	1.06%	84.4	1.14%
14	1.5	0.02%	0	0.00%	105.7	1.37%	93.8	1.27%
15	0.2	0.00%	0.8	0.01%	73.1	0.95%	65.3	0.88%

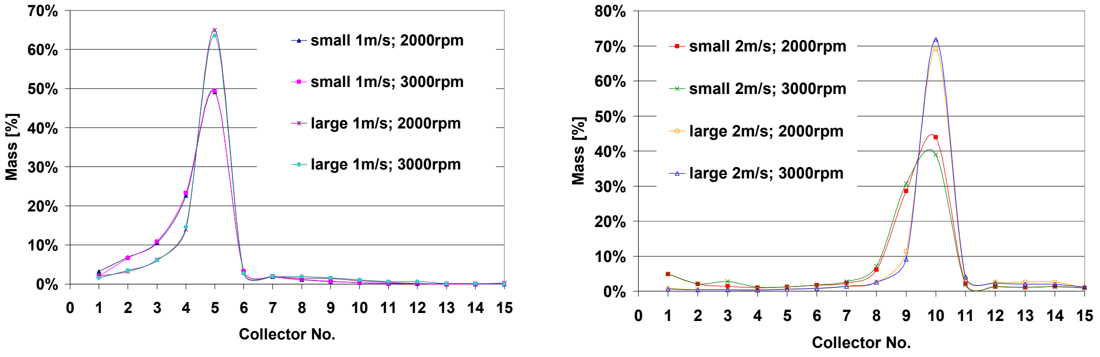


Figure 0-10 *Comparing mass distribution of different size fractions between collectors when using same parameters*

Appendix XXVII

XRF-analysis results of bottom ash processing final products

Table 0-71 *Results of XRF analysis for composition of the process products [%]*

SAMPLE	**S3**	**S1**	**S4**	**S2**	**S5**
Element	**Fines -1.18 mm [%]**	**Magnetic +6.25 mm [%]**	**Magnetic +1,18-6.25 mm [%]**	**Coarse Granulate (+6.25mm) mm [%]**	**Medium Granulate +1,18-6.25mm [%]**
Al	7.60	5.70	5.40	4.50	5.80
Ba	0.11	0.15	0.08	0.07	0.11
Ca	11.00	6.20	5.40	6.50	6.10
Cl	0.36	0.11	0.07	0.06	0.12
Cr	0.06	0.12	0.09	0.06	0.02
Cu	0.23	0.39	0.18	0.03	0.13
Fe	4.10	17.00	20.00	0.78	1.50
K	1.80	1.30	1.40	1.10	2.30
Mg	1.50	1.00	1.30	1.00	1.60
Mn	0.12	0.16	0.15	0.03	0.05
Na	2.60	3.50	3.50	7.60	4.40
Ni	0.01	0.03	0.02	< 0,01	< 0,01
P	0.90	0.31	0.46	0.32	0.86
Pb	0.11	0.14	0.03	0.06	0.09
Rb	0,008	0,006	< 0,01	0,007	0,01
S	0.95	0.15	0.14	0.07	0.12
Sb	< 0,01	< 0,01	0,01	< 0,01	< 0,01
Si	22.00	18.00	17.00	29.00	27.00
Sn	0.02	0.04	0.06	0.01	0.01
Sr	0.03	0.03	0.02	0.02	0.04
Ti	0.74	0.55	0.56	0.28	0.45
Zn	0.30	0.24	0.12	0.09	0.17
Zr	0.01	0.02	0.01	0.04	0.02

Appendix XXVIII

Results of leaching test on the process final products

Table 0-72 *Results of leaching tests for composition of the final product of bottom ash processing [mg/l]]a) untreated bottom ash, b)Fines -1.18mm, c) Medium Granulate, d) Coarse Granulate, e) magnetic product Coarse, f) magnetic product +6.25mm. Values which exceeds the limit values of regular MSW landfill are highlighted with grey*

	UNTREATED BOTTOM ASH	
Sample	**h**	
L/S ratio	**2**	**10**
pH	11.5	11.4
Element	**leaching values mg/kg**	
As	0.01	0.01
Ba	0.14	0.6
Cd	0.002	0.003
Cr	0.32	0.56
Cu	6.2	7.4
Hg	<0.0002	<0.001
Mo	0.87	1.1
Ni	0.03	0.04
Pb	0.28	1.3
Sb	0.12	0.47
Se	<0.10	0.29
Zn	0.24	0.67
Cl-	1360	1681
F-	86	84 *
SO_4^{2-}	280	639
DOC	280	341

	SLUDGE -1.18 mm	
Sample	**S3**	
L/S ratio	**2**	**10**
pH	10	10.8 *
Element	**leaching values mg/kg**	
As	<0.004	<0.02
Ba	0.45	1.3
Cd	0.001	0.004
Cr	0.68	1.5
Cu	4.7	8
Hg	<0.0001	<0.0005
Mo	0.76	1.3
Ni	0.02	0.04
Pb	0.01	0.17
Sb	0.15	0.83
Se	<0.10	<0.50
Zn	0.06	0.37
Cl-	570	890
F-	24	35
SO_4^{2-}	990	2000
DOC	110	270

	GRANULATE 1.18-6.25mm	
Sample	**S5**	
L/S ratio	**2**	**10**
pH	10.4	10.2 *
Element	**leaching values mg/kg**	
As	<0.004	<0.02
Ba	0.22	0.74
Cd	<0.001	<0.003
Cr	<0.02	<0.10
Cu	0.39	0.63
Hg	<0.0001	<0.0005
Mo	0.15	0.23
Ni	<0.004	<0.02
Pb	0.1	0.22
Sb	0.1	0.4
Se	<0.10	<0.50
Zn	0.09	0.38
Cl-	110	150
F-	<20	<27
SO_4^{2-}	270	690
DOC	34	54

c

	GRANULATE +6.25 mm	
Sample	**S2**	
L/S ratio	**2**	**10**
pH	11	10.8 *
Element	**leaching values mg/kg**	
As	<0.004	<0.02
Ba	0.08	0.22
Cd	<0.001	<0.003
Cr	0.05	0.18
Cu	0.23	2
Hg	<0.0001	<0.0005
Mo	0.08	0.12
Ni	<0.004	0.03
Pb	0.11	0.21
Sb	0.06	0.2
Se	<0.10	<0.50
Zn	0.05	0.27
Cl-	75	90
F-	3	5.3
SO_4^{2-}	180	320
DOC	20	33

d

	MAGNETIC +1.18-6.25 mm	
Sample	**S4**	
L/S ratio	**2**	**10**
pH	10.7	10.7 *
Element	**leaching values mg/kg**	
As	<0.004	<0.02
Ba	0.26	1
Cd	<0.001	<0.003
Cr	<0.02	<0.10
Cu	0.29	0.64
Hg	<0.0001	<0.0005
Mo	0.21	0.33
Ni	<0.004	<0.02
Pb	0.003	0.13
Sb	0.07	0.28
Se	<0.10	<0.50
Zn	0.03	0.47
Cl-	89	110
F-	4	6.3
SO_4^{2-}	280	550
DOC	30	49

e

	MAGNETIC +6.25 mm	
Sample	**S1**	
L/S ratio	**2**	**10**
pH	9.8	10.0 *
Element	**leaching values mg/kg**	
As	<0.004	<0.02
Ba	0.41	1.7
Cd	<0.001	<0.003
Cr	<0.02	<0.10
Cu	0.12	0.29
Hg	<0.0001	<0.0005
Mo	0.31	0.52
Ni	<0.004	<0.02
Pb	0.01	0.02
Sb	0.06	0.3
Se	<0.10	<0.50
Zn	0.03	0.13
Cl-	150	160
F-	2.8	3.5
SO_4^{2-}	280	420
DOC	18	32

f