North Yorkshire Waste Action Group Objection to Allerton Waste Recovery Park:

RISKS OF INCINERATOR ASH

December 2011

CONTENTS

SUMMARY

1. Ash comprises **Incinerator Bottom Ash** (**IBA**, collected from the grate - some 20-30% of the weight of the feedstock), **Grate siftings** (the finer particles of the grate ash), **Boiler ash** (from the energy recovery boiler), **Fly ash** (the ash removed prior to the pollution abatement system) and **Air pollution control residues** (containing unspent reagent and the entrained pollutants or reaction products). The collection of these ashes is controlled by the design of the incineration plant; often bottom ash, grate siftings and boiler ash are collected together as are fly ash and APC residues.

2. Fly ash (10-20% of total ash) is more of a potential health hazard than the IBA because it often contains high concentrations of heavy metals such as lead, cadmium, copper and zinc as well as small amounts of dioxins and furans. In the UK it is disposed of in special waste landfills due to its lime content and the concentrations of heavy metals. Its safe disposal usually involves additional waste miles and the need for specialist toxic waste landfill elsewhere. The transport of this material could lead to a traffic accident involving spillage and spread of the ash – the risk is low but the potential impact is high.

3. There is some controversy over whether IBA represents an environmental hazard since pollutants such as heavy metals in the original waste do not burn and are therefore concentrated. Even so, its use in road construction is widespread despite public concern associated with incinerators and their releases. Since it is less hazardous than Fly Ash, it may go to ordinary landfill sites after appropriate testing. Despite the generally positive views of only a few years ago, incinerator operators could have to treat IBA as hazardous waste because of doubts over its ecotoxicity and this could significantly increase costs; this depends on whether or not IBA is seen as ecotoxic; this depends on the view on the difficult to identify zinc and lead compounds and around 40% of IBA could become ecotoxic. However, it can be difficult to determine whether ash exceeded ecotoxicity thresholds and operators are likely to carry on consigning ash as non-hazardous.

4. Leaching of Hazardous and/or toxic materials could take place either from waste prior to it going into the incinerator or from any IBA left out for weathering. Leaching could include hazardous and/or toxic materials present in the rubbish and leachate could enter the local land and groundwater and hence affect people, crops and animals. Leaching from any ash left out to weather should be monitored over a period.

5. Concern over IBA's ecotoxicity dates from October 2005 when the Health and Safety Executive reclassified zinc oxide (a potential compound in ash) as ecotoxic, joining zinc chloride and all lead compounds. Zinc oxide has been given an ecotoxic classification (H14 by R50/53, very toxic to aquatic organisms and may cause long-term effects in the aquatic environment). If tests show that some IBA is ecotoxic, it could all have to be treated to make aggregate, thereby increasing incineration costs. It would also call into question the classification of IBA as '*inactive waste*' by the Treasury. Inactive wastes only pay £2.50 landfill tax per tonne, compared with £40/tonne for 'active' materials.

6. AmeyCespa state that the plant will produce '*an inert bottom ash material*'. The Landfill Directive sets the definition of inert waste:

   "*Waste is considered inert if:*

   1) It does not undergo any significant physical, chemical or biological transformations;

   2) It does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and

   3) Its total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater."

7. IBA does not meet the criteria for being considered an inert waste. IBA is subject to a number of potential health and environmental risks and appears to have caused some actual harm. As there are financial incentives to use it as a replacement for naturally occurring raw materials, it is important that regulation should be strengthened without regard to short-term financial consequences. It is particularly important that testing for and judging the ecotoxicity of IBA should be carried out regularly and independently, as is the practice in the USA.

8. The large amounts of ash from incinerators contribute to the environmental harm they produce. This means that granting planning permission for the EfW (incinerator would These include:

   - The RSS which includes Policy YH1 Overall Approach and Key Spatial Priorities, which recommends (among others) that plans, strategies, investment decisions and programmes should aim to: "*Avoid exacerbating environmental threats to the region and reduce the region's exposure to those threats.*"
   - The Waste Local Plan which includes: *"Policy 4/1 Waste management Proposals - Proposals for waste management facilities* which specifies that they *will be permitted provided that:*

   b. the proposed method and scheme of working would minimise the impact of the proposal;

   c. "there would not be an unacceptable environmental impact";
   g. "the proposed transport links are adequate to serve the development"
   As discussed above, granting planning permission for the EfW (incinerator) would contravene these policies due to the nature of fly ash/APC residues

9. There is a broader policy issue, that of **Sustainable development**. Fly ash and APC residues are classified as hazardous waste. Indeed, incineration is unique among waste management technologies in producing hazardous waste where none existed before. Moreover, IBA contains toxic chemicals and some of it is ecotoxic. Thus incinerator ash is harmful to the environment so the EfW (incinerator) plant at AWRP would not be a sustainable development.

10. Finally, we object to a choice of technology that alone, among waste management options knowingly creates hazardous waste where none existed in the feedstock (municipal solid waste). **As there are cleaner and cheaper waste management options available that also avoid landfill, planning permission for the EfW (incinerator) should be refused.**

1: INTRODUCTION

11. Incinerators produce bottom and fly ash which amount to *30-50% by volume of the original waste* in total (if compacted), and require transportation to landfill sites. While landfill sites are becoming less available, incineration will not solve the landfill problem unless much of the ash is used as an aggregate since it can only reduce the bulk by a third to just under a half.

12. According to a report by AEA Technology[1], there are several types of solid residue arising from the present designs of municipal waste incinerators:

    - **Incinerator Bottom Ash** - the bulk of the ash collected at the first stage of the combustion process from the grate. This can comprise some 20-30% of the weight of the feedstock
    - **Grate siftings** - the portion of the waste and grate ash that passes through gaps in the grate and is characterised by the finer particles of the grate ash. It is typically 0.5% of the feedstock.
    - **Boiler ash** - the ash that is collected from the energy recovery boiler. It is characterised by finer particles due to entrainment and condensed alkali metal salts. It is typically only 0.5% of the feedstock.
    - **Fly ash** - the ash removed prior to the pollution abatement system. It consists of entrained ash particles and thus is of a fine particle size and contains high levels of metals and other pollutants. It is removed from the flue gas by the use of cyclones, electrostatic precipitators or fabric filters either singly or in combination. It is typically 2% of the feedstock mass.
    - **Air pollution control (APC) residues** - These wastes comprise the residues from the systems used to remove the acid gases, micro-organic pollutants, mercury and NOx and consists of unspent reagent (lime, NaOH or activated carbon depending on the pollution abatement system) and the entrained pollutants or the reaction products. Typically the mass of this fraction is about 2% of the feedstock mass.

13. Whilst these ashes and residues are described separately their collection is controlled by the design of the incineration plant. Often bottom ash, grate siftings and boiler ash are collected together and the fly ash and APC residues are also combined. Mixing of the fly ash / APC residues with the grate ash was carried out at some plants. In many countries, including the UK, this practice is now prohibited.

14. Directive 94/904/EC (EC 1994) sets out the definition of hazardous wastes for Europe and this is enshrined in national law in member countries. It requires that wastes containing specified substances and exhibiting hazardous properties are specified as hazardous waste. Wastes may contain the specified substances without exhibiting the hazard properties either through inactivation or low concentration and in this case the waste is not considered hazardous. These regulations imply that whilst fly ash and APC residues are considered as hazardous waste they can be downgraded to non-hazardous waste by treatment to reduce the leaching characteristics. Bottom ash is by and large considered as non-hazardous but is often required to pass a composition or leaching test (or both) to be acceptable for landfill or reuse.

15. Another challenge is the disposal of the ash after combustion. Ash can contain high concentrations of various metals that were present in the original waste. Textile dyes, printing inks, and ceramics, for example, contain the metals lead and cadmium. Separating waste before combustion can solve part of the problem. For instance, because batteries are the largest source of lead and cadmium in the solid waste stream, they should be taken out of the mix and not burned[2]. *The question of what waste separation takes place prior to combustion in a particular incinerator is therefore crucial to the characteristics of the ash from that incinerator.* More generally, the better the pollution control the more toxic the residues will be and the more expensive they will be to deal with[3].

1.1: Features of the AmeyCespa Design

16. Paragraph 1.7.41 of the Planning Statement states that the plant will produce ”*an inert bottom ash material*” (that will be processed on site and sold as aggregate for use in construction products) and an Air Pollution Control Residue (APCR) waste which will be sent to a hazardous waste facility for disposal. Relevant plant features are:

    - Flue Gas Treatment/Air Pollution Control – An integrated air pollution control system will treat all flue gas prior to emission via a 70m tall chimney (as we state elsewhere, we think this is insufficiently tall) intended to keep emission levels within safe and statutory limits. Flue gas residues including fly ash will be transported off site in sealed tankers for disposal at an appropriately licensed facility.

    - An IBA Recycling Facility. The IBA will be removed from the EfW incineration plant by a covered conveyor and discharged into storage bays within the IBA processing building. The ash will be screened, graded and then stored as a secondary aggregate. Thus the IBA derived from the EfW incineration plant will be processed through a plant capable of processing up to 50 tonnes construction aggregates per hour with the intention to sell it for use in “construction products”. Once processed, the stock is stored as a secondary aggregate prior to onward transfer for appropriate reuse applications

17. As is made clear later, we do not believe that the term ‘*an inert bottom ash material’* can justifiably be used.

18. Paragraphs 1.7.57 *et seq* of the Planning Statement give more details of the IBA processing facility. It will be located in a building (25m long x 50m wide x 14.8m high) 56m to the north of the EfW incinerator building, linked by a covered conveyor that transports the IBA for processing to create secondary aggregates. The accompanying storage facility will be approximately 20m by 30m, with a height of 12.3m. IBA will be removed from the EfW incineration plant by enclosed conveyor and discharged under cover within the IBA processing area. Following acceptance checks and quality analysis (not specified here) have been undertaken, the IBA will be processed (screened and graded) within a dedicated building. Once processed, the stock is stored as a secondary aggregate prior to onward transfer for what AmeyCespa call “appropriate reuse applications”.

19. The capacity of the IBA processing facility is 50,000tpa. AmeyCespa say that in 3-4 hours of daily operation the plant will be capable of processing all of the IBA produced at the EfW incinerator. They state that any oversize or reject materials (typically 10% of volume by weight) from the processing facility will be categorised and then sent for reuse, recycling or disposal at an appropriately licensed facility.

20. Paragraphs 1.10.126 *et seq* of the Planning Statement discuss the co-location of the IBA Recycling Facility in the AWRP site. AmeyCespa say that IBA is classified as a non-hazardous waste that can be reprocessed into a recycled aggregate capable of beneficial use as a replacement for primary aggregate. They claim that “*while not classified as a recycled material, the re-processing of IBA has obvious sustainability benefits*”. As set out below, we dispute this claim.

21. We accept that co-locating the IBA recycling facility on the AWRP Site accords with the principles of proximity identified within PPS10 and policy ENV14 of the YHRSS for managing waste where it arises (though having a single site for all North Yorkshire and York waste does not). It is true, as claimed, that co-locating the facility on the same site minimises vehicle movements by avoiding the need to transport the IBA to elsewhere (e.g.an alternative recycling facility). However, we believe that there are cheaper, cleaner alternatives to incineration so this merely recognises that if the EfW (incinerator) plant were by granted planning permission (to which we strongly object) then it makes sense to co-locate the EfW incinerator and IBA processing plant.

2: POLICY CONTEXT

22. The Regional Spatial Strategy (RSS) includes Policy YH1 Overall Approach and Key Spatial Priorities, which recommends (among others) that plans, strategies, investment decisions and programmes should aim to: "*Avoid exacerbating environmental threats to the region and reduce the region's exposure to those threats.*" As other parts of our evidence makes clear, the AWRP proposal, and especially the EfW (incinerator) plant, would go further than merely exacerbating existing environmental threats; it would introduce new ones both through its inappropriate siting and, more especially by the health and environmental risks arising from the EfW (incinerator) plant. A further issue is that it creates hazardous waste (fly ash and air pollution control residues) where none existed before. In addition, IBA is not environmentally inert and some may be ecotoxic (see below)

23. According to AmeyCespa, the Waste Local Plan includes the following relevant saved policies:

"*Policy 4/1 Waste management Proposals - Proposals for waste management facilities will be permitted provided that:*

b. the proposed method and scheme of working would minimise the impact of the proposal; the opposite is true since incineration is the worst technology other than landfill from a global warming standpoint and has more adverse environmental and health impact than any other waste management technology. One of the adverse impacts arises from the hazardous nature of fly ash and APC residues while some IBA is ecotoxic.

c. "there would not be an unacceptable environmental impact"; incineration is the worst technology other than landfill from a global warming standpoint and has greater adverse environmental impact than any other waste management technology. Again, the hazardous nature of fly ash and APC residues and ecotoxicity of some IBA contribute to this.

g. "the proposed transport links are adequate to serve the development"; the issues are around the acceptability of the additional traffic, the need for some additional work on junctions close to the site and the suitability of North/South links. This includes the transport of ash in general. An accident involving fly ash/APC residues could spread hazardous material over a significant area, possibly in a town. This is a low risk, high impact event.

24. There is a broader policy issue, that of **Sustainable development**. It is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come[i]. The term was used by the World Commission on Environment and Development[4] convened by the United Nations in 1983 – perhaps more commonly known as the Brundtland Commission. They coined what has become the most often-quoted definition of sustainable development as

> "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*".

25. Today's environmental problems are largely a consequence of the unsustainable consumption of natural resources and the mismanagement of waste products. Sustainability is about environmental protection, sustained economic growth and social equity. As shown below, fly ash and APC residues are classified as hazardous waste. Indeed, incineration is unique among waste management technologies in producing hazardous waste where none existed before. Moreover, IBA is not inert (as AmeyCespa claim) but contains toxic chemicals. Some of it is ecotoxic (see below). Thus incinerator ash is harmful to the environment so the EfW (incinerator) plant at AWRP would not be a sustainable development.

---

[i] This is sometimes taught as **ELF**-Environment, Local people, Future.

3: FLY ASH / APC RESIDUES

26. Abatement equipment in modern incinerators merely transfers much of the toxic load, notably that of dioxins and heavy metals, from airborne emissions to the fly ash (10-20% of total ash). Fly-ash is known to sorb chemicals from the flue gases. Around half of emitted dioxins are sorbed on fly-ash[5] . Fly-ash is also responsible for the so-called dioxin memory effect[6] whereby slow *de novo* synthesis of dioxins occurs on the surface of the fly-ash; the dioxins then slowly desorb into the flue gases for prolonged periods after the implementation of beneficial changes to the incineration process. There is recent evidence[7] that fly-ash from larger incinerators (into which category the AWRP incinerator plant would fall) has higher content of volatile components and higher leaching toxicity.

27. Fly ash is light, readily windborne and mostly of low particle size. It represents more of a potential health hazard than IBA because it often contains high concentrations of heavy metals such as lead, cadmium, copper and zinc as well as small amounts of dioxins and furans[8] and the combination of pollutants in fly ash can amplify their toxicity[9] (*via* synergistic effects). Indeed, fly ash (and APC residues) is highly toxic and listed as an absolute hazardous substance in the European Waste Catalogue (BSEM[10]).

28. PCBs, PBBs and PBDEs can be present in waste materials. Dioxins (PCDDs and PCDFs) are not normally present in waste, but are formed when chlorine-containing organic substances (eg PVC) are burned. If combustion takes place at temperatures of about 850C, any dioxins already formed are destroyed, but can re-form again post-combustion. Cunliffe and Williams[11] found that "*formation of PCDD/PCDF on flyash deposits in the post-combustion plant of incinerators can result in the release of significant amounts of PCDD/PCDF to the flue gas stream*". Littarru[12] has shown that about 57% of emitted dioxins (in terms of TCDD equivalents) are in the flue gases, with about 43% sorbed on the fly-ash.

29. There is a trade-off with modern incinerators. The less air pollution produced, the more toxic the ash. Today, an incinerator burning 400,000 tonnes of waste annually over 25 years would produce about half a million tonnes of highly toxic fly ash (BSEM, *op cit*). The safe disposal of the highly toxic fly ash usually involves additional waste miles and the need for specialist toxic waste landfill elsewhere; sometimes with concerns for local residents as has been the case in Bishops Cleeve, Gloucestershire, UK[13].

30. The AEA report (*op cit*) states that Fly/APC ash within the UK is disposed of in special waste landfills due to its lime content and the concentrations of heavy metals. In some other countries stabilisation of the fly ash is required through either cementation or vitrification. (BSEM, *op cit*) argue that, apart from vitrification, no adequate method of disposing of fly ash has been found.

31. Transportation of fly ash needs from the incinerator can involve lengthy journeys which themselves present an important hazard. (BSEM, *op cit*) note that an accident could potentially make an area uninhabitable, as happened at Times Beach, Missouri, due to dioxin contaminated oil. It is unclear if these risks are taken into account in cost calculations of incinerators. The problem is that the risk of occurrence is small but the consequences potentially large. This is admittedly a low probability event but also a high impact event.

32. We object to a choice of technology that alone, among waste management options knowingly creates hazardous waste where none existed in the feedstock (municipal solid waste). **As there are cleaner and cheaper waste management options available that also avoid landfill, planning permission for the EfW (incinerator) should be refused.**

4: INCINERATOR BOTTOM ASH

33. What goes in the incinerator will determine what ends up in the ash. This could include heavy metals PCCD/Fs and perhaps even asbestos or small quantities of radioactivity from smoke alarms. In considering the disposal of Incinerator Bottom Ash (IBA), it is important to consider whether or not it is

hazardous. Unfortunately, there is a degree of controversy over whether IBA represents an environmental hazard. The most obvious point is that pollutants such as heavy metals in the original MSW do not burn and are therefore concentrated. Nor, for economic and administrative reasons, are any of these metals usually removed prior to incineration[14], though the mechanical treatment facility at AWRP will presumably remove a proportion of them. However, aluminium is a common constituent if IBA and recycling of aluminium from bottom ash becomes increasingly important[15].

34. IBA contains similar proportions of heavy metals (except cadmium, which is lower than in fly-ash). Under the List of Wastes (England) Regulations 2005, IBA is classed as non-hazardous. However, Dearden[16] reports that the Environment Agency recently confirmed, in a letter to Mr Alan Watson[17], that 12 out of 96 bottom ash samples that they tested met the criteria for hazardous waste, and the EA website [Environment Agency 2006] now states that zinc oxide has been given an ecotoxic classification[18] (H14 by R50/53, very toxic to aquatic organisms and may cause long-term effects in the aquatic environment). If the testing of IBA showed the presence of chemicals that meant that it was classified as hazardous waste, this would impact significantly on the economics of the operation. Dearden notes that The Netherlands will soon require a higher immobilisation efficiency of bottom ash treatment[19] [Xiao et al 2008].

4.1: Recycling IBA

35. It is hardly surprising that AmeyCespa intend to recycle IBA from the EfW incineration plant. There are clear incentives to recycle IBA: it reduces landfill and saves using primary aggregate (i.e. saves raw materials) and thereby reduces costs both to the incinerator operator and (presumably) to the user (assuming appropriate market values). The Environment Agency estimates that up to 469,000 tonnes of IBA could be used each year and that this could save businesses over £47,350,000 each year, largely due to landfill charges, and creates markets worth over £5.8 million a year[20]. Over 710,000 tonnes of IBA was produced by incinerators in England and Wales in 2007, with about 55%)some 390,000 tonnes) going to non-hazardous landfills, with the rest being 'weathered', through exposure to air and rain, before being used as an aggregate (ENDS[21])[ii].

36. According to WRAP[22], Recycled and Secondary Aggregates (RSA) can be used in a range of construction materials:

- Concrete is a common construction material consisting of coarse and fine aggregates mixed with cement and water. There are many different types, classes, specifications and uses for concrete and WRAP summarise the opportunities for using Recovered Secondary Aggregate (RSA) in concrete applications and sets out specifications that must be met.

- Bituminous materials are principally composed of coarse aggregate and fine aggregate filler; aggregates typically contribute 90-95% of the mass of bituminous material. These aggregates are bound together by bitumen, a black, sticky mix of hydrocarbons, to produce what is collectively termed bituminous bound material or 'asphalt'.

- Hydraulically Bound materials (HBM) are simply materials which set and harden with the addition a binder material and water. They include Cement Stabilised Material (CBM) (i.e. mixtures based on the fast setting and hardening characteristics of cement) and hydraulically bound mixtures based on slow setting and hardening binders made from industrial by-products such as PFA[iii] and blast furnace slag

[ii] The Agency is developing a protocol for IBA to define the point at which it is can be classed as a product and so outside waste controls (ENDS Report 389, p 17). A technical working group is assessing IBA's impacts on water and health when used as aggregate, but is not assessing whether the material is ecotoxic**.**

[iii] Pulverised fuel ash (shortened to PFA), is a by product of pulverised fuel (typically coal) fired power stations. The fuel is pulverised into a fine powder, mixed with heated air and burned. Approximately 18% of the fuel forms fine glass spheres, the lighter of which (c. 75 %) are borne aloft by the combustion process. They are extracted from the flue gasses by cyclones and electrostatic precipitation. The resultant material is used as engineering fill and as a component for concrete. It has been widely used, particularly in the UK, for concrete block production. Source: http://en.wikipedia.org/wiki/Pulverised_fuel_ash

(Slag bound materials) HBM have potential to be used in a range of paving and non-paving applications, these opportunities are discussed within this section.

- Unbound materials collectively comprise a vast array of different materials, which may range in size from fine grains less than a millimetre in diameter up to stony material several centimetres in diameter. Unbound materials are used in embankments, as fill materials, as capping, and to form the sub-base of paved areas. All recycled and secondary aggregates (RSA) can potentially be used as the constituents of unbound materials used in construction, and often form 100% of such material.

37. There are a range of regulations covering the management of waste and WRAP[23] offer an overview of the regulations affecting waste, from the European Directives to the legislation valid in England and Wales, as at February 2010. It also gives links to the Environment Agency created the *NetRegs* website[24] which provided guidance on how to comply with environmental law, including waste legislation, as well as advice on good environmental practice. This has now migrated to "Business Link: Environment and efficiency" for England[25] and parallel sites for other parts of the UK.

38. However, there must be a major proviso; that the IBA is safe and does not harm ecosystems or the environment[iv]. Discussion of this is hampered by two facts:

- AmeyCespa do not say how the products from the IBA processing facility will be used – "*secondary aggregate*" and "*appropriate reuse applications*" encompass a range of possibilities

- It is unclear how the "*secondary aggregate*" material is to be stored while awaiting sale, especially if stocks build up significantly due to difficulties in selling it.

39. There are risks associated with IBA as discussed below. It can cause health and safety, environmental and ecological problems. Thus the Precautionary Principle (as discussed in our Health Risks chapter) should apply to any considerations around planning permission issues relating to IBA.

4.2: Risks

40. Until recently, sanguine views were taken on the issues of dioxins and heavy metals in IBA, as in the Environment Agency's 2002 report[26]. This concluded, among other things, that "*Bottom ash can safely be recycled as secondary aggregate – e.g. for construction blocks, asphalt, or bulk fill – because dioxin levels are similar to those typically found in urban soils*". As FoE point out[27], the EA report fails to consider the implications of heavy metals, organic carbon, and other toxic material apart from dioxins and does not adequately consider the variability of ash which could make a small proportion of ash much more toxic than the average. Moreover, the EA judged dioxin levels on those in urban soils rather than those in natural rural soils where the level is close to zero. Comparison with levels in some urban soils is inappropriate (better to reduce them where they are too high).

41. Thus IBA is used and the European Standards organisation has set out a number of standards for the use of secondary aggregate in various applications[28]. These cover the use of bound and unbound mixtures in civil engineering and road construction and aggregates for concrete and there are British Standards and other specifications for the UK. Demand for aggregates is expected to rise in the UK so that there will be a market both for virgin (i.e. naturally derived) aggregates and aggregates derived from IBA. The latter depends on views taken over ecotoxicity and safety.

[iv] An important objective of the Waste Framework Directive (WFD; Directive 2006/12/EC on waste) is to ensure the recovery of waste or its disposal without endangering human health and the environment. The WFD has been largely implemented in the UK through the Environmental Protection Act 1990 (as amended), the Duty of Care and Carriers and Brokers regimes and regulations and the Environmental Permitting (England and Wales) Regulations 2010.

42. Concern over IBA's ecotoxicity dates from October 2005 when the Health and Safety Executive reclassified zinc oxide (a potential compound in ash) as ecotoxic, joining zinc chloride and all lead compounds[29]. Bottom ash contains similar proportions of heavy metals (except cadmium, which is lower than in fly-ash). Under the List of Wastes (England) Regulations 2005, IBA is classed as non-hazardous. However, the Environment Agency recently confirmed, in a letter to Mr Alan Watson[30], that 12 out of 96 bottom ash samples that they tested met the criteria for hazardous waste, and the EA website stated in 2006[31] that zinc oxide has been given an ecotoxic classification (H14 by R50/53, very toxic to aquatic organisms and may cause long-term effects in the aquatic environment). If the testing of bottom ash showed the presence of chemicals that meant that it was classified as hazardous waste, this would impact significantly on the economics of the operation. It should be noted that The Netherlands will soon require a higher immobilisation efficiency of bottom ash treatment[32].

43. Despite the generally positive views of only a few years ago, incinerator operators could in future have to treat bottom ash as hazardous waste because of doubts over its ecotoxicity and this could significantly increase costs (ENDS, *op cit*). If tests show that some IBA is ecotoxic, it could all have to be treated to make aggregate, thereby increasing incineration costs (ENDS *op cit*). It would also call into question the classification of IBA as '*inactive waste*' by the Treasury. Inactive wastes only pay £2.50 landfill tax per tonne, compared with £40/tonne for 'active' materials.

44. ENDS report a generic problem in that the EA leaves classification to operators. Contrast with the situation in the USA where ash from waste-to-energy plants is tested by the EPA to make sure it is not hazardous[33]. The American test looks for chemicals and metals that would contaminate ground water through leachate (see below), or water trickling through a landfill[v].

45. As noted above, paragraph 1.7.41 of the Planning Statement states that the plant will produce '*an inert bottom ash material*'. In normal parlance, inert materials are materials that are devoid of active properties and unable or unlikely to form compounds[34]. According to WRAP, The Landfill Directive[35] sets the definition of inert waste:

"*Waste is considered inert if:*

> *1) It does not undergo any significant physical, chemical or biological transformations;*
>
> *2) It does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and*
>
> *3) Its total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater*."

46. The evidence cited above suggests that IBA is in breach of the third condition, at least in terms of ecotoxicity.

47. We contend that IBA does not meet the everyday definition of inert. Moreover, there are examples of where it clearly breaches one or more of the three criteria set out in the Landfill Directive. For that reason, we do not consider that IBA can be considered inert. Evidence is set out in the following sub-sections.

4.1.1: Leaching of Hazardous and/or Toxic Materials

48. Leaching could take place either from waste prior to it going into the incinerator or from any IBA left out for weathering. Leaching is a complex phenomenon so simply knowing the composition of a material is not sufficient to predict leaching. It depends on such factors as chemical composition,

[v] Ash that is safe can be reused for many applications. About one-third of all the ash produced is used in landfills as a daily or final cover layer, to build roads, to make cement blocks, and even to make artificial reefs for marine animals.

chemical/geochemical/mineralogical speciation, fraction of a species available for leaching, properties of the leachate (e.g. pH and the presence of any complexing factors), and liquid-solid ration in the leaching system[36]. For this reason, leaching has to be established by a series of experiments.

49. If the IBA is weathered on-site then leaching of chemicals and metals into the environment could take place. The chemical behaviour of MSW IBA in monofills has been examined by the Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG)[37] in order to predict the short-term (months to years) and long-term (> 30 years) chemical behaviour of IBA. Their work was based on IBA composition and laboratory kinetic studies of IBA with water. IBA ash after the quench tank is a reactive mixture in which slow and fast acid/base reactions occur. Intrinsic acid/base reactions continue for at least several months, and the end point is not yet known. The heavy metal concentrations observed in the aqueous extracts reflect primarily the advance of these reactions. Consequently leaching tests based solely on short-term (hours to months) extraction procedures cannot predict the chemical behaviour of bottom ash in monofills. However, laboratory experiments with IBA samples in which the intrinsic acid/base reactions have proceeded differently, provide useful information on the nature of chemical reactions significant in the short- and long-term. These results suggest that leaching from any ash left out to weather should be monitored over a period.

50. There is a significant amount of heavy metals in IBA. According to recent Chinese studies[38], IBA accounts for between 61 and 94% of heavy metals (except for Cd) in incinerator ash but is usually far less leachable than those in APC residues. Heavy metal release from bottom ash is influenced by a number of factors including the solid matrix, the extractant type and concentration, contact time with the extractant and liquid-to solid ratios. The leaching process is usually solubility controlled and dependant on the precipitation/dissolution/absorption equilibrium.

51. Leaching of hazardous material may also take place where IBA has been re-used. For example, the AEA (*op cit*) found that the reuse of road construction materials containing processed IBA in a bound form as loose fill after the service life of a road in which it has originally been used has the greatest potential for environmental impact because the material has a larger surface area available for leaching. They found that the greatest concern focussed on copper; using processed IBA in bound applications for road construction is not likely to lead to environmental benchmarks being exceeded except in the case of copper in soft water areas. In such areas, they see a careful case by case analysis as being appropriate.

52. A Swedish team monitored a test road constructed with IBA from a municipal solid waste incineration over a 36 months period[39]. They used chemical and toxicological characterisation to evaluate the environmental impact of leachates from IBA and compare it with leachates from gravel. Initial leaching of Cl, Cu, K, Na, NH4–N and TOC (toxic organic compounds) from bottom ash was of major concern. However, the quality of the bottom ash leachate approached that of the gravel leachate with time.

53. Taken together, these studies suggest that leaching of hazardous or toxic materials from IBA is a legitimate cause for concern. This breaches the third condition for waste being considered inert, namely that '*total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater*'. Total leachability and pollutant content (and perhaps the ecotoxicity) of its leachate are **not** always insignificant.

4.1.2: Risks when used as a Filler

54. IBA requires a licence from the Environment Agency (EA) before it can be used in construction. However, the EA claim they have no jurisdiction over the incinerator ash once it has been incorporated in other building aggregate - officially it ceases to be defined as incinerator waste (BBC [40]).

55. This can lead to problems as happened at when Tesco were building a new store at Gerrards Cross (Annex 1 reproduces the BBC report). It was to be a groundbreaking construction built on a specially designed tunnel over a railway line (BBC *op cit*). One of the construction materials used to construct the store's

foundations was IBA and the EA approved its use. A section of the tunnel collapsed in June 2005, bringing down not only hundreds of tonnes of rubble and concrete but also the IBA. The ensuing clear-up led to some 27,000 tonnes of building materials including IBA being dumped in a farmer's field in an area of outstanding natural beauty in the Chilterns. An analysis by the local council found levels of heavy metals and dioxins which exceeded guidelines established for commercial or industrial.

56. Greenpeace tested some of the material which remained at the Gerrards Cross site. They found high levels of lead and dioxins (BBC, *op cit*). The BBC (*op cit*) reported that a Tesco spokesman as saying that "*the material is inert and safe and it has been signed off be the relevant authorities including the Environment Agency"* However, the BBC quoted scientist Dr Paul Johnston as saying that "*some of the other chemicals (in the material tested) that are present are known carcinogens*" and that "*the levels of lead that are present in this material would certainly give me cause for concern*"

57. While this case may be unusual, it illustrates the risks in using a material such as IBA which contains heavy metals and dioxins when unforeseen circumstances can lead to it entering the environment. It is certainly in breach of the second and third condition for being an inert waste – namely that:

    '2) It does ... ... adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health;' Clearly there was environmental pollution and potential harm to human health in this case.

    '3) Its total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.' Clearly pollutant content is **not** insignificant and there is clear potential for such materials to endanger the quality of any surface water or groundwater.

4.1.3: Use and Risks in Road Construction

58. Use of IBA for road construction (after some processing) is widespread in a number of European countries including the UK and this reduces primary aggregate consumption. In this use IBA is commonly is sealed under a cover of asphalt. In the UK the use of processed IBA as aggregate gave rise to significant public concern following publicity given to the use in Newcastle-on-Tyne of a mixture of incinerator fly ash and bottom ash for constructing paths in allotments and elsewhere. The mixed ash was from the Byker heat station, which burnt refuse derived fuel by a process significantly different to that used in mass burn waste incinerators in the UK. (This incident arose from a time when even fly-ash was not regarded as toxic, which led to the Byker disaster[41 42]).

59. Views on using IBA in road construction vary:
    - The AEA report (*op cit*) finds that IBA is generally considered a non-hazardous waste.
    - The AEA *(op cit*) also reviewed the use of IBA in other European countries. This showed a wide variation in approach ranging from those countries for which IBA use in road construction is routine and those in which it is presently not permitted. They found a limited number of publicly available risk assessments of processed IBA use in road construction and noted that where assessments have addressed risk, concerns have principally surrounded occupational exposure to the IBA and the leaching of metals from the ash to the surrounding environment.
    - BSEM[43] note that IBA is a less severe hazard than fly ash, but still contains significant quantities of dioxins, organohalogens and heavy metals. However, the AEA report (*op cit*) tested leaching from bound IBA and found that leachates from their samples did not present an environmental hazard. Similarly, Paine et al (2002)[44] found that leaching from IBA used as cement bound material (CBM) for use in sub-base and road-base layers did not represent an environmental hazard.

60. The main thrust of the AEA report (*op cit*) was use of the IBA and it focussed entirely on the risk which might arise from the use of processed IBA in asphalt or cement bound material in the road base either as

an asphalt bound material or in cement bound material. Specifically, it excluded IBA use in unbound applications and in the surface course of the road. It saw the environmental advantages of encapsulating IBA as greatly reducing the potential for leaching. For both bound and unbound uses of processed IBA the most significant ecosystem exposure route during the existence of the road is likely to be through leaching of metals into local surface waters, though they did not see this as a significant risk. In addition, they suggested that for unbound uses, measures such as an impermeable cap might provide sufficient protection from leaching. However, they did not test this.

61. The above evidence is somewhat contradictory but does suggest that there are circumstances when leaching can lead to significant harm, including to the quality of any surface water or groundwater.

4.1.4: Use and Risks in Concrete

62. Foam Concrete[vi] is widely used - most commonly in utility trench filling and road construction –for example, it is sometimes used on Highways Agency contracts as trench reinstatement and for filling voids such as redundant structures and for other road construction application

63. Two workers sustained injuries after an explosion in August 1009 at Mill Green, Hertfordshire at a sewage pumping station was being decommissioned for Thames Water[45] as a result of a gas explosion. In this incident, a dry well had been filled with a large volume of foamed concrete over the previous three days and a spark from an angle grinder being used to cut handrails is believed to have ignited an explosive gas mix that had accumulated.

64. An investigation by the Health and Safety Executive (HSE) identified several issues. The foamed concrete mixture contained IBA which may in certain circumstances produce hydrogen gas. Aluminium metal particles present in the IBA react with the water and cement to generate hydrogen, the volume of hydrogen produced being proportional to the quantity of aluminium metal being present in the IBA.. Foamed concrete is sometimes used on Highways Agency contracts as trench reinstatement and for filling voids such as redundant structures and for other road construction applications.

65. Subsequently the Highways Agency[46] issued a guidance note (Interim Advice Note 127/09 The Use Of Foamed Concrete – see Annex 1) which advised that "*foamed concrete containing IBA must not be used on any Highways Agency contracts from the date of this document until the HSE investigations are complete*". The Interim Advice Notice (IAN) refers to several incidents including that at Mill Green. It states that the foamed concrete mixture contained IBA which may in certain circumstances produce hydrogen gas. Aluminium metal particles present in the IBA react with the water and cement to generate hydrogen, the volume of hydrogen produced being proportional to the quantity of aluminium metal being present in the IBA. At the time of the IAN (October 2009), HSE investigations were on-going. As a precaution, Highways Agency banned the use of foamed concrete containing IBA must on any Highways Agency contract until the HSE investigations were complete.

66. The HSE have subsequently confirmed that the cause of the explosion was ignition of the flammable gas hydrogen evolved from foamed concrete. The liquid concrete had been aerated, or foamed, by mixing air into it by agitation in the presence of a foaming agent (surfactant) and the hydrogen was produced from the concrete as it was setting. HSE investigated the mechanism by which hydrogen was generated. The particular concrete mix included *incinerator bottom ash aggregate* (IBAA), which has been shown to contain a significant proportion of aluminium. Aluminium is known to react with cement/concrete mixtures to form hydrogen gas.

[vi] Foam concrete is cement bonded material manufactured by blending a very fluid cement paste (slurry) and then injecting stable, pre-formed foam into the slurry. The volume of slurry to foam dictates the density of the foam concrete
Source: http://www.foamconcrete.co.uk/what_is_foam_concrete.html

67. As a result HSE advise that where use of IBAA is being considered it is advisable to adopt the certain precautions[vii]

68. HSE confirms that it has taken no action requiring the omission of IBAA from foamed or general concrete mixtures for use in civil engineering works, and has thus not 'banned' IBAA from being used.

69. This incident breached the first two conditions for waste being considered inert:

1) It does not undergo any significant physical, chemical or biological transformations; In this case the waste did undergo a significant chemical transformation which led to hydrogen production. This is a safety hazard.

2) It does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; ; In this case the waste did undergo a significant chemical transformation which led to hydrogen production. This led to harm to two workers (i.e. damaged their health through injury)

5: ENSURING SAFETY AND THE COSTS OF ASH

70. BSEM (*op cit*) argue that the Stockholm Convention[viii] makes it clear that dioxins and furans should be destroyed which currently means using vitrification. They note that in Japan this is done responsibly and much of the fly ash is now treated by plasma gasification but that this is not done in the UK. BSEM consider that the toxicity of bottom and fly ash means there should be a full assessment of the cost of a clean-up operation for both water and land contamination and that environmental clean-up costs should be shown as part of the cost of incineration, and, when relevant, of other waste disposal strategies. Doing this could change the balance of economic advantage of different technologies.

6: CONCLUSION

71. The large amounts of ash from incinerators contribute to the environmental harm they produce. This means that granting planning permission for the EfW (incinerator would These include:

- The RSS which includes Policy YH1 Overall Approach and Key Spatial Priorities, which recommends (among others) that plans, strategies, investment decisions and programmes should aim to: "*Avoid exacerbating environmental threats to the region and reduce the region's exposure to those threats.*"
- The Waste Local Plan which includes: *"Policy 4/1 Waste management Proposals - Proposals for waste management facilities* which specifies that they *will be permitted provided that:*

b. the proposed method and scheme of working would minimise the impact of the proposal;

c. "there would not be an unacceptable environmental impact";
g. "the proposed transport links are adequate to serve the development"
As discussed above, granting planning permission for the EfW (incinerator) would contravene these policies due to the nature of fly ash/APC residues

---

[vii] Test the IBAA for the production of hydrogen by adding a sample to a solution of sodium hydroxide. If no bubbling is observed after several hours, the aggregate can be used in foamed concrete mixtures;
If aggregates which produce bubbling when added to sodium hydroxide solution are to be used in foamed concrete, further checks should be made for hydrogen evolution when the aggregate is included in a test sample of the intended concrete mixture. If no bubbling is observed after several hours on laboratory-scale, the IBAA can be used in applications of foamed concrete;
If concrete mixtures which produce hydrogen are to be used in civil engineering projects, the risk of fire and explosion must be assessed. Adequate natural or forced ventilation should be provided to keep the concentration of hydrogen in air well below the lower explosive limit. The ventilation requirements can be established using maximum rates of hydrogen production per unit mass measured in laboratory-scale experiments. In addition, sources of ignition should be avoided in the working area.
[viii] The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically and accumulate in the fatty tissue of humans and wildlife. Source: http://chm.pops.int/Convention/tabid/54/language/en-US/Default.aspx

72. There is a broader policy issue, that of **Sustainable development**. Fly ash and APC residues are classified as hazardous waste. Indeed, incineration is unique among waste management technologies in producing hazardous waste where none existed before. Moreover, IBA contains toxic chemicals and some of it is ecotoxic. Thus incinerator ash is harmful to the environment so the EfW (incinerator) plant at AWRP would not be a sustainable development.

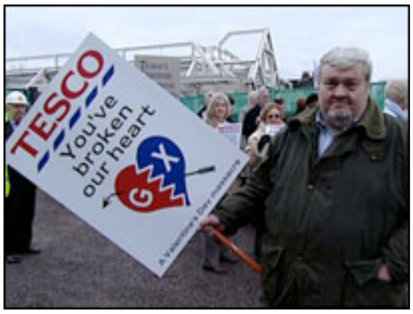
73. Abatement equipment in modern incinerators merely transfers the toxic load, notably that of dioxins and heavy metals, from airborne emissions to the fly ash (10-20% of total ash). This fly ash is light, readily windborne and mostly of low particle size. Fly ash along with APC residues are treated in the UK as hazardous waste and is disposed of in special waste landfills due to its lime content and the concentrations of heavy metals.

74. Safe disposal of Fly Ash usually involves additional waste miles and the need for specialist toxic waste landfill elsewhere. The transport of this material could lead to a traffic accident involving spillage and spread of the ash – the risk is low but the potential impact is high

75. IBA does not meet the criteria for being considered an inert waste. IBA is subject to a number of potential health and environmental risks and appears to have caused some actual harm. As there are financial incentives to use it as a replacement for naturally occurring raw materials, it is important that regulation should be strengthened and that this should be done without regard to short-term financial consequences. It is particularly important that testing for and judging the ecotoxicity of IBA should be carried out regularly and independently, as is the practice in the USA.

76. Finally, we object to a choice of technology that alone, among waste management options knowingly creates hazardous waste where none existed in the feedstock (municipal solid waste). **As there are cleaner and cheaper waste management options available that also avoid landfill, planning permission for the EfW (incinerator) should be refused.**

ANNEX 1 – GERRARDS CROSS INCINERATOR BOTTOM ASH



Residents of Gerrards Cross protest

Local residents in Gerrards Cross are not naturally inclined to take to the streets in protest, but one unpopular neighbour has motivated them to do just that.

Their neighbour is none other than Britain's biggest retailer - Tesco.

For 17 years they have been trying to move into the area by building a new store, but this is no ordinary supermarket - it was to be a groundbreaking construction built on a specially designed tunnel over a railway line.

However it is not mere "nimbyism" which motivates them - rather a strong suspicion that one of the building materials used to construct the store's foundations - what is known as Incinerator Bottom Ash - is toxic and is exposing them to health risks.

The material is known as Incinerator Bottom Ash or IBA. It's what's left on the incinerator floor after municipal waste is burnt. After some processing - it's been quite widely used in road building where it is sealed under a cover of asphalt.

Tesco planned to use incinerator ash as a filler material around and above the tunnel it was building - and the Environment Agency approved its use.

Tunnel collapse


Tunnel collapse exposed residents to health threats?

When a huge section of the tunnel collapsed in June 2005 - bringing down not only hundreds of tonnes of rubble and concrete but also the incinerator ash - a massive clear up job was needed.

27,000 tonnes of building materials including Incinerator Ash was shipped out and dumped in a farmer's field in an area of outstanding natural beauty in the Chilterns.

It was only yards from the home of Ruth Marshall and her two young children.

Ruth became concerned about the vast "Pyrennian" mountain of ash when her children appeared to suffer breathing problems.

Unbeknown to Ruth, the local council had conducted an analysis which found levels of heavy metals and dioxins which exceeded guidelines established for commercial or industrial land - even more startling in a rural location.

Shocking results

When we revealed to her the results she was unsurprisingly shocked and concerned.

In fact the local authority recommended that the material could only stay on site if it was dampened to prevent dust blowing and also covered. It ordered the spoil's removal from Coleshill at the end of last year.

Thousands of tonnes of the material remain however at the Gerrards Cross site. Greenpeace have tested some of the material from the site and their test results show high levels of lead and dioxins.

Scientist Dr Paul Johnston believes that "some of the other chemicals (in the material tested) that are present are known carcinogens". He also said "the levels of lead that are present in this material would certainly give me cause for concern"

Environmental expert Alan Watson has also expressed his concern.

He says the material on site shouldn't be left like this - fine dust exposed to the elements and free to blow around… places where children would come into contact with it.

Michael Kissman from Tesco says "the material is inert and safe and it has been signed off be the relevant authorities including the Environment Agency".

Is Incinerator Bottom Ash a health risk to residents?

Despite the concerns of experts Tesco insist the material has been tested by the relevant bodies and it is safe.

A number of residents however have been concerned about the dust containing IBA that they were exposed to from the site. Local shopkeeper Kalpana West said "The dust was settling literally everywhere.

Strict procedures

Tesco says "we have strict procedures in place we have strict procedures in place for when we work the material in case of the creation of dust such as damping down the site, which will be adhered to when we work the material.

"At the moment the material is being left, it's in a safe state it's in a constant safe state with a hardened crust and poses no risk to the local environment".

Incinerator Bottom Ash requires a licence from the Environment Agency before it can be used in construction which Tesco received.

However, in this case it was never envisaged that the material would be exposed to the elements for such a long time.

As the Health and Safety Executive are continuing their investigations into the causes of the collapse all work has ceased on site therefore a quantity of Incinerator Ash mixed with other material also remains on site.

Worryingly the Environment Agency claim they have no jurisdiction over the incinerator ash once it has been incorporated in other building aggregate - officially it ceases to be defined as incinerator waste.

Thus it has remained in a place open to the elements - free to blow across the town - apparently unregulated and unchecked by the Environment Agency.

Residents feel that the buck for this material is passed to and fro.

Meanwhile the bewildered resident of Gerrards Cross are left facing another summer of dust and growing fears that their green and pleasant corner of England is being contaminated.

Source: http://www.bbc.co.uk/insideout/london/series11/week7_designer_homes.shtml

ANNEX 2 : Highways Agency - Interim Advice Note 127/09

October 2009

THE USE OF FOAMED CONCRETE

SUMMARY

This Interim Advice Note provides guidance on use of foamed concrete.

INSTRUCTIONS FOR USE

This IAN takes immediate effect.

Use of foamed concrete

Background
The Health and Safety Executive (HSE) has identified several incidents involving foamed concrete, including a serious accident on 21st August 2009 at a sewage pumping station being decommissioned, when contractors were injured as a result of a gas explosion. In this incident, a dry well had been filled with a large volume of foamed concrete over the previous three days and a spark from an angle grinder being used to cut handrails is believed to have ignited an explosive gas mix that had accumulated.

Identified Issues
The foamed concrete mixture contained Incinerator Bottom Ash (IBA) which may in certain circumstances produce hydrogen gas. Aluminium metal particles present in the IBA react with the water and cement to generate hydrogen, the volume of hydrogen produced being proportional to the quantity of aluminium metal being present in the IBA. HSE investigations are on-going. Foamed concrete is sometimes used on Highways Agency contracts as trench reinstatement and for filling voids such as redundant structures and for other road construction applications.

Action
As a precaution, the use of foamed concrete containing IBA must not be used on any Highways Agency contracts from the date of this document until the HSE investigations are complete and if necessary further research by the Highways Agency has been undertaken.

The use of foamed concrete without IBA is not affected.

Implementation
This IAN should be disseminated across all of the HA Supply Chain. It should be used with immediate effect on all HA schemes and contracts

Withdrawal conditions
Once the HSE investigations are complete, the prohibition on the use of foamed concrete containing IBA will be reviewed.

Contact details
If you have any questions regarding the use or content of this document, please contact:
Neil Loudon
Email. neil.loudon@highways.gsi.gov.uk **Tel. 01234 796107**

GLOSSARY

AEA	Atomic Energy Authority
APC	Air pollution control
APCR	Air Pollution Control Residue
AWRP	Allerton Waste Recovery Park
BSEM	British Society for Ecological Medicine
CBM	Cement bound material
EA	Environment Agency
EAWAG	The Swiss Federal Institute for Water Resources and Water Pollution Control
EfW	Energy from Waste – here used in the sense of incinerator + electricity generation
ENDS	Environmental Dara Services
EPA	Environmental Protection Agency
HBM	Hydraulically Bound materials
HSE	Health and Safety Executive
IBA	Incinerator Bottom Ash
IBAA	incinerator bottom ash aggregate
MSW	Municipal Solid Waste
NO_x	Oxides of nitrogen
PBBs	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzodioxins (commonly called *dioxins*)
PCDFs	Polychlorinated dibenzofurans (commonly called *furans*)
PCCD/Fs	PCDDs and/or PCDFs
RSA	Recycled and Secondary Aggregate
TCDD	2,3,7,8-tetrachlorodibenzo-para-dioxin
UK	United Kingdom
USA	United States of America
WRAP	Waste & Resources Action Programme

REFERENCES

[1] J Abbott, P Coleman, L Howlett, P Wheeler
Environmental and Health Risks Associated with the Use of Processed Incinerator Bottom Ash in Road Construction: A report produced for BREWEB - Oct 2003 – Report AEAT/ENV/R/0716
http://www.breweb.org.uk/pdf/IBA_risk_assessment.pdf

[2] http://www.eia.doe.gov/kids/energyfacts/saving/recycling/solidwaste/wastetoenergy.html

[3] The Health Effects of Waste Incinerators, 4th Report of the British Society for Ecological Medicine, Second Edition, June 2008, Moderators: Dr Jeremy Thompson and Dr Honor Anthony

[4] Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987.
Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment August 2, 1987

[5] Littarru P. Repartition of PCDD and PCDF in the emissions of municipal solid waste incinerators between the particulate and volatile phases. *Waste Management* 26 (2006) 861-868.

[6] Cunliffe A.M. and Williams P.T. Desorption of PCDD/PCDF from municipal solid waste incinerator flyash under post-combustion plant conditions. *Chemosphere* 68 (2007) 1723-1732.

[7] Jiang J.G., Xu X., Wang J., Yang S.J. and Zhang Y. Investigation of basic properties of fly ash from urban waste incinerators in China. *Journal of Environmental Sciences—China* 19 (2007) 458-463.

[8] Behaviour of metals in MSW fly ash during roasting with chlorinating agents, PhD Thesis by Chan, C.C., Chemical Engineering Department at University of Toronto, 1997
http://www.collectionscanada.gc.ca/obj/s4/f2/dsk2/ftp03/NQ27620.pdf

[9] Markus T, Behnisch P, Hagenmaier H et al. Dioxinlike components in incinerator fly ash: A comparison between chemical analysis data and results from a cell culture bioassay. Environ Health Perspect 1997; 105(12): 475-81 Cited in 5

[10] The Health Effects of Waste Incinerators, 4th Report of the British Society for Ecological Medicine, Second Edition, June 2008, Moderators: Dr Jeremy Thompson and Dr Honor Anthony

[11] Cunliffe A M and Williams P T *Desorption of PCDD/PCDF from municipal solid waste incinerator flyash under post-combustion plant conditions.* Chemosphere 68 (2007) 1723-1732

[12] Littarru P *Repartition of PCDD and PCDF in the emissions of municipal solid waste incinerators between the particulate and volatile phases*. Waste Management 26 (2006) 861-868.

[13] http://www.epa.gov/solar/energy-and-you/affect/municipal-sw.html and http://www.elc.org.uk/papers/2005vansteenis.doc

[14] R C Porter, The economics of waste
http://books.google.co.uk/books?id=0GiiauhF6PwC&pg=PA75&lpg=PA75&dq=Disposal+of+incinerator+ash&source=bl&ots=58FBwvjs3X&sig=oqId7ij5p-6wUQDs_ODlS8x_ukE&hl=en&ei=e2gQSoixJc-MjAfDhoGzBg&sa=X&oi=book_result&ct=result&resnum=8#PPA75,M1

[15] Yanjun Hu and Peter Rem, *Aluminium alloys in municipal solid waste incineration bottom ash* Waste Management and Research Vol. 27, No. 3, 251-257 (2009) http://wmr.sagepub.com/cgi/content/abstract/27/3/251

[16] Memorandum submitted by Professor J C Dearden (Waste 69), Waste Strategy for England 2007 - Environment, Food and Rural Affairs Committee http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenvfru/230/230we57.htm

[17] Watson A. E-mail to J.C. Dearden dated 8.2.08 titled: Waste PQs on incinerator bottom ash classification.

[18] Environment Agency. Classification of incineration bottom ash. www.environment-agency.gov.uk/ourviews/857198/1498985/ (2006) .

[19] Xiao Y., Oorsprong M., Yang Y. and Voncken J.H.L. *Vitrification of bottom ash from a municipal solid waste incinerator*. Waste Management 28 (2008) 1020-1026.

[20] Incinerator Bottom Ash http://www.environment-agency.gov.uk/business/topics/waste/114416.aspx

[21] ENDS Report 410, March 2009, pp 23-24,© Haymarket Business media.

[22] Opportunities to Use Recycled and Secondary Aggregates (RSA)
Opportunities: http://aggregain.wrap.org.uk/opportunities/index.html
Materials: http://aggregain.wrap.org.uk/opportunities/materials/index.html

[23] Waste Management Regulations http://aggregain.wrap.org.uk/waste_management_regulations/background/index.html

[24] http://www.netregs.gov.uk/

[25] http://www.businesslink.gov.uk/bdotg/action/layer?r.s=tl&r.lc=en&topicId=1079068363

[26] Environment Agency, Solid Residues from Municipal Waste Incinerators in England and Wales, May 2002.

[27] Friends of the Earth Briefing: The safety of incinerator ash A review of an Environment Agency Report, 2002 http://www.foe.co.uk/resource/briefings/safety_incinerator_ash.pdf

[28] Rufford Energy Recovery Facility: Incinerator Bottom Ash http://www.docstoc.com/docs/23116984/Rufford-Energy-Recovery-Facility-Incinerator-Bottom-Ash

[29] Memorandum submitted by Professor J C Dearden (Waste 69), Waste Strategy for England 2007 - Environment, Food and Rural Affairs Committee http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenvfru/230/230we57.htm

[30] Watson A. E-mail to J.C. Dearden dated 8.2.08 titled: Waste PQs on incinerator bottom ash classification.

[31] Environment Agency. Classification of incineration bottom ash. www.environment-agency.gov.uk/ourviews/857198/1498985/ (2006)

[32] Xiao Y., Oorsprong M., Yang Y. and Voncken J.H.L. Vitrification of bottom ash from a municipal solid waste incinerator. *Waste Management* 28 (2008) 1020-1026.

[33] http://www.eia.doe.gov/kids/energyfacts/saving/recycling/solidwaste/wastetoenergy.html

[34] www.rcaam.org/educate/glos-ghi.htm

[35] Directive 1999/31/EC on the landfill of waste
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:182:0001:0019:EN:PDF

[36] Sipila K and M Rossi, *Power production from waste and biomass IV – Advanced concepts and technologies* (2002) http://www.vtt.fi/inf/pdf/symposiums/2002/s222.pdf#page=153

[37] Chemical Behaviour of Municipal Solid Waste Incinerator Bottom Ash in Monofills
H. Belevi, D.M. Stämpfli and P. Baccini, Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG), CH-8600 Dübendorf, Switzerland
http://wmr.sagepub.com/cgi/content/abstract/10/2/153

[38] Hua Zhang1, Pin-Jing He1 , Li-Ming Shao1 and Xin-Jie Li1
Leaching behaviour of heavy metals from municipal solid waste incineration bottom ash and its geochemical modelling http://www.springerlink.com/content/w461826413v16821/

[39] Solvita Orea, Jelena Todorovica, Holger Eckea, b, Kerstin Grennberga, Sofia Lidelöwa and Anders Lagerkvista, *Toxicity of leachate from bottom ash in a road construction*
Waste Management, Volume 27, Issue 11, 2007, Pages 1626-1637
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFR-4MWXT77-1&_user=10&_coverDate=12%2F31%2F2007&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1235849968&_rerunOrigin=scholar.google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=bbf28f9ad855428ac22a17899ec63af6

[40] BBC Inside Out – London (updated to August 2008), Incinerator Bottom Ash
http://www.bbc.co.uk/insideout/london/series11/week7_designer_homes.shtml

[41] Ares E and Bolton P *Waste incineration* House of Commons Research Paper 02/34, 9.5.2002.

[42] Tangri N *Waste incineration: a dying technology* Report for Global Alliance for Incinerator Alternatives, 14.7.2003.

[43] The Health Effects of Waste Incinerators, 4th Report of the British Society for Ecological Medicine, Second Edition, June 2008, Moderators: Dr Jeremy Thompson and Dr Honor Anthony

[44] Paine, K. A., Dhir, R. K., Doran, V. P. A., 2002. Incinerator Bottom Ash: Engineering and Environmental Properties as a Cement Bound Paving Material. *International Journal of Pavement Engineering*, 3 (1), pp. 43-52. http://opus.bath.ac.uk/12938/

[45] St Albans & Harpenden Review, *Explosion - Thames Water statement,*
http://www.stalbansreview.co.uk/news/4558670.Explosion___Thames_Water_statement/

[46] Highways Agency Interim Advice Note 127/09: The Use Of Foamed Concrete
http://www.standardsforhighways.co.uk/ians/pdfs/ian127.pdf