ESA PROTOCOL FOR THE ASSESSMENT OF HAZARD STATUS OF INCINERATOR BOTTOM ASH – EXPLANATORY NOTE

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1. Background

Incinerator Bottom Ash (IBA) is a heterogeneous material consisting of ash, metal items and inert components such as glass. It can be classified as non-hazardous or hazardous waste depending on the outcome of an assessment against 15 hazard properties. The hazard assessment methodology applicable to IBA is detailed in the Environment Agency's Guidance WM2 (2011)[1].

Data collated from the UK EfW facilities for the first six months of monitoring using the ESA protocol suggests that at the large scale of overall production the gross characteristics of IBA is essentially consistent from day to day,. In practice the large number of waste input loads to the plant in any one day would serve to mitigate any variability between the input loads. At the very small 'gram' scale at which it is tested in the laboratory it can be more variable. Given the potential for processed IBA to be used as a substitute for virgin aggregate, with an associated environmental benefit, it is necessary to ensure that a testing regime is in place which is appropriate to the level of risk involved in aggregate substitution.

In 2010 the Environmental Services Association (ESA) published a 'Sampling and Testing Protocol' to support the assessment of hazard status for IBA. The Protocol was developed with the support of the Environment Agency and was approved by the Agency in December 2010.

This short non-technical note has been prepared by WRc, the authors of the Sampling Protocol. It outlines the reasoning behind the approach laid out in the protocol, and should be read in conjunction with it.

2. Overview of the Sampling Protocol

The protocol sets out sampling and testing requirements for IBA to evaluate hazard status. Detailed guidance is provided on sample collection, sample preparation for testing and minimum analytical testing suites. Use of the protocol is intended to ensure a consistent approach to assessing IBA across the sector. The protocol can be used by each plant operator to develop a site-specific plan to allow for operational and site conditions at each plant. The sampling frequency requirements of this voluntary protocol are more onerous (24 samples per annum) than the standard quarterly compliance monitoring required by the Environmental Permit for each plant (four samples per annum). This increase provides a considerable step change in monitoring and is consistent with other manufacturing sectors and waste treatment plant. Samples taken collectively and prepared in accordance with the protocol should be representative of the IBA waste stream from that plant.

The approach provided in the protocol for classifying the hazard status of IBA from a plant adopts a 90th percentile compliance standard (rather than an average or absolute maximum standard). The percentile standard approach focuses on regulating the performance of the process *across a period of time*, accepting that a limited number of sample exceedances are to be expected due to normal operating variability and sample heterogeneity. The percentile standard must be breached beyond reasonable doubt before the IBA from a plant is declared as hazardous, quantified in this case as a less than 5% chance of falsely declaring non-compliance. This approach, and in particular a 12 month assessment period is used extensively in the wastewater sector (e.g. effluent discharge consents[2]) and other waste sectors to control processes within prescribed limits, whilst making allowance for occasional exceedances due to inherent sample heterogeneity or process variability. This regime is recognised by the Environment Agency as providing appropriate environmental protection.

[1] Environment Agency Hazardous Waste: Interpretation of the definition and classification of hazardous waste (2nd edition v2.3)

[2] The Urban Waste Water Treatment (England and Wales) Regulations (1994) http://www.legislation.gov.uk/uksi/1994/2841/made

3. Sampling

The protocol contains guidance on how to develop a plant-specific sampling plan which ensures that sufficient samples are taken to:

- provide an accurate snapshot of the quality of the ash on the selected day of sampling;
- provide a valid estimate of IBA quality that averages out small-scale variability; and
- be representative of the IBA being produced at the plant across a year.

The prescribed sampling regime requires a morning and an afternoon sample to be collected on a pre-scheduled, randomly chosen day each month, providing 24 separate measures of IBA quality each year.
This is an example of a stratified random approach as detailed in PD CEN/TR 153101:2006[3]. The sampling day is not fixed to specific times or days. Different days of the week are randomly selected for sampling within the known operating schedule for that month by the operator. Undertaking this ahead of schedule ensures that samples are representative of the ash being generated by the plant over time rather than the operator being allowed to choose 'good' days or the results being biased by specific waste inputs that arrive on any given day.

The protocol now requires that a randomly selected load or time period is identified within each 12 hour period of the chosen sampling day, although for health and safety considerations sampling of the ash produced in the chosen time period may be within the normal working day. This exercise generates two composite samples that are used to provide a measure of within-day variation in IBA composition. The regime as a whole is designed to provide a good measure of the quality of ash being produced at the plant over the annual monitoring period.

Each composite sample is collected from 20 incremental (spot) samples taken from the ash conveyor, ash pit, or during transfer from the ash pit to the lorry. These must be collected from a quantity of IBA that is equivalent to a vehicle load of IBA (commonly 20 to 40 tonnes) as it would leave the site for recycling or disposal. These samples should be taken as swipe samples from the full width of the conveyor as it transports the IBA to the collection pit or samples from fresh IBA in the collection pit using a mechanical grab or excavator bucket (full details are provided in Section 2.5 of the ESA Sampling and Testing Protocol). This is in line with the procedures laid out in PD CEN/TR 15310-2:2006.

The incremental samples are combined to produce a single circa 200kg heap of IBA which is representative of a vehicle load of IBA leaving the site. The 200 kg heap is reduced down to a circa 40 to 50 kg sample suitable for analysis by a procedure based on the method of coning and quartering detailed in British Standard BS EN 932[4]. This is done by using a hand shovel to transfer the material into a new cone-shaped pile three times, in such a way as to give thorough mixing. The resulting pile is then divided into four roughly equal segments and two segments are discarded. This exercise will generate a pile of approximately 100 kg and the whole process is repeated to give a final circa 40 to 50 kg sample that is sent to an analytical facility for testing.

The entire sample is put into a number of suitable sample containers, labelled with the plant, date and time of collection prior to delivery to the analytical facility for preparation and testing. Fixing a common scale of sampling i.e ' a load' for all the EfW facilities in the UK means that we can compare the test data at both an individual plant level and combine the data from a number of plants to provide information on the quality of IBA across the UK as a whole and over time.

4. Sample Analysis

The entire sample submitted to the analytical facility is dried and ground in preparation for testing (full details are provided in the ESA Sampling and Testing Protocol).

[3] PD CEN 15310-1:2006 Waste – Technical Report on Sampling – Part 1: Information on the selection and application of a basic statistical approach to sampling under various conditions.

[4] BS EN 932 Tests for general properties of aggregates: Part 1 Methods of Sampling.

Once the sample has been finely ground it is subjected to a range of analytical tests to determine the concentrations of key metals, and major cations and anions[5] that are relevant to the hazard assessment.

Collection of a large sample at the plant, made up of a large number of increments, helps to ensure that the mean of any test results is as close as possible to the actual mean concentration of the chemical compounds of interest in the overall load.

The concentration of metal compounds in IBA is highly variable, even in a finely ground powder. Examination of the variability in metal concentrations in historic IBA monitoring data identified that 11 separate replicate tests are required specifically for metal analyses which exhibit the most variability to generate a mean result that provides an adequate representation of the mean concentration of each metal.

5. Classification Assessment Procedure

The protocol requires the operator to consider results over a one year period when classifying IBA. The procedure for each month's samples comprises two steps:

1. The results for each sample are compared to hazardous waste threshold values from WM2 and action taken if they are exceeded by a factor of four.
2. The results from each set of monthly samples over the twelve month period are combined and a hazardous waste assessment performed by a responsible person at the plant. The IBA is classified accordingly. This data is available for review by the Environment Agency.

The following sections explain these two steps in more detail.

5.1 Assessment of results from individual loads

The hazardous waste assessment is based on taking a series of representative samples from randomly selected loads to provide an accurate classification of the entire IBA waste stream from a plant. It is not designed to provide a hazardous waste classification for individual loads, although action is taken if any sample exceeds the WM2 threshold values by a factor of four.

The hazard assessment will have highlighted which of the many compounds that are hazardous at concentrations above relevant thresholds might be present in IBA.

A sample is judged to be satisfactory if the test sample result is below the relevant WM2 hazard threshold limit value, and is judged to be in exceedance if it equals or exceeds the limit value. This is termed a face value test because the mean result is compared directly with the limit value. No allowance is made for the uncertainty in the estimated mean concentration because the test result is derived from 20 incremental grab samples and results from 11 analytical sub-samples and so the probability of inaccurately defining a sample in terms of WM2 compliance is very low.

5.2 Hazardous assessment and classification of IBA from the plant

The second step in the assessment scheme is to use the standards defined in the protocol to judge whether or not the plant's IBA waste stream, as represented by the samples, should be deemed hazardous or non-hazardous.

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[5] e.g. As, Al, Ba, Cd, Co, Cr, Cr, Cr(VI), Cu, Fe, Hg, Mn, Mo, Ni, Pb, V, Zn, Na, K, Ca, Mg, Li, Br, F, SO_4, SO_3, CO_3, NH_3, CN^-.

The classification procedure in the protocol, as approved by the Environment Agency, is based on a 90th percentile (90%ile) standard. This means that for IBA to be non-hazardous no more than 10% of the samples should exceed the threshold concentration. The Protocol requires the plant operator to judge compliance with the 90th percentile by counting the number of samples that exceed the WM2 thresholds.

Whilst the large scale characteristics of IBA are consistent from day to day at the small 'gram' scale relevant to testing it is still variable. The '6 out of 24' approach is needed to ensure that random variability at the test scale does not cause false fails and that are not a true reflection of the quality of the IBA at the scale of production.

Although, 10% equates to 2.4 exceedances in every 24 samples, even a compliant IBA process may experience as many as 6 exceedances over the year due to random sampling variation. For that reason up to 6 exceedances are allowed in order to demonstrate beyond reasonable doubt that the IBA from a plant is hazardous and to limit to 5% the chance of IBA being mistakenly classified as hazardous waste (i.e. a 'false' fail). Following this approach, if six or fewer of the 24 samples in the first year of monitoring are classed as exceedances, the IBA is classified as non-hazardous. If seven or more of the 24 samples exceed any hazard threshold in the initial twelve month period, the IBA must be classified as hazardous from that point on. The IBA is classified as hazardous on the 7th exceedance, even if this occurs before all twenty-four samples have been taken. Action is then required by the plant to identify the underlying cause of the deterioration in ash quality and increased monitoring is required until it can be shown that the IBA has consistently improved. The protocol also requires that the plant investigate, and if appropriate take remedial action, with respect to exceedances that occur even if there are insufficient to trigger a hazardous classification.

This provides a greater margin of safety than using a mean concentration, or 50th percentile, where approximately half of the samples (12 of 24) would be at or above the threshold concentration.

Percentile compliance standards differ from absolute standards (which allow no exceedances of the limit value) in that they focus on the regulating the performance of the process across a period of time, accepting that a limited number of sample exceedances are to be expected due to normal operating variability and sample heterogeneity. To provide protection against one-off gross exceedances, the percentile test is supplemented by an additional check which classifies the IBA as hazardous if the mean concentration of any sample from a load is more than four times the limit value (see section 6(b) below).

6. Action Required if a WM2 exceedance Identified

Although variation of results is expected in a heterogeneous waste, the Protocol contains additional safeguards and sets out actions the plant operator should take if there is an abnormal test result on individual samples:

a) **Action in the event of a sample showing limit exceedance:** In the event of a single sample exeedance the operator is required to try and identify a cause. This might include: investigating plant operating parameters; looking at waste inputs for a potentially anomalous source, checking that the sampling regime was correctly carried out; looking at the analytical data to see whether an extremely high data point has affected the overall mean, all to try and establish a likely cause. If there is no likely explanation then a repeat sample may be needed to establish that this was a random failure due to chance. Where two samples show a limit exceedance this is less likely to be due to chance and this would require immediate repeat sampling (a morning and afternoon sample) in addition to the normal compliance schedule action taken to identify the cause and determine if there is an on-going problem. Repeat sampling is also required where an exceedance is greater than four times a threshold value and in this case the ash would be classed as hazardous until the operator can show otherwise (see b).

b) **Action in the event of an exceedance greater than four times a threshold value:** If the mean concentration of any sample is more than four times a given limit threshold the IBA should be considered hazardous (regardless of how many previous satisfactory or exceedance results have been observed) until the operator can show otherwise. Whilst a percentile compliance scheme provides a good level of protection over a defined time period it does not provide protection against the magnitude of failure and this provision provides that protection.

7. Changes to Sampling Frequency following IBA Classification

The protocol also stipulates changes to sampling frequencies following a classification, which are summarised in a flow-chart within the protocol:

c) **Sampling frequency to be used following a 'hazardous' classification:** The plant operator must take quantifiable measures to improve IBA quality and must continue to sample at a minimum frequency of a pair of samples per month until it can be demonstrated that the IBA is non- hazardous. Only when they have taken appropriate measures, for example excluding an input waste that gave rise to the exceedances, can reassessment be considered. At that point, if the IBA is deemed to be hazardous, twelve samples (two samples on at least six occasions) must be taken at intervals within a period of not less than one month and no greater than six months. If four or fewer of the twelve samples are classed as exceedances, the IBA will be re-classified as non-hazardous and the process is then closely monitored and the monitoring frequency reverts to two samples every month for the next twelve months. If however five or more of the twelve samples are classed as exceedances, the IBA will continue to be classified as hazardous and a further twelve samples must then be taken. The higher frequency of sampling during this period (up to twelve per month) allows operators to minimise the time period over which IBA might be hazardous and is considered reasonable because the representativeness of the sampling is not considered to vary with the length of time over which the sampling is done.

d) **Sampling frequency following a 'non-hazardous' classification:** The protocol currently provides an option to reduce the sampling frequency in the second year where in the first twelve months' testing, the plant has recorded six or fewer exceedances of the hazard threshold limits in WM2 (i.e. it has passed the 90%ile standard). In this instance it is proposed that the operator has demonstrated the plant controls deliver a low risk a lower sampling frequency of two samples once every two months could be considered. Note, if a >4 times exceedance of a threshold limit has been recorded the IBA would be classed as hazardous. Once operating at the lower sampling frequency, previous test results are ignored and no more than four exceedances are permitted in any twelve samples.

After one year using the lower sampling frequency, a rolling assessment is conducted on the previous twelve samples. If there are five or more exceedances of the hazard threshold limits in WM2 in any twelve month period (using twelve assessments per year), the IBA is deemed to be hazardous, otherwise the IBA can be classed as non-hazardous and monitoring can continue at the lower frequency. If substantial changes are made to the operating process or input feedstock two samples should be taken in that month to ensure the quality of the ash has not changed.

Note: At the current time the UK EfW facilities continue to monitor at a frequency of 24 samples per annum and the option to drop to a lower sampling frequency will not be implemented without the agreement of the Environment Agency.