Obtainable Residual Carbon Content in Slags and Ashes from Waste Incineration Systems

Part II: Loss on Ignition and Residual Carbon in Ashes from Municipal Waste Incinerator Plants (MSWIP) and in Slags from Hazardous Waste Incinerator Plants (HWIP)

The following Part II continues Part I of this work, already published in VGB Kraftwerkstechnik/PowerTech 9/2000.

Loss on Ignition and Carbon Content of Incineration Residues

The loss on ignition and the carbon content described in the Sections below: "MSWIP Grate Slag and Sewage Sludge Ash From a Multiple Hearth Furnace", and "HWIP Rotary Kiln Slag", were all determined using finely ground samples – as provided for in the draft of the European standard [21]. Inclusions of residual coke must be exposed by fine-grinding, since otherwise the measurements lead to arbitrary results – a claim which has often been made with regard to loss on ignition, for example. Only finely ground slag samples, especially in the case of high levels of residual carbon, can give reasonable, reliable results (Figure 9). Sample exposure by drying and grinding requires a great deal of effort, but is unavoidable.

MSWIP Grate Slag and Sewage Sludge Ash From a Multiple Hearth Furnace

VGB [22] gave the authors access to the individual data (LOI, TIC, TOC, BOC) on their extensive inter-laboratory test [3] for which grate slags from three MSWIPs were used, in order to enable the authors to obtain a well-founded comparison with rotary kiln slag and sewage sludge ash following a multiple hearth furnace (see Section below). In order to recognize correspondences and differences between grate slag and rotary kiln slag, it is necessary to make the effort to view every parameter – initially on the residues from the incineration of municipal waste and sewage sludge:

Figure 10 shows the TOC and the LOI of grate slag. Values have also been added which show sewage sludge ash from the BAYER multiple hearth furnace. The industrial sewage sludge incinerated in the multiple hearth furnace is (prior to mechanical dewatering) a lime-conditioned mixed sludge [17].

It is immediately clear that the assignment of "TOC ≤ 3 % or LOI ≤ 5 %" in the case of grate slag and sewage sludge ash is appropriate. The Technical Code on Waste apparently is orientated on these types of – in the sense of lime burning "mildly burned" – incineration residues [18]: Extremely high bed temperatures (>> 850 °C) apparently do not occur during the passage through a grate incinerator or multiple hearth furnace, which means that carbonates and hydroxides are not rendered inert. As a result, the burned lime (CaO) remains reactive and can therefore hydrate to form $Ca(OH)_2$ in its subsequent passage through the wet slag extractor in the MSWIP or during wetting in the ash conditioning stage downstream of the multiple hearth furnace.

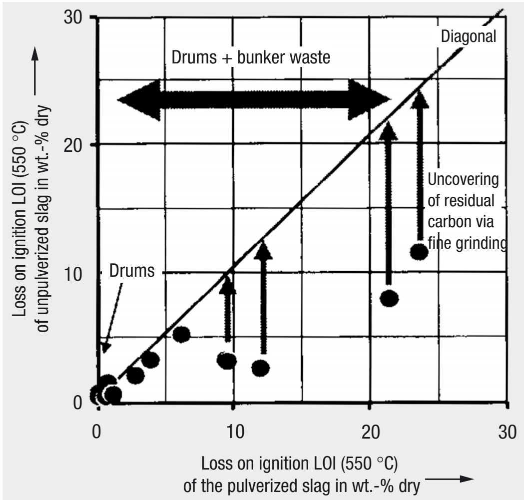

Figure 9. Loss on ignition on coarse and finely ground rotary kiln slag from a rotary kiln at BAYER AG (experimental).

To ensure that the "mild $CaCO_3$-burning temperature" of 850 °C" is not greatly exceeded in grate incinerators and multiple hearth furnaces, it has also been proven that the TIC content (or more precisely: C_{carb} content) > 0, Figure 11.

Figure 12 shows the so-called BOC which was determined according to [3], i.e. the actual organically bound carbon C_{org}, in comparison to the so-called TOC = BOC + C_{el}. The arching curve shown runs proportionally to $(TOC/\%)^{2/3}$ and is a freely devised speculative "BOC envelope curve". The difference to the diagonal in Figure 12 describes the content of elementary carbon C_{el} for every monitoring point. The special attraction of this BOC envelope curve concerns not only the daring speculation, but rather the impressive fact (proven in the Section on rotary kiln slags below) that this curve showing the

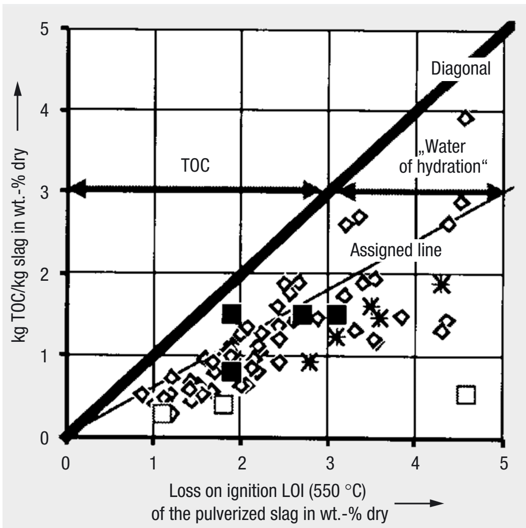

Figure 10. TOC and loss on ignition of grate slag from three MSWIPs as well as (lime conditioned) sewage sludge ash following a multiple hearth furnace (black squares).

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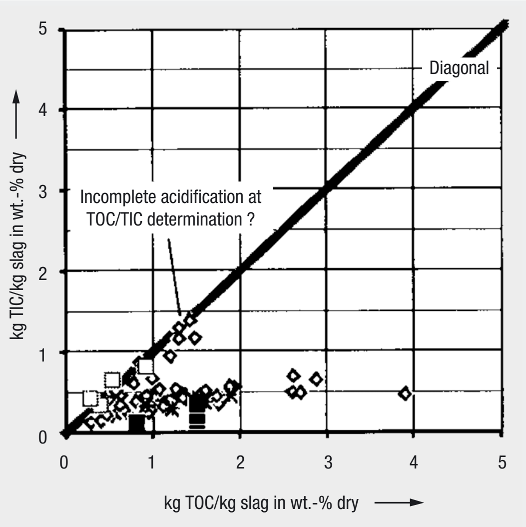

Figure 11. So-called TIC and so-called TOC of grate slag from three MSWIPs as well as of sewage sludge ash following a multiple hearth furnace (black squares).

BOC content of MSWIP grate slag also encompasses the BOC content of HWIP rotary kiln slag.[4]

HWIP Rotary Kiln Slag:

Residues From Incineration of Hazardous Waste

Figure 13 again compares the so-called TOC and LOI – but in this case for HSWIP-rotary kiln slag. The points collected in the area LOI < 5 % are shown in an enlarged window to be easily discernible. In contrast to Figure 10 for grate slag and the sewage sludge ash from the multiple hearth furnace, a considerable correspondence between the so-called TOC and LOI can be seen in the rotary kiln slag in Figure 13. It is possible to explain this as follows: due to the higher temperatures in the rotary kiln this slag is rendered inert in the sense of lime burning. This means that the rotary kiln slag can no longer be hydrated as it passes through the wet slag extractor. For this reason the LOI is quite a precise measure of the so-called TOC in rotary kiln slag, and vice versa.

In contrast to the grate slag in Figure 10, rotary kiln slag is apparently almost fully deacidified as a result of the higher "burning temperatures". This means that their so-called TIC content (more precisely: C_{carb} content) is virtually zero (Figure 14).

In Figure 15 finally, the BOC from rotary kiln slag from a total of five rotary kiln incinerators is compared to the so-called TOC: the BOC, i.e. the content of actual organically bound carbon (Figure 12), is also entirely ≤ 3 % for all rotary kiln slag, and is essentially ≤ 2 %.

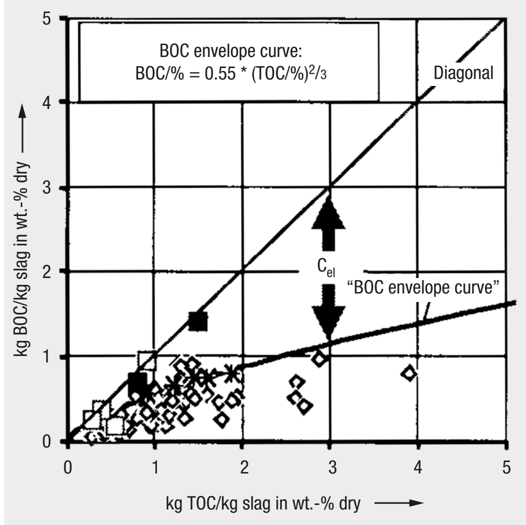

Figure 12. Biological oxidizable carbon (BOC) and so-called TOC of grate slag from three MSWIPs as well as of sewage sludge ash following a multiple hearth furnace (black squares).

In this case as well the points collected in the lower LOI-range < 5 % are shown in an enlarged window. The curve shown here again is the former speculative "BOC envelope curve" which encompassed the BOC content of grate slag in the range of a comparatively low carbon level (Figure 12).

Comparison of Slag and Ash From Various Waste Incineration Plants

The requirement for incineration residues as specified by the Technical Code on Waste, namely the maintenance of a percentage of organic matter ≤ 3 % is met by all MSWIP grate slag, the sewage sludge ash from the multiple hearth furnace (Figure 12), as well as all HWIP rotary kiln slag (Figure 15), regardless of their residual carbon content, i.e. independent of the so-called TOC or LOI.

The comparison from the perspective of the residual organic content (BOC) also showed that requiring very high temperatures, i.e. the discharge of highly liquid slag from rotary kiln incinerators cannot be objectively supported by disposal necessities. A liquefication of all slag is known to cause considerable wear of the expensive refractory lining (reducing its service life). Objectively speaking, very high kiln temperatures are unnecessary as in many other cases (e.g. 1200 °C in the secondary combustion chamber for the purpose of destroying dioxins and furans).

Summary and Outlook

Fluctuations in the residual carbon content from slag from MSWIPs and especially HWIPs are unavoidable, unless the incinerators, especially the hazardous waste incinerators, are not operated at "underload" conditions. Slag from grate incinerators (municipal waste), rotary kilns (hazardous waste) and sewage sludge ash from a multiple hearth furnace showed, however, that the critical content of actual residual organic substances, i.e. the BOC content of all of these incineration residues is consistently ≤ 2 wt.-% dry (wf.) to a maximum of ≤ 3 wt.-% dry (wf.), virtually independent of the total residual carbon content. This result is so convincing that it would be possible to limit the control analyses of the slag with respect to LOI, so-called TOC, TIC and BOC (laboratory expenses) in the case of responsible incineration.

The distinguishing viewpoints with special consideration of the elementary carbon C_{el} as part of the actual TIC and not of the TOC, was accepted in 1997 by the BMU (German Federal Ministry for the Environment) which, with the "European Technical Code on Municipal Solid Waste", recommended the following to the EC commission in charge as the requirement for the loss on ignition of municipal solid waste and its incineration residues:

LOI (minus inorganic volatile matter such as hydroxide water and minus C_{el}) ≤ 3 %.

This viewpoint was integrated in the landfill permit of the BAYER disposal center at Leverkusen-Bürrig already in 1997.

In Spring of 1998 a technical discussion took place on a major scale at the Landesumweltamt in the German federal state of North Rhine-Westphalia with regard to the European standard draft [21] on the TOC regulation in

[4] Note on the "BOC envelope curve" according to Vosteen in Figure 12: If one is willing to make such an assumption, it would be possible to suppose that after pyrolysis the C_{fix} as the unvolatized part of combustibles is remaining in the bulk bed in the form of many finely distributed "equally sized C_{fix} particles" whose grain size decreases as the burn-up progresses. The decrease in the carbon content would be accompanied by a corresponding reduction of the external surface of these C_{fix} particles. In this way the carbon content at the discharge outlet of the bed (slag) would be proportional to a) the number of C_{fix} particles and b) their final grain mass; in the case of spherial form the particle diameter would therefore be proportional to the cubed root of the TOC content. Since the surface area goes with the square root of the particle diameter, the external particle surface could then be proportional to the TOC content ^2/3 in total. Traces of high-boiling BOC compounds could be reabsorbed on this surface, e.g. by "local overcooling" at the slag discharge outlet.

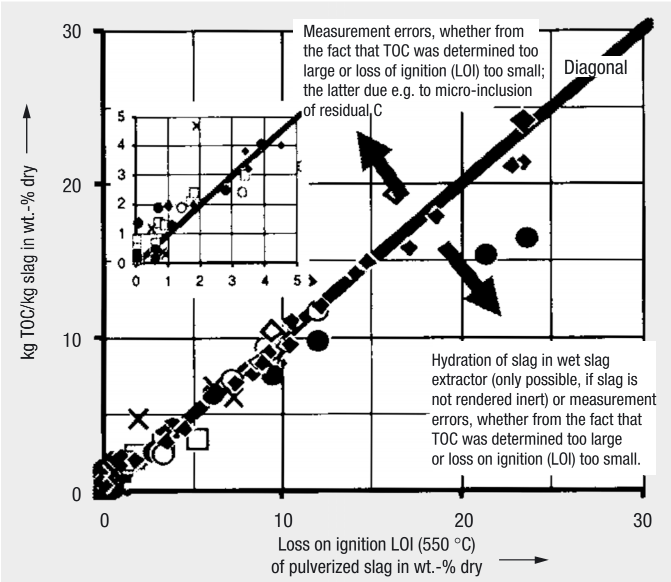

Figure 13. So-called TOC and loss on ignition of pulverized rotary kiln slag from four HWIPs operated by BAYER AG and from one public HWIP (data from normal operation and high-capacity experiments in 1996/1997).

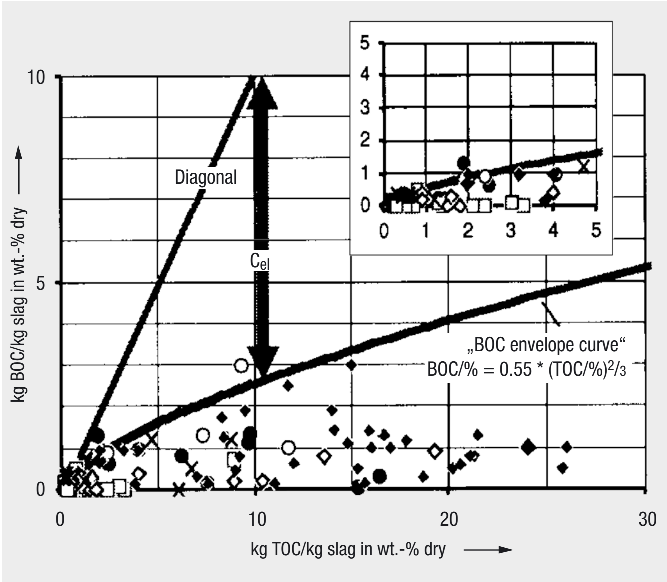

Figure 15. BOC and so-called TOC of pulverized rotary kiln slag from four HWIPs operated by BAYER AG and from one public HWIP (data from normal operation and high-capacity experiments in 1996/1997).

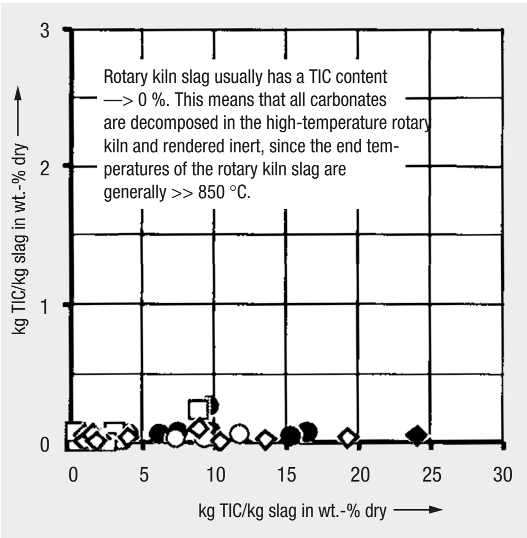

Figure 14. So-called TIC and TOC of pulverized rotary kiln slag from four HWIPs operated by BAYER AG and from one public HWIP (data from normal operation and high-capacity experiments in 1996/1997).

solid materials and incineration residues. BAYER reported on the results of this work [23] as well as on the current testing of an alternative measurement method with the LECO system [24]. At this meeting it was determined by mutual agreement that C_{el} must be subtracted in the TOC or LOI regulation.

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