Mining Incinerator Bottom Ash for Heavy Non-Ferrous Metals and Precious Metals

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In 2012 the Dutch Waste-to-Energy sector agreed upon a Green Deal [1] with the government to either clean the Municipal Solid Waste Incinerator (MSWI) bottom ash stemming from Waste-to-Energy, or find other applications for it rather than the *IBC* application in embankments (closed application; IBC = isolation, management and control). As a member of the Dutch Waste Management Association, N.V. HVC was one of the companies that signed this Green deal and committed to the goal stated therein.

From the beginning of this process the target was to clean the bottom ash and apply it in the usual applications such as embankments and foundation layers for road construction, since we believe(d) the market volume of alternative applications (e.g. as a granular additive for pavement blocks) to be insufficient in size. Moreover, landfilling of bottom ash is forbidden in The Netherlands, so some kind of useful application has to be achieved in the future within the framework of the Green Deal.

From 2011 onwards we therefore embarked in a development process with Boskalis Environmental to modify the well-known wet soil cleaning process into a washing process for (raw) bottom ash. Finally this resulted in the implementation of a treatment plant (Figure 1) of which the washing stages were the principal innovation.

Figure 1:

Washing plant for bottom ash at Alkmaar

Cleaning bottom ash, in the sense that its leaching behaviour of heavy metals and salts diminishes, requires additional effort relative to the classical treatment of bottom ash which predominantly aims at producing a course fraction suitable for road construction. Additional effort means additional costs. So as any other Waste-to-Energy operator in the Netherlands, we were faced by this downside of the Green Deal (whereas the benefit of the Green Deal clearly is the continuation of useful application of bottom ash in the future).

Hence, to soften this financial burden as much as possible we embarked into a process to optimize the recovery of (heavy) non-ferrous metals and precious metals. A process that will be highlighted in this article.

1. Implementing the washing process

During the summer of 2016 the classical (dry) bottom ash treatment plant of at Alkmaar was retrofitted with wet sieving and washing. Basically, the iron separation and crushing remained unchanged (i.e.: remained dry), but before the traditional sieving step to divert the 0–40 coarse fraction over parallel eddy-current separators, an additional wet sieve was installed. This sieve essentially removes all particles smaller than 3–4 mm. This is about half of the mineral fraction of the bottom ash stream.

The effect is that the following (unchanged) set-up for non-ferrous metal (NF) separation (i.e. the dry sieve and the parallel eddy-currents) works far more efficiently.

Table 1: Separation efficiencies of dry and wet treatment

	Dry	Wet
	%	
raw bottom ash input	100.00	100,00
output bottom ash	89.40	77.20
sludge landfilled (dry basis)	–	9.40
non combusted material	0.80	1.50
iron scrap	**6.30**	**6.70**
bulky scrap	**0.40**	**0.40**
NF from granulate	**2.60**	**3.30**
stainless & 25+ NF	**0.50**	**1.10**
HNF from sand	**–**	**0.30**
overall yield metals	**9.80**	**11.85**

These eddy-currents never were designed to remove NF particles smaller than 4 mm, so they benefit from the lower mass throughput, but are not affected by the absence of the fines. In addition, their performance increased even more due to the fact that small sludge and sand particles have been rinsed off from the metal parts which, literally, are freed from ballast and are more easily separated by the existing eddy-currents. This improvement in performance is depicted in Table 1, which compares the yield of several products from raw bottom ash before (dry) and after (wet) the implementation of the washing process.

With respect to the fraction smaller than 4 mm: this is separated into a sludge fraction (0–63 µm) which is to be landfilled and a sand fraction (63 µm – 4 mm). The only metal separation applied to this sand fraction is a density separator which essentially removes only heavy non ferrous metal (HNF) particles. This is the HNF yield mentioned in the lower part of Table 1.

The overall mass balance which has been established (averaged) in the timeframe mid 2016 – mid 2018 is represented in Figure 2. Note that this is the raw balance in metric tons per year and does not denote purity of metal fractions and/or humidity of the wet sludge fraction.

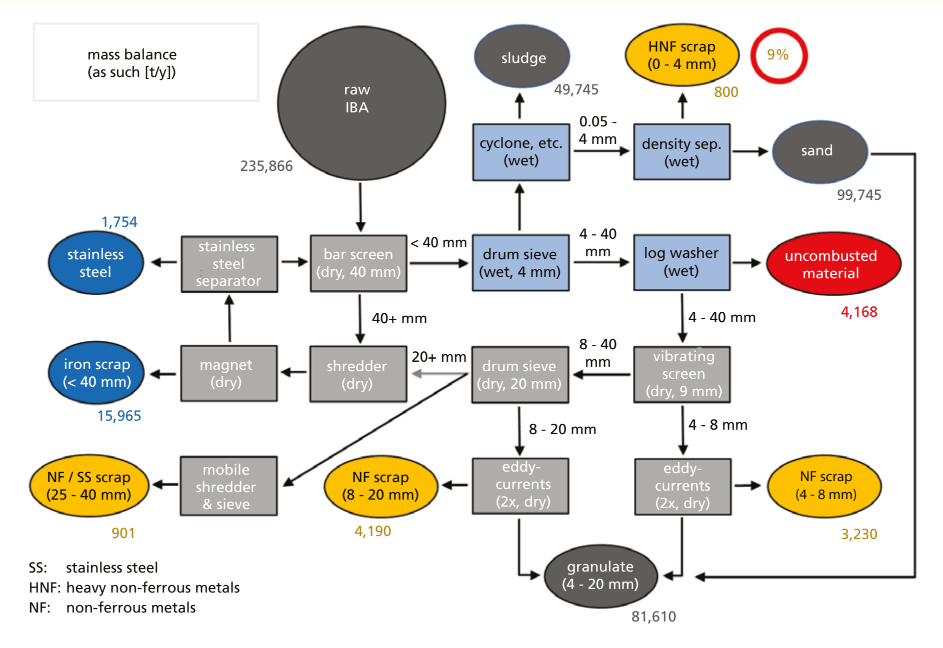

Figure 2: Overall mass balance wet treatment

Also we changed the stainless-steel (SS) recovery in the course of these two years of operation. The current operation for this is a mobile shredder which crushes all the 20+ fraction, that normally was recycled to the stationary shredder, every two weeks. This way we improved the recovery of stainless steel since particles of stainless steel that are crushed to 20 mm or smaller were not recovered in our installation.

2. Focus of classically obtained heavy non-ferrous metals and its composition

Besides the benefits of having a wet treatment process and the subsequent enhanced recovery of non-ferrous metals we embarked on a systematic analysis of the composition of the classical NF mix that is typically produced by the eddy-current separators.

The normal procedure is to send the mixture to a sink-float operator who basically separates this mixture into an aluminium fraction (LNF = light non-ferrous metals), a heavy non-ferrous fraction (HNF) and a residue that resembles bottom ash. The latter fraction is delivered back to us and fed into the treatment installation, similar to raw bottom ash. This way the disposal costs for this residue fraction can be diminished.

In general, the revenues for the non-ferrous mixture which is shipped to the sink float company is reported as a lump sum price for LNF and HNF separately. With respect to the latter fraction normally no specification is given for precious metals (neither composition, nor price). In some cases the sink float company separates jewellery by handpicking out of the fraction > 12 mm of the HNF and reports the yields of gold and silver. In most cases, however, the operator of the eddy-current (and shipper of the resulting non-ferrous mixture) has no clue of the precious metal content of the classical non-ferrous mixture. The effect is not only that the price setting for the HNF fraction in the non-ferrous mix might not be optimal, but also the operator of the eddy-current separator is deprived of valuable information for optimization the settings of the eddy-current apparatus.

To shed some light on this issue, we followed the approach which is schematically visualized in Figure 3. Note that this scheme mentions non-ferrous mixture obtained by the eddy-current operator, but actually we produce a 4–8 mm fraction and 8–20 mm fraction since we have a parallel eddy-current setup.

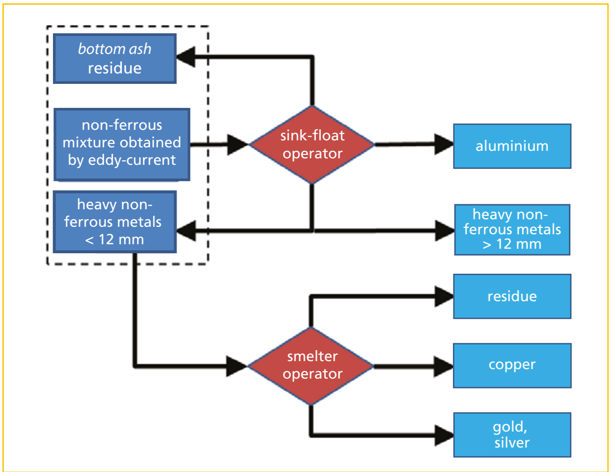

Figure 3:

Approach to shed light on HNF (heavy non ferrous metals) composition

So, basically we take back the fine fraction (< 12 mm) of the HNF from the sink float operator and ship this – either directly or not – to a smelter operator. They normally report levels of copper, residue and precious metals. Of the latter gold and silver are common, and, depending on the levels, also sporadically concentrations of platinum and palladium are reported. Of the other non-precious metals sometimes levels of lead are mentioned.

Over the reported period (mid 2016 – mid 2018) we gathered information from sink float companies and smelters of, in total 37, batches of HNF < 12 mm as produced by sink float operators given the non-ferrous mixture we sent them. The results of the 8-20 mm non-ferrous mixture that is obtained from one (larger coarse fraction) of the parallel eddy-current stream are summarized in Figures 4. Note that, naturally, this mixture contains only a small fraction of < 12 mm HNF. So only a limited amount of the HNF is subsequently sent to a smelter and analysed for precious metals.

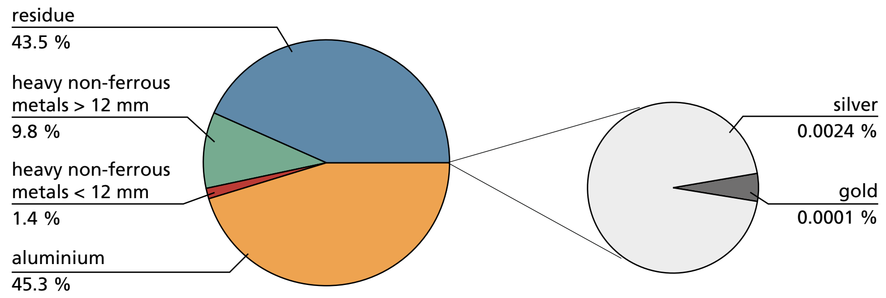

Figure 4: Composition of 8–20 mm non-ferrous mixture

Likewise the results for the finer (4–8 mm) non-ferrous mixture, obtained by the other parallel eddy-current apparatus contains more HNF < 12 mm.

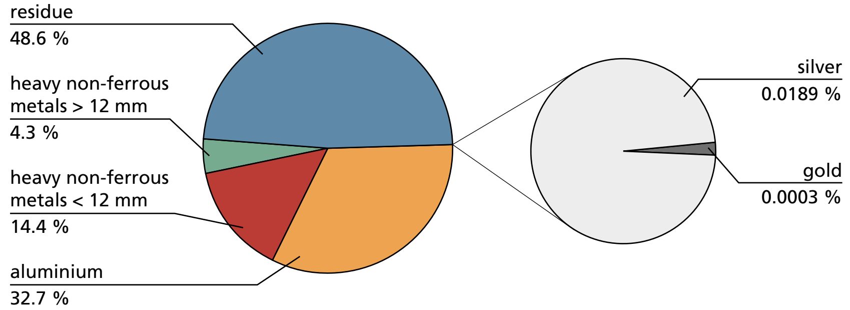

Figure 5: Composition of 4–8 mm non-ferrous mixture

So, these figures teach us that the amount of gold in the 4–8 mm non-ferrous product obtained by one parallel line of eddy-current separators is threefold richer than that of the other (8–20 mm) line. Care should be taken with this result, since we did not analyse the fraction > 12 mm of HNF and we probably miss a good part of the gold and silver in / as jewellery.

Finally, it is worth mentioning that we ship our non-ferrous mixture to 4-6 different sink float companies. By doing so we get a fairly good picture of the benchmark of sink floaters. Also, for the HNF analyses we use 3–6 different smelters to ship the material to. We learned that some of these companies report consistently different concentrations of HNF and also use different calculations of the value represented by that HNF. So by carefully selecting companies for the offtake of HNF optimal financial revenues can be obtained.

3. Heavy non-ferrous metals from sand

The wet nature of bottom ash washing, in combination with a separation of the bottom ash in three fractions (sludge, sand, granulate), makes it possible to apply a basic wet density separation on the sand fraction.

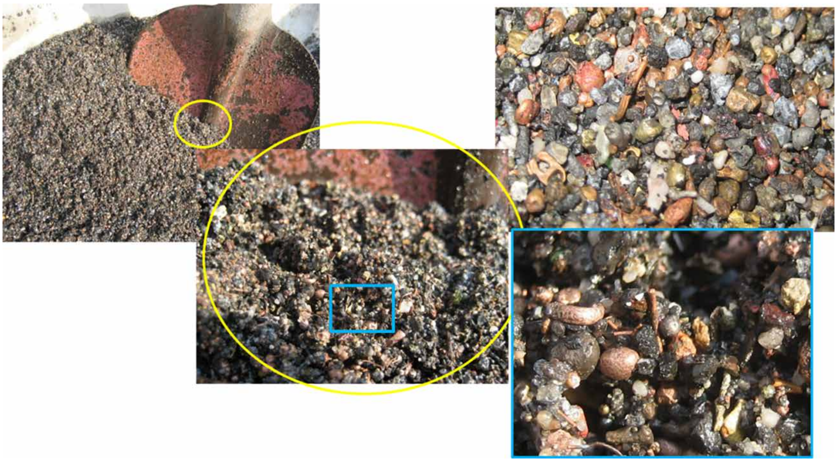

Figure 6: Impression of the heavy non-ferrous metals mixture obtained by density separation

By applying this technology we implicitly refrain from capturing LNF (presumably predominantly aluminium). In the future we consider applying eddy-current technology to recover LNF, but we assume for now that in this wet environment with much electro chemistry noticeable active (hydrogen formation!), much of the aluminium will be oxidised. The financial yield of this LNF stream will be low in our view.

With respect to the density separator: it is not easy to get this operational in the sense that a constant and consistent mixture is obtained. This mixture, currently some 800 metric tons annually, is sent directly to smelters. The final analysis of the smelter is typically reported 2–6 months (!) after delivery, making it virtually impossible to use these data (as feedback) to obtain operational excellence of the density separator. Surely much room for optimisation still exists for this part of our metal recovery results. But the results so far (based on 45 different batches analysed) are very encouraging. Figure 7 gives an insight in the average composition of the HNF mixture we obtained.

Note that this material contains some 50 ppm of gold and 900 ppm of silver, so the precious metals contribute heavily in the financial yield of this stream. In general, the gold alone contributes for 50 % of the value of this HNF mixture. Silver contributes for 15 % of its value and the remaining 35 % is accounted for by copper.

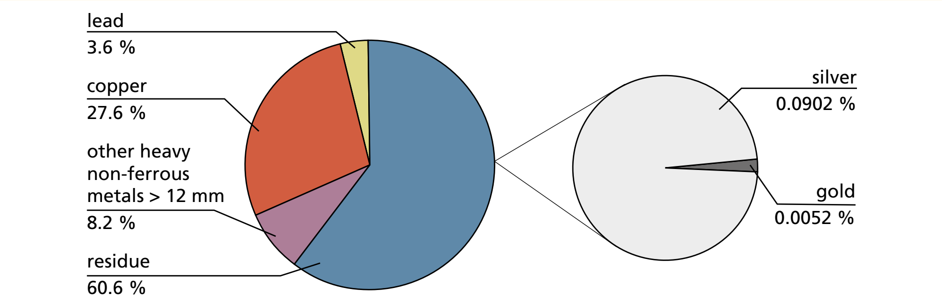

Figure 7: Composition of heavy non-ferrous metals (HNF) < 4 mm obtained from sand

4. Overall Mass Balances

Similar to Figure 2, we are now able to depict the yield of LNF as well as HNF over the various outputs of our wet bottom ash treatment plant. Again, we condensed the results of two year operation and present it as an annual average. This is visualised in Figure 8. The data therein represent the pure metals, i.e.: we used the reported HNF and LNF concentrations in the mixtures we shipped to either sink floaters and/or smelters to calculate these figures.

The most striking outcome of Figure 8 is probably the importance of the density separator. From Figure 2 we already learned that this – for bottom ash – innovative technology represents 9 % of the raw metal mixtures recovered. But in terms of pure HNF recovered, this material stream represents 19 % of all the HNF accounted for.

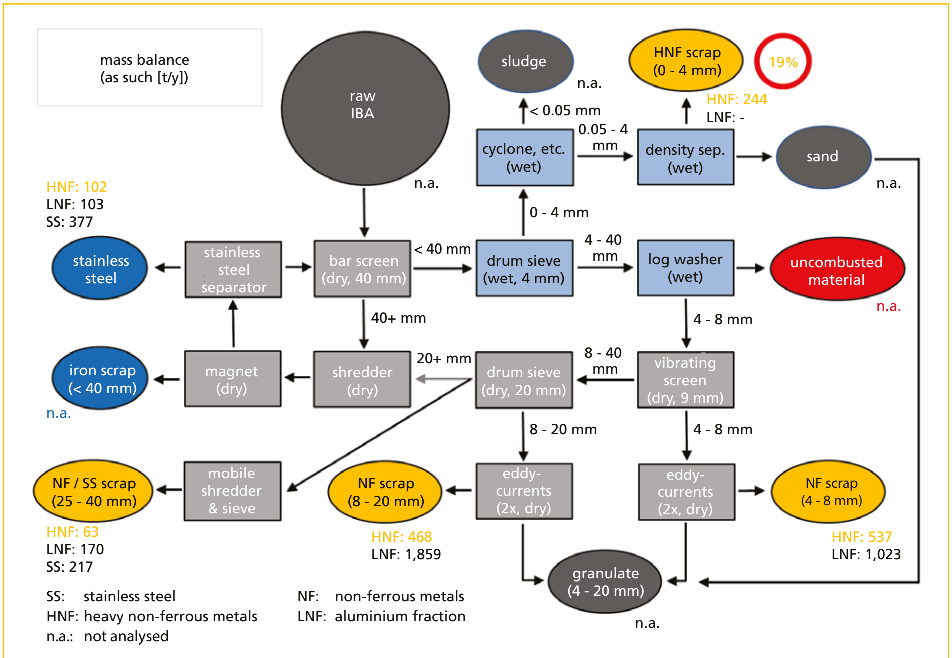

Figure 8: Overall mass balance pure light (LNF) and heavy (HNF) non-ferrous metals

With respect to the recovered and accounted precious metals a similar scheme can be composed (Figure 9).

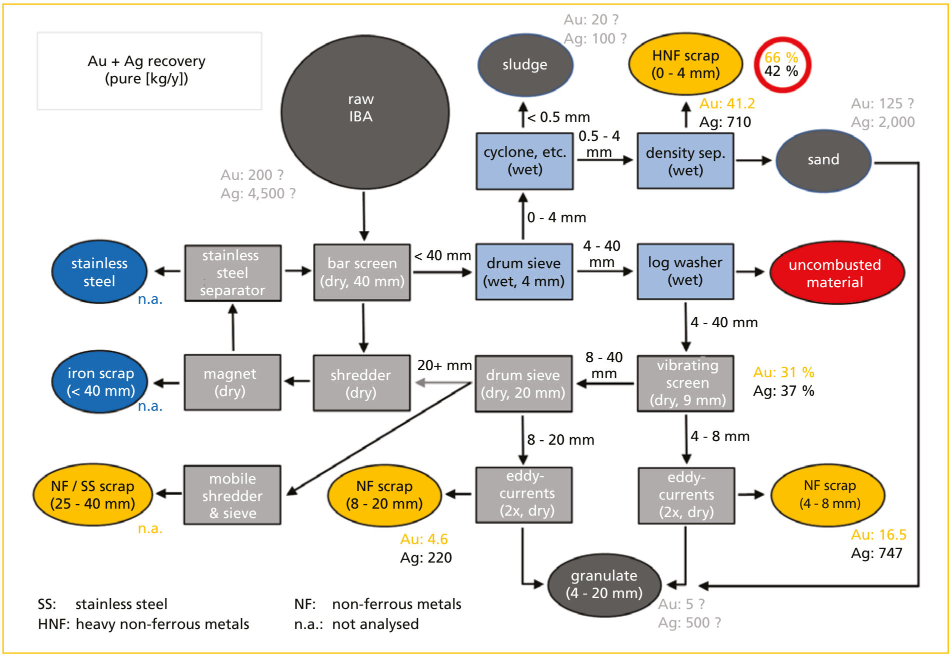

Figure 9: Overall mass balance pure gold and silver

Note that the importance of the density separator is overwhelming in the balance. Not less than 66 % of the gold, and 42 % of the silver, that is accounted for is obtained from the sand of MSWI bottom ash.

Based on information derived from this article as well as inside information within the Dutch Waste Management Association, we have made an attempt to assess the amount of gold and silver potentially present in raw bottom ash. This is done in Figure 9. The grey figures with an added question mark are estimates of the total composition of the products from MSWI bottom ash (granulate, sand, sludge). If we add these numbers with the amounts of gold and silver that have been accounted for in this article we and up with the guestimate that perhaps 200 kg gold and 4.5 metric tons of silver is present in the bottom ash that we treat annually in Alkmaar.

5. Source of precious metals

We already stated that given the particle size of the non-ferrous mixtures we had analysed (< 12 mm), jewellery cannot be an important source of gold and silver in this study. Our interpretation of the data is that electronics are the predominant source of these precious metals present in MSWI bottom ash. We find evidence of this assumption in the ratio of HNF (predominately copper) versus gold or silver. We have analysed values of HNF and precious metals in 0–4 mm, 4–8 mm and 8–20 mm coarse fractions of non-ferrous mixtures. If we bluntly average these ranges to 2, 6 and 14 mm the following Figure 10 can be composed.

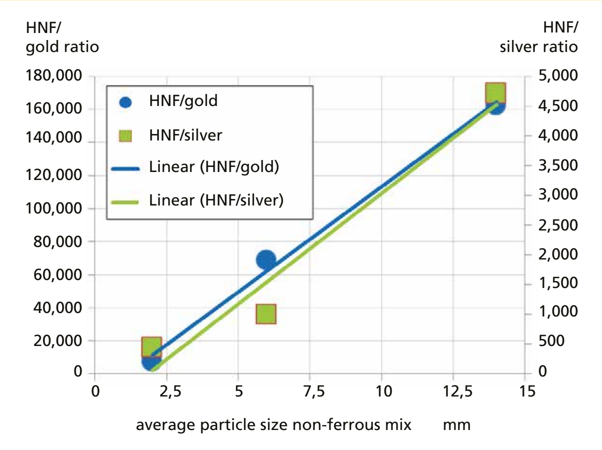

Figure 10:

HNF/gold and HNF/silver ratio as function of particle size

Apparently the precious metals are far more abundant in the fine non-ferrous fractions. This may have two causes.

- electronics (gold plated connectors etc.) in waste tend to end up in fine particle range and
- precious metals are less prone to oxidation than non-ferrous in general, a property that is more important the smaller the particles become.

6. Conclusions

Apart from the obvious financial benefits of recovering as much as possible metals from MSWI bottom ash, we can conclude that bottom ash is an ever increasing source of recoverable metals. We benefit from the fact that waste combustion is chemically speaking a concentration step for incombustibles. Normally this is seen as a drawback in terms of heavy metal (leachable) content. But as far as the metallic fraction of these heavy metals is concerned it is a benefit, since recovery of them is financially more worthwhile with increasing content.

Gold recovery is the first to be worthwhile. Not only because of its exceptionally high value, but also due to the fact that is does not oxidise. This property preserves its (metallic) value and has as side effect that the density of gold remains high (the oxides of heavy metals are less dense than the metallic state) which makes it relative easy to recover them using density separation.

Based on our data and a guestimate based on earlier (not published) data of the Dutch Waste Management Organisation, we guestimate that raw bottom contains roughly 1 ppm of gold and 20 ppm of silver. We are now able to recover roughly one third of that amount.

We argued that the predominant source of these common precious metals are electronics.

7. References

[1] Ministerie Infrastructuur en Milieu en Vereniging Afvalbedrijven: Green Deal Verduurzam nuttige toepassing AEC-bodemas; Den Haag, 7 maart 2012

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