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Combination of SRF-Production and Recycling – Method, Results and Case Study

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ABSTRACT

In the Austrian waste management system, quality criteria and quality assurance measures for Refuse Derived Fuels (RDF) burnt in co-incineration plants like cement kiln are defined in the national “Waste Incineration Ordinance (WIO), where limit values are given for the heavy metals content which are related to heating value.

The largest Austrian Solid Recovered Fuel (SRF) – SRF is a sub-group of RDF – production plant ThermoTeam (treatment capacity: 100,000 tons year^{-1}) is an important part of this system. Over there, various non-hazardous wastes from household, industry and trade (i.e. high calorific fractions from mechanical (biological) treatment plant, non-recyclable plastics from plastic sorting plants, etc.) are used in multi-stage processing plants, including classifying and sorting of material fractions as well as separation of ferrous (Fe) and non-ferrous (NON-Fe) metals and PET, PVC and interfering heavyweight inert materials (e.g., stones), for production of high quality and quality assured premium SRF for cement industry. In the meantime, the plant was optimised and expanded with a near infrared (NIR) sorting device for sorting out of PET-for recycling and rejecting of unwanted material fractions like PVC plastics.

The cooperation between the ThermoTeam and the Chair includes various scientific projects. In the present paper, chemical-physical specification on delivered input waste materials, technology applied and the quality assurance concept implemented at the ThermoTeam plant are described. Additionally, in the reported case study, selected results and findings, based on experience accumulated while long-time (ca. 3 years) on-site investigations, on sorting out efficiency of installed NIR sorting technology, as well as characterization of separated PVC fractions and chemical-physical quality of produced SRF are given.

KEYWORDS

Solid recovered fuels (SRF), ThermoTeam, SRF Quality, SRF Quality Assurance

INTRODUCTION

In present chapter, the Austrian waste management system, including position and role of the alternative fuel production plant ThermoTeam as well as legal requirements on SRF quality together with quality assurance measures are described.

Waste Management System

Modern waste management consists of a system of elements with mutual dependencies that requires a combination of different types of waste treatment plants. The individual systems are interrelated and interdependent. The plants are both, elements but also subsystems of the entire system defined as: “Thermal utilization of wastes”. The connections between the conceptual elements are material- and freight-flows. In Figure 1, the system “Thermal utilization of waste” is depicted by the example of an Austrian waste management company. The assignment of waste streams to an appropriate plant types is made according to the quality of wastes. [Pomberger & Sarc, 2012]

Splitting plants treat mixed commercial waste and operate on the principle of qualitative splitting of the waste stream. They produce furnace-ready, medium-calorific Solid Recovered Fuel (SRF) for fluidized bed systems, as well as a high-calorific light fraction for the subsequent SRF-production for the primary burner of a grey clinker rotary kiln. The waste delivered to the splitting plant is mixed commercial waste originating from commercial and industrial sources. The accepted waste can be described by the following properties (specifications): low moisture content, low organic fraction, good processability, high heating value. Determining sub-fractions are plastics, paper, cardboard, wood, metals and mineral shares. [Pomberger & Sarc, 2012]

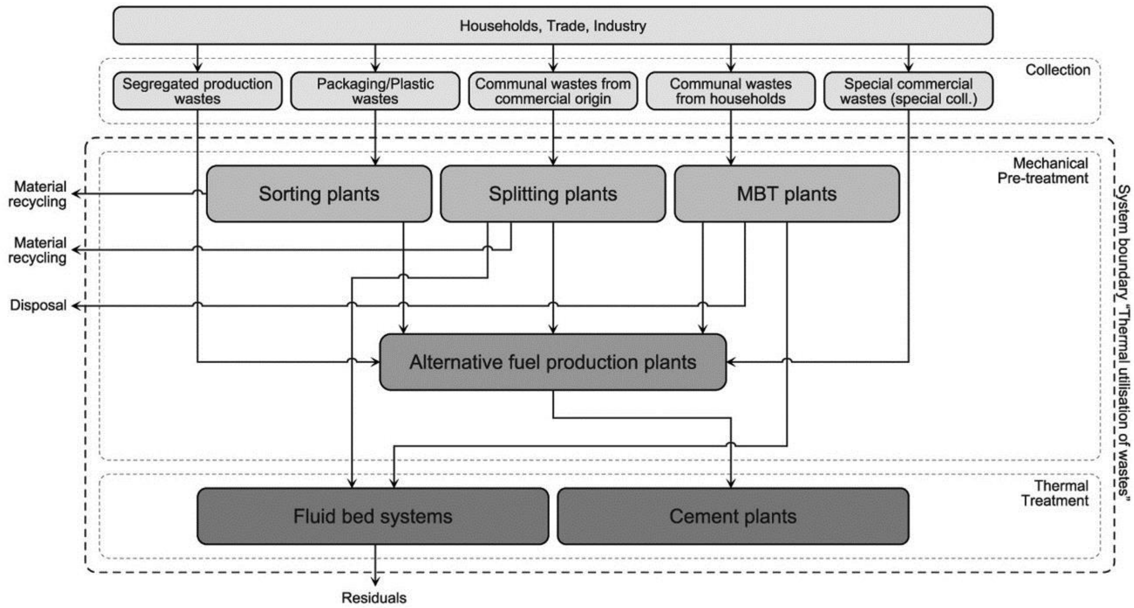

Figure 1: System overview “Thermal utilization of wastes” [Pomberger & Sarc, 2012]

Austria´s largest “Alternative fuel production plant“, is operated by “*ThermoTeam Alternativbrennstoffverwertungs GmbH*” and located in Retznei/ Styria. In this plant (as shown in Figure 1) pre-processed wastes from Sorting plants, Splitting plants and Mechanical-Biological Treatment (MBT) plants as well as mono-fraction material and special collected waste are treated only. Finally, the produced quality assured, premium SRF, so-called “ASB- Aufbereiteter Substitut Brennstoff” (engl. processed substitute fuel), is delivered to the cement kilns of the plants in Retznei, in Mannersdorf etc. in Austria. (Sarc et al., 2014a)

Legal requirements on SRF Quality and Quality Assurance Procedure applied in Austria

In Austria, the definition of **"waste fuels"** or "**Refuse Derived Fuels**" (**RDF**) is given in the legally binding national "Waste Incineration Ordinance" (WIO) (BMLFUW, 2010) as:

"...waste that is used entirely or to a relevant extent for the purpose of energy generation and which satisfies the quality criteria laid down in this directive...".

Therefore, after adequate and extensive (pre-)treatment in different processing plants and applying strictly defined quality assurance measures, various non-hazardous and/or hazardous waste materials from households, commerce and industry can be used as **RDF** in co-incineration plants: e.g. sewage sludge, waste wood, high calorific fractions from mechanical-physical (MPT) or mechanical-biological treatment (MBT) plants, calorific fractions of household and commercial wastes, shredder light fractions (e.g., from old vehicles and waste electric and electronic equipment (WEEE)), scrap tyres, waste oil and used solvents, etc. (Lorber et al., 2012).

In the narrow sense of the definition, only solid waste fuels which are prepared from non-hazardous sorted or mixed solid wastes (i.e. municipal waste fractions, commercial wastes, production wastes, construction and demolition waste, packaging wastes, lightweight fractions from MBT-plants, etc.) including legally defined quality assurance measures are classified as "**Solid Recovered Fuels**" (**SRF**) (Lorber and Sarc, 2012b).

Limits for the delivered (unburnt) waste fuel

Limits for the delivered (unburnt) waste fuel define which kind of material the SRF producer can deliver to the cement plant by giving legally binding threshold values for heavy metals in the input-material the cement plant can accept. It is possible for the cement plant to set even stricter or additional acceptance criteria (e.g., specifications) than these legal requirements if desired. The concentration limits in guidelines and regulations are commonly expressed in two ways:

- as absolute concentrations (mg heavy metal per kg dry matter SRF); or
- as a ratio between the quantity of heavy metals and the energy content of the SRF (mg heavy metal per MJ energy content). [Sarc et al, 2014b]

Table 1: Austrian limit values [mg MJ_{DM}^{-1}] for co-incineration of RDF in cement plants. Note: Data in parentheses are for RDF with quality assurance, EU-waste code 19_12_12 [BMLFUW, 2010].

Parameter	**Median**	**80th percentile**
Sb	7	10
As	2	3
Pb	20	36
Cd	0.23 (0.45)	0.46 (0.7)
Cr	25	37
Co	1.5	2.7
Ni	10	18
Hg	0.075	0.15

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Note: () for RDF with quality assurance, waste code 19_12_12

Due to the heterogeneous distribution (i.e. 80th percentile / median ≥ 1.5) of heavy metals in SRF, median and 80th percentile values are used for definition of limit values instead of the mean value. [Grech, 2013] This is a special feature of the Austrian "Waste Incineration Ordinance" (WIO). For the first time, statistical methods are used instead of the principle of fixed limit values. [Pomberger & Curtis, 2012]

Quality assurance measures on SRF in Austria

When talking about quality assurance in accordance with the Austrian WIO [BMLFUW, 2010] and Guideline for Waste Fuels [BMLFUW, 2008], five focus areas have to be considered [Sarc et al., 2014b].

1) Sieving analyses:

   For the determination of the parameters: particle size (d_{95}), bulk density (kg m^{-3}), etc.

2) Representative sampling concept and sampling procedure:

   The sampling concept, the calculation methods and formulas, etc. applied in this reported case study are extensively discussed in Lorber et al. [2012].

3) Internal continuous analyses:

   To ensure that all relevant legal requirements (cf. Table 1) are fulfilled when SRF is co-incinerated in cement kilns, there are two possibilities for continuous investigations:

   a) "Supplier control" (quality control is done by the supplier of the SRF); or

   b) "Consumer control" (quality control is done by the user at the plant).

   Both cases are extensively described in Lorber et al. [2012].

4) External monitoring or SRF quality control:

   If the continuous investigations required for quality assurance are carried out by an external authorised specialist or specialist institute, external monitoring in accordance with section 2.14 of the WIO [BMLFUW, 2010] is not required.

5) Analytical methods applied in own and external lab in accordance with different standards, mentioned in Lorber et al. [2012].

In Austria as shown, the quality assurance measures and limit values are legally defined and have to be applied for all types of RDF (i.e. solid and liquid) when used in co-incineration plants, whether produced from non-hazardous and/or hazardous waste materials. As mentioned before, SRF is a subgroup of RDF, which is also subject to legally defined quality assurance measures and limit values and means, as defined in CEN [CEN, 2011], "…*only solid fuel prepared from non-hazardous waste…"*. [Sarc et al. 2014b]

In this paper, selected results of a comprehensive study on SRF production and quality assurance in the SRF processing plant ThermoTeam, Retznei (A) as well as SRF specifications are presented and discussed.

SRF PRODUCTION PLANT THERMOTEAM

In the following chapter, chemical-physical specifications on delivered input waste materials, technology applied and quality assurance concept realized in SRF production plant ThermoTeam are described.

Chemical-physical specifications on delivered input waste materials

In ThermoTeam plant in Retznei, five different pre-treated types of waste materials have to fulfil selected criteria (cf. Table 2) to be processed to high quality SRF:

1) Production waste – unmixed or homogeneous waste material,
2) High calorific fraction – mixed waste material (household and industry),
3) High calorific fraction – mixed waste material (commerce),
4) High calorific fraction – mixed waste material (packaging waste processing),
5) High calorific fraction – mixed waste material (mechanical-biological treatment plant). [ThermoTeam, 2015]

Table 2: Selected chemical-physical specifications of input waste materials at ThermoTeam plant [ThermoTeam, 2015]

Parameter	**Unit**	**Value**
Chlorine Content	[$\%_{DM}$]	< 0.7
Lower Heating Value	[MJ kg_{DM}^{-1}]	> 22
Moisture Content	[$\%_{OS}$]	< 25
Lead (Pb)	[mg kg_{DM}^{-1}]	< 200
Cadmium (Cd)	[mg kg_{DM}^{-1}]	< 4.0
Mercury (Hg)	[mg kg_{DM}^{-1}]	< 1.0
Impurities (inert materials and metals)	[w$\%_{OS}$]	< 13
Particle size (d_{95})	[mm]	< 300 (exception: foils)

Applied technology

The company *ThermoTeam Alternativbrennstoffverwertungs GmbH* is located nearby the cement plant of Lafarge Zementwerke GmbH in Retznei/ Southern Styria. In the plant, five before mentioned types of waste materials are processed by several mechanical units like shredders, magnetic separators, eddy-current separators and wind-sifters to quality assured, pneumatically transportable and “ready-to-burn” SRF for cement industry.

It has turned out to be advisable, to separate the input material after pre-crushing into a three-dimensional (3D) and into a two-dimensional (2D) waste stream by wind sifting. 3D-material usually contains more impurities (like: Fe and NON-Fe metals, stones, concrete etc.) and furthermore shows unfavourable combustion behaviour in the kiln, compared to 2D materials (like plastic foils, etc.). Hence, the 3D-waste stream has to undergo a more complex preparation process, consisting of 2 step magnetic separation (removal of Fe-metals) followed by eddy-current separation (removal of NON-Fe metals) and air-classifying (removal of the heavyweight fraction of coarse impurities) before it is finally shredded to a grain size < 10 mm. The 2D-waste stream, on the other hand, only requires size reduction down to < 30 mm. After combining the two waste streams again, the resulting semi-product is subjected to the final refining and confectioning step, consisting of additional magnetic separation, disc-screening (< 40 mm) and once again magnetic separation. For removing the metals efficiently from SRF, it is important to apply magnetic separation (and eddy-current separation, if required) steps repeatedly after each size reduction (shredder, crusher) step. Especially iron (Fe) tends to be strongly embedded in a fluffy type of waste matrix and deliberation and separation of metal is much easier after breaking down the structure of waste by comminution. [Lorber et al, 2012]

Additional important issue in SRF production is the chlorine content that may cause a well-known problem in the production process of clinker. In case of increasing substitution rates, the problems with chlorine are getting bigger if there are no special activities. That is why NIR (near-infrared) sorting technology was installed in 2012 to improve the quality of the input material by separation of chlorine. The installed two-stage NIR (near-infrared) sorting device removes PET and PVC from the input material. The used technology is to decrease the total amount of chlorine in waste and to ensure an average chlorine (organic and inorganic) content of 0.8%. The flow chart of the ThermoTeam plant is shown in Figure 2. [Sarc et al., 2014a]

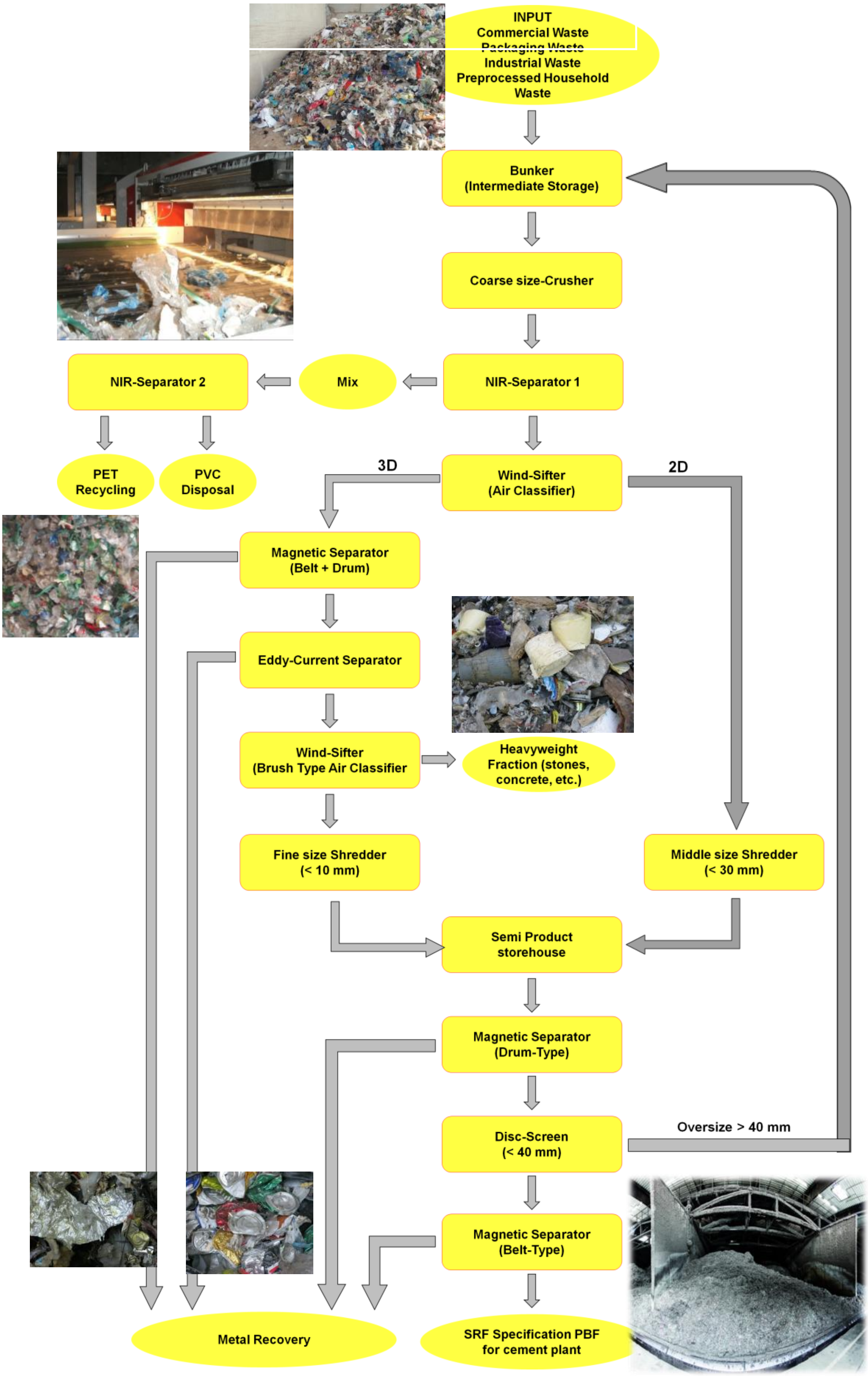

Figure 2: Multistage processing scheme of 100,000 tonnes year^{-1} ThermoTeam plant for separation of Fe & non-FE metals, PVC, PET, Heavyweight Fraction and manufacturing of premium SRF [reproduced from Sarc et al., 2014a].

As shown in Figure 2 and Figure 3, a two-stage NIR sorting device is installed at the ThermoTeam plant (2 x REDWAVE 2800 NIR 64 sensor2-Way to remove certain plastics (PET and PVC) and 1 x REDWAVE 1200 NIR 64 2W to remove PET) [REDWAVE, 2015]. Due to these devices it can be assured, that the average content of chlorine in SRF produced is about 0.8%$_{OS}$. Potential peaks of chlorine content can also be topped by the used technology. [Sarc et al., 2014a; Sarc, 2015]

The two in parallel arranged devices, which are located at the beginning of the treatment line, remove PET and PVC, the third device eliminates PET only. The operation principle and mode of NIR sorting technology is described by Sarc et al. [2014a] and Sarc [2015].

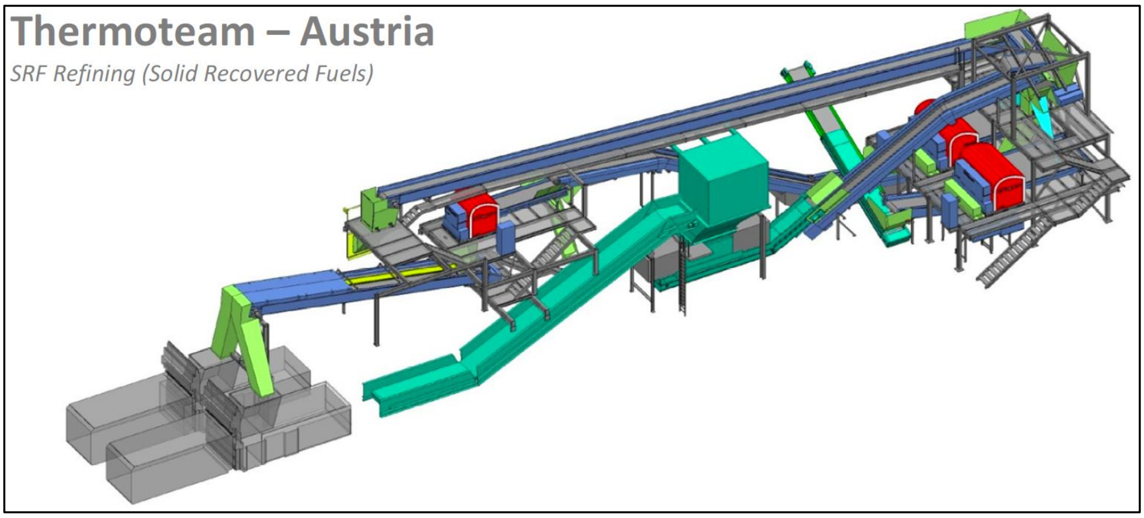

Figure 3: Positioning of REDWAVE NIR sorting devices for removal of PET and PVC at the SRF production plant ThermoTeam [REDWAVE, 2015]

Quality assurance concept for SRF at ThermoTeam plant

As already mentioned, the quality assurance concept for SRF is to be performed according to the legal requirements laid down in Austrian WIO [BMLFUW, 2010]. In case of ThermoTeam plant, sampling rules and procedures for waste with particle size (d_{95}) < 30 mm and waste streams > 40,000 t year^{-1} including lot size, increment amount, number of increments for a field sample etc. have to be applied. The detailed information on the quality assurance concept for waste streams > 40,000 t year^{-1} is extensively described in Lorber et al. [2012]. Here, summarized features of the quality assurance concept for primary burner SRF of ThermoTeam is depicted in Figure 4.

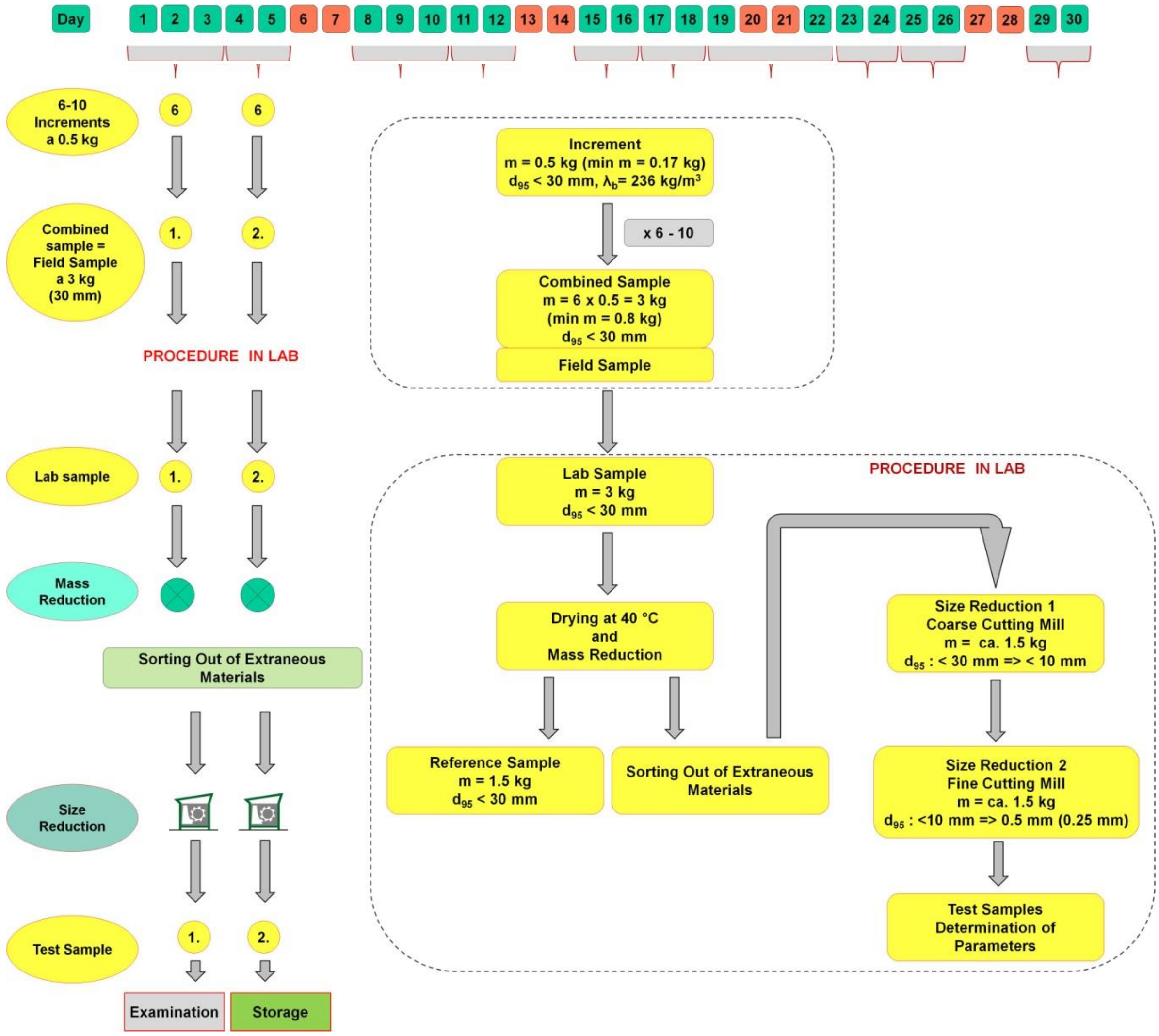

Figure 4: Sampling procedure and sample preparation scheme of the first lot (in first year) for primary burner SRF, waste fuel stream > 40,000 t y^{-1} [Lorber et al., 2012].

CASE STUDY: PRODUCTION OF PREMIUM QUALITY SRF AT THERMO TEAM PLANT IN RETZNEI; AUSTRIA

Present chapter describes the research and development (R&D) approach, the investigation steps and selected results gained at the SRF production plant ThermoTeam.

Materials and methods

A real comprehensive study was carried out on the characterization of delivered input waste materials but also of produced SRF during last three years (2012-2014).

Delivered input waste material was investigated by customer-specific testing, where three times ca. 150 t of customer waste was processed. In total, five customers have been investigated extensively. During customer-specific testing, PCV fraction was separately sampled, sorted and analysed too.

By using an automatic sampling device installed after the last magnetic separation step (cf. Figure 2) and directly before the truck loading station, representative SRF samples were recovered. For investigation purposes, the described sampling device was adapted for representative grab sampling of one increment after every 200 seconds. In total, the truck loading process takes ca. 35 Minutes or 2,100 seconds respectively. Therefore, 10 increments à about 1,000 g were sampled per truck and used for collection of one representative combined sample of ca. 10 kg per truckload. Finally, extensive physical-chemical investigations were carried out at the own accredited laboratory of the Chair of Waste Processing Technology and Waste Management at the Montanuniversitaet Leoben.

Results achieved from investigations

As shown below, three selected and for this paper relevant results and findings are presented:

1. Sorting out efficiency of installed NIR sorting device for chlorine,
2. Characterization of PVC fraction,
3. Chemical-physical quality of produced SRF.

Sorting out efficiency of installed NIR sorting device for chlorine

For determination of the sorting out efficiency of applied NIR sorting technology concerning the chlorine content in SRF produced at ThermoTeam, a statistical method has been applied. [Zahrnhofer, 2013] Based on extensive on-site results and own measurements (n = 65 before installation of the NIR equipment and n = 23 after the installation) it could be shown that the average chlorine content in the SRF was 0.86%$_{OS}$ before using NIR sorting. After installation of the NIR sorting technology, the average chlorine content was reduced to 0.64%$_{OS}$. Consequently, it is statistically proven that the use of NIR sorting technology in SRF-processing leads to a significant chlorine reduction of about 25% on an average. Additionally, the 95% confidence interval (i.e. distribution of single results) is reduced by about 33% (cf. Figure 5).

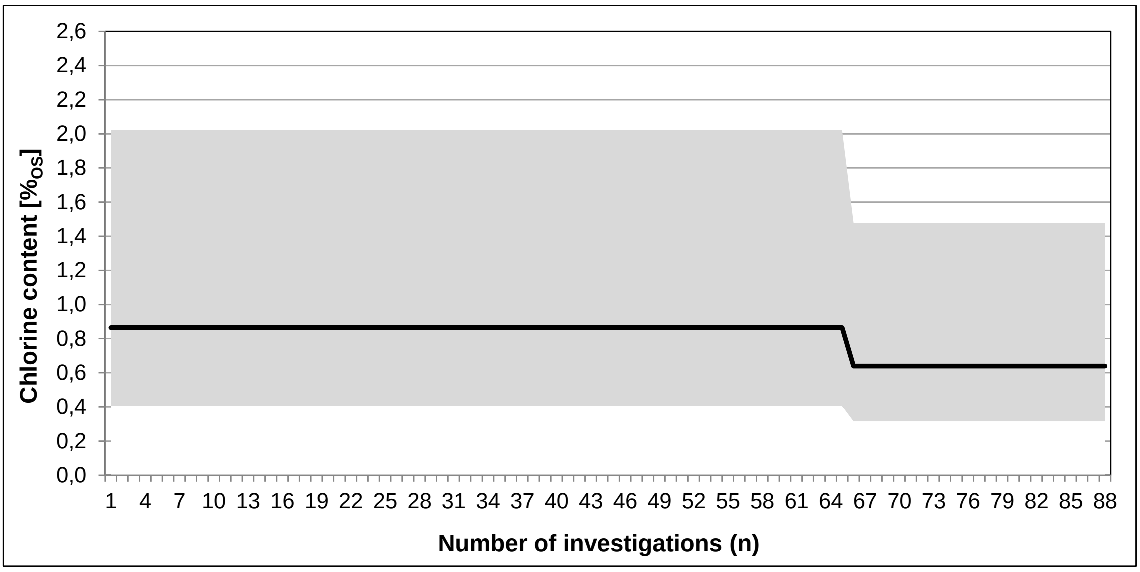

Figure 5: Summarized results (mean values) from the statistical analysis of the chlorine content in SRF before installing the NIR sorting device (n = 0-65) and after installing the NIR equipment (n = 66-88). Reduction of the 95% confidence interval (grey area). [Sarc, 2015]

Characterization of PVC fraction

The comprehensive characterization of the PVC fraction that was sorted out at the SRF plant ThermoTeam was performed by David [2014]. In this paper, selected and subject-relevant results are presented only. Results from sorting analyses according to four specific criteria (i.e. “soft”, “hard”, “transparent” and “intransparent”) are presented in Figure 6. Amounts of the selected four material criteria represent about 90-95 wght% of total PVC fraction separated by NIR sorting technology described.

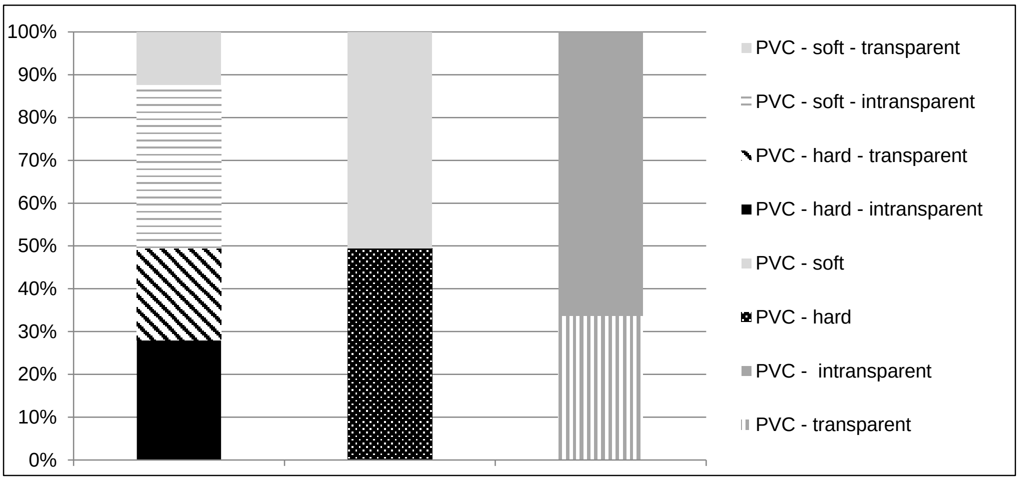

Figure 6: Composition and characterization of the NIR separated PVC fraction according to four material criteria [David, 2014]

Furthermore, the chlorine content of the entire PVC fraction and that of each sub-fraction (i.e. sub-fraction defined by one before mentioned sorting criteria) have been determinate. As shown in Figure 7, the chlorine content of unsorted PVC amounts to about 23%$_{DM}$ on an average. Besides, it appears that the chlorine content in sub-fraction “PVC-hard“ (about 40%$_{DM}$) is significantly higher than in sub-fraction “PVC-soft“ (about 7%$_{DM}$) only. In addition, the chlorine content of sub-fraction “PVC-transparent” (about 33%$_{DM}$) is higher compared to sub-fraction “PVC- intransparent” (18%$_{DM}$).

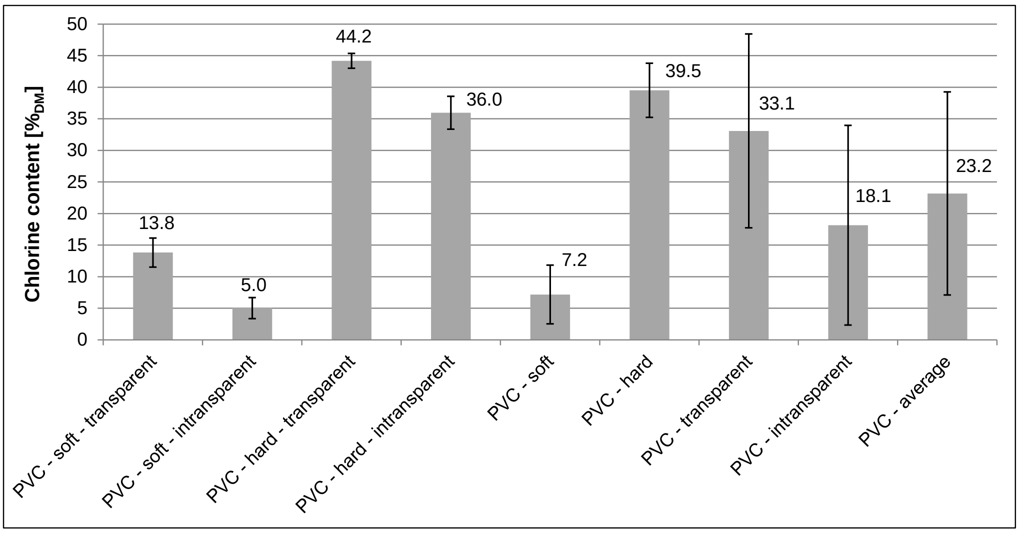

Figure 7: Sorting criteria-specific distribution of chlorine in PVC fractions. Average chlorine content incl. standard deviation [%$_{DM}$] of the individual (sub-)fractions [David , 2014]

Chemical-physical quality of produced SRF

The classification into different SRF qualities or specifications usually depends on the parameter: lower heating value (LHV) [MJ kg_{OS}^{-1}], particle size d_{95} [mm], ash content [wght$\%_{DM}$], chlorine content [wght$\%_{OS}$], total carbon content [wght$\%_{DM}$] and moisture [$\%_{OS}$]. Here, summarized selected results from extensive chemical-physical analyses of SRF produced at ThermoTeam plant are presented (cf. Table 3). It becomes obvious that SRF PREMIUM Quality has relatively high lower heating value and moisture content acceptable for cement industry. Additionally, it has to be noted that the heavy metal content of SRF reported is well below the limit values for input material (cf. Table 1) when using SRF for energy generation in co-incineration plant (i.e. cement industry). [Sarc, 2015]

Table 3: Selected chemical-physical specifications of produced SRF [Sarc, 2015]

Parameter	**Unit**	**Median**	**80th percentile**
Moisture Content	[$\%_{OS}$]	16.8	14.0
Lower Heating Value	[MJ kg_{DM}^{-1}]	26.0	27.3
Lower Heating Value	[MJ kg_{OS}^{-1}]	21.2	22.1
Ash Content	[wght$\%_{DM}$]	15.3	16.5
Chlorine Content	[wght$\%_{OS}$]	0.9	1.1
Total Carbon Content	[wght$\%_{DM}$]	50.6	52.7
Fossil CO_2 Emission factor	[g MJ_{DM}^{-1}]	49.5	56.1

CONCLUSIONS

Co-incineration of quality assured SRF has become an important tool in Austrian waste management system. The requirements for legal compliance, guarantee of supply, product quality as well as quality assurance (based on the national Waste Incineration Ordinance and international guidelines according to the CEN/TC 343 – Solid Recovered Fuels) are important preconditions for the utilization of SRF in Austrian cement industry, where already substitution rates of up to 75% [VÖZ, 2015], have been reached. The quality of premium SRF manufactured depends primarily on the type of input waste materials as well as on type and extent of waste treatment steps applied in the multistage (mechanical/physical) SRF processing plants. As shown on the example of Austrian ThermoTeam plant, when innovative sorting techniques like NIR sorting systems are installed in the manufacturing process, PET and/or PVC can be separated out of production stream and the final quality of SRF produced can be obviously increased. Selected results presented in the paper show that the use of NIR sorting technology leads to a significant chlorine reduction of about 25% in average and at the same time to a reduction of the 95% confidence interval by ca. 33%. Results on characterization of the NIR separated PVC fraction show that the chlorine content of entire PVC fraction amounts to about $23\%_{DM}$ on an average. Additionally, it can be concluded that the chlorine content in sub-fractions “PVC-hard” and “PVC-transparent” is higher, compared to sub-fractions “PVC-soft” and “PVC-intransparent”. Finally, selected fuel parameters (i.e. LHV and chlorine content and/or fossil CO_2-emission factor) that describe the quality of premium SRF produced at ThermoTeam, but also in other SRF production plants in Austria [Sarc et al., 2014b], show a “conflict of interests”. In most cases, an increase of LHV is directly related to a parallel increase of chlorine content and fossil CO_2-emission factor in SRF. Nevertheless, the successful application of SRF for energy generation in the (Austrian) cement industry has become “State of the Art”.

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