Assessment of Emission and Ash Management Regulations
The European Perspective

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INTRODUCTION

To reduce the impact on the environment, the emission requirements on waste incineration have increased rapidly in Europe during the last 10 years. Priority has been laid on the reduction of gas emissions. It is important to state that the regulatory requirements on air emissions differ a lot between the European countries. The Directives, approved by the European Community, EC, in 1989 are still being implemented. But, the EC member states are free to impose more stringent requirements than the EC Directive and some countries in the Central Europe: the Netherlands, Germany, Austria and Switzerland have done so. The situation during 1989-1992 could be characterized as a race between these countries in tightening the emission standards. The most conspicious are the extremely strict requirements introduced in the Netherlands in 1989. Those standards have confused and worried the operators and other parties in other European countries because of the risk that it might serve as a model for a new EC Directive.

The misgivings soon turned out to be justified as the EC Commission started the preparation of a revised directive for waste incineration. The last draft proposal was presented in 1994. It is strongly influenced by the strict standards of the Central European countries, but not as far-reaching as the Dutch regulation. Anyhow, objections were raised by several countries to the frequent tightening up of the emission standards claiming that the financial consequences are unacceptable. The new EC Directive is still in the pipeline, but there is no fixed time for the approval.

Efficient gas control does not mean that the harmful compounds disappear. They are to also found in the residues from the gas cleaning. In Europe, we can observe a growing concern about the environmental consequences of ash disposal, especially the long term risk of leachate discharges. An increasing number of countries will no longer accept land disposal unless the residues are properly treated. The very strict standards on gas emissions in many countries will probably be followed by as strict requirements on the control of residues.

This paper reports on the emission and ash management regulatory requirements for waste incineration in Europe and reviews the level of emission controls, current technologies and enforcement practices. The development of emission standards in different European countries during the last 10-15 years is illustrated as background for the now actual situation. The proposed European Directive is discussed and compared with the American regulations under the Clean Air Act. The adopted objectives and strategies are discussed and other means of control exemplified.

GAS EMISSIONS

Emission standards (1, 2, 3, 4)
The emission standards for waste incineration in the European Community, EC, and in some of the memberstates are presented in **table 1**. The presentation does not comprise the complete conditions. The table is meant to illustrate the essential features of the different regulations. The consideration of more sophisticated discrepancies is not within the scope of this paper, but it is important to observe that the standards have different reference conditions in different countries. The following list comprises the most important differences.

- The average values must be met as over varying time periods, from 1/2 hour to 1 month.
- The values are related to differing O2- or CO2- levels.
- The sampling and analysis methods (hence what is actually measured) are different.
- There are differences regarding standard status: whether it is target values or limit values and the

measures and penalties that a transgression will lead to.

- The times for the given standards to be fulfilled are different.
- Whether they are valid for existing plants or only the new ones.
- The figures in the table are valid for big plants, for the small ones there are normally other, less strict requirements.

The selection of standards in the table is meant to illustrate the stepwise development of the standardised requirements on air emissions from waste incineration in Europe and reflect the different priorities concerning pollutants in the mentioned countries.

The background to the rapidly increased emission requirements in Europe during the last 10 years is to be found further back in the growing awareness of the threatening pollution of our society and its impact on the human health and the environment. But, the starting point for strongly sharpened requirements on waste incineration came with the Swedish standards of 1986, focusing on dioxins and mercury. The preparatory work for this regulation started in 1984-85 as a result of public concern in Sweden about dioxins and the uncertainty concerning the impact of dioxins on the human health. Dioxin had been detected in mothers milk and waste incineration was pointed out as one of the main sources of the emissions. The course of events in Sweden attracted special attention internationally since the Swedish Environmental Protection Board declared a temporary moratorium on the construction of new incineration facilities waiting for the result of a thorough investigation. In 1986 the result of the effort was published in the report "Energy from Waste". The overall conclusion of the study was that it is possible to reduce the emissions to the levels acceptable to human health and the environment by the implementing improved operation and gas cleaning. Consequently the moratorium for new plants was lifted in 1986. Dioxins and mercury were singled out as critical pollutants, whose high toxicity, resistance and accumulation in the eco systems required very strict control. The emission standards set down in 1986 as a consequence of the investigation were at that time much more strict regarding these two pollutants than in any other country. Total dust emissions were also strictly regulated because of the high correlation with the emissions of several hazardous pollutants as cadmium, lead etc. The acids were not prioritized, since the emissions of those compounds from waste incinerators were evaluated as being of minor importance to health and the environment. It is interesting to observe that the Swedish authorities have not followed the Netherlands and Germany regarding the later, fundamentally tightened standards for especially acids in those countries. The reason is most likely the study of 1986.

While Sweden in 1986 pointed out dioxins and mercury as critical pollutants, Germany gave during the early 80´s special attention to acids like HCl, HF and SO2. At the end of the 80´s, the real revolution concerning emission requirements came when other countries in Europe combined the two priorities into very strict requirements on all pollutants. In 1989, the Netherlands introduced extremely strict requirements and Austria was close behind. Germany took up the challenge by new stricter guidelines and so did Switzerland.

The European Community, EC, approved a directive on waste incineration in 1989, closely following the older, less strict standards of 1986 from Germany, without specified requirements on dioxins and with moderate requirements on mercury. As a consequence of the tightened standards in the Netherlands, Germany and other Central European countries, EC started the preparation of a revised directive for waste incineration in the beginning of the 90´s. The first draft editions were targets for strong criticism but gradually the proposal became much more balanced. The last draft directive was presented in August 1994. It is practically identical with the German Standards of 1990.There are still a few substantial objections, but as a whole the proposal seems to be acceptable. The most important objection, and that is a fundamental one, is the lack of a scientific risk assessment and a cost/benefit analysis as a basis for the emission requirements.

Since EC presented the proposal on tightened Waste Incineration Directives in 1994, we have not experienced any new official initiative in this field from the Commission. They are said to work on a cost/benefit analysis, for the new standards. That must be understood as a response to the critical reactions to the proposal. In December 1996 the European Council of Ministers adopted a Resolution on an updated Community Strategy for Waste Management. In that paper the Council "invites the Commission to consider the scope for the amendment of Community legislation in relation to the incineration of waste with energy recovery". That opens up for a prompt accomplishment of the revised European Directive, most likely very close to the draft proposal. Everything seems to indicate that most countries will approve the new Directive unchanged, but some countries will remain with their stricter requirements.

Glancing at the table, the Dutch standards seems to be fairly close to the draft EC standard. But there is a fundamental difference in the measuring period for the plants to comply with the requirements: 1 versus 24 hours. The difference is obvious when comparing the short-period requirements for the two standards. Apart from that the most salient discrepancy is the maximum emission level of 70 mg/m3 (see table 1) in the Dutch standards. As the low level has an obvious impact on the gas treatment cost, it has stressed the debate concerning the reasonableness of the figure. It is said that a cost analysishas been conducted in the Netherlands, but so far I have not heard about any changes of their standards.

Based on later evaluations it is questioned if the very strict requirement on dioxins (0.1 ng/m3) introduced by Sweden 1986 is scientificly justified.

Indirect measures on emission reduction (2, 4)
The European standards according to the draft EEC Directives or national regulations normally include operational measures in excess of the emission limits with the intention to achieve low emissions. Here are some examples on that type of measures:

- the oxygen level may not fall below 6%
- the combustion temperatures must always be at least 850°C
- the residence time at 850°C must exceed 2 seconds
- auxiliary burners must be installed and operated in the start-up phase

There has been a strong opposition from the operators to this type of restrictions, not least in Sweden. There are experiences telling us that auxiliary burners sometimes may lead to deterioration instead of improvement. For some types of incinerators it is not obvious that an oxygen level of at least 6%, a lowest temperature of 850°C or a minimum residence time is relevant. There is an obvious risk that this type of regulation puts a negative influence on the technical development and the optimization of plant operation.

Comments to the draft EC Directive (2, 4)
As mentioned above, the draft proposal of 1994 to a new EC Directive on waste incineration has caused substantial opposition to arise from several operators and other experts. The following list illustrates subjects of discussion in connection with official regulations.

- The frequent change of standards - the new proposal coming up before the previous has been implemented - leads to poor operation and increased costs. The standards must be long term, permanent, to make it possible to operate plants economically and technically optimal.
- The emission requirements must be based on consequence analysis regarding impact on the environment compared with cost expenditures. The margin effects of increased requirements must be carefully considered. Expenditures should correspond to environmental benefits.
- The emission standards should be based on accurate considerations of the alternatives for energy production and waste treatment. If the requirements are more strict than for the alternatives, the net result will be an unfavourable use of the society resources. There is also an obvious risk that incineration will be replaced by other methods, which may give more pollution to the environment while consuming a higher quantity of fossile fuels.
- The principle of BAT (Best Available Technology) is unrealistic since it does not consider the financial consequences. It means as well frequent changes, leading to unstable operating conditions and uncertancy, not to say action paralysis. BAT must be combined with cost restrictions, which means growing into the principle of BATNEC (Best Available Technology, No Excessive Costs).
- There are no reason at all to put standardized requirements on operating conditions, like process temperatures and auxiliary burners, in addition to the emission requirements. That holds back the technical development and limits the possibility to optimize the plant operation.
- Too frequent measuring of emissions are unwarranted. No expert can honestly concludethat there are acute toxicity or acidification risks at modern waste incinerators. It is only the long term average emissions, that are of interest. The frequency and type of measuring must be adapted to that fact.

Comparison of European and American Standards (4)
In april 1996, the ISWA Working Group on Thermal Treatment organized a specialized seminar in Copenhagen addressing "European requirements and its consequences". That session developed a comparison between the proposed EC Directive and the corresponding USA standard, according to the Clean Air Act (CAA). Coincidentally, the two documents were promulgated at about the same time. Since then, the administrative handling of the two standards has been different. The USA standard has been approved but so far not the European.

There are significant differences between the two directives. The American one focuses entirely on air quality standards. The European is more far-reaching, adressing as well pollution standards for emissions to soil, surface- and groundwater. A comparison between the two directives is no simple task. First of all they must be normalized regarding equivalent units. The EC Directive is referred to 11 % oxygen content, 0°C (32°F) and a pressure of 101,3 kilopascals (29,92 inches of mercury) whereas the US CAA Standards is referred to 7 % oxygen, 68°F (20°C) and the same pressure. The EEC Directive is based on the metric system where the US CAA Standards are based on the English system of weights and concentration (i.e. parts per million, grains per dry standard cubic foot etc.). The measurement periods, on which the emission values are based as average values, differ significantly between the two standards.

The European and the American standards are compared in **Table 2** with the American values converted to the European equivalent units. The differences in sampling methodsand averaging periods has been ignored. The conclusion is that the two standards are fairly close numerically to each other, but can be very different in actual stringency.

Comments to adopted objectives and strategies (4)
It stands to reason that the reduction of emissions from waste incinerators, as from other emitting activities, is to protect the human health and the environment. To stipulate the acceptable level of

emission a risk assessment has to be accomplished. The European countries and EC have so far in general assumed an unresponsive attitude towards scientifically based risk assessments. The chosen approach is "technology oriented", which means that it is based on the principle that the best available technology (BAT) must be put into practice regardless of what is required to protect health and environment. The economic consequences and the requirements on competing waste treatment and energy production alternatives are not considered.

Here we find an interesting comparison between Europe and America, reflecting differences in the approach to the problem. The US Clean Air Act Standards have a more "objective oriented" approach, aiming at what is necessary for the protection of human health and the environment. That means the same assessment undependant of type of emittent and consequently equality between different waste treatment and energy production options. The result of the European approach is very rigorous restrictions for waste incinerators compared with other waste treatment and energy production alternatives. It is of course technically possible to apply gas control technology at waste incinerators capable of meeting every demand including unmeasurable emission. But it leads to very high investment and operation costs as well as reduced reliability as a consequence of increasingly complex technology.

Other means of control

There are other means of administrative control besides air emission standards that have influence on the emissions from waste incineration. Here are a few examples from Europe.

- Requirements on separate collection of hazardous wastes as batteries and chemical residues makes the feeded waste fuel cleaner and helps to reduce the pollution of the exhaust emissions. According to studies in Sweden, such measures have reduced the mercury load with the waste fuels heavily and thereby substantilly contributed to the reduced mercury emissions. Another similar measure is the ban on the use of cadmium in some European countries.
- Taxes and other economic means of control has been put into practice in some countries. In France a tax of 150 FFr (about 25 US dollar) per ton gas is imposed for HCl, SOx and NOx with further taxes being planned for particulates and organic compounds. Another example is the Swedish charge system on emission of nitrogen oxides from energy producing units, undependant type of fuel. The system is as a whole a zero-sum game, favourising low emissions. The charge is 40 SEK (about 5 US dollar) per kg NOx-emission with a refund proportional to produced amount of energy. That means incentive for continous improvements and technological development as long as it is inside the scope of the fee level.
- According to the applied solid waste management hierarchy, landfilling has the lowest priority. But recycling and recovery, not just modern energy-from-waste plants, have difficulties in competing financially with landfilling, especially with the very strict requirements in the Central European countries. A growing number of countries have inaugurated taxes or governmental charges on landfilling in order to support recycling and recovery. But the cost gap is too big to be bridged over by these loadings. Another means of cost equalization being introduced in several countries is the ban on landfilling of waste without pretreatment. Such a restrictions make incineration of unusable, unrecyclable organics a necessity independant the cost levels. But that type of restriction involves a risk that cost/benefit assessments of emissions reductions will be ignored.

AIR POLLUTION CONTROL

Control technologies and enforcement practices (2, 3, 4, 5, 6, 7, 8, 9, 10)

Since long time ago, at least since the beginning of the seventieth decade, it has been obvious that waste incineration plants must have gas cleaning equipment to avoid adverse impacts on the public health and the environment. The measures were at that time concentrated on dust reduction, normally by means of electrostatic precipitators. A changed attitude came with the eighties and a better understanding of the impact on the environment from all type of emissions. It started with acid gasses and different types of wet scrubbers were tested and introduced, especially in Germany. But the real break-through came with the Swedish alarm about dioxins in 1984-85. The Swedish investigation during 1985-86 represented in my opinion the ideal model for a target directed achievment. It was organized as an extensive, cooperative joint effort of regulatory authorities, plant operators and other experts. Everyone realized the gravity of the situation and was devoted to solution of the problem. That created a breeding ground for realistic conclusions about impact on human health and environment, required reduction of emissions, technological solutions and economic considerations. The importance of waste as fuel and energy supplier was emphasized and expressed through the title of the report: "Energy from waste". As a follow-up of the investigation, essential development was performed in Sweden during the rest of the eighties, not only about gas cleaning equipment, but as the other factors affecting the emissions: the quality of waste as fuel, the combustion process and the energy production. A typical design used cyclone or elctrostatic precipitator for primary cleaning followed by dry scrubber and bag filter for emission polishing.The result was rapid and impressive, which is shown in **table 3** as a summary for the total number of incineration plants in Sweden.

The introduction of the even more strict standards in the Netherlands in 1989 raised a question whether it was possible to find gas cleaning systems capable of coping with those standards, at least if the economic consequences are concidered. Anyhow, a new market opened for the manufacturers of gas cleaning equipment. The air pollution control systems became multistep, chemical factories.

A system for air pollution control capable of meeting the strict requirements of today can be designed in many different ways. The gas cleaning equipment must be an integrated part of the total plant, which means influence from such factors as fuel quality, combustion process, energy recovery, handling of residues, reliability and flexibility. In some countries in central Europe, as Germany and the Netherlands the systems for gas cleaning have become very complex and expensive during the nineties. A total net waste treatment cost of 1000 SEK/ton (about 130 US dollars) is not exceptional. A typical layout is as follows:

- dust removal by electrostatic precipitators, cyclones and fabric filters
- two stage wet flue gas cleaning with acid and basic stage
- deNOx stage with non-catalytic (SNCR) and/or catalytic (SCR) reduction system
- active carbon filter or catalytic oxidation.

It is obvious that the implementation of such a complex system threatens the reliability and safety of the plant operation, at least during a transitional period. It is also obvious that it is possible to apply technology capable of achieving these and even stricter standards as long as the economic factor is neglected. The question remains: is this a nessessary measure and the right priority to maximize protection of human health and environment.

In other countries, as in Scandinavia, there has been a more pragmatic, cost-benefit characterized approach. The Swedish attitude has its origin in the investigation in the middle of the eighties. The chosen systems, dominated by dry scrubbers and bag filters, makes it possible to meet the now valid EC Standard and as well the dominating fraction of the proposed new Standard. A normal net waste treatment cost is about 300 SEK/ton waste (about 40 US dollars), significantly lower than in the Central

Europe. The difference reflects the very high additional costs that must be paid for a questioned benefit to the environment.

In this paper it is not possible to address technical descriptions on different systems and equipment for emission control. I do not think it is necessary either since the manufacturers serve the international market. I will mention one project, because it has a new technology under development in the SYSAV waste-to-energy plant in Malmö. A full size installation of a high dust (front end) catalyst has been in operation at the plant since 1996 to reduce NOx. Before that a selective non-catalytic reduction with urea injection has been in operation since several years ago resulting in a NOx-emission of about 100 mg/Nm3. It is well known that catalytic reduction of NOx with ammonia is very efficient if the catalyst is located after a fabric filter at the tail end. The problem is that this is a very expensive solution. A catalyst capabel to stand the conditions in the high dust position of an waste incineration plant would be much more cost effective. The full scale prototype in Malmö, which has been in operation since autumn 1995, was prepared by a 2-years promising test in a pilot plant. The full scale operation has so far been in accordance with the expectations with a further NOx-reduction of 40-50 % compared to the original SNCR installation.

THE HANDLING OF RESIDUES

The new challenge (11, 12)

As a result of efficient measures to reduce the gas emissions the hazardous pollutants are to be found concentrated in the residues: bottom ash (slag), fly ash (in this paper including boiler ash) and other gas cleaning products. The predominant ash management practice in Europe has been and is still disposal in landfills. But there is a growing concern about the environmental consequences of ash disposal, especially the long term risk of leachate emissions. Here we have a new challenge in taking care of the residues from the waste incinerators. Though the development of the residue management in Europe has been evolving for several years, the work is still in its start-up phase. The reason for that is the number of difficulties associated with the problem.

The ash residues produced in Europe makes a considerable amount to handle. The around 30 million tons of waste incineratad in Europe yearly will result in about 7-8 million tons of residues. Bottom ash is the dominating part, accounting for 80 to 95 % of the total, which means around 6-7 million tons. The rest is gas cleaning residues, around 1 million tons yearly. In Europe the bottom ash, the fly ash and the other gas cleaning products are normally managed separately.

The main objective of the handling of residues from waste incineration is, as for emission control, to protect human health and the environment. But there is as well another objective, attracting increased interest: the recovery of the residues. To meet both objectives the management of waste incineration residues in Europe gives priority to and even demands recycling. Economically and environmentally viable residue management alternatives are under development to meet the objectives. That means normally use of treated residues in construction, e.g. in roads. But there are other options as well. The residues contain concentrated substances from the waste and represents obviously a source of metallic raw material. The wet gas cleaning products are sources for the extraction of hydrogen chloride, sodium chloride and gypsum. Extraction of these valuables makes it possible to close resource cycles.

The residue management in Europe is generally aiming at
- reduced amount of residues,
- reduced content of hazardous pollutants in the residues

- maximized recycling of residues.

The quality of the waste, the type of incinerator and the efficiancy of operation is of the utmost importance for the possibility to comply with these objectives. It is normally a good strategy to design a waste incineration plant so that the toxic elements are concentrated in the fly ash and the gas cleaning products, leaving the bottom ash as "clean" as possible. An optimized operation will ensure minimal amounts of trace metals as cadmium and mercury, low content of organic constituents and high concentrations of stable mineral phases in the bottom ash. We have here an example on how important it is to look upon the total system of an incineration plant in order to optimize the total result, based on the prerequisite in the specific case concerning feeded waste, energy market, emission requirements, use of recycled slag, ash deposition etc. Several operators, manufacturers and other experts in Europe are acting in that direction.

Impact and regulations (11, 13)

As the dominating ash management practice in Europe still is landfilling the regulations for landfill disposal is of vital importance for the requirements on waste incineration residues. There are so far no approved EC Directive on landfilling, but a proposal is under final preparation. Current regulations are consequently national and differ a lot. An example of well developed landfill regulation is the German "TA Siedlungsabfall" which defines two different landfill classes with different demands on ash quality. Fly ash is classified as "hazardous waste" and consequently has the most demanding landfill requirements, normally in separate cells. As a consequence of a growing concern an increasing number of European countries will no more accept disposal unless the residues are properly treated.

For bottom ash the situation is different since the content of harmful pollutants are significantly lower than with the fly ash and there are obvious recycling options. The different countries have approved their own standards for the utilisation of slag, but these are stepwise being brought closer to each other as a result of exchanged experiences and extensive cooperation. In due time an EC standard will be approved but the memberstates will still have the possibility to require stricter standards.The requirements are under frequent alterations, based on new knowledge from research and development.

In the Central European countries (Germany, the Netherlands, France) the requirements have reached a quite strict level, considering especially the burnout and the leaching properties of the slag. The burnout is normally expressed by the loss on ignition (LOI) and/or the total organic carbon (TOC). Typical requirements are (weight percent):

- Loss on ignition less than 3 %
- TOC less than 1 %

The slag quality must comply with requirements on the maximum limits according to leaching tests (primarily trace elements and unorganic salts). As the limit values and the test methods are not harmonised for the different countries, a comparison is very difficult. As an example parts of the German standards according to "LAGA Merkblatt" is shown in **table 4.** The document is continuously revised.

Storage of the wet slag before use is normally a standardised requirement in order to transfer the strongly alcalic hydroxids into carbonates, thereby lowering the pH-value to 9.5 or lower, which also reduces the solubility of lead.

The treatment of residues (11,12, 13, 14))

To develope treatment practices and management options for waste incineration residues it is necessary to thorougly consider the physical and chemical characteristics of the materia. Those residues are heterogenious materials, whose properties vary over time in response to waste feed as well as plant design and operating conditions of incinerator and air emission control equipment. In general the ash residues from a waste incineration plant amounts to about 15-35 % of the weight of the waste fed. Bottom ash (slag) is the dominating part, accounting for 80-95 % of the total solid residues. That means about 150-300 kg per ton waste.Typical ranges of gas cleaning residues produced per ton of feeded waste are 20-50 kg (dry process, including fly ash), 15-40 kg (semi-dry process including fly ash) and 1-3 kg (wet condensing process excusive of the fly ash). The amount of fly ash precollected in the wet condensing process is 10-30 kg/ton waste. Wet condensing processes also produce 0,3-0,5 m3 of saline wastewater per ton waste.

To meet the requirements on proper treatment of the residues various treatment methods are beeing considered and several equipment manufacturers in Europe are currently developing methods and systems to meet the requirements. There are several commercial ash treatment plants in operation or under construction and many examples on test and demonstration projects. The methods and systems of interest are in different levels of technical development and validation. A few methods can be viewed as nearly established technologies but as to the rest there are still a considerable amount of improvement work to be done. The efficiency of the different methods are questioned and has to be confirmed, especially when speaking about the long term liability of deposited treated residues. Anyhow there are methods promising a long term stable and harmless product, which sets aside the need of controlled deposition and opens up for reuse.

An obvious problem with most of the ash treatment methods is the very high investment and operation costs. Added to the heavy economic burden of very strict gas emission control these costs can turn aside the construction of urgent new incineration plants in favour of landfilling or other inferior waste treatment alternatives. That should be an impelling force for the development of cheaper ash treatment and gas cleaning alternatives. Here we face an important challange for the manufacturers and contractors. In my opinion, deposition in landfills or longterm storage (for instance in German salt mines) should be accepted as an alternative to advanced treatment practices if the storage site conditions can meet strict requirements.

The available treatment processes under development and implementation can be classified as follows:

- Separation
- Stabilization
- Solidification
- Thermal treatment

The most widespread form of separation in Europe, in commercial operation since the early eighties, is the screening and sorting of bottom ashes for the recycling of metals, especially ferrous, and the use of the screened ash in construction. This has been done to varying degrees for many years in different countries.

Ash stabilization and solidification are often combined. The dominant solidification agent is cement, often a tailor-made compound. Removal of soluble salts such as calcium chloride before stabilization and solidification is sometimes necessary to meet longterm stability requirements.. A promising process for stabilization without solidification seems to be adding soluble phosphates, which form low solubility phosphate minerals.

Thermal treatment involves melting or sintering of the residues at high temperatures of 1200 to 1500 °C to transform the ash into a harmless and very stable glass (vitrification). Dioxins and other organic compounds are also destroyed. Thermal treatment is the most expensive of the actual methods involving high energy consumption and exotic technology. The need of further development is obvious.

Liquid discharges from wet scrubbers have been traditionally discharged to the sewers after treatment and that is still the case for some plants. But, there is increasing pressure to eliminate such discharges. One possibility is to use dry or semidry scrubbers. In Germany, there is the general opinion that these methods are not able to comply with the strict requirements on acids. Another method put into practice in Germany, is vaporization of the csrubber blow-down to make the plant a zero-discharge facility. Filter cakes from wet scrubbing systems are normally disposed of in special landfills.

Utilisation of residues (11, 12, 13)
The bottom ash has been utilised in some countries in Europe for more than 20 years for civil engineering purposes, particularly as subbase at parking lots, bicycling paths and residential as well as major roads (paved and unpaved). As a subbase material, the bottom ash usually substitutes gravel, which is a limited resource in many countries in Europe. Therefore, there is an incentive for utilization of bottom ash from a natural resource conservation as well as an economic point of view. An important limiting factor for recycling of residues from waste incineration is the difficulties to guaranty an acceptable longterm quality of the utilized residues and a low longterm impact on the environment.

In Germany, France, the Netherlands, Denmark and Schwitzerland a considerable part of the produced slags and minor parts of the fly ash are recycled, **table 5** . Other countries report lower levels of recycling of different reasons.

Raw slag from a waste incineration plant can normally not be utilized without treatment. Two treatment steps are in general required:

- Storage of the wet slag (maturing process, normally a formal requirement).
- Mechanical treatment - especially sieving and multistage magnetic separation, which sometrimes may be followed by a washing step.

The quenching of bottom ash in water involves some negative effects for recycling since several metals are oxidized and the iron scrap contaminated by calciumproducts. Methods for dry discharge has been introduced in Europe in order to eliminate these disadvantages.

The data on treatment practices and utilization options for slags available in different reports are often very difficult to compare and evaluate because of the discrepancies. The reason to that is the different sampling and analythical methods, misinterpretation of reported data and other mistakes.

A typical result of the treatment of waste incineration slags in Europe is as follows (weight percent):

- 80-85 % secondary construction material
- 10 % secondary raw material, mainly ferrous metal
- 5-10 % coarce fraction for dispösal or returned to processing

The fly ash and other gas cleaning products are of less interest as construction materials, mainly due to the higher contents of toxic inorganic (heavy metals) and organic (dioxins and furanes) compounds or water soluble salts. These residues can be utilized only after further conditioning or more sophisticated treatment. In the Netherlands fly ash is used as aggregate in asphalt and concrete. An interesting possibility practiced in Germany, requiring less treatment, is the use of such residues to fill underground salt mines. The extraction of high graded hydrochloric acid, gypsum etc for recycling is so far of less importance in Europe.

CONCLUSIONS

There is no doubt that the turbulence around the very restrictive requirements on waste incineration in Europe has given rise to impressive technical and operational progress. The operators have been much more target-directed and the contractors and manufacturers have met the increased demand for advanced equipment and methods. Waste incinerators complying with the new, strict emission standards are close to the zero-level of emissions. The rapid progress confirms that a drastic change in conditions sometimes is a driving force for the development.

The problem is that the costs associated with the measures have exploded. The new strict standards have in general been adopted politically with inadequate consequence conciderations. They are obviously not based on a scientific risk assessment concerning the impact on the human health and the environment. The environmental gains compared to the additional costs and operation difficulties have not been satisfactorily analyzed. That is of coarse a very serious consequence since there is an evident risk of mismanagement of society´s resources and the environment. Waste incineration runs the risk of beeing replaced by other, less favourable waste treatment methods not because it is bad, but because it costs too much to comply with the low benefit regulations.

It must be admitted that risk assessment in this case is difficult because of a lack of basic knowledge. The stringent requirements can be justified politically as being a precautionary measure. Today we have reached the level of knowledge and experience where we should try to define the point of reasonable emission levels and the prudent cost/benefit ratios for the emission control. That gives the opportunity to issue reasonable standards and offer the market stable long-term conditions.

The approach on waste incineration in Europe, not to say worldwide, seems to be based on the belief among the political decision makers that waste incineration is an extremely harmful **destruction** method, which must be hedged by very rigorous restrictions compared with most other activities in the society. The created atmosphere has a strong influence on public opinion and strengthens the negative attitude. The specific requirements on waste incineration stresses the public opinion that waste incinerators are very harmful. For the just acceptance of waste incineration and therefrom following fair requirements, it is in my opinion of utmost importance that the method be widely recognised as the environmentally friendly **energy production method** it really is.

It is possible that the future may bring such a changed attitude. The search for new energy sources, based on renewable fuels, is one possibility. Municipal and industrial wastes are to a large degree biofuels, which can reduce the need of fossile fuels. A broader adoption of the energy-from-waste concept is hopefully the key to a revised, more positive approach to waste incineration in Europe. Looking at the situation in the Nordic countries, where waste incinerators have been synonymous with energy production for many years gives at least a small hope for such an alteration in public attitude. Another balancing pressure is a better understanding of the problem with landfills, as beeing resource destructive and long-term risks to human health and the environment. The new waste management legislation under implementation in many countries bans deposition of waste without pretreatment, which opens up the arena for incineration.

Based on facts, the prospects for waste incineration with energy recovery should be very favourable.

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Table 1. European emission standards for waste incinerators

Pollutant (mg/m3)	Sweden 1986 1)	Germany 1986	Germany 1990 2)	EC 1989 3)	the Netherlands 1989 4)	EC (draft dir.) 1994 5)	1994 5)
HCl	100	50	10	50	10	10	60
HF	-	2	1	2	1	1	4
SO2	-	100	50	300	40	50	200
NO2	-	500	200	-	70	200	400
TOC	-	20	10	20	10	10	20
CO	100	100	50	100	50	50	100
Dust	20	30	10	30	5	10	30
Cd + Hg	Hg=0.08(0.03)	0.2	0.05+0.05	0.2	0.05+0.05	0.05+0.05	0.05+0.05
PCDD+PCDF (ngTEQ/m3)	0.1	-	0.1	-	0.1	0.1	0.1
Related to dry gas	10%CO2	11%O2	11%O2	11%O2	11%O2	11%O2	11%O2
Sample average (with some exceptions)	1 month	24 hours	24 hours	1 month	1 hour	24 hour	0.5 hour

1) According to ENA 1986. Sweden has later adapted the EC Directive of 1989 regarding stricter requirements.
2) According to17. Decree to BlmSchG, Dec 1, 1990.
3) According to Directives 89/369 and 89/429, Dec 1, 1990.
4) According to BLA, Aug 15, 1990.
5) According to Draft Directive Incineration of waste, Aug.1994 (GH016).

Table 2. Comparison of European and American Standards (converted into European equivalents)

Pollutant mg/m3	European standard EEC draft Directive	American Standard	American State Standards
HCl	10	28 or 95 % removal	28 or 95 % removal
HF	1	-	2
SO2	50	61 or 80 % removal	61 or 85 % removal
NO2	200	219	205
NH3	10	-	11
TOC	10	-	15
CO	50	175	79
Dust	10	17	17
Cd	0.05	0.026	
Hg	0.05	0.10 or 85 % removal	
PCDD + PCDF (ng TEQ/m3)	0.1	(0.13)	

Table 3. Total reduction of air emissions from the Swedish waste incinerators 1985-1994

Pollutant		1985	1994	Reduction
HCl	ton/year	8400	290	96 %
SO2	ton/year	3400	820	76 %
NO2	ton/year	3400	1600	53 %
Dust	ton/year	420	40	90 %
Hg	kg/year	3300	100	97 %
Cd	kg/year	400	15	96 %
Pb	kg/year	25000	300	99 %
PCDD + PCDF	g/year	90	2	98 %
Basic data				**Increase**
Number of plants		21	21	
Waste load	Mton/year	1.53	1.68	10%
Energy prod.	TWh/year	3.4	4.3	25%

Table 4. German standards and outlines for deposition and utilization of slags.

Compound	Unit	Deposition by TA Siedlungsabfall Class 1	Deposition by TA Siedlungsabfall Class 2	Utilization LAGA Merkblatt
Unburnt, organic				
LOI	weight %	3	5	3
TOC	weight %	1	3	1
Elutant by DIN 38414				
pH		5.5-13	5.5-13	7-13
TOC	mg/kg	200	1000	-
Pb	mg/kg	2	10	1
Cd	mg/kg	0.5	1	0.05
Cr(6)	mg/kg	0.5	1	0.5
Cu	mg/kg	10	50	5
Ni	mg/kg	2	10	0.4
Hg	mg/kg	0.05	0.2	0.01
Zn	mg/kg	20	50	3
Cloride	mg/kg	-	-	2500
Nitrate	mg/kg	-	-	5000

Table 5. Utilisation of bottom ash in some European countries

Country	Amount utilized	Applications
Germany	About 50 % or 1.5 Mtons/year 1)	Road construction (ptimarily as granular base).
France	About 50 % or 1.2 Mtons/year	Road construction
the Netherlands	About 90 % or 1 Mtons/year	Road construction, embankments, noise and wind barriers. Aggregate in asphalt and concrete
Denmark	About 90 % or 0.4 Mtons/year	Construction works (roads, parking lots, bicycle roads etc)
Sweden	Limited, under developement	Construction works (roads, parking lots, etc)

1) 1 M ton = 1,000,000 kg