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Toxic Fallout – Waste Incinerator Bottom Ash in a Circular Economy

This report uses independent empirical research to evidence that incinerator bottom ash is insidiously hazardous and underregulated. Risk is heightened by the fact that testing methods for its use as a building material are outdated. A list of fifteen concerns for public health and safety is provided in relation to the use of waste incinerator bottom ash in cement-based products and as road/pathway aggregate. Calls for the support of its use within a circular economy are premature, and, as per the precautionary principle, all ongoing usage should cease. Examination of independently analysed bottom ash provides a diagnostic on the operational steady state of waste incinerators, incidentally raising concerns about operational compliance with emissions legislation and the capacity of incinerators to produce benign bottom ash when fed with municipal solid waste.

(vecchi e nuovi stregoni fra alambicchi e business smisurati che trasformerebbero mefitici veleni in oro, per continuare a avvelenare GAIA. ndr noinceneritori)

Research Report - January 2022

Waste Incinerator Bottom Ash in a Circular Economy

Abstract

Bottom ash is fallout from the grate of mass-burn waste incinerators. Large quantities are produced and this residue has negative value. Visible proportions of sand, glass, and stones make it appear, on the surface, to be low hanging fruit for use in a circular economy; but bottom ash also contains appreciable quantities of toxic ‘high level of concern’ elements and persistent organic pollutants.
A secondary 'fallout' occurs when these substances leach from bottom ash into its surroundings across a range of conditions and timescales.

The waste incineration industry fails to mention these facts when advertising bottom ash as a ‘green’ building material.

In comparison to direct airborne pollution from waste incinerators, bottom ash has gone somewhat under the radar, making it ripe for greenwash.
This report uses independent empirical research to evidence that incinerator bottom ash is insidiously hazardous and underregulated. Risk is heightened by the fact that testing methods for its use as a building material are outdated. A list of fifteen concerns for public health and safety is provided in relation to the use of waste incinerator bottom ash in cement-based products and as road/pathway aggregate. Calls for the support of its use within a circular economy are premature, and, as per the precautionary principle, all ongoing usage should cease. Examination of independently analysed bottom ash provides a diagnostic on the operational steady state of waste incinerators, incidentally raising concerns about operational compliance with

emissions
legislation and the capacity of incinerators to produce benign bottom ash when fed with municipal solid waste.

1 Introduction

In Nature's biosphere, something's discarded effluence is something else’s resource. All naturally occurring 'waste' is readily
consumed in the efficient process of elemental recycling that operates at the Earth's surface. Within moments, creatures set about
its consumption in earnest. Waste does not occur in nature because nature abhors inefficiency.

In contrast, civilisation in the 21
st century has implemented an economic system which is proactively inefficient in terms of how it
utilises its natural resources (the finite budget of chemicals that form the Earth's lithosphere and biosphere and the energy
contained within their chemical bonds) by seeking to expedite disorder and create temporary, localised financial gain. In doing so, it
has taken human endeavour above and beyond stability - i.e. the natural recycling of elements within a finite budget -; and has
thrown it into the unstable realm of a throwaway society where, in an attempt to satiate this requirement, greater consumption of
goods, services, and fuel must occur in greater volumes than the year before, thus creating increasingly larger amounts of waste.

Prompted by numerous environmental concerns directly arising as a result of this system, and of the logic to transition away from it,
a number of ideas have been proposed which, rather than directly challenging the fundamentals of the system, suggest a
reconciliation. One of these is 'sustainable development' (Spaiser et al., 2017). Another is 'circular economy' (Ellen MacArthur
Foundation, 2014). Waste incineration is considered to be outside of the circular economy (ibid.). Reasons are that it is a destructive
process which provides 'back-end pull' for waste generation accentuated by contractual lock-ins (Muznik, 2017).

Currently, the European Union (EU) is examining whether the use of modern waste incinerator bottom ash could be worthy of
investment support within a future circular economy. The matter is being discussed as part of a wider EU Taxonomy (EU, 2020). To
be aligned, suitable activities must make a “substantial contribution” to at least one of six objectives:

1. Climate change mitigation,
2. Climate change adaptation,
3. Sustainable use and protection of water and marine resources,
4. Circular Economy Transition,
5. Pollution prevention and control, and
6. Protection and restoration of biodiversity and ecosystems;

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while simultaneously they must “do no significant harm” to any of the other objectives; in other words, progress towards one
objective must not be made at the expense of another. Compliance is assessed against specified “technical screening criteria”, which
require that evidence is “science based” [sic], and “developed via a robust
methodology”(PSF, 2021).

It is not the objective of this report to consider the de-merits of waste incineration within the circular economic model. It is its aim to
provide evidence against the aforementioned criteria: specifically, the use of bottom ash in both 'unbound' aggregates (i.e. for roads
and paths) and bound composites (e.g. cement based products like concrete and blocks). The topic has wider relevance to the
legislative, permitting, and planning sectors where claims are put forward by the incinerator industry that bottom ash can have
“many applications”, can be “carbon negative”, and even that it can assist with
“Climate change adaptation and greenhouse gas
emissions” (Powerfuel, 2020).

In this report, the hazard (if any) posed by the use of incinerator bottom ash is assessed using independent, empirical,
peer-reviewed scientific literature. Specifically, the total concentrations of toxic substances in bottom ash and their propensity to
leach out into the environment from subsequent products and applications. Current regulatory and testing safeguards within a
European context are investigated, while drivers and motivations for the proposed use of bottom ash are also discussed.

2 Background to Bottom Ash

In the mid-1800's, prior to the first municipal solid waste incinerator (MSWI) patent (Clark, 2007) societal waste comprised mainly
dust, ashes, and cinders (ca. 80% - the residue from fire grates), along with lesser quantities of vegetative matter, excrement,
bones, and animal carcasses; plus minor amounts of ceramics, rags, paper, and metals (Tanner, 2006). This detritus was frequently
piled up within the boundaries of rapidly expanding urban areas, and these refuse heaps were considered to be of some value
(Dickens, 1865). People lived among them, scavenging was permitted, and in one city at least a fee was charged for the privilege
(Melosi, 1973). Once all 'valuables' had been removed, the leftover ash and cinders were commonly used as a sub-base for paths and
carriageways; indeed, in 1848, the whole of London's Great Dust Heap (Figure 1) was reportedly sold to Russia for building the streets
of Moscow (Tilley, 2014).
Figure 1. King's Cross, London: the Great Dust-Heap, next to Battle Bridge and the Smallpox Hospital. Watercolour painting by E. H. Dixon, 1837 (Wellcome
Collection, no date).
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Modern incinerator bottom ash is markedly different from the ash and cinders which were used as a road base in the 1800s.
Municipal solid waste (MSW) now includes ubiquitous quantities of plastics and their additives, along with plastic/metal composites
such as printed circuit boards and other petrochemically coated substances like paper, packaging, and waste wood (Conesa et al.,
2021). A recent report listed over 2400 substances in waste plastic that are identified as of potential concern because they meet one
or more of the persistence, bioaccumulation, and toxicity criteria in the EU (Wiesinger et al., 2021).
The majority of modern waste incinerators are mass-burn, grate-fired systems, and the most massive quantity of residue that they
produce is 'fallout' from the main grate - 'bottom ash'. Though incinerators are not built to harvest bottom ash, their purpose is to
create it: the word's etymological route is a process for 'converting to cinders'. Some incinerators recover a quantity of the energy
contained in waste, so-called Waste-to-Energy (WtE) or Energy-from-Waste (EfW) plants. But the waste to electricity efficiency is
very low, at η ≤ 0.3, essentially meaning that at least 70% of the chemical functionality in waste is lost in the process of ‘converting
to cinders’ (Neuwahl et al., 2019).
In modern incinerators, approximately a third of the input waste is incombustible or goes uncombusted (Bielowicz, et al. 2021). This
equates to about a quarter of the input mass becoming bottom ash (Bunge, 2019; Hulgaard and Vehlow, 2011). The balance - a
smaller amount of solid residue - becomes entrained in the combustion gases and is either emitted into the atmosphere
(Particulate Matter Research Group, 2019) or captured by gas cleaning modules (Vehlow, 2015). These entrained particles are
termed fly ash and air pollution control residues (APCr) and are not part of this report.
The focus of legislation in Europe has been to minimise these airborne emissions, lately implemented via the Industrial Emissions
Directive (IED) (EU, 2010). This requires that the post-combustion gas [author's emphasis] must be subjected to at least 850°C for a
minimum of 2 seconds even under the most unfavourable of conditions, and that the bottom ashes/slag have total organic carbon
(TOC) content of <3 wt% or their loss on ignition (LOI) is less than 5 wt%. Limit values exist only for pollutant concentrations in the
airborne emissions and APCr system wastewater. The combustion environment above an incinerator grate is a hostile one to
monitor and, though little is known about localised variations, temperatures above the grate are believed to oscillate around 900°C
(Bunge, 2019).
At the macro-scale, bottom ash is mostly (between 50 – 97%) amorphous material, stones, shards of glass, chunks of metal, and
sandy grit (Buchholz and Landsberger, 1995; Caviglia et al., 2019). The amorphous fraction is often referred to as ‘slag’ and ‘clinker’; a

product of high temperatures in the combustion zone at which substances melt, aided by elements from groups 1 and 2 of the periodic table which are fluxing agents (Miles et al., 1995). The words ‘slag’ and ‘clinker’ are often used as synonyms for bottom ash.

Chemically, bottom ash has a pH in the 11-12 range (Bunge, 2019). Major constituents (ca. 90%) are oxides of sulphur (S), silicon (Si), calcium (Ca), iron (Fe) and aluminium (Al) bound, among which are numerous minor elements from different chemical groups, many of which are very toxic (Simon et al., 2021; Vateva, and Laner, 2020). Bottom ash also has some pure metals and a fraction of these are commercially extractable (Bunge, 2019).

Commercial extraction of metals is influenced by how bottom ash is temporarily stored upon discharge. Some incinerators have quenching systems (a water-filled tank) while others operate dry capture, often with a period of open air stockpiling known as weathering or ageing, each of which can alter bottom ash form and chemistry. Both ferrous (Fe) and non-ferrous (NFe) metals are extractable, but this refers to only unoxidised constituents (i.e. pure, native metals) and not to metal oxides which are grouped with the mineral constituents. Full recovery of all metals is not possible, with the remainder along with metal oxides left within what is sometimes called the ‘mineral fraction’ of bottom ash. This ‘left-over’ bottom ash residue is the subject of this report.

3 Method and Hazard Identification

Research was framed by two hypotheses:

1. The use of incinerator bottom ash could substantially contribute to the transition to a circular economy; and
2. Its utilisation will do no significant harm.

The research methodology was a literature review, with papers selected by date of publication from 2019 onwards, and only those which contained results derived from empirical research. Datasets were limited to samples of bottom ash produced by the incineration of MSW, i.e. household and commercial/industrial waste; studies reporting on special 'hazardous waste’ incinerators were excluded. Also excluded were publications either directly commissioned by industry, co-authored by, or co-funded by industrial sponsors. The scope was set within Europe, defined geographically; but, for organic substances, it was extended to include empirical studies from other continents which evidenced compliance with EU legislated operational minima and/or Best Available Techniques (BAT).

The potential hazards of bottom ash are a function of its intrinsic chemistry. Further hazards are created by the interaction of bottom ash with the chemistry of its external environment when applied in product form. Risk is assessed also as a function of the legislative framework of safeguards, if any, which govern product manufacture and point of use. Literature commonly expresses the chemical hazard by two metrics: a) the ‘total concentration’, which is the quantity per unit mass of specific elements and compounds; and b) the mobility of these elements and compounds from bottom ash, termed ‘leaching concentration’, and defined as the mass of substance per unit volume of liquid used to irrigate the sample.

In this report, chemical hazard identification was based on EU REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals). All the substances listed in Table 1 were present in the bottom ash as reported by the studies which comprise this report. All are considered as High Level of Concern by fulfilling one or more of hazard criteria under EU REACH (namely: very bioaccumulative; carcinogenicity; mutagenicity; reproductive toxicity; endocrine disruption; specific target organ toxicity upon repeated exposure; and chronic aquatic toxicity), combined with the large volumes produced, as identified by Wiesinger et al. (2021).

Phase change data is provided in Table 1 so that inferences can be drawn on the conditions inside the waste incinerator and by the presence and form of the substances in bottom ash.

Table 1. Selection of elements* found in MSWI bottom ash from studies in this report, and which are considered as High Level of Concern (Wiesinger et al.,
2021). * = Cl
-
is an ion and SO4
2-
is an ionic compound. ** Halkidiskis et al., 2019; Wiesinger et al., 2021.
Element Melting
Point
Boiling Point Origin in MSW**
Arsenic (As) Sublimes at 616°C Used in electronics and glass, wood preservative. Biocide in
plastics.
Barium (Ba) 729°C 1637°C Antioxidant, colourant, filler, heat and UV stabiliser in plastics.
Bromine (Br) -7°C 59°C Major constituent of flame retardants in plastics, foams and
textiles.
Cadmium (Cd) 321°C 756°C Heat stabiliser, antioxidant and pigment in plastics. Used in
metal plating and batteries.
Cobalt (Co) 1495°C 2870°C Catalyst and pigment in plastics. Widely used in magnets and
metal alloys.
Chloride (Cl
-
)* n/a n/a Plasticiser, heat stabiliser, colourant, antioxidant and catalyst
in plastics. Major constituent of polyvinyl chloride (PVC). Wood
preservative.
Chromium (Cr) 1860°C 2672°C Catalyst and pigment in plastics. Used in metal plating.
Copper (Cu) 1084°C 2567°C Biocide and pigment in plastics. Present as wiring in most
electrical goods.
Lead (Pb) 334°C 1740°C Colourant, antioxidant, UV and heat stabiliser in plastics.
Present in batteries, metal goods, glass, electronics.
Mercury (Hg) -39°C 357°C Catalyst, colourant, cross-linking agent, filler and biocide in
plastics.
Molybdenum (Mo) 2617°C 4612°C Catalyst, cross-linking agent and flame retardant in plastics.
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Nickel (Ni) 1453°C 2732°C Catalyst and biocide in plastics.
Antimony (Sb) 631°C 1635°C Main use is as a flame retardant in plastic, Also plastic catalyst,
antioxidant and pigment.
Sulphate (SO4
2-
)* n/a n/a Filler, colourant, heat and UV stabiliser in plastics.
Tin (Sn) 232°C 2270°C Biocide and antioxidant in plastics. Used as flame retardant,
and in metal plate, glass, ceramics.
Vanadium (V) 1887°C 3377°C Antioxidant in plastic. Also a lubricant in plastic manufacture.
Level of concern = vanadium oxide.
Zinc (Zn) 420°C 907°C Multiple uses as plastics additive: filler, heat stabiliser, flame
retardant, slip agent, pigment

(il documento completo, oltre che al link di GAIA, si trova fra i documenti in questo sito nella categoria documenti: "Tutto quello che non vi hanno mai detto")