“Management of Bottom Ash from WTE Plants”

An overview of management options and treatment methods
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The report is produced by ISWA, WGTT (Working Group Thermal Treatment)

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Abbreviations

BA  Bottom Ash
CEN  Comité Européen de Normalisation (European Committee for Standardization)
EC  European Council
EPA  Environmental Protection Act
EU  European Union
ISWA  International Solid Waste Association
L/S  Liquid/Solid
LAP  Landelijk Afvalbeheer Plan (Federal Waste Management Plan) (Dutch legislation)
LCA  Life Cycle Assessment
MSW  Municipal Solid Waste
MSWI  Municipal Solid Waste Incineration
NIMBY  Not In My Back Yard
NVOC  Non Volatile Organic Carbon
POP  Persistent Organic Pollutants
RDF  Refuse Derived Fuel
TOC  Total Organic Carbon
WGTT  Working Group on Thermal Treatment
WTE  Waste To Energy
Summary

As an on-going concern in waste management, more and more consideration is given to recycling and reuse of residues for construction purposes etc. The legislation for utilization is being tightened and the amount of MSWI bottom ash is rising.

This report presents the current (2006) MSWI bottom ash management situation in ISWA countries right now. The report intends to give an overview on national legislation, management practices and barriers for utilization. Due to difficulties to procure information on the subject several countries are left out, among others the U.S.A. The analysis was undertaken using 2003 as the reference year.

The present knowledge is acquired mainly through information from members of the ISWA Waste Thermal Treatment group, and their contacts with national experts in other countries.

In Europe, utilization of MSWI bottom ash is either practised (Denmark, France, Germany, Netherlands) or considered more and more as a viable option (Belgium, etc.).

In Denmark, France, Germany and in the Netherlands national legislation has been implemented to regulate utilization of MSWI bottom ash. Denmark and the Netherlands have set governmental targets for utilization of MSWI bottom ash, the target being 85 percent in Denmark and close to 100 percent in The Netherlands, whereas the actual utilization is 98 percent and 67 percent respectively. Though France and Germany have no governmental targets, high utilization rates are obtained, 72 percent and 65 percent respectively.

The legislation in all four countries is based on leaching criteria, but leaching limit values vary up to three orders of magnitude. Also there are great differences in test methods. Among other things the limit values are all expressed in mg/l, whilst referring to different tests. Danish criteria are based on a batch test using liquid solid ratio 2. French and German criteria are based on batch tests with liquid solid ratio 10 (the tests being slightly different), whereas the Dutch test is based on a column test with liquid solid ratio from 0.1 to 10.

Thus there are significant differences in the approaches used by regulatory bodies to develop criteria for utilization, there are also differences in the approach of the question of utilization or disposal itself.

Denmark relies almost exclusively on groundwater as a source of drinking water, and therefore has a strong need for strict protection of the ground water quality. The pollution contribution from secondary materials in a contemplated land use may not (altogether with known pollutions from the soil background, the pipe systems etc.) exceed the drinking water criteria, expressed as the result in mg/l in a batch test using a liquid/solid ratio of 2. In Denmark the authorities developed common rules for handling contaminated soil and inorganic residues such as bottom ash from MSW incineration and fly ash from coal fired power plants.

The Netherlands up till now aim to ensure marginal soil burdening when utilizing secondary materials. The leading principle is maintenance of the background soil quality. The legislation stipulates the maximum increase of 21 pollutants to one percent during a 100 year period due to the contemplated land use. Bottom ash is placed in a special category, because
bottom ash, as currently produced, does not always meet the regulatory requirements. It is anticipated that improvement in ash quality will bring the material within the regulatory specifications. Quality control programs and certification of bottom ash are in progress to ensure production of a marketable product. The special category is a provisional arrangement; from 2006 the MSWI bottom ash must meet the regulatory requirements in the Building Materials Decree. In 2007 new legislation is expected in the Netherlands which will replace the Building Materials Decree, the so called Decree of Soil Quality. It is expected that utilization possibilities for MSWI bottom ashes will be increased by this legislation.

Tightening of the regulations in Denmark and the Netherlands has lead to a mutual agreement between the producers of MSWI bottom ash and the authorities in the two countries to undertake programmes on upgrading possibilities.

France now having the most lenient leaching criteria, have initiated a study programme with regard to all Thermal Process Residues (RPT in French), including all waste incineration residues, fly ash from coal fired power plants, slag from metallurgy and siderurgy industries etc. The aim of the programme is to define a generic scientific based methodology for electing criteria and limit values. The programme takes in environmental assessments for all contemplated application scenarios.

German legislation is based upon two laws from 1996 and 1990. The aim is two-fold, to enhance utilization of secondary materials preserving natural resources and to protect the environment. This approach of a two-fold aim is also inherited in Danish, French and Dutch legislation. The latter law allows utilization only when any impact to the environment can be disclosed. As a consequence utilization is restricted to well defined construction applications. Industry guidelines for the use of mineral materials are under revision to coincide with the European CEN standards. However, the trend in Germany seems to move in the opposite direction to utilization by allowing mineral waste to be utilized as construction material even on dump sites, resulting in reduced efforts to produce high quality standard recycling materials.

In Switzerland where incineration is almost the exclusive management option for MSW, the current legislation basically allows utilization for the same application purposes currently practised elsewhere in Europe. Practically, however, there is a ban on utilization of MSWI bottom ash due to the demand for including MSWI bottom ash in the “Altlasten-Kataster” (cadastre for abandoned hazardous sites). This demand is basically the result of the intention not to create long term environmental pollution by utilizing polluted material in construction.

Thus the strategic approach on legislation and management is different all over Europe. Also there are different additional requirements for utilization associated with the category in question (bottom ash quality). For example the Netherlands require tight top cover using a triple layer of plastic, whereas the Danish legislation requires top cover to ensure that contact is avoided. The penetration rate of top cover depends on the type of material used. For the tightest material being asphalt and concrete, the penetration rate is stipulated to 10 percent, resulting in a controlled leaching from the application. The Danish leaching limit values are calculated on the basis of this scenario.

The trend is to favour large applications. The Netherlands encourage large applications by law (min. 10 000 tonne), whereas this trend is developing naturally in other countries.

Today (2006) approximately 11 million tonnes of MSWI bottom ash are produced in 11 European countries.
Managing MSWI bottom ash has the same concerns throughout Europe and because the utilization and disposal practises are more or less the same, it is considered desirable to create a level playing field for the marketing, utilization and management of MSWI bottom ash in Europe.

It is also important to devise standard test methods, to ensure that the environmental assessments are made on the same basis.

A general barrier in most countries is that people worry due to the fact that MSWI bottom ash originates from waste. Many practical and administrative barriers are identified.

A number of barriers for comparable utilization and management options in European countries are identified. Among those are different tax politics, different guidelines defining operations as utilization or disposal, and sometimes complex regulations for utilization. Furthermore difficulties associated with exporting MSWI bottom ash is also a barrier.
1 Introduction and scope of report

As a by-product of the treatment of municipal solid waste in waste to energy plants, roughly 230-280 kg of ashes are generated per tonne of waste incinerated, bottom ash being the major stream. Bottom ash can be either landfilled or utilized. The legislation and boundary conditions regarding the utilization of bottom ash appear to be different throughout the countries of the European Union, USA and Canada.

Since a large quantity of solid waste incineration bottom ash is generated, the impact of by-product utilization is large (both economically, environmentally and related to public acceptance). Recent experiences have shown that single events may influence the rate of utilization of bottom ash substantially.

The ISWA Working Group on Thermal Treatment (WGTT) has considered that a concise report regarding the utilization of bottom ash and the boundary conditions for utilization and export movements may contribute to a better understanding of the differences between regions in Europe and might help leading to a level playing field regarding this subject.

Therefore within the members of the working group a small task force was assigned the task of drafting a report on this subject.

The goal of this report is to present an overview of utilization possibilities and boundary conditions for utilization of MSW incinerator bottom ash including barriers. Other MSW Incinerator by-products are excluded.

1.1 Quality, management, market, barriers

The quality of the residues from waste-to-energy conversion is very diverse, as has been identified in the International Ash Working Group's (IAWG) book 'Municipal Solid Waste Incinerator Residues'.

The ash management practices are very different in different jurisdictions. As a result of the on-going concern for recycling and reuse in waste management, consideration is given to utilization and reuse of residues in construction purposes.

In Europe, utilization of MSWI bottom ash is either practised (Netherlands, Denmark, Germany, France) or considered more and more as a viable option (Belgium, Spain). In the Netherlands, France and in Denmark national legislation has been implemented to regulate utilization of MSWI bottom ash. In the Netherlands, bottom ash is placed in a special category, because bottom ash, as currently produced, does not always meet the regulatory requirements. It is anticipated that improvement in ash quality will bring the material within the regulatory specifications. Quality control programs and certification of bottom ash are in progress to ensure production of a marketable product. In the Netherlands during 2007 new legislation is expected that will broaden the utilization possibilities of MSWI bottom ashes.

Barriers for utilization are multiple. This necessitates a judgement on the short and long term environmental acceptability of utilization scenarios.
1.2 **WTE, bottom ash generation**

Waste-to-energy facilities produce clean, renewable energy through the combustion of municipal solid waste in specially designed power plants equipped with the most modern pollution control equipment to clean emissions. Municipal solid waste volume is reduced by 90 percent and the remaining residue is regularly tested and consistently meets strict national EPA standards allowing reuse or disposal in landfills.

There are more than 200 waste-to-energy plants operating in 14 European countries (1) managing about 23 percent of MSW in these countries, and there are 89 waste-to-energy plants operating in 27 states in USA (2) managing about 13 percent of America’s MSW.

The non-combustible fraction of the waste charged to the furnace forms a residue (ash) remaining on the grate at the completion of the combustion cycle. This material is generally referred to as bottom ash, but is also called grate ash, slag or clinkers. Bottom ash is generated at a rate of approximately 200-250 kg/t of waste incinerated. It is similar in appearance to a porous, greyish, silty sand with gravel, and contains small amounts of unburnt organic material and chunks of metal. The bottom ash stream consists primarily of glass, ceramics, ferrous and nonferrous metals, and minerals.

Figure 1.1. below shows all the streams of residues coming out from a WTE-plant.

![Diagram of WTE-plant](image)

*Figure 1.1. Mass burning waste-to-energy facility with production of electricity and hot water for district heating. The fluegas is cleansed for particulate matter, acid gasses, nitrogen oxides, heavy metals and dioxin before outlet. Bottom ash is collected separately whereas in this case residues from the total air pollution control system is collected in one fraction.*
Bottom ash must be taken out of the furnace in such a way that maintains control over the combustion process. A seal on the furnace is normally provided by a column of water. The water bath also serves to extinguish any remaining combustibles and cool the ash. Furthermore large pieces of clinker fracture when quenched, reducing their size. The bottom ash leaves the furnace wet thereby minimizing fugitive dust emissions.

1.3 **Properties of bottom ash (technical)**

The mechanical properties of MSWI bottom ash has been studied in several countries. In general the conclusion is that the MSWI bottom ash can replace not only sand but also natural gravel in unbound layers (subbase), if the content of organic matter is kept low.

It is recommended that a resilient modulus of 70 MPa should be used in design of constructions (measured values range between 75 and 200 MPa) and that the mean normal stress in the bottom ash layer is kept below 150 kPa.

Table 1.1 gives examples of test results from selected countries for a number of relevant mechanical parameters for evaluating MSWI bottom ash as a construction material.

<table>
<thead>
<tr>
<th>Mechanical properties of MSWI bottom ash</th>
<th>Denmark (7)</th>
<th>Spain (8)</th>
<th>Sweden (9)</th>
<th>Taiwan (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss on ignition (L.O.I.) at 550 °C in %</td>
<td>1.7 - 2.4</td>
<td>2 - 9</td>
<td>2.3 – 7.7</td>
<td>6 – 11 (1000 °C)</td>
</tr>
<tr>
<td>Grain size distribution</td>
<td>0/50 mm well-graded material</td>
<td>0/40 mm well-graded material</td>
<td>0/45 mm well-graded material</td>
<td>Not consistent with the gradation of subbase</td>
</tr>
<tr>
<td>Material &lt; 0.075 mm in %</td>
<td>8 - 9</td>
<td>16</td>
<td>8 - 10</td>
<td>6 - 15</td>
</tr>
<tr>
<td>Grain density kg/m³</td>
<td>2700</td>
<td>2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles test % loss</td>
<td>45 - 47</td>
<td>40 - 42</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>Water absorption in %</td>
<td>5.6 – 7.7</td>
<td>3.5 – 6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse fraction &gt; 4-5 mm</td>
<td>12.3 – 16.1</td>
<td>14.3 – 1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine fraction &lt; 4-5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compaction dry density kg/m³</td>
<td>1790</td>
<td>1550</td>
<td>1600 – 1700</td>
<td>1728</td>
</tr>
<tr>
<td>Optimum moisture content in %</td>
<td>15</td>
<td>16</td>
<td>14 - 19</td>
<td>15</td>
</tr>
</tbody>
</table>

* Table 1.1. Testing results for mechanical properties of MSWIBA from selected countries. The grain size distribution is classified as well-graded, meaning that there is equal abundance of coarse and fine material. Such uniform gradation is important to the compactability of bottom ash and the potential to utilise bottom ash as an aggregate substitute.

* Modern WTE-plants are capable of achieving low LOI’s (<2 percent)
Table 1.2 lists the major chemical constituents present in MSW combustor ash

<table>
<thead>
<tr>
<th>Element</th>
<th>Bottom Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicum</td>
<td>16.8 - 27.4</td>
</tr>
<tr>
<td>Calcium</td>
<td>5.12 - 10.3</td>
</tr>
<tr>
<td>Iron</td>
<td>2.11 - 11.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.19 - 1.18</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.72 - 1.16</td>
</tr>
<tr>
<td>Aluminium</td>
<td>3.44 - 6.48</td>
</tr>
<tr>
<td>Sodium</td>
<td>2.02 - 4.80</td>
</tr>
</tbody>
</table>

*Table 1.2. Typical chemical composition (percent) (5).*

The most abundant elements in municipal waste combustor ash are silica, calcium, and iron. Although ash composition can be expected to vary from facility to facility, these elements are present within relatively predictable ranges. This is reflected in the results presented in Table 1.2.

The presence of a relatively high salt content and trace metal concentrations, including such elements as lead, cadmium, and zinc, in municipal waste combustor ash (compared with conventional aggregate materials) has raised concerns in recent years regarding the environmental acceptability of using ash as an aggregate substitute material.

The presence of calcium and other salts in relatively high concentrations in MSW combustor ash makes the ash susceptible to hydration and/or cementitious reactions (particularly in the combined ash, which contains unreacted lime) and subsequent swelling. The presence of free aluminium in the ash when combined with water can also result in the formation of hydrogen gas. In addition, the high salt content also suggests that ash could be corrosive if placed in contact with metal structures, and that it would likely interfere with curing and strength development if used in Portland cement concrete.

If MSWI bottom ash is not managed properly it constitutes a possible environmental hazard. Proper legislation for reuse therefore is essential to ensure, that the environmental impact of contemplated land uses are restricted to an acceptable level. In Western Europe, the legislation is mainly based upon leachate limit values.
2 Bottom ash legislation

2.1 General overview of each country

2.1.1 Denmark

Incentives and targets for utilization of bottom ash
As a subbase material, the bottom ash is usually substituted for the diminishing supplies of natural gravel in various parts of Denmark. Thus, the incentives for utilization include both natural resource conservation and economic benefit. The impetus for wide spread use of ash stems from the imposition of a State tax on disposal which was initiated in 1987.

The governmental target for utilization of MSW incinerator bottom ash is 85 percent, stated in the government strategy “Waste strategy 2005 – 2008” from 2003. Due to the stated policy, the Danish road directorate is favourably disposed towards utilization of residues in road construction.

Statutory order Utilization of residues and soil for building and construction works
Utilization of MSWI bottom ash has been regulated since 1983. A new statutory order (Utilization of residues and soil for building and construction works No, 655 of June.27, 2000) was put into force by 1 January 2001, changing the principle for assessing the environmental impact. The principal idea behind the new rules is that the use or disposal is assessed on the basis of its pollution hazard (leaching) and less on the pollution class (total content).

All use of bottom ash should be covered (concrete or asphalt etc.) in order to avoid contact, and therefore limit all leaching to soil and ground water, which is the only environmental and human hazard impact possible.

Criteria for leachate quality are used to ensure a long term protection of environment specific to each contemplated land use.

Because of the similarity in the use or disposal of polluted soil and inorganic residues i.e. bottom ash etc., the authorities prepared common rules for handling of these products. The statute from 2001 covers both types of residues, and since the utilization is the same, the environmental impact of the applications is also the same, that is leaching of pollutants to the soil and groundwater.

Residues included in the statute are: bottom ash from MSW Incineration and bottom ash with fly ash from coal fired power plants. Applicants can apply for other residues i.e. boiler ash from MSW incineration to enter the list. If the physical and chemical properties meet the criteria described, they will be accepted. In Denmark MSWI bottom ash traditionally is defined as grate ash only, mixing with boiler ash is not allowed (set as a term in the operational license by the counties).

On the conditions given within the statute, residues can be utilised without permission. A notification, however, must be sent to the authorities, and/or the applicant must then wait four weeks. Each county council may refuse the project and require a closer study of the environmental impact to be undertaken.
The utilization statute classifies soil and inorganic residues into three different categories with different applications: (bottom ash never classified as category 1 due to its high content of inorganic pollutants).

<table>
<thead>
<tr>
<th>Category</th>
<th>Content</th>
<th>Leaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>As non-polluted soil or less</td>
<td>Stringent criteria</td>
</tr>
<tr>
<td>Category 2</td>
<td>No restrictions</td>
<td>Stringent criteria</td>
</tr>
<tr>
<td>Category 3</td>
<td>No restrictions</td>
<td>&quot;Lenient&quot; criteria</td>
</tr>
</tbody>
</table>

*Table 2.1. Classification of residue and soil*

Provided that the leachate from a CEN Compliance Batch Test with liquid/solid ratio 2 (L/S=2) does not exceed the maximum criteria for the category in question (table 2.1 and table 2.3), then the use will be considered as suitable concerning the applications related to the category (table 2.2). Total Organic Carbon (TOC) must in any case be below three percent (w/w), (CEN prEN13137, August 1999)

<table>
<thead>
<tr>
<th>Building and construction works included by the new statute</th>
<th>Applications for Category 2</th>
<th>Applications for category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>Yes</td>
<td>Yes (watertight pavement and draining off surface water)</td>
</tr>
<tr>
<td>Paths</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cable graves</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Floors and foundations</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Parking lots, Squares, etc.</td>
<td>Yes (lenient salt criteria until 2007)</td>
<td>No</td>
</tr>
<tr>
<td>Noise banks</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ramps, pads etc.</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Table 2.2. Applications for utilization of bottom ash*

The category 2 leaching limit values are very restrictive and implementation of the statute was followed by an obligation for the MSWI sector (mainly the incineration plants) to invest in upgrading the bottom ash quality. The category 2 salts criteria have been eased for a transition period until 2007 in order to ensure utilization of bottom ash. A revised version of the statute is under preparation and expected to come into force during 2007 at the latest.

Even with large investments, it seems very difficult to generate bottom ash complying to the category 2 limit values. MSWI bottom ash is utilized for applications exclusively according to category 3.
The leaching criteria are as follows:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cat.1+2</th>
<th>Cat.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg/ltr.</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Cl</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>SO4</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Na</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>As</td>
<td>0.008</td>
<td>0.16</td>
</tr>
<tr>
<td>Ba</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Pb</td>
<td>0.01</td>
<td>0.2</td>
</tr>
<tr>
<td>Cd</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>Cr, total</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Cu</td>
<td>0.045</td>
<td>0.09</td>
</tr>
<tr>
<td>Hg</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
<tr>
<td>Mn</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>Ni</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Zn</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Table 2.3. Utilization criteria. CEN prEN12457-3, L/S=2 batch leaching test.*

The utilization of inorganic residues (i.e. bottom ash) for building and construction purposes that meet the quality requirements described above is further subject to quantitative and environmental protective/application related restrictions. The general conditions are the following:

- All applications must be paved (watertight pavement is required if category 3);
- The distance to the nearest drinking water well must be 30 m or more;
- The residues must be placed above the highest ground water table;
- The maximum average thickness of the ash/residue layer is 1 m (paths: 0.3 m; ramps: 4 m; noise banks: 5 m).

*The Danish Environmental Protection Act*

Foundations in minor buildings in the countryside like stables etc. and road constructions are common applications approved in accordance with the statute. Parking lots and squares are only included in the utilization statute if the bottom ash concerned meets the criteria for category 2. Since the statute was came force in (2001) no applications for utilization of bottom has met the category 2 criteria.

Approximately 50 percent of all applications are regulated under the Environmental Protection Act (Section 3, “Protection of Soil and Groundwater” or section 5 “Concerns and Enterprises coursing pollution”). Marine applications for instance such as reclamation, harbour constructions etc., are not included in the “Utilization Statute" and must be approved in accordance with the Environmental Protection Act. Applications for parking lots and squares, are also approved in accordance with the EP Act because of the lack of category 2 quality. Approvals in accordance with the EP Act are based upon specific environmental appraisals of the utilizations concerned.

In general larger building and construction works have to apply for an environmental approval in accordance with the Environmental Protection Act providing a license for
operation. In these cases, the applicant will normally include the utilization of residues in the total package, making sure that estimation of the environmental impact will be based on contributions from all activities and assessed according to the rules in the Environmental Protection Act.

**Soil Pollution Act**

In accordance with the Soil Pollution Act from 1999 all applications should be notified to the authorities, and the site is registered on the central database for contaminated land. This registration makes the utilization of residues i.e. bottom ash less popular and considered a barrier for utilization.

**Additional requirements for utilization as road construction materials**

If the bottom ash is to be used as sub-base in road construction, it must comply with the following additional performance related conditions set by the Danish Highway Department, irrespective of which law or statute the approval is based:

- The bottom ash must be screened to maximum particle size of 50 mm, contain less than 9 percent (w/w) of fines below 0.075 mm, less than eight percent (w/w) of fines below 0.063 mm and the content of water must be between 17 and 25 percent.
- Less than 1.5 percent (w/w) of the fraction 16/50 may consist of paper, fabrics and food residues.

### 2.1.2 Finland

Finland has no legislation for utilization of bottom ash. There is only one 100 percent mass burning MSW Incinerator plant in Finland and all bottom ash is landfilled. (Mass burning systems are not the preferred technology in Finland. Typically household waste is sourced and separated before incineration in a RDF plant. Gasification of waste is the developing technique).

### 2.1.3 France

Several key general considerations should be taken into account to understand the way MSWI bottom ash is managed in France:

- Incineration is one of the two main treatment paths for MSW (42 percent in 2000), the other one being landfill (43 percent). This has two consequences: important tonnage of MSWI bottom ashes is generated (close to 3Mt in 2002), making its management an environmental priority; the companies or public bodies operating the MSW incinerators are organized to promote their common interests to facilitate MSWI bottom ash management.
- A dedicated national legislation exists (Circular of 9 May 1994) which provide a detailed regulatory framework to facilitate management. All the bottom ash management and recovery activities are based upon this regulation (see details below).
- Due to the size of the country, the regional availability and needs for natural gravel and the costs of transportation, means the success of MSWI bottom ash recovery is very heterogeneous across the country (e.g. successful in the Paris and North region, much more difficult in Centre or Alps region).
• The landfill capacity is continuously decreasing, leading to a general increase in landfill fees, thus encouraging operators to find alternative ways for bottom ash recovery.
• Whereas there is a growing interest in using recovered materials as substitutes for natural resources, the perception of this material is still mitigated both among potential final users (public work companies etc…) and among citizens.

The Circular of 9 May, 1994
As mentioned above, all the treatment of MSWI bottom ash must apply to a regulation made by the Ministry of Environment. A document, titled “Circular of May 9th, 1994 concerning the disposal of MSWI bottom ash” defines the conditions of recovery of bottom ashes in road constructions depending on their leachate characteristics. It applies exclusively to MSWI bottom ash, and not to boiler or fly ashes.

The test used to measure the potential environmental impact is based on three successive leaching tests performed as defined in the French NF XP X31-210 standard, which allows classification of bottom ash batches into three categories:
• MSWI bottom ash with low leachable fraction, called category “V” (stands for “Valorisable”, or “Recoverable”),
• Intermediate MSWI bottom, called category “M” (stands for “Maturable”, or “Able to follow a maturation process”),
• MSWI bottom ash with high leachable fraction, called category “S” (stands for “Stockable”, or “Storable”),

The document defines in detail how periodical compliance controls shall be performed, as well as conditions for categorizing the batches either in category V, M or S (see table 2.4). The sampling and testing methodology is further detailed in 2.2.2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Category</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>M</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Unburned fraction</td>
<td>&lt;5%</td>
<td>&lt;5%</td>
<td>&gt;5%</td>
<td></td>
</tr>
<tr>
<td>Soluble fraction</td>
<td>&lt;5%</td>
<td>&lt;10%</td>
<td>&gt;10%</td>
<td></td>
</tr>
<tr>
<td>TOC leachable (mg/kg)</td>
<td>&lt;1500</td>
<td>&lt;2000</td>
<td>&gt;2000</td>
<td></td>
</tr>
<tr>
<td>SO₄²⁻ (mg / kg)</td>
<td>&lt;10 000</td>
<td>&lt;15 000</td>
<td>&gt;15 000</td>
<td></td>
</tr>
<tr>
<td>As (mg / kg)</td>
<td>&lt;2</td>
<td>&lt;4</td>
<td>&gt;4</td>
<td></td>
</tr>
<tr>
<td>Pb (mg / kg)</td>
<td>&lt;10</td>
<td>&lt;50</td>
<td>&gt;50</td>
<td></td>
</tr>
<tr>
<td>Cd (mg / kg)</td>
<td>&lt;1</td>
<td>&lt;2</td>
<td>&gt;2</td>
<td></td>
</tr>
<tr>
<td>Cr(VI) (mg / kg)</td>
<td>&lt;1.5</td>
<td>&lt;3</td>
<td>&gt;3</td>
<td></td>
</tr>
<tr>
<td>Hg (mg / kg)</td>
<td>&lt;0.2</td>
<td>&lt;0.4</td>
<td>&gt;0.4</td>
<td></td>
</tr>
</tbody>
</table>

*Table 2.4. Criteria used to determine bottom ash category, based on NF X31-210 (AFNOR), L/S=10 batch leaching test.*

On raw bottom ash (tested at the outlet of the incinerator), the distribution in the three categories is roughly 50 percent V, 30 percent M, 20 percent S. After processing (three month maturation), the distribution evolves to roughly 85 percent V, 10 percent M, 5 percent S. The maturation process can be extended up to 12 months to further improve the bottom ash upgrading.

Depending on the category, each bottom ash batch is specifically assigned:
• the conditions of application in road construction for ashes from category “V”,
• the parameters and conditions of the process (maturation) that should be applied to ashes from category “M” on dedicated maturation platforms,
• how ashes from category “S” should be disposed of.

As mentioned earlier, the only applications currently authorised by the regulation for the MSWI bottom ash quality “V” are road constructions (lower layers), but also parking lots and embankments (see more details in 3.2.6). The use is constrained by the following additional requirements:

• Less than three metres thick for embankments;
• In areas not liable to inundation;
• Not in potable water catchments area;
• At least 30 metres far from nearest water well;
• Forbidden for backfilling trenches with metallic pieces for drainage systems.

Given this context, and in spite that “V” category criteria are reachable for a large majority of bottom ash batches, the operators estimate that only 50 percent of the currently produced MSWI bottom ash can effectively be recovered as secondary raw material. Whereas there is no official target for recovery, the goal is to recover 100 percent. New dedicated legislation would help to make additional steps towards this goal.

**Coming next : the “RPT” approach**

The French legislative framework for waste management is increasingly taking into account the concepts of environmental impact and eco-compatibility. Within this new framework, the 1994 circular, based on comparison of leaching tests which does not take into account the long term behaviour of bottom ash and the sensitivity of the receiving environment, will be complemented with additional requirements.

The Ministry of Environment and the French Environment Agency (ADEME) have initiated a study program with regard to all Thermal Process Residues (RPT in French), including all waste incineration residues, fly ash from coal fired power plants, slag from metallurgy and siderurgy industries, etc. The goal of this program is to define a generic methodology defining the orientation of the residues, to propose a scientific base to elect the criteria and thresholds, to propose application scenarios including environmental impact assessments, and to gather all these elements into new legislation.

This comprehensive task, initiated through a series of meetings in 2002 including all players, has not yet generated any draft text so far. In the meantime, the 1994 circular still applies.

**2.1.4 Germany**

The basis for utilization and disposal of waste is a German law, the so called “Kreislaufwirtschafts- und Abfallgesetz”, which came into force in 1996. The aim of the law is to enhance the recycling of materials and therefore preserve natural resources. It also provides guidance for an environmentally sound disposal of waste.

The law also draws a definition for the terms “disposal” and “utilization”, but overall, a clear preference is given to firstly avoid any waste. If this is not possible, the waste has to be utilised and finally, if this is not feasible for example due to economic reasons, disposal is allowed. Due to this hierarchy, the utilisation of waste has become more attractive in
Germany and it has even become more economic, in some cases, than the disposal of the waste.

With respect to waste incineration plants, clearly the avoidance of residues such as bottom ash is not possible at all, and therefore preference has always been given to utilizing the ash and thereby substituting natural mineral resources.

Another German law, the so called “Bundes-Immissionschutz-Gesetz”, which cares for the environment in Germany and came into force in 1990, states, that the utilization of waste is only allowed, if any impact to the environment can be disclosed. Since bottom ash may have substances like heavy metals that may have an environmental impact, the utilization is regulated and it restricts the use of bottom ash from waste incineration mainly to well defined road construction purposes.

In order to follow the need to recycle waste materials within these regulations, comprehensive guidelines for the use of mineral materials have been developed by the building industry over the years. These industry guidelines are currently under revision to match with the European CEN-Standards. The new guidelines will cover the following items:

- Quality assurance and –control for mineral materials;
- Terms of delivery of mineral materials;
- Testing requirements for mineral materials;
- Additional design requirements for technical constructions when using waste materials.

For the use of bottom ash in road construction for example, the following criteria have been defined:

- Composition; the content of mineral matter, inert fractions (glass and ceramics), metals and organic matter of the bottom ash has to be within a specified range.
- Stability of volume; the volume of the bottom ash has to be nearly constant to ensure, that technical buildings do not suffer any damage after the completion of the building.
- Resistance against frost; the bottom ash has to maintain its physical abilities at temperatures well below 0°C.
- Resistance against sudden impacts; the bottom ash has to withstand high load impacts and shall not suffer in structure.
- Distribution of grain size; the size of the mineral grain has to be within a certain range to ensure, that the physical properties of the material are stable.
- Shape of the grain; the surface structure of the grain is important for the physical properties of the mineral materiel.
- Defined density to which the bottom ash can be compressed during construction (Proctor density).
- Characteristics of the material to interact with water; the bottom ash has to be stable against water penetration. The leaching of harmful substances has to be reduced to a minimum.

Since Germany is a republic made out of a number of federal states, the local governments often enforce the German legislation with their own specific state regulations and thereby restrict the use of bottom ash as recycling material.
To enhance the utilisation of mineral wastes such as bottom ash, a new law was put into force in Germany this year, which allows mineral wastes to be utilised as construction materials even on dump sites ("Deponieverwertungsverordnung"). It is expected, that large amounts of mineral waste will now be re-directed to dumpsites due to attractive prices. Therefore the efforts to produce high quality standard recycling material such as bottom ash from waste incineration will be at stake again in Germany.

Using the German standard leaching test (DEV S4), the following limit values (Table 2.5) are set by LAGA (mg/l).

<table>
<thead>
<tr>
<th>Substance</th>
<th>LAGA 1994 criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>250 mg/l, 2500 mg/kg</td>
</tr>
<tr>
<td>SO4</td>
<td>600 mg/l, 6000 mg/kg</td>
</tr>
<tr>
<td>Na</td>
<td>Measured</td>
</tr>
<tr>
<td>As</td>
<td>Measured</td>
</tr>
<tr>
<td>Ba</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>0.05 mg/l, 0.5 mg/kg</td>
</tr>
<tr>
<td>Cd</td>
<td>0.005 mg/l, 0.05 mg/kg</td>
</tr>
<tr>
<td>Cr, total</td>
<td>0.2 mg/l, 2 mg/kg</td>
</tr>
<tr>
<td>Cu</td>
<td>0.3 mg/l, 3 mg/kg</td>
</tr>
<tr>
<td>Hg</td>
<td>0.0001 mg/l, 0.001 mg/kg</td>
</tr>
<tr>
<td>Mn</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>0.04 mg/l, 0.4 mg/kg</td>
</tr>
<tr>
<td>Zn</td>
<td>0.3 mg/l, 3 mg/kg</td>
</tr>
</tbody>
</table>

Table 2.5. Utilization criteria. DEV S4, L/S=10 batch leaching test.

2.1.5 Italy

Waste management in Italy is regulated by the Government decree n°22 of (5 February 1997), better known as “Ronchi decree”, which implements main European directives on waste. According to the decree n°22/97 MSW incineration residues need to be treated before they are disposed of.

Bottom ashes not containing hazardous substances can be utilized according to the Italian Ministerial Decree of 5 February 1998 either as raw material in the cement production or as aggregate in concrete production or for landscaping, embankments after the compliance of a proper leaching test.

The test consists of immersing a representative sample of at least 100 mg into deionised water at room temperature, which is periodically refreshed at fixed times. The L/S adopted is equal to 5. Refreshing is carried out after 2, 8, 24, 48, 72, 102, 168, and 384 hours (16 days). Refreshing consists of extracting the liquid phase by filtration. The extracted eluates are analysed, while contaminant concentrations of each eluate are summed and compared with the corresponding limits reported in table 2.6. For each eluate the measured pH must be within the range of 5.5 – 12.
<table>
<thead>
<tr>
<th>Substance</th>
<th>Utilization (cement, concrete, landscaping, embankments)</th>
<th>Landfilling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/l.</td>
<td>mg/kg (L/S = 5)</td>
</tr>
<tr>
<td>Cl</td>
<td>200</td>
<td>1000</td>
</tr>
<tr>
<td>F</td>
<td>1.5</td>
<td>7.5</td>
</tr>
<tr>
<td>SO4</td>
<td>250</td>
<td>1250</td>
</tr>
<tr>
<td>Na</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NO3</td>
<td>50</td>
<td>250</td>
</tr>
<tr>
<td>Cyanid (CN)</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>As</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>Ba</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Pb</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>Cd</td>
<td>0.005</td>
<td>0.025</td>
</tr>
<tr>
<td>Cr, total</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>Cu</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>Hg</td>
<td>0.001</td>
<td>0.005</td>
</tr>
<tr>
<td>Mo</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ni</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Zn</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Sb</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Se</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Sr</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Be</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Co</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>V</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Asbestos</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>COD</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>pH</td>
<td>5.5&lt;&gt;12.0</td>
<td>5.5&lt;&gt;12.0</td>
</tr>
<tr>
<td>Aromatic organic solvents*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogenic organic solvents</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorid organic solvents</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total pesticides not phosphorates</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DOC**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TDS***</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2.6. Criteria for utilization and disposal of MSWI bottom ash in Italy.

(*') Analysis must be carried out by the authorities only in cases where concentration limits are exceeded.

(**) In case of exceeding of limits of DOC, samples can be leached using a L/S = 10 l/kg and a pH of 7.5-8.0. The concentration limit is then equal to 80 mg/l. (An available method based on the norm prEN 14429 is being tested)

(***) It is permitted to use values of TDS as alternatives to chloride and sulfate values.
**Landfill**

According to the Italian Ministerial Decree n° 201 of 3 August 2005 bottom ashes containing hazardous substances must be disposed of in a landfill for hazardous waste or into a landfill for non hazardous waste after an adequate treatment of inertisation (vitrification, solidification, cement-stabilisation). The inert product must comply with the European CEN Compliance Batch leaching test 12457 part 4. The test consists of immersing a representative sample into deionised water producing a solvent/solid ratio of 10 L/1kg for 24 hrs. The analysis of eluate is compared to the concentration limits reported in table 2.6.

### 2.1.6 The Netherlands

The management of wastes is regulated in the Netherlands through the framework of the so-called Landelijk Afvalbeheer Plan (Federal Waste Management Plan), abbreviated as LAP. In this plan minimum standards are given for the management of wastes.

The minimum standards for bottom ash are:

- Bottom ash and fly ash must be collected and managed separately. No mixing is allowed.
- Close to 100 percent must be utilised (a total utilisation rate of 90 percent is considered the minimum standard for bottom ash + fly ash + APC residues).
- Utilisation in large scale controlled embankments is considered the minimum utilisation option.

Apart from the LAP standards the requirements in the Dutch Waste Incineration Directive have to be met, the main requirement being the loss on ignition must be lower than five percent.

The criteria of the European Waste Catalogue decide whether MSWI bottom ashes are considered as hazardous or not. The total contents of a number of inorganics determine this. Dutch bottom ashes are tested regularly for composition and are systematically categorized as non hazardous waste.

During utilisation the normal environmental legislation has to be met. In the Netherlands special legislation has been developed to protect the environment from the potentially adverse effects of leaching from construction materials, the so-called building Materials Decree, which was effected in 1998. In the fall of 2004 the Building Materials Decree was evaluated by the Dutch Parliament, who assessed that this regulation was too complicated and could form a barrier towards a level playing field with the neighbouring countries. Therefore, new legislation judging the environmental impact of building materials will be developed and enforced in 2007, the so called Decree of Soil Quality.

**Building materials Decree**

The requirements in the Building Materials Decree, forms a potential hindrance towards realisation of the goal of 100 percent utilization.

This Dutch Building Materials Decree, which came into force in 1998, presently forms the legislative framework for the environmental quality of construction materials, such as MSW.
incinerator bottom ash. The goals of the Building Materials Decree are twofold: soil protection and improved recycling of secondary materials.

The Building Materials Decree is part of the Soil Protection Law. It sets the rules towards the environmentally secure utilization of building materials. The principle of the Building Materials Decree is the so-called marginal soil burdening: The average soil quality should be maintained. The Building Materials Decree stipulates the maximum increase of 21 pollutants/components to one percent during a 100 years period due to the contemplated utilization. The 100 year emission of components in the soil through leaching from a building material is calculated – according to the Building Materials Decree - from the emission in laboratory leaching test (NEN 7343 column leaching test). Subsequently the calculated emission is compared with the emission requirements within the Building Materials Decree. Based on the level of measures against infiltration of leachate into the soil, two utilisation categories are distinguished with different boundaries for emission from laboratory leaching tests:

- Category 1, no restrictions and an estimated infiltration of 300 mm / year.
- Category 2, restricted utilisation, estimated infiltration of 6 mm / year as a consequence of the use of liners.

The criteria are valid for utilizations that are a maximum 15 m high.

It was clear since 1995 that MSWI Bottom ash presently does not meet the emission requirements for Category 2 building materials, because of too high leaching of Cu and Mo. To ensure a continued high utilisation rate, the Dutch Ministry of the environment provided a temporary so-called special Category MSWI-bottom ash with less severe leaching requirements for copper, molybdenum and antimony. In 2005, when it became clear that new legislation was to be developed, for the transition period, in a modification of the Building Materials Decree the requirements for the components Sb, Ba, Mo, Se, V, F and SO₄ were lessened by a factor of three. Furthermore for MSWI bottom ashes exclusion was given for Mo leaching measurements.

In table 2.7 an overview is given for Category 1, Category 2 and special Category emission requirements in the modified Building Materials Decree.

The special Category MSWI-bottom ashes has been extended several times and is now in operation until 1 January 2007, at which time all MSWI-bottom ashes should comply with demands in the new Decree of Soil Quality, assuming that is in force by then. The condition for the extensions of the Special Category was that the MSWI sector obliged itself to invest in upgrading processes of the MSWI bottom ash. Due to uncertainty around the legislation (what would the new demands be?) up till 2006 no structural investments in upgrading processes have yet been done.

If the MSWI bottom ash is to be utilized in accordance with a Special Category MSWI bottom ash approval, the following requirements must be met:

- The quantity of bottom ash used must be a minimum 10.000 tonne in foundations.
- The quantity of bottom ash used must be a minimum 100.000 tonne in embankments.
- A triple liner has to be used to cover the bottom ash.
- Leaching quality of the bottom ash has to be monitored.
Starting in 2007 the MSWI bottom ash must meet the requirements in the new Decree of Soil Quality.

The Dutch Waste Processing Association – sector MSWI – and the Dutch Ministry of the Environment have started a so-called Implementation Programme, to support upgrading possibilities for MSWI bottom ash. As part of the programme a report is required, assessing the present quality of Dutch MSWI bottom ash compared to the quality of Dutch MSWI bottom ash in 1990, highlighting the evolution in quality since 1990 and making proposals on the inventory of possible upgrading to bring MSWI bottom ash to the desired quality.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cat. 1 mg/kg</th>
<th>Cat. 2 mg/kg</th>
<th>Special Cat. MSWI bottom ashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>0.83</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Ba</td>
<td>6</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>0.022</td>
<td>0.061</td>
<td></td>
</tr>
<tr>
<td>Co</td>
<td>0.23</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>0.35</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>0.32</td>
<td>3.3</td>
<td>23</td>
</tr>
<tr>
<td>Hg</td>
<td>0.017</td>
<td>0.075</td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>0.51</td>
<td>2.5</td>
<td>23</td>
</tr>
<tr>
<td>Ni</td>
<td>0.70</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>0.97</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>0.09</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Se</td>
<td>0.09</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>0.08</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>3.15</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>2.3</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Br</td>
<td>3.4</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>560</td>
<td>8800</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>11</td>
<td>288</td>
<td></td>
</tr>
<tr>
<td>SO₄</td>
<td>3300</td>
<td>65 000</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.7. Utilization criteria. NEN-7343, column leaching test for granular materials.

Decree of soil quality
At this moment new legislation is in preparation, called the Decree of Soil Quality, which the Dutch Government intends to enforce in 2007. The Decree of Soil Quality will set limit values based on toxicological criteria; the principle of “Marginal Soil Burdening” will be left. It is expected that the leaching limit values for several components (such as Mo and Cu which are critical for categorization of MSWI bottom ashes) will become substantially less strict.

2.1.7 Spain
At least seven out of Spain’s nine incinerators are sited in the Catalonia region. The management of bottom ash (for utilization) is regulated by the Catalonia Government standards for bottom ash valorisation. The majority of bottom ash is, however, landfilled but
many studies have been undertaken to investigate the possibilities for utilization mainly in road construction.

Using the leaching test (DIN 38414-S4), the following limit values are set by Catalan Standard (mg/l):

<table>
<thead>
<tr>
<th>Substance</th>
<th>Catalan Standard criteria 1996</th>
<th>Catalan Standard criteria mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>0.005</td>
<td>0.05</td>
</tr>
<tr>
<td>Cd</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Cr, total</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>Pb</td>
<td>0.05</td>
<td>0.5</td>
</tr>
<tr>
<td>Zn</td>
<td>0.3</td>
<td>3</td>
</tr>
</tbody>
</table>

*Table 2.8. Spanish (Catalan) utilization criteria. DIN 83414-S4, L/S=10 batch leaching test.*

### 2.1.8 Sweden

**Incentives and targets for utilization of bottom ash**

In most parts of Sweden there is plenty of natural gravel and rock to crush, for use as road construction material. Therefore, the incentive for using bottom ash in construction works is small. In more densely populated areas hosting a MSW incineration plant, local authorities however, may favour the bottom ash to natural resources. This is of greater concern even when the availability of natural materials is limited.

The Swedish Environmental Protection has set a national target that in 2010 at least 15 percent of the ballast material shall be re-used material. Moreover, the landfill tax of €40/tonne is an economic incentive to avoid the landfilling of bottom ash.

**Regulation of, and criteria for, utilization of bottom ash**

There are no national regulations on the use of bottom ash as a construction material outside landfills. It is hence up to the regional or local environmental authorities to decide whether to allow the use of bottom ash as construction material or not. More often than not construction with bottom ash is not allowed due to environmental concerns. In a few cases, less than a dozen constructions, bottom ash has been allowed under the condition that it may not have any negative impact on the environment. This means that there must not be any groundwater (of drinking quality) in the vicinity of the construction site. Further, the soil must have low hydraulic conductivity, for example a clay moraine of at least one metre. The construction must also be covered by tarmac, the regional/local authorities must have a notification and a control programme must be set up. The control programme means a quality assurance of the bottom ash and groundwater monitoring with tubes placed at the site. The tubes are monitored for at least five years to ensure that the use of bottom ash has not had any negative environmental impact at the site.

At the moment the Swedish Environmental Protection Agency is developing guidelines for environmentally sound use of waste for civil works. Also the Swedish Geotechnical Institute (SGI) together with the Swedish Road Directorate, are developing a handbook for use of alternative materials for civil works.
2.1.9 Switzerland

The current legislation basically allows the utilization of bottom ash as long as it has not been mixed with filter ash, the ignition loss is below three percent and ferrous material has been removed. Utilization would be allowed under a waterproof top cover (e.g., under asphalt in road construction or, below buildings).

Practically there is a ban for utilization due to the demand for including utilized MSWI bottom ash in the “Altlasten-Kataster” (cadastre for abandoned hazardous sites). This demand is basically the result of the intention not to create long term environmental pollution by utilizing partially polluted material in construction. The argument is that sooner or later the constructions will be demolished and pollutants will be set free.

Of course this attitude is the result of the easy access to natural gravel in Switzerland. Contrary to other regions in Central Europe the excavation of gravel in Switzerland is enhanced by favourable deposits of natural resources.

Landfill

Landfill of MSWI bottom ash has to be performed on the landfill site under stringent requirements. Therein is the necessity to collect percolate water (Reaktor-Deponie).

According to the precaution in the last years it is very unlikely that the present management practice for MSWI bottom ash will be changed in the coming years.

2.2 Testing methods (environmental) – overview per country

An overview of testing methods in different ISWA countries is given below.

<table>
<thead>
<tr>
<th>Country</th>
<th>Name of test</th>
<th>General principle</th>
<th>L/S ratio</th>
<th>Other conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>EN 12457-4</td>
<td>Batch</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Czech Republic (2002)</td>
<td>Leaching characteristics of waste in accordance to Order of The Ministry of Environment No. 383/2001 Col.</td>
<td>Batch</td>
<td>10</td>
<td>Rotation along length – axis with 5 – 10 rpm for 24 hours at 15 – 25 °C. Paper filter 5 μm for eco-oxicological testing, membrane filter 0.45 μm for other analytical methods, no pH control</td>
</tr>
<tr>
<td>Denmark (EPA)</td>
<td>CEN prEN 12457-part3</td>
<td>Batch</td>
<td>2</td>
<td>Rotation along length-axis with 5-10 rpm for 6 hours at 22°C (15-25°C). Settling for 15 minutes and filtration through 0.45 μm filter. No pH control</td>
</tr>
<tr>
<td>Finland</td>
<td>prCEN/TS14405 (basic characterisation)</td>
<td>Percolation</td>
<td>10</td>
<td>Presented in a national guideline for the assessment of waste at landfill (draft)</td>
</tr>
<tr>
<td>France</td>
<td>NF (XP) X 31-210 standard (AFNOR)</td>
<td>Batch</td>
<td>10</td>
<td>L/S 10, 24 hours, no pH control</td>
</tr>
<tr>
<td>Germany</td>
<td>DIN 38414 S4</td>
<td>Batch</td>
<td>10</td>
<td>L/S 10, 24 hours, no pH control</td>
</tr>
<tr>
<td>Country</td>
<td>Methodology</td>
<td>Batch</td>
<td>Total fractions</td>
<td>pH Control</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td>Italy</td>
<td>Decree 5th February 1998 for utilization EN 12457 – 4, for landfilling</td>
<td>Sequential batch</td>
<td>5</td>
<td>Withdrawal of eluate and solvent refreshing after 2, 8, 24, 48, 72, 102, 168, and 384 hrs; pH &lt;&gt;5.5 –12; L/S 10, 24 hrs. no pH control</td>
</tr>
<tr>
<td>Netherlands</td>
<td>NEN 7384 (or NEN 7373)</td>
<td>Column test</td>
<td>10 (0.1-10)</td>
<td>Total fraction L/S 10 (mix of LS 0-1 and 1-10) or (NEN 7373) 7 eluate fractions from L/S 0.1-10, initially pH7, but uncontrolled, flow rate 0.5 L/S per day.</td>
</tr>
<tr>
<td>Norway</td>
<td>No official tests yet</td>
<td></td>
<td></td>
<td>The authorities have announced that regulations and requirements will be implemented in 2005.</td>
</tr>
<tr>
<td>Spain</td>
<td>DIN38414-S4 (Catalan Standard)</td>
<td>Batch</td>
<td>10</td>
<td>24 hours, no pH control</td>
</tr>
<tr>
<td>Sweden</td>
<td>No official tests, but SS-EN 12457-3 is normally applied</td>
<td>Batch</td>
<td>2 and 10</td>
<td>Serial batch test of L/S = 2 + L/S = 8 extraction.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>TVA Eluate test</td>
<td>Batch</td>
<td>10</td>
<td>Serial batch test of two L/S 10 extractions. CO2 bubbled through leachate to maintain pH at 5-6.</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>No official tests, EN 12457 is often used in tests</td>
<td>Batch</td>
<td>2 and 10</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.9. General overview of testing methods for all countries.

2.2.1 Denmark

The statute of 2001 (Utilization of residues (MSWI bottom ash, fly ash, etc.) and soil for building and construction works) prescribes the sampling and testing methods for bottom ash quality check. The producer of bottom ash (could be the incineration plant or the reprocessing plant) is responsible for making a declaration of the bottom ash. This declaration should contain documentation to prove the bottom ash environmental quality in the form of analysis featuring figures of content and leaching of trace elements. Quality tests should be performed on samples representing quantities of max. 5000 tonne.

The sample, which may be collected on-line from processing the stored bottom ash or from a stockpile, must be a composite of at least 50 sub-samples of 2kg each. The composite sample is passed through a 45 mm screen to remove large objects. In order to facilitate the subsequent crushing, ferromagnetic material, pieces of nonmagnetic metals, and pieces of unburned material (paper, fabric etc.) may be removed from the screened and air-dried ash sample, which is then reduced to 5kg by means of a riffle sampler. The amount of removals must be registered.

After crushing to <4 mm in accordance with the directions in the CEN standard (prEN 12457-3, CEN 1998), the sample is divided into two equal sized samples. One of these samples is used for batch leaching test (L/S=2, CEN prEN 12457-3), - the other one is further crushed to <2 mm and reduced to 100 g, which is subsequently ground (e.g. in a
mortar grinder) and analysed (As, Cd, Cr (total), Cu, Ni, Pb, Zn and TOC). The leachate from the batch test is analysed for the parameters shown in table 2.3. Metals determined by partial digestion with half-concentrated nitric acid for 0.5 hours at 1 atm followed by atomic absorption spectrophotometry, AAS or likewise techniques.

2.2.2 France

The testing method required by the 1994 Circular is mainly the French standard for leaching test NF XP X31-210. In this text, the ability to use bottom ash as a secondary raw material for public works is based on a set of physico-chemical properties (see 2.1.3 for details). Facing difficulties to have common practices within the profession, the SVDU (National Union of MSW Treatment and Recovery Operators) performed a study and provided two sets of recommendations one for sampling and one for testing, which are the operational references complementing the 1994 Circular.

Sampling
The document "Guides methodologiques pour l’échantillonnage des mâchefers d'UIOM" (Methological guides for MSWI bottom ash sampling) includes two guides, one for bottom ash coming directly from the incinerator, one for the bottom ash on treatment and maturation sites. The first one helps in characterising the result of a thermal process. The second one helps in characterising a bottom ash batch.

In both cases, the guide gives indications to define the:
- Number of samples (depending on the period of time represented by the sample, of the volume of the batch).
- Size of the sample (depending on the particle size distribution).
- Location of the sampling (on a conveyor or on a pile).

For example, for a daily sample procedure in a MSWI incinerator, the procedure could be taking six successive samples of 10kg, mix and then divide several times to get a 2 - 4kg final sample. Pre-filled forms are also proposed in the documents.

Testing
The document "Protocole technique pour la determination du potential pollutant des mâchefers d'UIOM » (Technical protocol for the determination of the polluting capacity of MSWI bottom ash) precises the procedures to follow for the characterization of the bottom ash.

Conditions of transfer to the laboratory are detailed (delays, packaging). The sample follows a first drying step at 105°C which at the same time gives its humidity content. The second step is grinding down to 4mm. This grinding is performed in several steps (with several gaps in the grinder) to limit the risk of overgrinding. Then the unburnt fraction is measured by heating the samples up to 500°C over 4 hours, followed by the leaching test according to NF XP X31-210 standard (L/S = 10, 3x16 hours). Finally the analysis of the leachate is performed according to French and European standards for As, Pb, Cr(VI), Hg, Cd, SO₄²⁻, TOC and soluble fraction. The thresholds for V, M or S classification are given in 2.1.3.

2.2.3 Italy
The MSWI bottom ash are analyzed according to the methods described in the Standard UNI 108002 which is in turn derived by the European standard prEN 12457 –1. Major physical properties are examined such as granularometry, bulk density, water absorption, thaw resistance. Chemical composition is also carried out with the aim to classify the sample as hazardous (CER code 19.01.11) or non hazardous (CER code 19.01.12). Contaminants are determined by digestion with an acid solution followed by Inductively Coupled Plasma Spectrometry or likewise technique.

2.2.4 The Netherlands

To characterise the Solid Waste Incineration Bottom ash the following groups of test methods must be used:

- Physical characterisation methods according to:
  - NEN-EN 13242 for granular road materials. Amongst others grain size distribution, skewness, grain form and grain strength are measured periodically.
  - The Waste Incineration Directive the Loss on Ignition (or alternatively the Total Organic Content (TOC)) are measured.
  - BRL 2307 additionally the magnetic iron content is measured.

- Chemical characterisation methods:
  - Composition is measured twice yearly to verify whether the bottom ash is considered non hazardous.
  - Leaching behaviour is measured regularly to verify the classification according to the Building Materials Decree.

2.2.5 Sweden

There is no national standard method for testing bottom ash as a road construction material. Availability and leaching (CEN prEN 12457-3) tests have been applied.

2.3 Relevant legislation from the EU

No EU legislation directly related to the utilization of MSW incinerator bottom ash is expected in the near future. However, legislation that will indirectly influence the utilization of bottom ash is in the offing. This chapter shortly goes through upcoming legislation from EU that might affect the future regulation of MSWI bottom ash.

The national legislation situation is presented in 2.

Much of the upcoming legislation focuses on the question/definition of utilization and disposal, a subject which could be decisive for the future utilization of MSWI bottom ash.

2.3.1 Waste Incineration Directive

Referring to the existing directive from 2000 the Commission is under an obligation to present a report based on experiences with the use of the existing directive including recommendations for revisions before December 31, 2008. Proposals and negotiations of
drafts, administrative and political readings will last 3-4 years and therefore the next Waste Incineration Directive is expected around 2012.

2.3.2 Thematic strategy on the prevention and recycling of waste

The Commission published in May 2003 “Thematic strategy on prevention and recycling of waste” (COM(2003) 301 final). The final revised document was passed by Commission during December 2005. It has been sent for reading in the Council and the Parliament. Three readings are expected, meaning that the final approved document will come into force in the beginning of 2008. The thematic strategy sets the scene for development of environmental criteria to define when waste stops being waste. At the same time the Commission wishes to equalize competition criteria for utilization. This is believed to be done by developing EU standards on treatment and through work extending the IPPC directive to cover more recycling plants.

It shifts the focus of utilization from products to material streams, however, no new targets for utilization are set.

2.3.3 The Waste Frame Directive

The final proposal for revising The Waste Frame Directive also passed Commission by the end of 2005. The Parliament intends to make the readings of the Waste Frame Directive parallel to the readings of the Thematic Strategy resulting in the same time schedule. As a consequence of the thematic strategy the scene is set for a number of changes. First of all the Commission wants to simplify the legislation by joining the directive with the directive for hazardous waste and waste oil.

The proposal is expected to lay down a clearer definition of utilization. The Commission will present guidelines to estimate when a contemplated operation is a question of utilization and when it is a question of disposal. This might be presented as an appendix of the Waste Frame Directive or as a separate statutory order. It is expected, that the new guidelines will define more waste operations as utilization instead of disposal, when compared to the decisions made today. Simplifying the rules for utilization is expected to make export easier.

Furthermore, the proposal will revise the waste definition, but more importantly propose a definition of when a secondary material in the chain of utilization ceases to be waste.

The Directive intends to rule on an environmental basis, and proposes the following criteria to determine when a material is no longer waste but a product:

- The environmental quality (i.e. leaching quality) must resemble natural raw materials; and
- There should be a market for the secondary materials, and
- The environmental account should be positive.

The Waste Frame Directive requires the use of LCA tools in the assessments, strengthening the role of LCA.

It is expected to come into force in member states during 2009-2010.
2.3.4 **The EU Statutory Order on Transport**

The primary goal of the new revised Transport Statutory Order is to ensure, that export of waste will only take place when the treatment solution abroad as a minimum is just as good as any existing treatment solution in the home country.

The new statute provides more possibilities for the member states to object to export, mainly for utilization purposes, and therefore is expected to strengthen the national solutions.

2.3.5 **EU Statutory Order on POP**

An EU Statutory Order on POP (Persistent Organic Pollutants, including dioxin among others) (EC/850/2004) came into force by in 2004. It bans the production, marketing and utilization of POPs. However, limit values for the POP content in waste are not yet stipulated. At values lower than the limit value a material is not to be considered POP-waste and can be utilized freely. At values exceeding the limit value a residue is a POP waste and should be cleaned or disposed of in a designated landfill.

These limit values are expected to be laid down by the EU commission before the end of 2006.

Only dioxin/furan (PCDD/F) is of interest for MSW incinerator bottom ash. On a European scale there is still extensive discussion regarding the maximum limit values. The limit value for PCDD/F is expected to be between 1-15 µg/kg. If ultimately a low limit value (around 1 µg/kg) is defined, this does not seem to influence the utilization of bottom ash, which has considerably lower PCDD/F contents and leaching.

There is going to be a Council decision due to insufficient support for the Commission proposal. The Commission proposed a limit value for PCDD/F to be 15 µg/kg. Normally in these cases, the Council decides for the Commissions proposal.

2.3.6 **Hazardous waste**

In the newly revised list of dangerous substances in EU (Classification and Labelling of Dangerous Substances or correctly: Commission Directive 2004/73/EC of 29 April 2004 adapting to technical progress for the twenty-ninth (29th) time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances) a new limit value for lead was introduced, intended as a guide. New research reveals that lead is more hazardous to the water environment than previously believed.

Two key pieces of EU legislation aim at achieving a high level of protection of human health and the environment from chemicals: Directive 67/548/EEC (Dangerous Substances Directive) which sets out harmonised EU rules for classification, packaging and labelling of dangerous chemical substances and Directive 88/379/EEC (Dangerous Preparations Directive) which extends these rules to dangerous preparations.

The 29th List of Dangerous Substances (Directive 2004/73/EC of 29 April 2004) classify products with a content of lead compounds (index no. 082-001-00-6) higher than 0.25 percent as hazardous (dangerous for the water environment).
Deadline for implementing the 29th List of Dangerous Substances (Directive 2004/73/EC of 29 April 2004) was October 2005 for all member states. This low limit value might possess a barrier for utilization by means of classification; approximately 5 percent of all MSW incinerator bottom ash could be classified as hazardous waste.

The two mentioned Directives apply for substances, products and preparations. The link to waste is given by the following: The HWD (Hazardous Waste Directive) defines hazardous waste as wastes featuring on a list drawn up by the European Commission, because they possess one or more of the hazardous properties set out in the HWD. The list is known as the EWC (European Waste Catalogue). HWD Annex III identifies fourteen properties H1 to H14 which defines waste hazardous. For instance if the waste possesses the property “Ecotoxic” (H14), the waste is defined hazardous. The EWC 2002 does not link "Ecotoxic" to any risk phrases or provide specific concentration limits.

However, the Dangerous Preparation Directive (DPD) sets out the meaning of "dangerous to the environment" giving it the same definition as "ecotoxic" in HWD. Therefore, as the definitions of substances and preparations which are "dangerous for the environment" from the DPD and "ecotoxic" from the HWD are similar, the classification criterion for "ecotoxic" has to be based on the criterion for "dangerous for the environment" in the DPD. This is consistent with the approach used in the EWC 2002 for the hazardous properties H4 to H8, H10 and H11, where the limiting concentrations for these hazards are based on the concentration limits laid down in the DPD.

Using the concentration limits from the Dangerous Substances Directive (DSD) (List of Dangerous Substances) waste with concentration of lead compounds as specified in index 082-001-00-6 higher than 0.2 percent, are classified as hazardous waste with the attached risk phrases R52/53.

In most countries hazardous wastes are not allowed for utilization. Therefore, based on Danish experience, up to five percent of all MSWI bottom ash is expected to be classified as hazardous waste and therefore require disposal. Fortunately the content of lead in MSWI bottom ash is currently decreasing, minimising the problem, but if the lead content increases again (which might be possible if metal prices fall and therefore the incentive for removal declines), disposal of a small percentage of MSWI bottom ash must be accounted for.

2.3.7 Landfill Directive

The Landfill Directive (1999) sets the rules for a committee to define the leaching criteria for disposal on landfill. The committee has finished the work in The Council Decision 2003/33/EC. The acceptance criteria for inert waste and non-hazardous waste are quoted in table 2.10 for comparison with the national criteria for utilization of residues such as MSWI Bottom Ash.

Since the Landfill Directive is a so-called minimum directive, the EU member states are allowed to set stricter criteria nationally, if they can be justified by specific needs for protection of the environment. This is expected to happen in Denmark. The limit values for acceptance at mineral, non-hazardous and hazardous waste landfills are expected to be considerably lower then at inert waste landfills in the vicinity or slightly lower than the values laid down in Council Decision 2003/33/EC. Lower limit values for waste to be landfilled will of course influence the criteria for utilization (i.e. bottom ash). All though the
criteria for utilization in Denmark are already very stringent, an impact on the utilization criteria is not exclusive.

Even without tightening, the Council Decision criteria (for inert waste) are at least for some parameters very strict. This will be clear when comparing with the national criteria for MSWI bottom ash utilization. For each individual substance, the acceptance criteria for landfilling are either in the vicinity of the national leaching limit values for utilization or lower. The Dutch category 2 criteria for example are all more lenient than the criteria for disposal of inert waste. The most problematic substances with respect to the acceptance criteria are molybdenum and antimony.

This might influence the national criteria for utilization as one may consider it unthinkable, that criteria for utilization will be more lenient than criteria for disposal (of inert waste).

As an example, studies are undertaken in Denmark prior to implementing the Council Decision. It is expected that only landfills for inert waste will be allowed in non-coastal areas (far from the ocean recipient). Landfills for non-hazardous and hazardous waste will only be allowed at the coast. This might lead to a peculiar situation, where utilization of MSWI bottom ash will be allowed non-coastal, whereas landfilling will not.

2.4 Discussion on legislation

Overall only Denmark, France, Germany, The Netherlands, Italy (and partly Spain) possess specialised legislation for utilization of inorganic residues such as MSWI Bottom Ash. In these countries incineration forms an integrated means of managing MSW, thereby reducing landfilling requirements, and recovering the energy present in the waste being burned.

Denmark and The Netherlands have introduced a scientific based legislation within the last few years mainly focused on the leachate quality. The principal idea behind the new rule being that the use of utilization or disposal is assessed on the basis of its environmental impact (leaching) and less on the physical or chemical characteristics of the material.

France and Germany have older and therefore less developed and scientific based leaching criteria from 1994. While France have initiated a study program with the aim to provide a scientific base to elect criteria and thresholds, generic for all residues from thermal processes, Germany on the other hand this year commenced a new law, which allows mineral wastes to be utilised as construction materials even on dump sites. The law is expected to re-direct large amounts of MSWI bottom ash to dumpsites due to attractive prices, resulting in diminished efforts producing high quality standard recycling material from MSWI bottom ash.

In The Netherlands the Dutch Waste Processing Association – sector MSWI – and the Dutch Ministry of the Environment have initiated a so-called Implementation Programme to support upgrading possibilities for MSWI bottom ash. The Building Materials Decree is a part of the Soil Protection Act. The aim is to ensure marginal soil burdening when utilizing secondary materials. The leading principle being that the average soil quality should be maintained.

The organisation of larger MSWI plants in Denmark already has made great efforts in upgrading the bottom ash quality to apply to the most stringent criteria. It was found that even with chemical treatment it was not possible to meet the very low leaching criteria set by the Ministry of Environment, although it came close. The aim of the Utilization statute which is part of the Soil Protection Act is to ensure protection of the environment, especially
groundwater. Denmark relies almost exclusively on groundwater as a source of drinking water and therefore has a strong need for strict protection of the groundwater quality. The leading principle being that the groundwater quality should be maintained and the drinking water quality should not be affected.

In Switzerland, Austria and Sweden for instance MSW incineration also offers a widely used means of managing MSW. In Switzerland 100 percent of the combustible waste is incinerated. Despite this 100 percent of the MSWI bottom ash is landfilled. The government intends to avoid long term environmental pollution by utilizing partially polluted material in construction projects. Of course this attitude is the result of the easy access to natural gravel in Switzerland.

In Italy technical regulations concerning the utilization of recycled materials for civil works have only recently been put into operation. The new regulations allowed some initial experience of bottom ash recycling to develop. At the moment bottom ash are sorted out to obtain homogeneous iron or aluminium based scrap fractions; the remaining part of it is selected on the basis of size to become aggregate for concrete production. An older practice is to send MSWI ashes to Germany as filling material for salt mines.

In countries in the southern and eastern part of Europe and in U.K. incineration of waste is by no means a widespread practice of managing MSW. In the landfill directive and the packing directive EU set targets for the reduction of biodegradable waste and packing waste on landfill. Therefore, the amount of combustible waste to be incinerated is expected to rise, resulting in larger amounts of MSWI bottom ash.

Therefore, there is a need for focusing on recycling and utilization of MSWI bottom ash. On the grounds of avoiding transporting of waste across borders it would be of mutual interest for all member states to have more uniform regulations.

Looking at the leaching criteria there are large differences between each of the studied countries. The leaching limit values vary up to three orders of magnitudes for Hg and Cd, the lowest in Denmark and the highest in France. The test methods are also different. The French and German limit values are based on batch tests using liquid solid ratios of 10, Italy uses a liquid solid ratio on 5 and Denmark 2. In the Netherlands the limit values are based on a column test, referring to the liquid solid fraction 0.1-10. The latter test method makes a better reflection of reality but may be less practical.

Different test methods make it impossible to compare the limit values directly. Anyway the leaching limit values are converted from mg/l into mg/kg which expresses the leaching on the basis of the original product used. The conversion will not give a truly reliable picture of the limit values, but merely a comparable indication. The leaching limit values are listed in the table below (table 2.10). The figures are presented in mg/kg. For information on test methods see 2.2.
Table 2.10. Overview of limit values for element leaching from various countries. The criteria applied for utilization of MSWI bottom ash.

Obviously the leaching criteria for utilization must be at least the same as or lower than the leaching criteria for disposal to landfill. This contradicts the previously mentioned situation in 2.3.7. The fact that MSWI bottom ash cannot meet the acceptance criteria for disposal of inert waste, at least for molybdenum and antimony, might constitute a problem. In table 2.11 leaching characteristics for Danish MSWI bottom ash are compared with acceptance criteria in L/S=2 test.

Copper leaching declines with ageing (curing), but it seems impossible to meet the acceptance criteria (inert waste) for the elements chloride, sulphate, molybdenum and antimony. Will it be publicly acceptable to maintain more lenient utilization criteria than criteria for disposal (of inert waste – section 2.3.7)?

It is an unanswered question, but maybe with arguments based on specific, scientific calculations of the maximum allowable impact on the environment, calculated for each specific contemplated land use (type of construction work), it will be possible to persuade authorities.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Denmark Batch (L/S=2) 2000</th>
<th>France Batch (L/S=10) 1994</th>
<th>Italy sequential (L/S=5) 1998</th>
<th>Germany Batch (L/S=10) 1994</th>
<th>The Netherlands Column (L/S=0.1-10) 2005</th>
<th>Council Decision 2003/33/EC (L/S=10) 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cat. 2 mg/kg</td>
<td>Cat. 3 mg/kg</td>
<td>mg/kg</td>
<td>mg/kg</td>
<td>Cat. 1 mg/kg</td>
<td>Cat. 2 mg/kg</td>
</tr>
<tr>
<td>Cl</td>
<td>300</td>
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<td>F</td>
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<td>-</td>
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<td>3000</td>
<td>10 000</td>
<td>1250</td>
<td>6000</td>
<td>3300</td>
</tr>
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<td>As</td>
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<td>2</td>
<td>0.25</td>
<td>Measure</td>
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<td>Ba</td>
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<td>8</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>155</td>
</tr>
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<td>Pb</td>
<td>0.02</td>
<td>0.2</td>
<td>10</td>
<td>0.25</td>
<td>0.5</td>
<td>0.97</td>
</tr>
<tr>
<td>Cd</td>
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<td>0.08</td>
<td>1</td>
<td>0.025</td>
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<td>0.022</td>
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<tr>
<td>Cr, total</td>
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<td>1.5</td>
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<td>2</td>
<td>0.35</td>
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<tr>
<td>Cu</td>
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<td>4</td>
<td>-</td>
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<td>3</td>
<td>0.32</td>
</tr>
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<td>0.002</td>
<td>0.2</td>
<td>0.005</td>
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<td>0.017</td>
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<tr>
<td>Mn</td>
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<td>2</td>
<td>-</td>
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<td>0.4</td>
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<tr>
<td>Ni</td>
<td>0.02</td>
<td>0.14</td>
<td>-</td>
<td>0.05</td>
<td>0.4</td>
<td>0.7</td>
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<tr>
<td>Zn</td>
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<td>3</td>
<td>-</td>
<td>15</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Co</td>
<td>1.25</td>
<td>-</td>
<td>-</td>
<td>0.05</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Mo</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.084</td>
<td>1.2/2</td>
<td>0.06</td>
</tr>
<tr>
<td>Sb</td>
<td>-</td>
<td>0.084</td>
<td>1.2/2</td>
<td>0.084</td>
<td>1.2/2</td>
<td>0.06</td>
</tr>
<tr>
<td>Se</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
<td>0.031</td>
<td>0.27</td>
<td>0.1</td>
</tr>
<tr>
<td>Sn</td>
<td>-</td>
<td>0.08</td>
<td>2.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>V</td>
<td>0.125</td>
<td>3.15</td>
<td>96</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
and public opinion, that it is acceptable with utilization criteria more lenient than acceptance criteria (inert waste). 

<table>
<thead>
<tr>
<th>Substance</th>
<th>Council Decision 2003/33/EC (L/S=2) 2003 Inert Waste</th>
<th>MSWI Bottom Ash leaching (L/S=2) results 2005, average Vestforbrænding Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/kg</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Cl</td>
<td>550</td>
<td>1550</td>
</tr>
<tr>
<td>SO4</td>
<td>560</td>
<td>1600</td>
</tr>
<tr>
<td>Cu</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Mo</td>
<td>0.3</td>
<td>0.62</td>
</tr>
<tr>
<td>Sb</td>
<td>0.02</td>
<td>0.091</td>
</tr>
</tbody>
</table>

Table 2.11. Acceptance criteria (inert waste) in comparison with leaching characteristics for Danish MSWI Bottom Ash for chosen elements. Both acceptance criteria and leaching data apply for L/S=2 test and figures refer to mg/kg.

One desired effect of this ISWA report is an initiating of an international (ISWA) project on how to make a common basis for defining and measuring the criteria for utilization. First of all the member states must agree on a strategy or a leading principle for assessing the environmental allowable impact. A mutual understanding on considerations to be taken must be agreed on. For example considerations to soil quality, to ground water quality, to surface recipients, to corrosion of pipe systems etc. and the acceptable level of these qualities. Also the assessment criteria have to be agreed on.

Furthermore the test methods must be standardised. The Council Decision 2003/33/EC is a good example, describing leaching limit values on the basis of batch tests of both L/S=2 and L/S=10 and also on the basis of a column test, L/S=0.1-10.

**Non utilization strategy**

Some countries like Switzerland intends to avoid long term environmental pollution by utilizing partially polluted material in construction purposes. The argument being, that sooner or later the constructions will be demolished and pollutants will be set free.
3 Bottom ash management practices

3.1 Bottom ash quantities

The worldwide production of MSWI bottom ash is expected to increase in the coming years due to more widespread use of incineration practice as a means of managing MSW. In the future an environmental safe and sustainable means of utilization or disposal of MSWI bottom ash is required.

Although the incineration of MSW results in a mass reduction of approximately 80 percent, the amount of residues remaining to be utilized or disposed of is substantial. In Europe approximately 10 million tons of MSWI bottom ash is produced yearly and the figure is rising.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>225,000</td>
<td>No data</td>
</tr>
<tr>
<td>Belgium</td>
<td>Approx 500,000</td>
<td>No data</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>118,000</td>
<td>105,000</td>
</tr>
<tr>
<td>Denmark</td>
<td>644,626</td>
<td>629,278</td>
</tr>
<tr>
<td>France</td>
<td>2,995,000</td>
<td>2,366,000</td>
</tr>
<tr>
<td>Germany</td>
<td>3,140,000</td>
<td>2,025,700</td>
</tr>
<tr>
<td>Hungary</td>
<td>53,000</td>
<td>No data</td>
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<tr>
<td>Italy</td>
<td>753,390</td>
<td>151,180</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,075,000</td>
<td>950,000</td>
</tr>
<tr>
<td>Norway</td>
<td>197,000</td>
<td>102,000</td>
</tr>
<tr>
<td>Portugal</td>
<td>177,918</td>
<td>Landfill</td>
</tr>
<tr>
<td>Switzerland</td>
<td>640,000</td>
<td>Landfill</td>
</tr>
<tr>
<td>Spain</td>
<td>250,000</td>
<td>No data</td>
</tr>
<tr>
<td>Sweden</td>
<td>446,478</td>
<td>40,000</td>
</tr>
<tr>
<td>UK</td>
<td>725,000</td>
<td>410,000</td>
</tr>
<tr>
<td>USA</td>
<td>9,000,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>

Table 3.1. Bottom Ash quantities in selected countries. (Uncertain figures in italic.)

It is expected that in several countries like Norway and Sweden the waste to energy concept will extend in the coming years.

Extension of WTE plants in different countries is seen in the figure below (figure 3.1). The figure shows the potential for more WTE plants.
From figure 3.1 it can be seen that especially countries like Czech Republic, United Kingdom and USA have a large potential for increasing MSWI in the coming years.

### 3.2 Bottom ash upgrading practices

The main purpose for bottom ash treatment is to produce recyclable products.

At present only part of the total bottom ash produced is treated for the purpose of utilization because in some countries or in some regions landfilling is still the predominant MSWI bottom ash management option.

In some European countries (Denmark, France, Germany, The Netherlands), significant quantities (50 percent to 100 percent) of MSWI bottom ash are utilized for road construction and similar purposes. This kind of utilization requires removal of unwanted fractions in the ash.

Pre-treatment of MSWI bottom ash in these countries constitutes the following steps: screening, metal recovery and weathering to insure decrease of organics and low leaching of critical components. An overview is given in table 3.2.
<table>
<thead>
<tr>
<th>Country</th>
<th>Screening</th>
<th>Ferrous metal recovery</th>
<th>Non-ferrous metal recovery</th>
<th>Storage demand (decrease of organics, swelling and leaching)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>X</td>
<td>X</td>
<td>some</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Some cement stabilization</td>
</tr>
<tr>
<td>France</td>
<td>X</td>
<td>X</td>
<td>often</td>
<td>X</td>
<td>Some cement stabilization</td>
</tr>
<tr>
<td>Germany</td>
<td>X</td>
<td>X</td>
<td>some</td>
<td>X, Min. 3 months</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>X</td>
<td>X</td>
<td>some</td>
<td></td>
<td>Some cement and chemical stabilisation</td>
</tr>
<tr>
<td>Netherlands</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X, min. 6 weeks</td>
<td>Some cement stabilization</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>X</td>
<td>X</td>
<td>some</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2. Overview of Bottom Ash treatment in selected countries.

Figure 3.2. Typical bottom ash processing. Different screening mesh sizes are used in different countries. See 2 and/or 3.
3.2.1 Integrated scrubbing

If sintering of the bottom ash is achieved on the grate the leachates of the bottom ash are comparable to molten bottom ash and also to some natural materials. If surplus water is added to the bottom ash extraction device (fig. 3.3) the salt content of the bottom ash can be reduced by more than 50 percent.

![Integrated Scrubbing of Bottom Ash](image)

*Figure 3.3. Integrated scrubbing. Rüggenberger Damm MSWI plant in Hamburg.*

3.2.2 Screening and crushing

The grain size distribution of MSWI bottom ash is largely determined by the composition of the waste and the incinerator type. The grain size distribution is important for the mechanical properties of the bottom ash, and has to imitate the grain size of natural gravel.

Screening is carried out with standard drum or flat deck screens with a 45 - 50 mm mesh size resulting in a gravelly sand with an improved compaction performance without any further measures. In construction works an optimum compaction is essential to ensure that the aggregate does not settle after placement.

The oversize materials will contain refractory items, which may affect the mechanical properties. This fraction will also often contain a significant proportion of the partially combusted waste which has to be removed before reuse.

The amount of very fine particles (<63 μm) is important in the response to frost heave and thus the ability to withstand freeze-thaw cycles. The degree of fines will also affect the permeability and compaction properties and for most uses the fines should be minimised.

Removal of the finest fraction is not normally performed unless the target application is sensitive to frost or the ash has an excessive proportion of this material.

Crushing may be undertaken to reduce the particle size to make the ash suitable for some applications, such as in cement and concrete. However, crushing is not usually carried out...
because screening alone can provide the necessary grain size fractions for road construction applications without the expense associated with crushing.

3.2.3 Recovery of ferrous and non-ferrous metals

Lumps of ferrous and non-ferrous metal are separated from the ash through the use of magnets and eddy current separators.

Ferrous metal removal is standard practice in most countries whilst non-ferrous metal removal is less common although increasing in popularity as eddy current separators become more economic.

The recovered metals are recycled through the international scrap market.

The efficiency of the separator techniques could be improved and some trials are being undertaken to improve the processes to ensure that extraction performance is maximised whilst minimizing costs.

If metal recovery does not take place use of the ash can cause problems, particularly for use in cement bound materials where iron can cause discoloration and aluminium can lead to the generation of hydrogen leading to swelling and a decrease in the mechanical properties of the structure.

The recovery of the metals prior to combustion is preferable. The combustion process degrades the ease of recycling of the metals. Tin may become alloyed with the steel and aluminium melts capturing ash particles that require subsequent removal.

3.2.4 Weathering

MSWI bottom ash is exposed to the atmosphere to allow metal oxides and hydrates to react with water and carbon dioxide to form carbonate. These reactions reduce the leachability of the metals and reduce the potential impact on the environment.

Reactions with water can cause the material to swell, therefore weathering is essential.

Weathering is normally achieved by leaving the ash in a stockpile to allow rainfall and time to complete the reactions. For the new generation of incinerators a weathering time of at least 3-4 months is required.

The leachate produced during storing(weathering requires appropriate disposal as it may contain high concentrations of highly soluble salts and minor amounts of metals, especially copper, chlorides and sulphates.

3.2.5 Cement stabilisation

Cement stabilisation is typically carried out on the construction site by mixing the bottom ash with cement or other puzzolanic materials to form a monolithic material that effectively excludes moisture (physical encapsulation).

In addition, the cement environment provides a highly buffered environment that limits the solubility of most trace metals by maintaining a high pH. For some trace metals, however, the high pH provides higher solubility.
A particular concern is sulphate attack of the pozzolanic bonds. Also the matrix is not effective at binding some cations and the leaching of chloride salts can lead to loss of physical strength and durability.

### 3.2.6 Chemical stabilisation

In Denmark and the Netherlands the very strict limit values of the lower categories have led to a mutual agreement between the authorities and the MSWI incineration plants to undertake studies on upgrading bottom ash with respect to leaching quality.

The conclusion reached in the Danish studies is, that it is not possible within a reasonable economic framework to reduce the leaching of all elements making bottom ash apply to the most stringent criteria of category 2. The elements of problems in order of priority are \( \text{SO}_4 \), Na, Cl, Cu, Cr. More seldom As, Pb and Ni.

The leachate quality was brought close to the limit values by means of chemical treatment with soda or carbon dioxide. Even though the bottom ash sometimes succeeded to meet the criteria, the subsequent testing method, especially the pretreatment step of crushing the ash sample, exposed more ions to the water from the internal of the grains, resulting in a rise of concentration of the element concerned, thereby exceeding the limit values.

### 3.3 Utilization and disposal practices

In many countries there is an increasing shortage of suitable natural aggregate and lack of available landfill space and at the same time an increase in the amounts of MSWI bottom ash. This is the principle motivation for utilization of MSWI bottom ash.

The bottom ash is generally utilized for purposes mentioned within other places in this report. In all countries, however, a portion of the bottom ash is landfilled. In Denmark for example the lowest portion possible is landfilled consisting of larger amounts of non-crushable and non-recyclable lumps of bottom ash. Up till now no MSWI bottom ash is landfilled due to high content of organic matter or due to high leachability.
<table>
<thead>
<tr>
<th>Country</th>
<th>Major type of utilisation</th>
<th>Bottom ash Landfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Construction material</td>
<td>No data -</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Landfill construction</td>
<td>12 577 (11%)</td>
</tr>
<tr>
<td>Denmark</td>
<td>Building / road construction, Embankments</td>
<td>15 348 (2%)</td>
</tr>
<tr>
<td>France</td>
<td>Road construction</td>
<td>707 030 (23%)</td>
</tr>
<tr>
<td>Germany</td>
<td>Civil works</td>
<td>868 200 (28%)</td>
</tr>
<tr>
<td>Italy</td>
<td>Civil works, base material for landfill</td>
<td>602 940 (80%)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Road construction and embankments</td>
<td>150 000 (13%)</td>
</tr>
<tr>
<td>Norway</td>
<td>Landfill construction</td>
<td>95 000 (48%)</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Landfill</td>
<td>600 000 (100%)</td>
</tr>
<tr>
<td>Spain</td>
<td>Road construction</td>
<td>No data -</td>
</tr>
<tr>
<td>Sweden</td>
<td>Civil works and landfill construction</td>
<td>No data -</td>
</tr>
<tr>
<td>U.K.</td>
<td>Road construction, concrete aggregate</td>
<td>No data -</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>Road construction and landfill</td>
<td>No data (90%)</td>
</tr>
</tbody>
</table>

Table 3.3. Amount of MSWI bottom ash landfilled in different countries.

3.3.1 Denmark

Since 1974 bottom ash from MSW Incinerators in Denmark has been utilized as a subgrade or sub-base course in civil works and road construction purposes as unbound material substituting for gravel-type materials. Ninety seven to ninety eight percent of all bottom ash in Denmark is utilized mainly as granular sub-base material in industrial buildings, smaller roads, parking lots and paved squares for industrial purposes, and sometimes paths for bicycling. Also it regularly applies in embankments and fill in larger projects e.g. reclamation etc. Recently MSWI bottom ash has been applicable to large motorway projects as sub-base in ramps and access roads. It is not applicable to the motorway itself due to the lack of bearing properties. The Danish Highway Department recommends utilization only in projects with traffic load less than 400 trucks per day. (For specific conditions see paragraph 2.1.1). Trials have been performed using MSWI bottom ash as aggregate in bound layers in cement stabilised bases. This is not a wide spread use.

For utilization purposes the bottom ash is upgraded. The processes involved are sieving through screens with 40-45 mm mesh size. The oversize is sorted for removal of recoverable metals etc. and the rest is crushed and screened again. Ferrous metals are removed by means of magnetic separation and non-ferrous metals by eddy current separators. The removal of non-ferrous has only now become wide spread after the rise in metal prices making the separation process economically beneficial.

The bottom ash is stored in open air for at least one month to ensure completion of expansion processes together with hydration and carbonation processes. The time allowed
for these processes varies between facilities but typically six weeks to six months are employed.

Today almost every MSWI plant in Denmark has outsourced the upgrading process to special companies, which also market the bottom ash.

The high rate of utilization in Denmark is based on tradition since 1974. The Authorities strives towards complete utilization, but at the same time towards the highest level of environmental protection. The latter has resulted in a demand for mapping all applications in a central register leaving it classified as “polluted”. As the MSWI bottom ash is mainly marketed to the private sector, the resulting reduction of property value has lead to a lower degree of utilization. However, the upgrading and marketing facilities up till now have succeeded in finding other applications for those that disappeared, maintaining the utilization rate.

Mixing with other heaps of bottom ash is only allowed at the utilization site and only after declaration of the portions of bottom ash/residues. Mixing with soil is not allowed. Bottom ash applications must be held separate from clean soil.

The governmental strategy from 2003 (Strategy plan 2005-2008) sets the target for utilization of MWSI bottom ash to 85 percent. The balance between a high rate of utilization and a high degree of drinking water and environmental protection is the key to determine the rate of utilization.

The removed ferrous and non-ferrous metals are recycled through the international scrap market. Since aluminium is the major part of swelling and expansion processes, removal helps increase the quality of bottom ash.

The bottom ash is supplied to the market with a declaration according to the statute of utilization (see 2.1.1). The declaration is produced by the supplier and covers the environmentally quality of the bottom ash.

3.3.2 France

In France there is an increasing use of MSWI bottom ash for construction purposes, particularly in roads, rather than being disposed of in landfills. In France, this new approach has been promoted by the law of the 13 July, 1992, concerning waste elimination. Indeed, since the year 2002, only non-reusable wastes must be disposed of into landfills consequently to the substantial increase in the amount of waste. The MSWI bottom ash reuse depends on a French regulation that is only based on a few physico-chemical characteristics of wastes: soluble fraction, release of a few elements (As, Pb, Cr(VI), Hg, Cd, SO$_4^{2-}$) and total organic carbon content.

3.3.3 Germany

In Germany bottom ash is used in various fields, mainly as the bearing layer in roads or parking lots in the public or private sector. The bottom ash is mostly used without any additives, but for high bearing capacities eight to ten percent of cement is added to produce a concrete-like (hydraulically bonded) material, which is sold under the name of “emvau-mix”. Also, bottom ash is used in sound embankments or other comparable applications.
3.3.4 **Italy**

Most of MSWI bottom ashes (80 percent) are landfilled, often after a chemical stabilisation (i.e. the SOLIROC process applied by the plant of Modena) or solidification treatment. The inert product can be used as base material for landfill. The largest form of utilization is, however, the metal recovery (iron and aluminium scraps). Other incinerators send their solid residues to salt mines in Germany where they are used as filler and consolidation material. Recently a new plant for screening (30 000 t/y capacity) has been put into operation in Northern Italy. It allows separation of metal fractions and different size granulates of the inert fraction. The inert amount is sent to a concrete production plant.

3.3.5 **The Netherlands**

MSWI-bottom ashes from all Dutch municipal solid waste incineration plants are processed in a Bottom ash Upgrading Installation (BUI). In this "BUI" the following unit operations are performed.

Sieving (40 mm and 10 – 12 mm), crushing (>40mm), wind sifting, magnetic separation of iron scrap and non-ferrous separation. At most municipal solid waste incineration plants the BUI is part of the plant operation. Fresh bottom ashes are generally stored for maximum 3 days before treatment in the BUI. Directly following treatment in the BUI samples of the fresh ashes are taken for quality control (column leaching tests). One MSWI has an interim storage of a few weeks before treatment in the BUI.

Some MSWI plants have outsourced bottom ash upgrading. The upgrading is than discontinuous and the storage time before upgrading can be as long as a few months. After upgrading MSWI bottom ash has to mature for at least six weeks before utilisation can take place.

Since 1993 (as an average) the total production of upgraded MSWI bottom ash has been utilised, predominantly as an embankment material in large scale road construction projects up to a height of 15 m.

This high extent of utilisation is partly a result of the effective co-operation between municipal solid waste incineration plants and the authorities that also act as the main buyer of MSWI-bottom ashes. MSWI-bottom ash is supplied to the market with a quality certificate according to the BRL 2307 (a so called assessment guideline) from July 1999. The certificate is issued by KIWA, an independent certification agency and it covers the technical and the environmental quality of MSWI-bottom ash.

Scrap metal is sold to the scrap and old metal traders. All MSWI plants are equipped with both magnetic iron separation and non-ferrous separation (Eddy Current).

3.3.6 **Sweden**

There are not normally any facilities for bottom ash treatment at the waste incineration plants. Instead an entrepreneur is treating the bottom ash. The equipment includes a drum sieve (approx 40 mm) and an overhead magnet separator. There are a few plants that sort the bottom ash more thoroughly. Therefore the bottom ash is sieved 0-50 mm, wind shifted, and separated from scrap metals by an overhead magnetic separator and an Eddy-Current separator. The bottom ash is then stored for at least six months before use as a construction material.
3.3.7 Switzerland

One hundred percent of MSWI bottom ash is landfilled under the most stringent requirements. Therein is the necessity to collect percolate water (Reaktor-Deponie).

According to the precaution in the last years it is very unlikely that the present management practice for MSWI bottom ash will be changed in the coming years.

3.4 Present market volumes

MSWI bottom ash represents only a limited volume determined by the amount of combustible solid waste in society. In Denmark and Sweden bottom ash represents less than a few percent of the market volume of materials for civil works. The amount of MSWI bottom ash in civil construction works is lower than its potential.

<table>
<thead>
<tr>
<th>Country</th>
<th>MSWI BA production Ash available ton pa</th>
<th>Market volume Ash reused ton pa</th>
<th>Market volume in % of produced MSWI BA</th>
<th>Market volume in % of produced MSWI BA if all combustible MSW was incinerated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>225 000</td>
<td>No data</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Belgium</td>
<td>Approx 500.000</td>
<td>No data</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>118 000</td>
<td>105 000</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Denmark</td>
<td>644 626</td>
<td>629 278</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>France</td>
<td>2 995 000</td>
<td>2 366 000</td>
<td>79</td>
<td>50</td>
</tr>
<tr>
<td>Germany</td>
<td>3 140 000</td>
<td>2 025 700</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>Hungary</td>
<td>53 000</td>
<td>No data</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Italy</td>
<td>753 39</td>
<td>151 18</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1 075 000</td>
<td>950 000</td>
<td>88</td>
<td>80</td>
</tr>
<tr>
<td>Norway</td>
<td>197 000</td>
<td>102 000</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>Portugal</td>
<td>177 918</td>
<td>Landfill</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Switzerland</td>
<td>640 000</td>
<td>Landfill</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spain</td>
<td>250 000</td>
<td>No data</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>446 478</td>
<td>40 000</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>UK</td>
<td>725 000</td>
<td>410 000</td>
<td>57</td>
<td>5</td>
</tr>
<tr>
<td>USA</td>
<td>10 000 000</td>
<td>1 000 000</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3.4. Market volumes of MSWI bottom ash. * Utilization on landfills.

The figures in table 3.4 shows that only Denmark and the Netherlands are close to the maximum utilization rate (the utilization share expressed on the basis of the possible amount of MSWI bottom ash provided that all burnable waste is incinerated).
Even if 100 percent of all combustible waste is incinerated, and all the MSWI bottom ash produced is utilized, it would only account for less than a few percent of the total market of materials for civil works.

The major applications (utilizations) for MSWI bottom ash are in civil construction works (road construction, building construction), embankments, filling material for reclamations etc.

3.5 Market trends

The market for utilizing MSWI bottom ash in construction business is difficult due to environmental demands and is becoming increasingly crowded, with more and more recycled demolition waste and cleaned (former polluted) soil coming into the market.

There is, at least in the Netherlands and Denmark, a tendency towards utilization in larger projects (embankments, reclamations, motorways etc.). Applications in larger projects are well controlled, the environmental impact well investigated, bottom ash is accumulated at one spot, and the building or project owner are mostly authorities. Additionally, large projects offer better delivery security for the supplier of bottom ash.

3.6 Future management development

Germany among other countries recommends developing reprocessing methods for MSWI bottom ash. Thus, instead of just removing iron and other metals as has been done so far, also glass should be separated. The remaining mineral fraction should be screened, so that the fraction of > 0.5 mm can be used for asphalt manufacture. For the fraction of < 0.5 mm there is no application, but new applications may be developed in the brick industry.

With reference to the Danish and Dutch results of investigations on chemical stabilisation, it is considered possible that some kind of stabilisation procedure is going to be normal practice in the future.
4 Barriers for utilization

4.1 Specific examples from selected countries

4.1.1 Denmark

Leaching of salts and trace metals poses a barrier for utilization. Denmark relies almost exclusively on groundwater as a source of drinking water and therefore has a strong need for strict protection of the groundwater quality. This is reflected in the leaching criteria for utilization of inorganic residues, which are the strictest criteria in Europe.

All MSWI bottom ash in Denmark is utilized in accordance with the more lenient set of criteria for utilization (category 3). Approvals in accordance with the lenient category 3 criteria posses limited applications, therefore a potential tightening of the lenient criteria (2.1.1) might posses a barrier for utilization, or at least an added limitation of applications.

Soil Protection Act Requirements for register properties with bottom ash applications (Soil Protection Act) has lead to reduced demands for MSWI bottom ash. Removal of the bottom ash is only allowed when other regulations are applied and therefore is expensive. These restrictions cause a potential risk of environmental based demands for removal of the “pollution” (bottom ash) in the future so reducing property value. When utilizing bottom ash at your property, you do not only deposit bottom ash but also a dormant expense.

The risk of property value reduction is primarily a subject for the private sector. Authorities do not fear reduction in value (for instance the value of ground beneath a road), but they might fear environmental problems resulting in a demand for removal.

An unbalanced discussion with the local authorities poses another barrier. In several regions MSWI bottom ash is unwanted because of its potential environmental impact. These regions refuse to approve applications of MSWI bottom ash, practically laying a ban on the utilization of bottom ash. Not being aware of the scientific and legislative facts however, the local authorities tend to have an emotional approach to the subject, influenced by public opinion.

The trend is in larger projects with the authorities (especially the Danish Road Directorate) as an active player.

4.1.2 France

France has a good long history of recycling MSWI bottom ash and the application regulation is reasonable. However, as stated before in this report, it is more difficult to find a market in the southern part of France, which has better access to low cost natural aggregates.

4.1.3 Germany

In certain parts of Germany people worry about utilization of bottom ash due to the fact that it originates from waste.

At the same time, a number of other recyclables have entered the market.
Germany recommends developing reprocessing methods for slag. Thus, instead of just removing iron and other metals as has been done so far, also glass should be separated. The remaining mineral fraction should be screened, so that the fraction of > 0.5 mm can be used for asphalt manufacture. For the fraction of < 0.5 mm there is no application, but new applications may be developed in the brick industry.

4.1.4 The Netherlands

Uncertainty regarding the upcoming legislation forms one of the main utilization barriers in the Netherlands. The government still has not set the definite leaching limits for the Decree of Soil Quality, which forms a barrier towards further investments in upgrading. Without the specific demands, MSWI’s will not invest.

Furthermore it is a barrier towards utilization that there is no continuity in large scale construction projects. In some periods of low construction activities there is over capacity of MSWI bottom ash.

Regulations for international transportation of MSWI bottom ash are strict and often the testing regime between two countries varies. Therefore it is difficult – though not impossible – to realize international projects.

That bottom ashes originate from waste and the subsequent NIMBY discussions regarding the health impact of large scale projects with MSWI bottom ashes often proves to be a barrier towards utilization.

4.2 General barriers

A general barrier in most countries is that people worry due to the fact that MSWI bottom ash originates from waste.

MSWI bottom ash contains a variety of pollutants which eventually may lead to soil and water pollution. These pollutants are spread by leaching as long as the application is left disposed of in the environment.

This necessitates a judgement on the short and long term environmental acceptability of such utilization scenarios. A mutually agreed scientific based concept defining the framework and criteria of an environmental sustainable utilization may provide the persuasive basis that may overcome the public barriers.

Countries like the Netherlands and Denmark have already made criteria for environmental sustainable utilization. The maximum acceptable impact has been defined, and the leaching criteria calculated on this basis. The application of utilization requires registration so that each successive removal of the MSWI bottom ash has to apply for registration, under the current regulations for managing residues as MSWI bottom ash.

Hazardous waste
As mentioned in 2.3.6 a small percentage of the generated MSWI bottom ash is at risk of being classified as hazardous waste due to its concentration of lead (>0.25 percent).

Competition from other recyclables
At the same time, a number of other recyclables have entered the market strengthening the competition. In some cases there is the alternative of other less polluted recyclables or the environmentally friendlier quality MSWI bottom ash.

**Easy access to landfill**
Cheap prices for landfill disposal will discourage utilization as in Germany e.g. that has put a new law into force which allows mineral wastes to be utilised as construction materials even on dump sites.

**Easy access to natural resources**
Abundance of cheap gravel and soil etc. close to everything also serves as a barrier for utilization, which for instance is the case in Switzerland.

**Export**
Possibilities of disposal on landfills/mines in neighbouring countries may have the same effect as cheap prices for landfilling.

**Economical barriers (as a consequence of registration in accordance with The (Danish) Soil Protection Act)**
The consequences of registration are a barrier, as are restrictions on property (use of area with bottom ash, removal only allowed when special rules are applied), reduction in property value (commercialisation of the environmental risk) and uncertain future spending on environmental measures (maybe removal is required by authorities in the future).

**Unbalanced discussion with the (local) authorities**
Not being aware of the scientific and legislative facts, the local authorities tend to have an emotional approach to the subject influenced, by public opinion.

**Unbalanced, unscientific regulations**
If a judgement on the short and long term environmental acceptability of utilization is not based upon scientific facts, it may lead to emotionally based criteria unbalanced with scientific facts.

**Leaching of salts and trace metals**
Besides being the reason of public objection, pollution of surroundings by leaching may be an obstacle for utilization (exceeding strict leaching criteria) when deciding on approval of contemplated applications. As mentioned in 2.3.7 the EU acceptance criteria for disposal of inert waste is lower than the actual leaching performance of MSWI bottom ash. There is a risk that these very low inert acceptance criteria will set the maximum limit values for utilization, resulting in a severe barrier for utilization, because it is impossible for MSWI bottom ash to meet these strict criteria.

**Practical barriers**
If the building owner and hired consultant are not aware of the possibility of using MSWI bottom ash it may be difficult to persuade them later in the process. Another example of practical barriers are local authorities that take too long time to reach an approval decision, of which the building owner cannot wait. Finally limited amounts of MSWI bottom ash is an obstacle to delivery of large projects.

4.2.1 **Overcoming general barriers**
In the Netherlands, Germany, France and Denmark it is considered environmentally sustainable to utilize bottom ash from MSWI, among other residues from thermal processes.

Utilization in larger projects (embankments, reclamations, motorways etc.) is believed future practise, as applications in large projects are well controlled, the environmental impact well investigated, bottom ash is accumulated at one spot, and the building or project owner are mostly authorities, which excludes the question of reduction in property value.

4.3 **Barriers for a level playing field in EU**

A level playing field in EU might be obtained by means of harmonisation and standardisation of legislation. This is provided by consensus on an environmental politic on the subject, and consensus on the strategic considerations to be taken, (what is to be protected (soil, water, drinking water, special areas, several levels for protection etc.). There has to be a mutual agreement on the methodology for LCA analysis of MSWI bottom ash land uses, also on the level for environmental protection and finally on the practical methods for protection (allowance of top liners for instance). Also of great importance is standardisation of testing methods for MSWI bottom ash environmental quality control.

This political strategy for utilization and the scientific base for laying down criteria for leaching etc. are missing.

Standardisation of testing methods is likely to be done in CEN. Initiatives have been taken as for example in the new landfill directive that expresses the leaching criteria in both batch test L/S=2 and L/S=10 as well in column test.

A level playing field also involves standardisation of tax politics, meaning an unambiguous definition of utilization and disposal. A proposal for revising The Waste Frame Directive is expected to lay down a clearer definition of utilization as described in 2.3.3. Another crucial question is when waste stops being waste.

The commission wishes to equalize competition criteria for utilization by developing EU standards on treatment.

The new guidelines are expected to define more operations as utilization instead of disposal, and simplifying the rules for utilization is expected to make export easier drawing in to a more commercial market.

Contrary to the initiatives in the Waste Frame Directive proposal the new Transport Statute proposal provides more possibilities for the member states to object to export for mainly utilization purposes, and therefore is expected to strengthen the national solutions. This contradicts a level playing field across borders.

MSW incineration is by no means a widespread practice of managing waste in all EU countries, implying that many countries have no legislation on utilization of inorganic residues. Among countries where MSW incineration is given high priority as a waste managing practice, therefore having legislation on the subject, there are differences both in speed of development of managing practices and legislation, and also in strategies on the environmental subject.
To level the playing field in EU it is considered important, that the countries make mutual agreements on the strategy for environmental protection using MSWI bottom ash, including clarifying which considerations are important.
5 References


2. CEWEP, “Workshop on 31st January 2006: Research in the waste area – towards the FP 7”


7. Larsen, P, Geo project nr. 28340, Rapport 1, may 2006 / AFATEK.

8. Izquierdo, M, "Use of bottom ash from municipal solid waste incineration as a road material", 2001 International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper 37


11. www.rvf.se

12. www.verenigingafvalbedrijven.nl


### 6 Annex list

<table>
<thead>
<tr>
<th>Annex</th>
<th>-</th>
<th>Description</th>
</tr>
</thead>
</table>
| Annex A | - | Legislation key table 2003  
|         |   | p/1-2                                                                        |
| Annex B | - | Bottom Ash Quantities 2003  
|         |   | p/1-2                                                                        |
| Annex C | - | Testing Methods key table 2004                                              |
|         |   | p/1-14                                                                      |
| Annex E | - | Amount of MSW, MSW incinerated and bottom ash                               |
## Legislation key table 2003

<table>
<thead>
<tr>
<th></th>
<th>Targets to utilisation</th>
<th>Regulated (Yes / No)</th>
<th>Criteria on the basis of Leaching or composition</th>
<th>Additional criteria for applications</th>
<th>One or more classes</th>
<th>Generic or related to residues</th>
<th>Exceptions for BA (other regulations)</th>
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<tr>
<td>Austria</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium -Flanders</td>
<td>yes</td>
<td></td>
<td>Leaching of metals, concentration of organics</td>
<td>User certificate , externally verified quality certification</td>
<td>1 class</td>
<td>Related to waste</td>
<td></td>
</tr>
<tr>
<td>Belgium - Wallonia</td>
<td>100%</td>
<td>Yes</td>
<td>Leaching of metals, concentration of organics</td>
<td>Bookkeeping and user certificate</td>
<td>1 class</td>
<td>Related to waste</td>
<td></td>
</tr>
<tr>
<td>Czech Republic (2005)</td>
<td>Not fixed</td>
<td>Yes</td>
<td>leaching and composition</td>
<td>physical – mechanical characteristics</td>
<td>3 leaching classes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Denmark</td>
<td>85%</td>
<td>yes</td>
<td>leaching</td>
<td>Max. height of ash layer Min. dist. to nearest wells. Applicat. above groundwater level More …</td>
<td>2 classes</td>
<td>Inorganic residues and polluted soil</td>
<td>MBL (Environmental Protection Act)</td>
</tr>
<tr>
<td>France</td>
<td>100 %</td>
<td>yes</td>
<td>leaching</td>
<td>Max. height of ash layer Min. dist. to nearest wells. Applicat. above groundwater level. More …</td>
<td>3 classes</td>
<td>Inorganic residues and polluted soil</td>
<td>/</td>
</tr>
<tr>
<td>Germany</td>
<td>100 %</td>
<td>Yes</td>
<td>Leaching and composition</td>
<td>Construction and engineering regulations</td>
<td>No classes</td>
<td>Mineral residues from MSWI</td>
<td>Regulation for water protection area</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>100%</td>
<td>yes</td>
<td>leaching</td>
<td>Minimum quantity 100 000 tons. Min. distance to highest groundw. level 0.7 m. Double liner on top.</td>
<td>2 classes</td>
<td>generic</td>
<td></td>
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<td>Norway</td>
<td>Not fixed</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>2 according to the</td>
<td>-</td>
<td>-</td>
</tr>
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<td></td>
<td>European List of Wastes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Restricted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Not fixed(^1) no none none</td>
<td>none</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Environmental objective: In year 2010, fifteen percent of the ballast material shall be re-used material.
## Bottom Ash quantities 2003

<table>
<thead>
<tr>
<th>Bottom ash produced</th>
<th>Bottom ash utilised</th>
<th>Iron scrap and non ferro</th>
<th>Type of utilisation</th>
<th>Approximately utilisation costs</th>
<th>Bottom ash Landfilled</th>
<th>Approxi-mately landfill costs (Inclusive taxes)</th>
<th>Landfill Taxes (as part of the total costs)</th>
</tr>
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<tbody>
<tr>
<td>tonne</td>
<td>tonne</td>
<td>%</td>
<td>tonne</td>
<td>%</td>
<td>€ / t</td>
<td>tonne</td>
<td>%</td>
</tr>
<tr>
<td>Austria</td>
<td>225 000</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>no</td>
<td>-</td>
<td>225 000 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Belgium</td>
<td></td>
<td></td>
<td>Construction material</td>
<td>Landfill construction</td>
<td>3 - 25</td>
<td>12 577 (11%)</td>
<td>max. 25</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>118 359</td>
<td>105 782 (89%)</td>
<td>7 463 (6%)</td>
<td>Building / road construction, Embankments, reclamations</td>
<td>15 – 30</td>
<td>15 348 (2%)</td>
<td>90 - 120</td>
</tr>
<tr>
<td>Denmark</td>
<td>644 626</td>
<td>629 278 (98%)</td>
<td>31 500 (5%)</td>
<td>Road construction</td>
<td>0.8 to 4 €/t (not treated with cement) 4 to 8 €/t (treated with cement) without transport</td>
<td>707 030 (23%)</td>
<td>60-70</td>
</tr>
<tr>
<td>Finland</td>
<td>9 781</td>
<td>0 (0%)</td>
<td>-</td>
<td>no</td>
<td>-</td>
<td>9 781 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>France</td>
<td>2 995 000</td>
<td>2 146 000 (72%)</td>
<td>141 960 (5%)</td>
<td>Civil works</td>
<td>20 - 40</td>
<td>868 200 (28%)</td>
<td>50 - 70</td>
</tr>
<tr>
<td>Germany</td>
<td>3 140 000</td>
<td>2 025 700 (65%)</td>
<td>246 000 (8%)</td>
<td>Cement industry</td>
<td>20 - 40</td>
<td>534 629 83%</td>
<td>85 -110</td>
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<td>Italy</td>
<td>641 533</td>
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<td>Road construction and embankments</td>
<td>20</td>
<td>150 000 (13%)</td>
<td>60</td>
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<td>1 200 000</td>
<td>800 000 (67%)</td>
<td>250 000 (20%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 The landfill cost for bottom ashes in Flanders (2003) are low (reduced) because the bottom ashes are used as structural material or intermediate cover layer in the landfill construction (useful application). The landfilling of bottom ashes from Flemish waste incinerators is exempted from environmental taxes, as taxes have already been collected for the incineration of the waste. Otherwise a tax of 59.41 EUR/ton has to be paid (2003).
<table>
<thead>
<tr>
<th>Country</th>
<th>Capital</th>
<th>Economy 1</th>
<th>Economy 2</th>
<th>Landfill construction</th>
<th>Landfill</th>
<th>Extern use</th>
<th>One plant</th>
<th>Civil works and landfill construction</th>
<th>Duration</th>
<th>Capacity1</th>
<th>Capacity2</th>
<th>Number</th>
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<tr>
<td>Norway</td>
<td></td>
<td>19 000</td>
<td>102 000</td>
<td>13 000 (13%)</td>
<td>Landfill</td>
<td>15-30</td>
<td>95 000 (48%)</td>
<td>105-145</td>
<td>45</td>
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<tr>
<td>Switzerland</td>
<td>640 000</td>
<td>0</td>
<td>40 000</td>
<td>Landfill</td>
<td>600 000 (100%)</td>
<td>50</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Approx. 15</td>
<td>75-130</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>446 478</td>
<td>40 000</td>
<td>No data</td>
<td>Civil works and</td>
<td>No data</td>
<td></td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
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Annex B / p2
## Testing methods key table 2004

**Official used Testing methods for leaching test from MSWIBA in different countries**

<table>
<thead>
<tr>
<th>Country</th>
<th>Name of test</th>
<th>General principle</th>
<th>L/S ratio</th>
<th>Other conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>EN 12457-4</td>
<td>Batch</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Czech Republic (2002)</td>
<td>Leaching characteristics of waste in accordance to Order of The Ministry of Environment No. 383/2001 Col.</td>
<td>Batch</td>
<td>10</td>
<td>Rotation along length – axis with 5 – 10 rpm for 24 hours at 15 – 25 °C. Paper filter 5 µm for ecotoxicological testing, membrane filter 0.45 µm for other analytical methods, no pH control</td>
</tr>
<tr>
<td>Denmark (EPA)</td>
<td>CEN prEN 12457-part3</td>
<td>Batch</td>
<td>2</td>
<td>Rotation along length-axis with 5-10 rpm for 6 hours at 22°C (15-25°C). Settling for 15 minuets and filtration through 0.45 µm filter. No pH control</td>
</tr>
<tr>
<td>Finland</td>
<td>prCEN/TS14405 (basic characterisation) CEN EN12457-part 3 (compliance test)</td>
<td>Percolation/Batch</td>
<td>10</td>
<td>Presented in a national guideline for the assessment of waste at landfill (draft)</td>
</tr>
<tr>
<td>France</td>
<td>NF (XP) X 31-210 standard (AFNOR)</td>
<td>Batch</td>
<td>10</td>
<td>L/S 10, 24 hours, no pH control</td>
</tr>
</tbody>
</table>
| Germany             | DIN 38414 S4  
DIN EN 12457 – 4, only for the production of the leaching substances | Batch             | 10        | L/S 10, 24 hours, no pH control  
None                                                                                                                                 |
| Italy               | Italian test according to Ministerial Decree of 5th Feb. 1998                | Serial batch      | 5         | 100 mg in deionised water. The water is refreshed 8 times with increasing intervals. The sum of all eluate concentrations must not exceed the limit value. |
| Netherlands         | NEN 7384 (or NEN 7373)                                                       | Column test 10    | (0.1-10)  | Total fraction L/S 10 (mix LS 0-1 + 1-10) or (NEN 7373) 7 eluate fractions from L/S 0.1-10, initially pH7, but uncontrolled, flow rate 0.5 L/S per day. |
| Norway              | No official tests yet                                                        |                   |           | The authorities have announced that regulations and requirements will be implemented in 2005.                                  |
| Switzerland         | TVA Eluat test                                                               | Batch             | 10        | Serial batch test of two L/S 10 extractions. CO₂ bubbled through leachate to maintain pH at 5-6.                              |
| Spain               | DIN38414-S4 (Catalan Standard)                                               | Batch             | 10        | 24 hours, no pH control                                                                                                        |
| Sweden              | No official tests, but SS-EN 12457-3 is normally applied                    | Batch             | 2 and 10  |                                                                                                                                 |
| United Kingdom      | No official tests, EN 12457 is often used in tests                          | Batch             | 2 and 10  |                                                                                                                                 |
MUNICIPAL SOLID WASTE BOTTOM ASH

MANAGEMENT:
Total MSW Production : 5 099 000 t/y
Tonnage of MSW incinerated : 918 000 t/y
Number of WTE Facilities : 5
Bottom Ash Production : 232 000 t/y

BOTTOM ASH MANAGEMENT:
Reuse for Civil works or other appl. : 0 %
Disposal to Landfill : 100 %
Av cost of Landfill : - €/t

BOTTOM ASH MANAGEMENT TECHNOLOGIES:
Total quantity of reused Bottom Ash : 0 t

TYPE OF BA TREATMENT
Ferrous Metal Recovery : (Indaver) 100 %
Non Ferrous Metal Recovery : (Indaver) 0 %
Screening and/or Crushing : (Indaver) 0 %
Ash Washing and Fractionation : (Indaver) 0 %
Thermal Treatment or Vitrification : 0 %
Salts and Soluble Metal Extraction : 0 %
Cement Stabilization : 50 %

TESTING REQUIREMENTS AND CRITERIA FOR REUSE:
No recovery.

RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:
Projects are carried out with the aim to improve the landfilling behaviour of the MSWI bottom ash. This includes the treatment of the BA but also qualitative waste prevention, which can have an effect on the composition of MSW and as a consequence on the composition of the BA.

Currently some new WTE plants are under construction or in the stage of start-up, therefore the incineration capacity and as consequence the volume of BA will increase obviously.

REGULATORY BODIES RESPONSIBLE FOR MSWBA:
Federal Ministry of Agriculture, Forestry, Environment and Water Management.

Applicable regulation:
Landfill ordinance: above all limit values regarding the - leaching behavior
(EN 13657 Characterization of waste – Digestion for subsequent determination of aqua regia soluble portion of elements)
- total contenst of pollutants (e.g. heavy metals)
(EN 12457-4 Characterisation of waste leaching – Compliance test for leaching of granular material. – part 4: One stage batch (L/S=10) for materials with particle size below 10 mm (without size reduction)

ISWA / REPORT ON BOTTOM ASH
Testing and Management methods for Bottom Ash

AUSTRIA 2004

REFERENCE INFORMATION:
(Associations, Documents, Web Site)

Federal Ministry of Agriculture, Forestry, Environment and Water Management:
http://www.lebensministerium.at

Environmental Protection Agency:
http://www.umweltbundesamt.at

www.cewep.com
### Municipal Solid Waste Bottom Ash Management:

- **Total MSW Production:** t/y
- **Tonnage of MSW incinerated:** 2,350,000 t/y
- **Number of WTE Facilities:** 20
- **Bottom Ash Production:** t/y

### Bottom Ash Management:

- **Reuse for Civil works or other applications:** %
- **Disposal to Landfill:** %
- **Av cost of Landfill:** 21 €/t

*(in Flanders 2003, the cost is low because the ashes are used as intermediate cover layers)*

*getallen uit 2002, op basis van cewep site*

### Bottom Ash Management Technologies:

<table>
<thead>
<tr>
<th>TYPE OF BA TREATMENT</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metal Recovery: (Indaver)</td>
<td></td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery: (Indaver)</td>
<td></td>
</tr>
<tr>
<td>Screening and/or Crushing: (Indaver)</td>
<td></td>
</tr>
<tr>
<td>Ash Washing and Fractionation: (Indaver)</td>
<td></td>
</tr>
<tr>
<td>Thermal Treatment or Vitrification:</td>
<td></td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction:</td>
<td></td>
</tr>
<tr>
<td>Cement Stabilization:</td>
<td></td>
</tr>
</tbody>
</table>

### Regulatory Bodies Responsible for MSWBA:

- **Flanders:**
  - Applicable regulations: Flemish regulations on waste management (VLAREA)
  - Contact: (OVAM) Public Flemish Waste Company

- **Wallonia:**
  - Applicable regulations: Decree of the Walloon government of 14 June 2001 promoting the valorization of certain waste types (l’Arrêté du Gouvernement wallon du 14 juin 2001 favorisant la valorization de certains déchets)
  - Contact: Office Wallon des Déchets

### Recent Activities and Significant Projects:

### Testing Requirements and Criteria for Reuse:

- Content of organic contaminants, leaching of heavy metals

### Reference Information:

- **(Associations, Documents, Web Site)**
- [www.cewep.com](http://www.cewep.com)
  - Site of Indaver that gives an overview of their bottom ash treatment facility
# Municipal Solid Waste Bottom Ash Management

- **Total MSW Production**: 4,639,000 t/y
- **Tonnage of MSW incinerated**: 406,500 t/y
- **Number of WTE Facilities**: 3
- **Bottom Ash Production**: 118,000 t/y

## Bottom Ash Management

- **Reuse for Civil works or other applications**: 89%
- **Disposal to Landfill**: 11%
- **Av cost of Landfill**: 3 - 26 €/t

## Bottom Ash Management Technologies

- **Total quantity of reused Bottom Ash**: 106,000 t

### Type of BA Treatment

- **Ferrous Metal Recovery**: all 3 plants, total 7,500 t of ferrous metal
- **Non Ferrous Metal Recovery**: 0
- **Screening and/or Crushing**: 0
- **Ash Washing and Fractionation**: 0
- **Thermal Treatment or Vitrification**: 0
- **Salts and Soluble Metal Extraction**: 0

## Recent Activities and Significant Projects

- Realization of fractionation (0-40 mm, more than 40 mm) in Liberec (2005).
- Non ferrous metal recovery, crushing and fractionation planned in Brno (after plant reconstruction in 2008)


Criteria for reuse in accordance to Order of The ministry of Environment No. 383/2001 Col. (regarding limits of leached pollutants from materials, reused for construction purposes)

- Reusing also in accordance with Order n. 383/2001 Col.
- Waiting for The European Regulation on POP No. 2004/850/EC, that will define concentration limits for POPs in bottom ash

## Regulatory Bodies Responsible for MSWBA (2005)

- Czech Ministry of Environment
- The Czech Environmental Inspectorate
- Authorized persons (certification from waste to product)

Applicable regulations:
- EU waste concerning regulations
- Czech waste management regulations
- Quality management act (building materials)

## Reference Information

### (Associations, Documents, Web Site)

- Information system for waste management [http://ceho.vuv.cz](http://ceho.vuv.cz) - ISOH (only czech version)
**Municipal Solid Waste Bottom Ash Management:**

- Total MSW Production: 3.8 mill. t/y
- Tonnage of MSW incinerated: 3,287,000 t/y
- Number of WTE Facilities: 31
- Bottom Ash Production: 644,626 t/y

**Bottom Ash Management:**

- Reuse for Civil works or other applications: 98%
- Disposal to Landfill: 2%
- Av cost of Landfill: 30-60 €/t

**Bottom Ash Management Technologies:**

- Total quantity of reused Bottom Ash: 629,278 t

**Type of BA Treatment % of plants**

- Ferrous Metal Recovery: 100%
- Non Ferrous Metal Recovery: > 10%
- Screening and/or Crushing: 100%
- Ash Washing and Fractionation: 0%
- Thermal Treatment or Vitrification: 0%
- Salts and Soluble Metal Extraction: 0%
- Cement Stabilization: 0%

**Recent Activities and Significant Projects:**

- **Application:** Highway near Aarhus
  - **Project:** Tonne
  - **Tonnes:** 435,000

  Report: Environmental report on the Søften-Sködstrup highway project is provided at following contact: www.aaa.dk, road department or heet@akv.aarhus.dk for amount used.

  Report in progress: MSWI bottom ash – Marine applications. Environmental investigation paradigm. Contact: kc@vestfor.dk

  Project initiated: Influence of incineration on MSWI Bottom ash (and fly ash). Contact: uja@amfor.dk

**Regulatory Bodies Responsible for MSWBA:**

- Danish EPA (Miljøstyrelsen)

Criteria for utilization of inorganic residues and polluted soil are based on leaching. Content of heavy metals are measured to ensure it is not hazardous waste.

Applicable regulations

Application requests are directed to the local authorities, who also superintend the application.

- www.mst.dk (Danish EPA)
- www.vd.dk (Danish Road Directorate)

**Testing Requirements and Criteria for Reuse:**

- Sampling of minimum 50 samples of minimum 2 kilograms.

- Batch test CEN prEN 12457-3 at L/S = 2. Rotation along length-axis with 5 - 10 rpm for 6 hours at 22 (15 - 25 °C). Settling for 15 minutes and filtration through 0.45 μm filter.

- No pH control during test.

**Reference Information:**

(Associations, Documents, Web Site)

- www.affalddanmark.dk (Association of big incinerators)
- www.renosam.dk (Association of smaller incinerators)
- CERES. Center for residues research

Report on LCA on MSWIBA application in road construction.

Denmarks Technical University, DTU, E&R, proff. Thomas H. Christensen, thc@er.dtu.dk

Report in progress: DAFONET (All incineration plants in DK): Demonstration Place for Full scale Leaching at Ydernæs on south Zealand. v/Kim Crillesen, I/S Vestforbrænding.

ELSAM A/S, AFATEK A/S, I/S Vestforbrænding and I/S Amagerforbrænding.

Full scale Bottom Ash Washing.

## Municipal Solid Waste Bottom Ash Management

<table>
<thead>
<tr>
<th>Total MSW Production:</th>
<th>t/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnage of MSW incinerated:</td>
<td>600 000 t/y</td>
</tr>
<tr>
<td>Number of WTE Facilities:</td>
<td>3</td>
</tr>
<tr>
<td>100% mass burning:</td>
<td>1</td>
</tr>
<tr>
<td>Bottom Ash Production: (1 plant 2003)</td>
<td>9 781 t/y</td>
</tr>
</tbody>
</table>

### Bottom Ash Management:
- Reuse for Civil works or other applications: 0%
- Disposal to Landfill: 100%

### Bottom Ash Management Technologies:
- Total quantity of reused Bottom Ash: t

### Type of BA Treatment: % of plants
- Ferrous Metal Recovery: %
- Non Ferrous Metal Recovery: %
- Screening and/or Crushing: %
- Ash Washing and Fractionation: /
- Thermal Treatment or Vitrification: /
- Salts and Soluble Metal Extraction: /
- Cement Stabilization: 0%

### Regulatory Bodies Responsible for MSWBA:
- Contact:
  - Waste incineration
  - Management of wastes from building and road construction and recovery of various wastes in building and road construction

### Recent Activities and Significant Projects:

### Testing Requirements and Criteria for Reuse:
- Environmental requirements:
  - Geotechnic characteristics:

### Reference Information:
(Associations, Documents, Web Site)
MUNICIPAL SOLID WASTE BOTTOM ASH

MANAGEMENT:
Total MSW Production: 45,682,000 t/y (Source ADEME ITOM 2002)
Tonnage of MSW incinerated: 12,598,000 t/y (Source ADEME ITOM 2002)
Number of WTE Facilities: 130 (Source MEDD janvier 2005)
Bottom Ash Production: 2,995,000 t/y (Source ADEME ITOM 2002)

BOTTOM ASH MANAGEMENT:
Reuse for Civil works or other applications: 79%
Disposal to Landfill: 21%
Av cost of Landfill: 60-70 €/t

BOTTOM ASH MANAGEMENT TECHNOLOGIES:
Total quantity of reused Bottom Ash: 2,366,000 t

TYPE OF BA TREATMENT % of plants
Ferrous Metal Recovery: 97%
Non Ferrous Metal Recovery: 76%
Screening and/or Crushing: 97%
Ash Washing and Fractionation: /
Thermal Treatment or Vitrification: /
Salts and Soluble Metal Extraction: /
Cement Stabilization: 22%

RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:
Bottom ash platforms in France using complete treatment (*):

<table>
<thead>
<tr>
<th>Platform</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>YPREMA – Lagny sur Marne I</td>
<td>200,000</td>
</tr>
<tr>
<td>SNVE – Rouen</td>
<td>90,000</td>
</tr>
<tr>
<td>SPL – Argenteuil</td>
<td>55,000</td>
</tr>
<tr>
<td>TTM – Custines</td>
<td>45,000</td>
</tr>
<tr>
<td>Perrier TP – Saint Priest</td>
<td>45,000</td>
</tr>
</tbody>
</table>

(*) some details are given in the ADEME report into Treatment and maturation bottom ash platforms

REGULATORY BODIES RESPONSIBLE FOR MSWBA:
Applicable regulations
Circular of 9th May, 1994
Directive of 4th December 2000

CONTACT:
Francine.berthier@environnement.gouv.fr: waste incineration
corinne.plan@environnement.gouv.fr: management of wastes from building and road construction and recovery of various wastes in building and road construction

TESTING REQUIREMENTS AND CRITERIA FOR REUSE:
Environmental requirements:
Defined in the Circular of 9th May, 1994:
leaching test according to NF X 31-210 standard
Parameters analysed: soluble fraction, unburnt and release of few elements like As, Hg, Pb, Cd, Chrome 6, SO₄²⁻ and total organic carbon content

Geotechnic characteristics:
MSWI BA are classified in the French road construction guide “Guide des Terrassements Routiers”

REFERENCE INFORMATION:
(Associations, Documents, Web Site)
http://aida.ineris.fr/textes/circulaires/text0398.htm
www.ademe.fr/htdocs/publications/lettre/76/76enbref.htm
ADEME report (2002) into Treatment and maturation bottom ash platforms
http://www.ademe.fr/htdocs/actualite/comptes-rendus/Documents/machefers.PDF
<table>
<thead>
<tr>
<th>MUNICIPAL SOLID WASTE BOTTOM ASH MANAGEMENT</th>
<th>REGULATORY BODIES RESPONSIBLE FOR MSWBA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total MSW Production: 32 000 000 t/y</td>
<td>Federal government and local communities</td>
</tr>
<tr>
<td>Tonnage of MSW incinerated: 12 000 000 t/y</td>
<td>Applicable regulations:</td>
</tr>
<tr>
<td>Number of WTE Facilities: 56</td>
<td>European Regulations</td>
</tr>
<tr>
<td>Bottom Ash Production: 3 140 000 t/y</td>
<td>Federal Regulations:</td>
</tr>
<tr>
<td></td>
<td>- Ablagerungsverordnung</td>
</tr>
<tr>
<td></td>
<td>- Deponieverwertungsverordnung</td>
</tr>
<tr>
<td></td>
<td>- for building and construction (LAGA)</td>
</tr>
<tr>
<td>BOTTOM ASH MANAGEMENT:</td>
<td>Environmental regulation (Bodenschutz Gesetz)</td>
</tr>
<tr>
<td>Reuse for Civil works or other applications: 65 %</td>
<td>Contact:</td>
</tr>
<tr>
<td>Disposal to Landfill: 28 %</td>
<td>Umweltbundesamt Dessau (UBA)</td>
</tr>
<tr>
<td>Av cost of Landfill: 50 – 70 €/t</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BOTTOM ASH MANAGEMENT TECHNOLOGIES:</th>
<th>TESTING REQUIREMENTS AND CRITERIA FOR REUSE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total quantity of reused Bottom Ash: 2.025.700 t</td>
<td>Leaching standards:</td>
</tr>
<tr>
<td></td>
<td>DIN EN 12457 – S4, only for the production of the leaching substances</td>
</tr>
<tr>
<td>TYPE OF BA TREATMENT:</td>
<td>Chemical composition of the original substances (e. g. unburnt carbon, heavy metals, salt etc.)</td>
</tr>
<tr>
<td></td>
<td>Physical testing of the BA for construction utilisation (volume expansion of the BA – Raumbeständigkeitsverfahren)</td>
</tr>
<tr>
<td>Ferrous Metal Recovery: 98</td>
<td></td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery: 55</td>
<td></td>
</tr>
<tr>
<td>Screening and/or Crushing: 100</td>
<td></td>
</tr>
<tr>
<td>Ash Washing and Fractionation: 0</td>
<td></td>
</tr>
<tr>
<td>Thermal Treatment or Vitrification: 0</td>
<td></td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction: 0</td>
<td></td>
</tr>
<tr>
<td>Cement Stabilization: 0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:</th>
<th>REFERENCE INFORMATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road construction</td>
<td>(Associations, Documents, Web Site)</td>
</tr>
<tr>
<td>Containerterminal Altenwerde/Hamburg</td>
<td>Environmental protection agency (uba):</td>
</tr>
<tr>
<td>Filling under pavements</td>
<td><a href="http://www.uba.de">http://www.uba.de</a></td>
</tr>
<tr>
<td>R&amp;D Project Wet fraction aging</td>
<td>Ministry of Environmental affairs (BMU)</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.bmu.de">http://www.bmu.de</a></td>
</tr>
<tr>
<td></td>
<td>Association of waste incineration plants in Germany (ITAD):</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.itad.de">http://www.itad.de</a></td>
</tr>
<tr>
<td></td>
<td>VGB PowerTech – Association of the German power plant operators</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.vgb-power.de/">http://www.vgb-power.de/</a></td>
</tr>
</tbody>
</table>
## Municipal solid waste bottom ash management

**Total MSW Production:** t/y  
*Source:*

**Tonnage of MSW incinerated:** 260 000 t/y  
*Source: cewep.com*

**Number of WTE Facilities:** 1  
*Source: cewep.com*

**Bottom Ash Production:** Ca. 53 000 t/y  
*Source: Calculated*

## Bottom ash management

- **Reuse for Civil works or other applications:** %
- **Disposal to Landfill:** %
- **Av cost of Landfill:** €/t

## Bottom ash management technologies

- **Total quantity of reused Bottom Ash:** t

### Type of BA treatment

- **Ferrous Metal Recovery:** %
- **Non Ferrous Metal Recovery:** %
- **Screening and/or Crushing:** %
- **Ash Washing and Fractionation:** /
- **Thermal Treatment or Vitrification:** /
- **Salts and Soluble Metal Extraction:** /
- **Cement Stabilization:** 0 %

## Testing requirements and criteria for reuse

### Environmental requirements:

### Geotechnic characteristics:

## Recent activities and significant projects

## Regulatory bodies responsible for MSWBA

- **Contact:**
- **waste incineration**

management of wastes from building and road construction and recovery of various wastes in building and road construction

## Reference information

(associations, documents, web site)
Municipal Solid Waste Bottom Ash Management:

| Total MSW Production | 8,000,000 t/y (*) |
| Tonnage of MSW incinerated | 4,500,000 t/y |
| Number of WTE Facilities | 11 |
| Bottom Ash Production | 1,075,000 t/y |

Bottom Ash Management:

- Reuse for Civil works or other applications: 80%
- Disposal to Landfill (**) : 0%
- Av cost of Landfill : 50 €/t

(*) Combustible waste (municipal solid waste and company waste)
(****) At this moment 20% is stored temporarily as stock forming for new projects. No bottom ash is landfilled definitively

Bottom Ash Management Technologies:

<table>
<thead>
<tr>
<th>TYPE OF BA TREATMENT</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metal Recovery</td>
<td>100</td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery</td>
<td>90</td>
</tr>
<tr>
<td>Screening and/or Crushing</td>
<td>100</td>
</tr>
<tr>
<td>Ash Washing and Fractionation</td>
<td>0</td>
</tr>
<tr>
<td>Thermal Treatment or Vitrification</td>
<td>0</td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction</td>
<td>0</td>
</tr>
<tr>
<td>Cement Stabilization</td>
<td>0</td>
</tr>
</tbody>
</table>

Recent Activities and Significant Projects:

In 2004 MSWI bottom ashes were delivered to the following major projects:
- Several projects landfill cover materials
- Project N31 Leeuwarden (embankment material for a highway fly over)
- Several small projects
- Export to Germany

Focus for further development is quality improvement (Cu and Sb leaching reduction) through 2 types of techniques:
- Wet fractionation
- Artificial ageing

Several pilots and demo’s were carried out.

Regulatory Bodies Responsible for MSWBA:

- Ministry of Public housing and environment (VROM)
- VROM Inspection

Applicable regulations:
- Building Materials Decree (in 2007 the Building Materials Decree will be adjusted)
- European Waste Catalogue
- Regular civil engineering regulations

Contact:

Testing Requirements and Criteria for Reuse:

Leaching test conformous to NEN 7343; 19 components to comply with standards; 2 Categories, viz.
Cat. 1 – unrestricted re-use
Cat. 2 – use under strict isolation measures

Bottom Ashes must comply with European Waste Catalogue for non hazardous waste.

Reference Information:

- Dutch Association of Waste Companies (VA)
- Yearly reports on residue management of municipal solid waste incinerators
- www.verenigingafvalbedrijven.nl
## MUNICIPAL SOLID WASTE BOTTOM ASH MANAGEMENT:

- **Total MSW Production:** 2,277,000 t/y
- **Tonnage of MSW incinerated:** 798,000 t/y
- **Number of WTE Facilities:** 21
- **Bottom Ash Production:** 197,000 t/y

## BOTTOM ASH MANAGEMENT:

- **Reuse for Civil works or other applications:** 52%
- **Disposal to Landfill:** 48%
- **Av cost of Landfill:** 60-100 €/t

## BOTTOM ASH MANAGEMENT TECHNOLOGIES:

- **Total quantity of reused Bottom Ash:** 102,000 t

### TYPE OF BA TREATMENT:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metal Recovery</td>
<td>98</td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Screening and/or Crushing</td>
<td>85</td>
</tr>
<tr>
<td>Ash Washing and Fractionation</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Thermal Treatment or Vitrification</td>
<td>0</td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction</td>
<td>0</td>
</tr>
<tr>
<td>Cement Stabilization</td>
<td>0</td>
</tr>
</tbody>
</table>

## TESTING REQUIREMENTS AND CRITERIA FOR REUSE:

No criteria are established, as Annex II to the EU landfill directive is still not implemented. Normally the EU criteria are applied (Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC). Reuse apart from landfill construction purposes is very limited and no criteria are implemented.

## RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:

- Pilot plant on fractionation in Bergen.
- Tests on use in asphalt in Oslo.
- Joint project on characterisation of MSWBA from 13 waste incineration plants.

## REGULATORY BODIES RESPONSIBLE FOR MSWBA:

- Norwegian EPA (Statens Forurensningstilsyn)
- County environmental department (Fylkesmannens miljøvernadvdeling)

Applicable regulations:
- Regulation on recycling and treatment of waste (FOR-2004-06-01-930)
- Regulation on pollution prevention (FOR-2004-06-01-931)

## REFERENCE INFORMATION:

**(Associations, Documents, Web Site)**

- Norwegian EPA:
  - [http://www.sft.no/](http://www.sft.no/)
  - [http://www.sft.no/english/](http://www.sft.no/english/)
- EPA pages on solid waste:
  - [http://www.sft.no/arbeidsomr/avfall/](http://www.sft.no/arbeidsomr/avfall/)
- The Ministry of Environment’s pages on solid waste:
- Official statistics on solid waste:
  - [http://www.ssb.no/soppel/](http://www.ssb.no/soppel/)
- Official statistics on incineration of waste:
  - [http://www.ssb.no/emner/01/05/avfhand/tab-2004-12-08-02.html](http://www.ssb.no/emner/01/05/avfhand/tab-2004-12-08-02.html)
## Municipal Solid Waste Bottom Ash

### Management:
- Total MSW Production: 4,701,092 t/y (Source INR 2003)
- Tonnage of MSW incinerated: 1,002,011 t/y (Source INR 2003)
- Number of WTE Facilities: 2 (January 2005)
- Bottom Ash Production: 177,918 t/y (Source LIPOR and VALORSUL 2003)

### Bottom Ash Management:
- Reuse for Civil works or other applications: 0%
- Disposal to Landfill: 100%
- Av cost of Landfill: 11-25 €/t

### Bottom Ash Management Technologies:
- Total quantity of reused Bottom Ash: 0 t

### Type of BA Treatment:

<table>
<thead>
<tr>
<th>% of plants</th>
<th>Ferrous Metal Recovery</th>
<th>Non Ferrous Metal Recovery</th>
<th>Screening and/or Crushing</th>
<th>Ash Washing and Fractionation</th>
<th>Thermal Treatment or Vitrification</th>
<th>Salts and Soluble Metal Extraction</th>
<th>Cement Stabilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>97%</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

## Testing Requirements and Criteria for Reuse:

### Environmental Requirements:

### Geotechnic Characteristics:

## Recent Activities and Significant Projects:

- Bottom ash platforms in Portugal:
  - **Platform** | **Capacity**
    - ITVE – Lisboa | 200,000 t per year

## Regulatory Bodies Responsible for MSWBA:
- Applicable regulations: Decreto Lei nº 152/2002, 23rd May 2002
- Contact:
  - Instituto dos Resíduos
    - Avenida Almirante Gago Coutinho, nº 30, 5º
    - 1000-017 Lisboa

## Reference Information:

- MSW Report “Quantidade de Resíduos Sólidos Urbanos produzida - 2002 e 2003”
  - [http://www.inresiduos.pt/portal/page?_pageid=53,31723&_dad=portal&_schema=PORTAL&id_doc=120](http://www.inresiduos.pt/portal/page?_pageid=53,31723&_dad=portal&_schema=PORTAL&id_doc=120)
- LIPOR - Oporto Incineration Plant
  - [http://www.lipor.pt](http://www.lipor.pt)
- VALORSUL - Lisbon Incineration Plant
  - [http://www.valorsul.pt](http://www.valorsul.pt)
MUNICIPAL SOLID WASTE BOTTOM ASH MANAGEMENT:

- Total MSW Production (2002): \( t/y \) (Source cewep.com)
- Tonnage of MSW incinerated (2002): \( 1,240,000 \ t/y \) (Source cewep.com)
- Number of WTE Facilities: \( 9 \) (Source cewep.com)
- Bottom Ash Production: \( 250,000 \ t/y \) (Source calculated)

BOTTOM ASH MANAGEMENT:

- Reuse for Civil works: Minority
- Disposal to Landfill: Majority
- Av cost of Landfill: \( €/t \)

BOTTOM ASH MANAGEMENT TECHNOLOGIES:

- Total quantity of reused Bottom Ash: \( t \)

<table>
<thead>
<tr>
<th>TYPE OF BA TREATMENT</th>
<th>% of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metal Recovery</td>
<td>%</td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery</td>
<td>%</td>
</tr>
<tr>
<td>Screening and/or Crushing</td>
<td>%</td>
</tr>
<tr>
<td>Ash Washing and Fractionation</td>
<td>/</td>
</tr>
<tr>
<td>Thermal Treatment or Vitrification</td>
<td>/</td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction</td>
<td>/</td>
</tr>
<tr>
<td>Cement Stabilization</td>
<td>%</td>
</tr>
</tbody>
</table>

TESTING REQUIREMENTS AND CRITERIA FOR REUSE:

- Environmental requirements:
  Parameters analysed: Release of few elements like As, Cd, Cr, Cu, Pb, Zn.
- Geotechnic characteristics:
  MSWI BA proved to comply with the Spanish Road Regulations for use as an aggregate substitute in unbound Granular layers in road pavement.

REGULATORY BODIES RESPONSIBLE FOR MSWBA:

- Contact:
  waste incineration
  management of wastes from building and road construction and recovery of various wastes in building and road construction

RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:

REFERENCE INFORMATION:

(Associations, Documents, Web Site)
MUNICIPAL SOLID WASTE BOTTOM ASH MANAGEMENT:

Total MSW Production: 4,211,290 t/y
Tonnage of MSW incinerated: 1,893,090 t/y
Number of WTE Facilities: 28
Bottom Ash Production: 446,478 t/y

BOTTOM ASH MANAGEMENT:

Reuse for Civil works or other applications: - %
Disposal to Landfill: - %
Av cost of Landfill: 75-130 €/t

BOTTOM ASH MANAGEMENT TECHNOLOGIES:

Total quantity of reused Bottom Ash: Outside landfills only at one plant (40,000) t, It varies a lot from year to year

TYPE OF BA TREATMENT:

Ferrous Metal Recovery: common about 15% of BA
Non Ferrous Metal Recovery: one plant in Sweden (about 1% of BA)
Screening and/or Crushing: screening common, no crushing
Ash Washing and Fractionation: no
Thermal Treatment or Vitrification: no
Salts and Soluble Metal Extraction: no
Cement Stabilization: no

TESTING REQUIREMENTS AND CRITERIA FOR REUSE:

Varies depending on the local authority, but availability test is one example. Locally, in Malmö, BA can be used if the local authorities receive a notification. The BA must be stored for at least six months. The BA must be analysed in an availability test where the amounts of Cd, Cr, Cu, Ni, Pb, Zn, pH and amount of organic material is tested. The construction with BA must be at place where groundwater is not used as drinking water. The soil must consist of at least one meter thick layer of claymoraine. The surface must be asphalted and groundwater observation tubes must be placed around the site. Testing of groundwater quality is made for five years.

RECENT ACTIVITIES AND SIGNIFICANT PROJECTS:

Development of guidelines for use of alternative materials for civil works, Swedish Geotechnical Institute

Development of guidelines for environmentally sound use of waste for civil works - The Swedish Environmental Protection Agency

Bottom ash is most commonly used as a construction material on landfills.

In Malmo about 8 projects (totally 100,000 tonnes of BA) with bottom ash as a construction material have been carried out outside landfills since 1997.

REGULATORY BODIES RESPONSIBLE FOR MSWBA:

It can be either a local municipal authority or a regional environmental authority. There are no national guidelines, which means that the local/regional authorities has to make their own independent decisions. This makes it very difficult to get a decision from them.

REFERENCE INFORMATION:

(Associations, Documents, Web Site)

Swedish Geotechnical Institute (SGI)- www.swedgeo.se
Swedish ashes from energyproduction (Svenska Energiaskor) – www.energiaskor.se
Research & Development Institute (Värmeforsk) – www.varmeforsk.se
Svenska renhållningsverksföreningen (RVF)- www.rvf.se
Sysav-www.sysav.se
# Municipal Solid Waste Bottom Ash Management

- **Total MSW Production**: 3,000,000 t/y
- **Tonnage of MSW incinerated**: 3,000,000 t/y
- **Number of WTE Facilities**: 30
- **Bottom Ash Production**: 640,000 t/y

## Bottom Ash Management

- **Reuse for Civil works or other applications**: 0%
- **Disposal to Landfill**: 100%
- **Av cost of Landfill**: 50 €/t

## Bottom Ash Management Technologies

<table>
<thead>
<tr>
<th>Type of BA Treatment</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metal Recovery</td>
<td>36,000 t/y</td>
</tr>
<tr>
<td>Non Ferrous Metal Recovery</td>
<td>8,000 t/y</td>
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<tr>
<td>Screening and/or Crushing</td>
<td>yes</td>
</tr>
<tr>
<td>Ash Washing and Fractionation</td>
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<tr>
<td>Thermal Treatment or Vitrification</td>
<td>no</td>
</tr>
<tr>
<td>Salts and Soluble Metal Extraction</td>
<td>no</td>
</tr>
<tr>
<td>Cement Stabilization</td>
<td>no</td>
</tr>
</tbody>
</table>

## Recent Activities and Significant Projects

Recovery of non ferrous metals is rapidly advancing. Currently 50 percent of Swiss BA is being processed. Within two years it is estimated, that 85 percent of BA will be processed.

BA is crushed, screened and separated on eddy current separators. Cost of processing is approximately covered by revenue from sale of nf-metals. The residual “BA-sand” is landfilled.

## Regulatory Bodies Responsible for MSWBA

- Applicable regulations. Technische Verordnung über Abfälle (TVA)
- Contact: BAFN Abteilung Abfall
  - www.bafn.ch

## Testing Requirements and Criteria for Reuse

- No reuse, but extraction of non-ferrous metals (mainly Cu, brass, Al) down to size 4mm.

## Reference Information

(Associations, Documents, Web Site)
<table>
<thead>
<tr>
<th>Country</th>
<th>Municipal Solid Waste</th>
<th>Incineration of waste tonnes</th>
<th>Bottom Ash production tonnes</th>
<th>Bottom Ash reused tonnes</th>
<th>Bottom Ash Landfilled tonnes</th>
<th>Cost of Landfilling plus tax €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>2 350 000</td>
<td>587 500</td>
<td></td>
<td></td>
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<tr>
<td>Czech Republic</td>
<td>4 639 000</td>
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<td>Denmark</td>
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<td>2 500 000</td>
<td>500 000</td>
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<td>Netherlands 1)</td>
<td>8 000 000</td>
<td>5 180 000</td>
<td>1 075 000</td>
<td>950 000</td>
<td>125 000</td>
<td>60</td>
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<td>2 025 700</td>
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<td>Norway</td>
<td>2 277 000</td>
<td>798 000</td>
<td>197 000</td>
<td>102 440</td>
<td>94 560</td>
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<td>1 002 011</td>
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<tr>
<td>USA 2)</td>
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<tr>
<td>Spain</td>
<td>1 240 000</td>
<td>250 000</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

1) 1.5 million tonne composted, leaving the combustible amount of MSW at 6.5 million tonne.

The percentage for USA is calculated on the basis of the total amount of MSW generated (combustible and non-combustible).