Technical Requirements and General Recommendations for the Disposal of Meat and Bone Meal and Tallow

Commissioned by the Federal Ministry for Environment, Nature Protection and Reactor Safety

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15. Zusätzliche Angaben
Dem Bericht sind zwei Anlagen beigefügt.

16. Kurzfassung
Im Dezember 2000 und Januar 2001 wurde der aktuelle Stand des Wissens und der Erfahrungen bei der Verbrennung von Tiermehl, Tierfett und sonstigen bei der Tierkörperbeseitigung anfallenden Stoffe zusammengetragen und gesichtet. Auf dieser Grundlage, und gestützt auf die einschlägige neuere Literatur sowie auf bereits bestehende Empfehlungen und Regelwerke, wurden Handlungshilfen abgeleitet, um schnellstens bundesweit den Betreibern von geeigneten industriellen thermischen Prozessen und Abfallverbrennungsanlagen sowie den beteiligten Genehmigungs- und Überwachungsbehörden einen einheitlichen Handlungsrahmen für die thermische Behandlung dieser Stoffgruppe zur Verfügung zu stellen. Es wurden auch Wissens- und Erfah- Erfahrungsdefizite identifiziert; dazu werden im Bericht entsprechende Hinweise und Empfehlungen gegeben.

Die Arbeitsplanung sah eine enge inhaltliche Diskussion mit den einschlägigen Unternehmensverbänden der Betreiber von thermischen Behandlungsanlagen einerseits und den beteiligten Bundesministerien und Bundesämtern sowie der Tierkörperbeseitigungsindustrie andererseits vor. Zu diesem Zweck wurde in Abstimmung mit Auftraggebern (BMU und UBA) und den zu beteiligenden Institutionen ein Projektverteiler festgelegt, der Personen benannte, die für ihre jeweilige Institution sprachen und bei der inhaltlichen Diskussion tätig wurden.
Der Projektverteiler liegt dem Bericht in der Anlage 1 bei.

Der Bericht liefert Angaben über Stoffdaten von Tiermehl und Tierfett, stellt aktuelle Erfahrungen bei der Verbrennung dieser Stoffe zusammen und formuliert Anforderungen sowie Empfehlungen.

17. Schlagwörter
Abfallverbrennung, Abfallmitverbrennung, Tierkörperbeseitigung, Tiermehl, Tierfett, BSE-Erreger, Arbeitsschutz, thermische Abfallbehandlung, Müllverbrennungsanlagen, Sonderabfallverbrennungsanlagen, Klärschlammverbrennungsanlagen, Kohlekraftwerke, Zementwerke, Vergasungsanlagen, Wirbelschichtverbrennung

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16. Abstract
In December 2000 and January 2001 the current state of knowledge and experience of the combustion of meat and bone meal (MBM) and tallow was compiled and examined. Taken into account the existing regulations and recommendations, this report was written in order to provide guidance on techniques and standards for the thermal treatment of these materials. It is supposed to assist both operators of incineration plants and authorities to evaluate the suitability of a process and determine the necessary prerequisites. Lacks of knowledge are identified, and recommendations for gathering further information and experience are given in the report.

The preparation of this report involved extensive discussions with representatives of incineration plants, governmental departments and MBM processing plants. A list of all the institutions involved and their representatives is attached to this report as appendix 1.

The report includes physical and chemical data on MBM and tallow. It compiles the current experience with the combustion of MBM and offers requirements and recommendations.

17. Keywords
waste incineration, meat and bone meal, MBM, tallow, BSE, industrial safety regulations, thermal waste treatment, waste incineration plants, hazardous waste incineration plants, sewage sludge incineration plants, coal power stations, cement plants, gasification plants, fluidized bed incineration plants

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1. Project distribution list
2. List of German rendering works

Preliminary remarks

The present technical requirements (hereafter "guide") were produced to meet the following specifications:

The current state of knowledge about and experience with incinerating meat and bone meal (MBM), tallow and other materials arising in the disposal of animal remains was to be collected and reviewed as fast as possible. This, together with the recent literature and existing recommendations and regulations, was to be used as the basis for practical conclusions, in order to provide the operators of suitable industrial thermal and waste incineration plants in Germany, as well as the licensing and supervisory authorities concerned, with a unified framework for the thermal treatment of this substance group.

A survey of operators was to record and summarise clearly the expertise and current experience in incinerating MBM at various types of plant which are or could be made available for thermal treatment of bone meal and related substances. The focus was also to be on identifying gaps in knowledge or experience, and to offer advice and recommendations for filling them, where possible.

Firstly, the technical, hygienic, environmental and economic conditions surrounding MBM incineration were to be examined, while the legal aspects were only to be considered incidentally.

However, in view of the current variety of legal conditions surrounding MBM incineration in Germany, and the resulting lack of uniformity in technical and operating requirements, the legal framework was not to be ignored completely.

It was planned that the content of the guideline texts would be discussed in as much detail as possible by industry associations representing the operators of thermal treatment plants, the animal remains disposal industry and the relevant federal ministries and agencies. Thus the commissioning bodies (Environment Ministry and FEA) and the participating institutions agreed a project distribution list, containing the names of authorised representatives of the various institutions discussing the texts. This list can be found in Appendix 1.

Starting on 4th December 2000, the project was conducted as follows:

1. Preparations for research in each process group, in contact with operators' associations (ITAD, VGB, VKS/VKU, Arbeitskreis Sonderabfallverbrenner in Deutschland, VDZ, ATV, SVZ), project distribution list drawn up.
2. Review and evaluation of survey results received from associations.
3. Taking stock of the technical, hygienic, environmental, economic and administrative conditions surrounding incineration of MBM and tallow in the facility groups, as well as the corresponding literature.
4. Rough draft of the guidelines for distribution on 15/01/01
5. Consideration of responses from the distribution list and producing the final draft based on the best information available to the authors at the time
6. Final internal review by the authors, text presented to commissioning bodies by 31st January 2001.

The present document is based on information, some of which had to be accepted without detailed expert scrutiny, owing to restrictions on time and human resources. Alongside engineering and legal issues, information from other disciplines, such as veterinary or human medicine and occupational or preventive health, was also included. The authors are aware that gaps, inaccuracies or outright errors cannot be rules out, and would be grateful for any corrections on the part of the guidelines' readers. Any such suggestions will be carefully considered for inclusion in a future edition.

The authors would like to thank all the institutions and individuals who offered their knowledge and experience, especially the representatives of the commissioning bodies, the Environment Ministry and the FEA. Particular thanks also goes to the institutions and associations, and to their representatives.

The authors

Berlin / Hamburg, 23rd February 2001

1.0 Current state of affairs

1.1 General situation

The first case of BSE in Germany confirmed by the Federal Research Institute for Viral Illnesses in Animals on 26/11/00, caused the Bundestag to ban giving certain animal feeds to livestock (e.g. pigs, poultry) with immediate effect from 01/12/00. At the same time, importing these feeds to EU countries and their export outside the EU were also banned. The feeds listed in the Act are essentially substances commonly termed bone meal, which arise in disposal of animal remains and in dedicated facilities. In Germany, they undergo high pressure sterilisation (steam pressure ≥ 3 bar, temperature ≥ 133 °C, time ≥ 20 min., grade < 50 mm) and had previously been used as animal feed. Until recently, high pressure sterilisation was not used for all meat meal, blood, feathers or tallow, although these substances were also used as feeds or feed additives. Some tallow, which is liquid at temperatures of 50 - 70 °C, is reused in industry and engineering or as a support fuel.

Feeding MBM to cattle, sheep or goats has been banned within the EU since 01/07/1994. The complete feedstuff ban assumes that contamination cannot be ruled out during the production of feedstuffs for ruminants and that current knowledge about transmission paths and the quantities of pathogens is incomplete. Our knowledge about the conditions required to adequately destroy the BSE pathogen (infectious prions) must be considered equally incomplete [1, 18]. Infectious prions can currently be detected only when they appear at concentrations of at least a thousandth of the concentrations found in the brains and spinal chords of clinically infected cattle [25].

The most recent research suggests that the possibility of BSE being transmitted to humans is likely. Much evidence indicates a link to new variant Creutzfeld-Jacob Disease (nvCJD). Even if findings do not yet constitute proof positive that BSE can be transmitted to humans, the circumstantial evidence has become far more compelling [20, 23, 31, 44].

For precautionary reasons, this state of affairs rules out the recycling paths for MBM which have been practised up to now, and new paths for treatment or recycling are needed. The German government assumes provisionally that MBM and tallow cannot even be used for other purposes, such as in composting or biogas plant or as fertiliser, although the aforementioned Animal Feedstuffs Prohibition Act does not explicitly prohibit these.

The government currently sees the only possible alternative in thermal disposal, as this form of disposal destroys potential BSE pathogens in exothermic processes (incineration or gasification) where the material remains in sufficiently hot incinerators for long enough, with an adequate oxygen supply, and thereby rules out the risk of subsequent infection as far as possible. Only industrial and local authority thermal plants which are already in operation and which are available and suitable for accepting MBM and tallow can be considered for this form of treatment.

Dedicated incineration plants for MBM, as they are currently being set up in England, only appears sensible where sufficient quantities of MBM can be guaranteed in the long term. Another possible approach might be for the renderers to carry out the thermal treatment themselvesand recover the thermal energy through some form of CHP. Owing to the time required for licensing and implementation, these options are only available in the medium term, and cannot therefore contribute to relieving the current disposal problem, and their economic viability must still be examined.

A publication by Brown et al [18] about a risk of infection remaining at 600 °C is currently being discussed. The authors report that samples of brain from infected hamsters still revealed traces of infectiousness after thermal treatment at 600 °C. A possible explanation under discussion is an anorganic "molecular template", capable of triggering a biological replication of the pathogen.

As well as the scientific validity of this hypothesis, the question of whether thermal treatment of infected tissue samples in the laboratory allows conclusions to be drawn as to the efficiency of industrial incineration of potentially BSE contaminated MBM with up to date technology is important for these guidelines.

The authors have an evaluation of the study by the Federal Research Institute for Viral Illnesses in Animals in Tübingen, which describes its hypothesis as highly speculative, and casts no doubts on the effectiveness of MBM incineration in destroying BSE pathogens, given the technology available in large incinerators, where they comply with the requirements for combustion under the 17th BImSchV [39]. This view is confirmed by a brief evaluation by the Institute for Biotechnology Safety and the TÜV Süddeutschland of incinerating MBM in Bavarian waste incineration plants [42], which examines in detail the differences between laboratory and real-life conditions for incineration (see 4.2.1, Incineration process and Residues/products). The evaluation was made simultaneously with, but independently of the evaluation by the Federal Research Institute for Viral Illnesses in Animals.

Furthermore, processes without incineration have the following problems:

Disposal to landfill is not an option, as simply burying the material cannot destroy any potential BSE pathogens. In addition, this form of disposal is banned for highly organic materials by the Landfills Ordinance [28].

Nor are biological treatment methods (e.g. biogas, fermentation, bio-mechanical processes) feasible, because biological transformation alone cannot irreversibly destroy organic material [29]. Biological processes may impair the reactivity of treated materials, but will not destroy the prions, which are scarcely biodegradable, if at all [30]. Nonetheless, these methods could be used in combination with thermal treatment.

Recycling MBM and tallow cannot be considered, unless in combination with thermal treatment, as any form of cold recycling could not rule out the risk of infection, in the absence of thermal destruction of potential BSE pathogens.

1.2 Production of the technical guidelines

Faced with the MBM disposal problem caused by the feeding ban, the German Environment Ministry, through the Federal Environmental Agency and in agreement with the Ministry for Consumer Protection, Food and Agriculture, commissioned a "Guide to Incinerating MBM and Tallow" from Dr.-Ing. A. Nottrodt GmbH, Dipl.-Ing. Jürgen Chibiorz in Berlin, and wandschneider + gutjahr ingenieurgesellschaft mbh in Hamburg, with participation by representatives of all affected institutions and associations (see App. 1).

Advice on the legal aspects of the guide was given by Dr. Bodo A. Baars of Hamburg, under a commission from Dr.-Ing. A. Nottrodt GmbH.

The framework conditions for and experience with MBM and tallow incineration were compiled and summarised in Chapters 3 and 4 of this guide. The subsequent recommendations can be found in Chapter 5.

2.0 Purpose of the technical requirements

Where the short time available has allowed, this guide has gathered together the current state of knowledge about and experience with meat and bone meal (MBM), tallow and other substances arising in the disposal of animal remains. The aim is to provide German operators of waste incinerators or other suitable industrial processes and other participants with clear, sound recommendations for thermal treatment of this substance group. In addition, owners of MBM and tallow will be able to discover the requirements affecting them and make any necessary adjustments to their facilities.

Questions about licensing requirements for the use of MBM in incinerators and industrial processes, MBM storage or supervision of proper disposal should be addressed to the legally responsible bodies.

An essential aim of the guide is to improve public information, and thereby acceptance, with an objectively sound presentation our current knowledge, along with its deficits and clear recommendations for future action. This applies equally to employees at incinerators treating (or prepared to treat) MBM and tallow.

The following groups of incineration plant were examined:

- Waste incineration plants
- Hazardous waste incineration plants
- Coal-fired power stations
- Cement works
- Sewage sludge incineration plants
- Gasification plants
- other thermal industrial processes

The guide presented here summarises the technical, hygienic, environmental, economic and administrative conditions surrounding incineration of MBM and tallow, drawing conclusions about the suitability of various thermal treatment processes. It proposes minimum requirements to be met during the incineration of MBM.

The core recommendation, to some extent already practised, is for steady cooperation to be built up between the producers of MBM and tallow (generally renderers) and suitable nearby incinerators. This is the simplest way to guarantee that technical and company activities can be harmonised, and any special cases can be considered as fully as possible.

Close cooperation with the responsible authorities is also recommended, in order to complete the necessary administrative steps as fast and efficiently as possible.

3.0 Substance data on meat and bone meal (MBM) and tallow

The large proportion of MBM in Germany is produced at 43 rendering works, and almost as much is produced at specialist companies (see Table 3.1). Appendix 2 contains a list of German rendering works.

The following shows a basic flow diagramme for the processing of animal cadavers and abattoir waste:

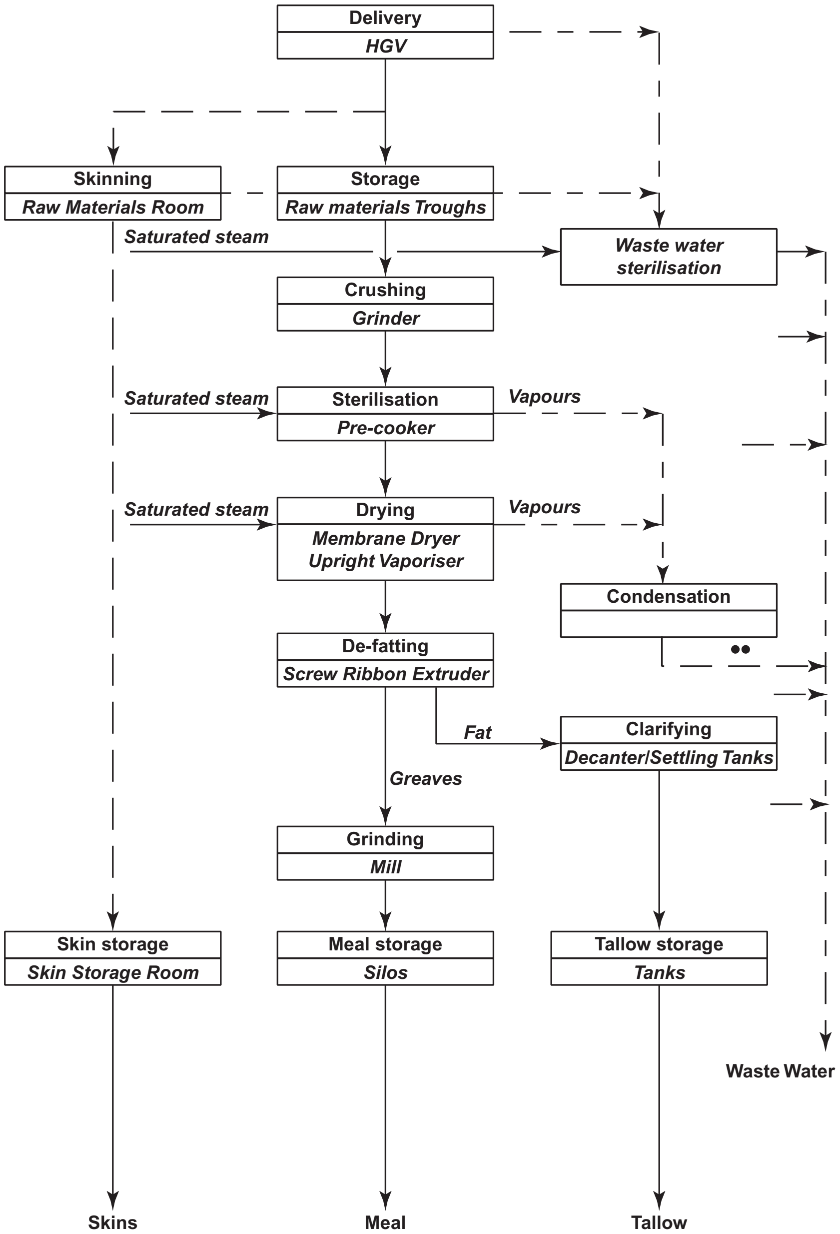

Fig 3.1: Basic flow diagramme for processing animal cadavers and abattoir waste [35]

Under a decision by the EU Commission on 29th June 2000, specified risk materials (SRM) which contain an increased risk of BSE are defined, [9]. Appendix 1 of the guideline lists essentially the skulls (including brain and eyes), tonsils, spinal cords and ileum of cattle, sheep and goats over twelve months old. The MBM industry claims that this SRM is sent exclusively to suitably equipped renderers.

This guide assumes the following:

- MBM and tallow from SRM are produced and stored separately.
- MBM and tallow, whether SRM or not, are produced using high pressure sterilisation.
- All cattle actually suffering from BSE are considered SRM.

For clarity's sake, it should be noted that the guide, as intended, concerns predominantly technical questions. The above assumptions should not be construed as making the reverse recommendation, that MBM which has not been high pressure sterilised, or not at 133 °C, must not be used. This decision, as decisions on the use of MBM in incinerators in general, is the responsibility of the authorities.

Note also that MBM imported from other EU countries, if it has not been treated as laid out in Appendix I of 99/534/EG [47] (133 °C, 20 min, 3 bar), may only be used in certain incinerators (waste incineration plants). These are notifiable under Article 4 §2d of 97/735/EG [48] and are published in a list. They are permitted to accept mammal remains which has not been processed according to App. 1 of 99/534/EG [47] from other member states, and incinerate them or reuse them as fuel. On 30th January 2001, 16 German incineration plants were on the list.

3.1 Quantities

The quantities of meat processed in Germany in 1999 are shown in the following figure:

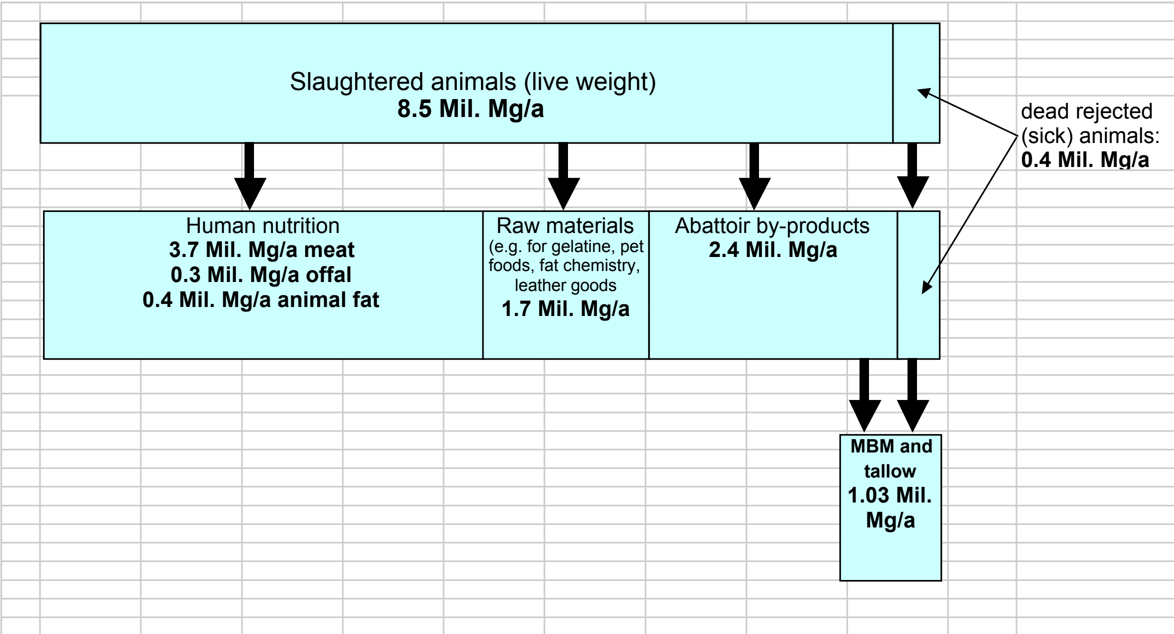

Fig 3.1: Meat processing 1999 [16]

The MBM and tallow produced in 1999 breaks down as follows:

	quantities (Mg/a)	produced from	produced at
MBM	378,000	Cadavers, cadaver parts, abattoir waste	Renderers (43 in Germany)
SRM MBM	72,000	Specified risk material (SRM)	Specialist renderers
Tallow	370,000	Cadavers, cadaver parts, abattoir waste	Renderers, specialist renderers and fat renderers
Bone meal	215,000	Abattoir waste with high bone content	Specialist renderers (10 in Germany)
Blood meal	22,000	Animal blood classed as suitable	Blood meal works (6-7 in Germany)
Feather meal	16,000		Feather meal works
Poultry meal	30,500		Poultry meal works (3 in Germany)
Total	**1,031,500**		

Table. 3.1: Estimated annual incidence of MBM and tallow in Germany, [3, 16]

Owing to changes in the law, these quantities should not be taken as a secure basis for planning. The authors are not aware of the exact quantities currently being produced or in storage. Future quantities may vary widely according to how the BSE crisis develops in Germany, for example the slaughter of 400,000 head of cattle has been announced.

The authors do not expect the quantities for incineration to reach the level of just under 0.5 Mil. Mg/a predicted by the Ministry for Consumer Protection, Food and Agriculture. Experience with comparable crises leads them to expect that large quantities will find different uses in the medium term, possibly when current production processes for MBM are modified.

On the other hand, it can be assumed that SRM will require incineration for a long time.

3.2 Composition of MBM and tallow

The composition of these substances is given in the literature as follows:

Substance and source (see Ch. 6, Literature)	units	MBM analysis, Bavaria [27]	MBM sample Rep. Ireland [5]	MBM sample Portugal [6]	MBM sample [8]	tallow [7]
Net calorific value H_u	MJ/kg	18.0	15.7	17.8	16.13	39
Water	%	4.6	18.9	2.2	7.53	0.1-0.4
Ash	%	22.03	29.4	23.6	31.0	-
Nitrogen	%	7.65	5.8	10.6	7.3	-
Sulphur, total	%	0.62	0.5	0.4	0.33	-
Hydrogen	%	5.86	7.7	6.9	5.07	-
Carbon	%	40.83	37.2	47.3	36.3	-

Table 3.2: Composition of MBM and tallow

Table 3.3 compares MBM, a potential support fuel, with other primary and secondary fuels [19]:

	units	Coal	Domestic waste	Sorting residues	MBM	Sewage sludge
Carbon	%	82 - 92	28 – 40	44 - 63	37.2	22 - 31
Hydrogen	%	3 - 6	4 – 5	/	7.7	3 - 4
Nitrogen	%	1.3 – 1.9	1 - 2	<0.1	5.8	1.9 - 6
Sulphur, total	%	0.6 – 1.1	0.3 – 0.5	<0.1	0.5	0.5 – 1.3
Oxygen	%	2-10	16 - 22			11 - 16
Fluoride, total	%	<0.03				
Chlorine, total	%	0.01 – 0.3*	0.4 – 1.0	1.2 – 2.2	0.5	0.05 – 0.4
Cyanide, total	mg/kg					
Arsenic	mg/kg	1 - 50		2.3 – 12.3	0.3	
Lead	mg/kg	9 - 70	390 - 1830	14.5 - 258.5	4.25	206 - 390
Cadmium	mg/kg	0,1 - 2	1 - 33	8.5 - 66.2	0.43	3.6 - 4.3

	units	Coal	Domestic waste	Sorting residues	MBM	Sewage sludge
Chrome, total	mg/kg	10 - 70	30 - 2760	15.4 - 68.6	8.31	64 - 72
Copper	mg/kg	5 - 70	60 - 2080	51.8 - 7278	29.4	322
Nickel	mg/kg	15 - 100		3.4 - 27.8	3.1	34
Mercury	mg/kg	0,08 - 2	0.5 - 12	<0.1	0.18	2.3
Zinc	mg/kg	10 - 300	470 - 6530		140	
Incandescent heat loss	% weight	70 - 90		80 - 93		
Calorific value	MJ/kg	25 - 30	7.5 - 15	18.2 - 28.2	15.7	8.0 - 11.5

* sometimes up to 1 %

Table 3.3: Comparison of primary and secondary fuels with MBM [19, 16, 41]

It should be noted that most of the chlorine in MBM is present as NaCl (common salt).

Data on substances which are important for incineration from producers of various MBM products can be found in table 3.4. Type 55 bone meal is a fatty bone meal containing 55% protein.

	Type 55 bone meal [16]	**MBM [16]**	**Blood meal [16]**
Org. substance	75 %	56.9 %	88.2 %
Raw fat	12 %	10 %	0.5 %
Raw ash	21 %	39.5 %	3.6 %
Phosphorous	3.1 %	6.1 %	0.16 %
Calcium	6.0 %	12.0 %	0.17 %

Table 3.4 Contents of MBM contents [16]

The composition of the ash produced is also important when incinerating MBM, and is listed in Table 3.5, which shows the high levels of phosphorous and calcium:

Components	MBM sample, Bavaria [27], % weight
SiO_2	1.42
Al_2O_3	0.19
Fe_2O_3	0.45
CaO	43.9
MgO	3.01
Na_2O	8.52
K_2O	1.36
SO_3	2.08
P_2O_5	37.7

Table 3.5: Composition of ash from an MBM sample [27]

The pollutant content of various MBM samples is given in Table 3.6, as well as the limits from the Sewage Sludge Ordinance, by way of comparison. The available analyses show that MBM has a comparatively low pollutant content.

Substance, source	**Units**	**MBM, Bavaria [27]**	MBM, Rep. Ireland [5]	**MBM, Portugal [6]**	**Tallow, Bavaria [27]**	Limits in Sewage Sludge Ordinance, § 4 (12) & §4 (10)
Chlorine, total	%	0.67	0.5	0.5	0.0031	
Chlorine, organic	mg/kg	-	-	55	-	
Lead	mg/kg	< 5	4.25	1.5	0.4	900
Mercury	mg/kg	< 0.2	0.18	0.2	< 0.01	8
Cadmium	mg/kg	< 1	0.43	0.4	< 0.05	10 (5)
Chrome	mg/kg	2.6	6.31	6.3	0.3	900
Copper	mg/kg	12	29.4	12.4	0.5	800
Nickel	mg/kg	< 4	3.1	3.3	< 0.1	200
Zinc	mg/kg	110	-	-	-	2500 (2000)
Dioxins/Furane (TEQ)	ng/kg	-	0.3	0.2	-	100

Table 3.6.: Pollutants in MBM

Detailed studies of PCB, PAH, PCP and HCH are available for two MBM samples. Where quantities are undetectable (–), the detectable limits are given in brackets:

Substance, source	**Units**	**MBM, Rep. Ireland [5]**	**MBM, Portugal [6]**	**Sewage sludge**
Dioxins/Furane (TEQ)	ng/kg	0.3	0.2	10-20
PCB				0.3-4.5 mg/kg
PCB-28	µg/kg TM	3.1	– (1)	
PCB-52	µg/kg TM	0.93	– (1)	
PCB-101	µg/kg TM	0.84	– (1)	
PCB-138	µg/kg TM	3.4	– (1)	
PCB-153	µg/kg TM	2.5	– (1)	
PCB-180	µg/kg TM	1.4	– (1)	
PAK				0.6-19 mg/kg
Naphthaline	µg/kg TM	– (10)	– (10)	
Acenaphtylene	µg/kg TM	2	– (5)	
Acenaphthene	µg/kg TM	16	– (5)	
Fluorene	µg/kg TM	81	– (5)	
Phenatrene	µg/kg TM	156	9	
Anthracene	µg/kg TM	25	– (10)	
Fluoranthene	µg/kg TM	– (10)	– (10)	
Pyrene	µg/kg TM	– (10)	– (10)	
Bezo(a)anthracene	µg/kg TM	– (10)	– (10)	
Chrysene	µg/kg TM	– (10)	– (10)	
Benzo(b)fluoranthene	µg/kg TM	– (10)	– (10)	
Benzo(b)fluoranthene	µg/kg TM	– (10)	– (10)	

Substance, source	Units	MBM, Rep. Ireland [5]	MBM, Portugal [6]	Sewage sludge
Benzo(k) fluoranthene	µg/kg TM	– (10)	– (10)	
Benzo(a)pyrene	µg/kg TM	– (10)	– (10)	
Indeno(1,2,3-cd)pyrene	µg/kg TM	– (5)	– (10)	
Benzo(ghi)pyrene	µg/kg TM	– (5)	– (10)	
Dibenz(ah)anthracene	µg/kg TM	– (5)	– (10)	
PCP	µg/kg TM	– (5)	– (20)	
HCH				
α-HCH	µg/kg TM	– (20)	– (20)	
β-HCH	µg/kg TM	– (20)	– (20)	
γ-HCH	µg/kg TM	127	– (20)	
δ-HCH	µg/kg TM	– (20)	– (20)	
ε-HCH	µg/kg TM	– (20)	– (20)	

Table 3.7: PCB, PAH, PCP and HCH concentrations in MBM

There are analyses of PCB and HCH in German MBM [27], all with undetectable levels, below 20 µg/kg.

The mechanical properties of MBM vary according to where it is produced and cannot be specified in general. However, production processes do already attempt to achieve a grade distribution which meets the existing requirement from the feedstuffs industry for minimum dust creation. The increased danger of explosion associated with a high proportion of fine particles also means that this is avoided where possible ([11], [35]).

MBM has a browny colour and a bulk weight of c. 600 kg/m^3, as well as an intense sweet odour. It should be noted that, if stored improperly in damp conditions, MBM provides an ideal medium for every kind of bacterium, fungus or vermin.

Experience shows that only ground MBM with a water content of under 5% and a fat content of under 14% can be transported pneumatically, and there are reports of problems arising with fat contents above 10%. Since there is rarely less than 10% fat in MBM, pneumatic transport is more practical for lower-fat bone and blood meal.

3.3 From rendering to incineration

MBM is normally stored temporarily in silos at rendering works, and is transported in silo lorries - until now to feedstuffs producers. This transport and unloading MBM from silo lorries is BAT and works well. Few rendering works possess bagging equipment for direct supply to agriculture, and this equipment is inadequate for bagging total production on site. Further processing and packaging of animal feed or MBM for sale, i.e. in sacks, used to take place a feedstuff producers.

The existing transport system - silos at rendering works - is well-suited for bringing MBM to incinerators in closed vehicles.

It would also be possible for renderers to supply MBM in greaves (see Fig. 3.1). This is stripped dry unground MBM in lumps of up to 50 mm, and gives rise to virtually no dust during handling. A decision to supply MBM to incinerators in greaves would mean that the composition of the final product could be optimised for incineration by modifying production at the rendering works, as no grinding is required. The cost savings for renderers would be slight, as grinding consumes only electricity.

Some MBM is also provided in the form of granulate or pellets.

A medium-term option is to optimise MBM production for incineration, i.e. omit any stages in the process which become unnecessary and provide a fuel which is optimised for handling and incineration. The associated savings can be maximised by building on cooperation between renderers and incineration plants.

4.0 Experience to date

The following presents experiences to date in, and gaps in our knowledge of incineration for MBM and tallow. Note that MBM and tallow are support fuels in all plant types, as they use other materials as the main fuel.

Experiences are detailed by plant type, and follow a fixed scheme corresponding to the process stages, although not every stage is relevant in every case.

4.1 Current implementation of law

Faced with pressure for action, different *Länder* have interpreted differently the legal framework they are responsible for implementing on MBM and tallow, as well as feedstuffs containing them, which cannot be resold - because of the act prohibiting the use of certain animal feedstuffs, and their import and export within the EU, which came into force on 02/12/2000 - and which must therefore be disposed of (incinerated).

Disposal (incineration) is therefore conducted in terms of the Animal Remains Disposal Act, the Closed Substance Cycle Waste Management Act or the Feedstuffs Act.

In view of this unsatisfactory situation, a discussion between the *Land* and national governments took place on 01/02/2001, aimed at harmonising implementation. The conclusions of this discussion will shortly be published.

4.2 Technical and operational experience

Operational experience to date with incineration of MBM or tallow is presented here for each plant group. It must be emphasised that, owing to different plant structures within groups and yet to be optimised operating conditions, experiences naturally contradict one another from time to time. With a few exceptions (e.g. [2]), plants are not identified specifically.

4.2.1 Waste incineration plants

MBM is currently incinerated in some 10 waste incineration plants in Germany, in some this has been the case for a considerable period of time. By the end of 2000, c. 40,000 Mg were being input, distributed as follows:

Hamburg:	In 3 plants c. 20,000 Mg
Bremen, Bremerhaven:	In 2 plants c. 6,000 Mg
Baden Württemberg, Saarland:	In 2 plants c. 6,000 Mg
Bavaria:	In 2 plants c. 6,000 Mg

In one plant, MBM incineration has now been banned by the responsible Employment and Social Ministry.

A comprehensive report on experiences with MBM incineration has been provided by the Stellinger Moor plant in Hamburg, which has incinerated some 6,000 Mg MBM from the Republic of Ireland [2]. Interviews with the operators provided further information.

By 30/11/2000, only MBM from within the EU was being incinerated. Since the ban on feedstuffs came into force in Germany, incineration of small quantities produced in Germany is taking place in several plants.

Since tallow is not a well-suited fuel for waste incineration plants, no experience has been gathered in this area, except for one plant, where the oil burner has been successfully fuelled by tallow.

Delivery

MBM is generally delivered to waste incineration plants in standard skips. Depending upon the producer and the quality of the MBM, it can be delivered loose or packaged (e.g. as 25 kg or 50 kg sacks).

Delivery to one plant used large plastic sacks, which were opened and emptied automatically in a bunker. From there, the MBM was taken along a conveyor directly to the waste input funnel. This scheme was selected in response to the licensing authority, in order to ensure that no MBM lie open in the waste bunker. However, the scheme proved accident prone and hard to repair, and so the licensing authority agreed that the delivery method could be replaced by simply dumping the MBM into the waste bunker.

Vehicles unloaded into the bunkers, and no particular dust emissions were registered, owing to the relatively high levels of fat and water, not even when sacks burst.

Staff were given prior instruction on deliveries of MBM, and general handling guidelines and protective measures were established as a precaution. Hygiene rules were especially important, as many of the existing operating rules, on handling hazardous substances, for example, were applicable.

The following presents an incomplete list, in no particular order, of the protective measures for accepting MBM used in various plants. They are not necessarily identical with the authors' recommendations, which can be found in Ch. 5.2.1.3.

- MBM is to be tipped onto an existing bed of waste.
- MBM should be deposited in the bunker without visible dust forming.
- The funnel area by the feeder is to be disinfected at least once a day with chlorine bleach. A vet recommended using a 4% sodium hydroxide solution at another plant. (This requirement originates from plants where foreign MBM is incinerated, and there is no guarantee that high pressure sterilisation has been used).
- Delivery lorries must be disinfected (with chlorine bleach) before leaving the facility. (This requirement originates from plants where foreign MBM is incinerated, and there is no guarantee that high pressure sterilisation has been used).
- Delivery skips may not be stored on the premises.
- The quantities fed into the furnace should be limited to a maximum of 20%, 10 % or 5 %, respectively.
- Extended storage in bunkers should be avoided.
- Direct contact with MBM should be avoided.

Rules for cleaning the vehicles and conveyors vary from plant to plant.

<u>Storage and mixing</u>
Longer-term storage of MBM deliveries in the waste bunker has been explicitly avoided up to now, with deliveries being made daily. With deliveries following a 5-day week, and incineration a 7-day week, only very small quantities of MBM have ever been present in the bunkers, and no particular emissions of dust or odour have been observed.

A key role of the waste bunker is to mix the MBM with the other waste, as the calorific value of MBM is significantly greater than the average for normal waste. Cranes with normal grabber arms were used to mix and homogenise the MBM with the rest of the waste. This has been successful, although some MBM flows out of the grabber arm onto the surface of the bunker. Where delivery is in sacks, mixing has also been able to produce an adequate distribution for incineration. No illegal dust emissions has been observed when some sacks are torn open by the grabber.

Essentially, temporary storage of MBM in waste bunkers has proved practicable, and growth in vermin populations have been observed only after several days storage. Some plants report that the addition of MBM, which raises the fat content, makes waste piles less stable and therefore reduces the amount which can be stacked or makes it difficult to keep the input areas of the bunkers free.

It was also observed that the bulk weight rose, as MBM tends to fill gaps in the waste pile. This sometimes led to the overload trip-switch being triggered on the grabber arm.

In general, the MBM-waste mixture can be brought to the incinerator by crane without problems.
The residues produced (slag, fly-ash, etc.) are removed by standard procedures with no recognisable effects. Bringing the MBM directly to the furnace input funnel via a conveyor, as in one case, has proved unworkable and is no longer in use.

No negative effects have been found during transport to the furnace.

Incineration
MBM is a highly calorific, easily flammable fuel, and must therefore be mixed well and homogenised with the other waste, as must other waste mono-fractions with similar properties (e.g. plastics). Experience has shown that the use of homogenised waste-MBM fuel improves rather than detracts from the performance of the incinerator. If the MBM does not exceed 10 - 25% of the total waste flow, the performance of the incinerator can easily be kept within operational limits. One plant even reported that incineration had become more stable.

Reports about the maximum ratio of MBM to other waste vary widely (5%, 10%, 25%), which can be explained partly by differences between plants. One plant burns an average mix with 25% MBM. It is not expected that MBM content of up to 10% in the waste flow will impair incineration.

The temperature in the waste on the grate is c. 800 - 1000°C [42] in the main incineration zone. Total exposure time on the grate is 30 to 45 minutes, of which c. 10 minutes are spent in the main incineration zone. Incineration gases remain for over 2 seconds at a temperature of over 850 °C.

TÜV-Süddeutschland [42] reports on the basic conditions in the furnace when compared with the test conditions of Brown et al.[18] as follows:

„The test conditions for combustion are in no way comparable with conditions in an incinerator which complies with the 17th BImSchV. In our opinion, incineration conditions here are, thanks to the deliberate oxygen surplus, considerably better than in the tests, which were conducted on pyrolytic incineration.“

No wear above the norm on metal or ceramic components was observed when MBM was incinerated. Experience to date and the current state of knowledge give no indication of increased soiling or corrosion. In fact, some reports mentioned a reduction in soiling. However, it should be noted that the high levels of phosphorous in MBM lower the melting point of the ash, which can give rise to problems.

Emissions

Because of the relatively low levels of pollutants in MBM compared with domestic waste, as well as the comprehensive exhaust gas purification technologies in waste incineration plants, no effects on emissions could be observed when MBM was incinerated. The high phosphorous content of MBM does nevertheless indicate that catalytic de-nitrification could be impaired, although there is no robust evidence for this.

Residues/Products

As to a comparison between the inactivation rates of c. 10^8 [18] at 600 °C under test conditions with those achievable in incineration residues, TÜV-Süddeutschland [42] concludes:

„Inactivation rates of over c. 10^8 can be reached with combustion in a waste incinerator at 600° C within 15 minutes under the following conditions:

- *Water content significantly below 80%, as with the fresh material used*
- *Small particles (a few mm) inside the incinerator*
- *Surplus oxygen during combustion*
- *Ensuring that the material remains in the oven for at least 15 minutes at the given temperature.*

Current knowledge is that MBM, owing to pre-treatment and mixing with uncontaminated material at the rendering works, exhibits no concentrations of pathogens comparable with infected brain tissue. It can therefore be assumed that, under the above conditions, any prions in MBM will be totally inactivated.

Compliance with the 17th BImSchV guarantees that exhaust gases are fully combusted and indicates the grate temperatures in a waste incinerator. Exhaust should in any case be *treated appropriately, so that no infectious particle that might have spent too little time in the oven can escape. This exhaust treatment supplies an additional level of safety."*

TÜV Süddeutschland makes the following recommendations for residues from waste incineration plants:

- *„What falls through the grate should either be fed back into the incinerator or stored in such a way that it cannot spread uncontrolled.*
- *To ensure and prove empirically whether grate losses or slag contain prions, an analysis of the protein structures they contain is recommended.*
- *As a precaution, slag arising during the shutting down of a plant should be stored separately, as this involves a relatively rapid cooling and a correspondingly poor level of combustion.*
- *Potential inputs of amino compounds should be studied in the salt fractions recovered from washwater in incineration plants where this takes place."*

Products such as hydrochloric acid, common salt and plaster occur only in isolated plants. Specific influence by MBM incineration on these occurrences are unknown.

A distinction should be drawn between effects on incineration residues and those on exhaust purification residues. No qualitative or quantitative effect on exhaust purification residues has been observed.

An influence on the quality of slag in incineration residues was observed when the ratio of MBM to ordinary waste exceeded the intended level significantly, as a result or poor mixing. The slag was finer and browner, sometimes also malodorous. With low MBM proportions, i.e. below 5 - 10%, such changes were not observed. As often in such plants, the slag from MBM combustion was materially recycled without problems. Preliminary analyses of this slag are available, and they reveal the presence of apatite ($Ca_5(F, Cl, OH, CO_3)(PO4)_3$). This gives reason to suppose that the effects of the increased phosphorous content on the process will be minor.

In one case, preliminary analysis results, if verified, would indicate a negative impact on slag recycling.

Incineration trials to date have revealed no negative effects on grate losses. The only general observation is that negative effects can be expected with non-homogeneous inputs and MBM content of over 25% (sometimes merely > 10%). At plants where grate losses are returned to the oven or the waste bunker, this problem does not arise.

Capacity

Free capacity varies widely from plant to plant. With the total waste incineration capacity of c. 14 Mil. Mg/a waste, even a 5% MBM input could theoretically handle some 0.7 Mil. Mg MBM per annum.

Pricing

Treatment prices for MBM incineration are c. 200 - 300 DM/Mg, the standard cost for incinerating normal waste. The higher calorific value means that a tonne of MBM replaces c. 1.5 t domestic waste. The theoretically higher price which could follow from this will clearly be rejected by the market. This has led plants operating at almost full capacity to decide against actively pursuing MBM incineration for economic reasons.

4.2.2 Hazardous waste incineration plants

Three hazardous waste incineration plants have had experience with MBM in Germany, above all MBM from France.

Delivery, Storage, Conveyance

MBM is mainly delivered in loose form, with some in sacks, and stored in a closed bunker. It is tipped into the bunker similarly to waste incineration plants (see Ch. 4.2). It would not be possible to accept the material in closed packages. The MBM is taken to the rotary furnace by a crane with grapple arm, as in waste incineration plants.

Incineration

Combustion temperatures in rotary furnaces are 900 – 1,100 °C. During afterburning, the combustion gases are exposed to temperatures of at least 1,100 °C for over 2 seconds. Because of its calorific value, and to ensure full incineration, the input of MBM is restricted. No negative effects on the incineration process have been found under these conditions.

Emissions

The flue gas is passed from the rotary furnace into an afterburner with a temperature of at least 1,100 °C. Exhaust gas purification is intended for waste with considerably greater pollutant content, and no effects on emissions have been registered, nor are they expected.

Residues

With restricted use of MBM, no effects have been registered on residues or products.

Capacity

Germany's hazardous waste incineration plants do have spare capacity, and could accept c. 50,000 Mg/a MBM.

Pricing

Treatment prices are c. DM 300,- to DM 800,- per tonne.

4.2.3. Sewage sludge incineration plants

Most sewage sludge is incinerated in dedicated plants with stationary fluidised bed ovens. The suitability of these plants for MBM incineration is given by the following properties:

- MBM and sewage sludge are of a similar consistency and are dealt with in closed systems. Staff have experience with handling materials where there is a risk of infection (rakings, fats).
- Plants comply with the 17th BImSchV. Fluidised bed combustion makes it possible to heat even the ash components of fuels to at least 850 °C.

Some experience has been gained with MBM as a support fuel, and even tallow is already being used in a number of plants. In England, a new dedicated MBM incineration plant is being built, equipped with fluidised bed ovens (see Ch. 4.9.1).

Delivery, storage

Coarse material such as greaves or pellets is preferable, but fine grade material may also be used. Some existing facilities for accepting sludge from outside can be used to accept MBM. As MBM incineration becomes established in the long term, separate silos or bunkers are generally planned, to create a good mixture of MBM with the sewage sludge.

Conveyance

MBM is conveyed similarly to sewage sludge in a closed system. It is fed into the furnace after being mixed with the sludge or through separate feeders.

Incineration

According to operators, MBM inputs up to 10 - 20% dry weight are unproblematic. The limit to the ratio depends upon the type of furnace. Furnaces designed to incinerate more highly calorific materials, e.g. industrial sludge or dried sewage sludge, could cope with higher levels of MBM. Circulating fluidised bed ovens and layered ovens could also accept MBM ratios over 20% dry weight, and this must be clarified for each plant. In any case, the MBM must be susceptible to stirring (coarse grade, no greaves).

Residues/Products

The residue from sewage sludge incineration is ash, carried out via exhaust gas. It is unclear whether MBM inputs affect the ash's properties, nor a reduction in the ash melting point caused by higher MBM inputs could give rise to problems.

Emissions

It has been observed that the high nitrogen content of MBM causes NO_x levels to rise. However, where end-of-pipe denitrification measures are installed, to comply with the limits in the 17th BImSchV, this rise is not considered a problem; if this is not the case, changes in emissions are to be monitored, as input restrictions may become necessary. No other effects on emissions from MBM incineration are known.

Capacity

Operators claim that there is spare capacity at virtually every sewage sludge incineration plant, with potential inputs of 2,000 - 20,000 Mg/a per plant. There are also redundant incinerators which could be put into operation with the agreement of the licensing authorities. Total spare capacity is estimated at c. 15,000 Mg/a.

Pricing

No universal treatment price can be given, as it depends upon the specific plant and the disposal conditions.

4.2.4 Coal-fired power stations

See the source materials for the VDI guidelines on air quality [32] [33] for available techniques in using waste as a support fuel in coal-fired power stations.

The use of waste as a support fuel is restricted by storage space at the power station, the need for pre-treatment to produce a suitable form for feeding into the furnace, its behaviour when incinerated (including soiling, corrosion and effects on gas purification), impact on emissions, exhaust gas purification and combustion residues [33].

Large-scale experiments with MBM have been underway since 2000. Pilot operation under a 6-month licence has been taking place at Berlin-Oberhavel, for example, with 100 Mg MBM input per day, and several power stations have expressed an interest. A licensing procedure is currently underway for MBM as a support fuel in a station belonging to VSE AG at Ensdorf. The Staudiger power station in Hesse has also had experience with MBM.

Since December 2000, the circulating fluidised bed at an industrial power station belonging to Rethmann Lippewerke GmbH in Lünen has been incinerating MBM. The plant is designed for 78 MW (thermal) and is currently operating at c. 45 MW. It has a temporary licence to incinerate MBM, and c. 50 - 60% of furnace heat is currently being provided by MBM, with the remaining 40 - 50% apparently coming mainly from permitted secondary fuels and coal. In February, the MBM ratio is planned to rise still higher, eventually generating all heat from MBM. It has been reported that the use of MBM has improved combustion and led to more stable incineration. Emissions of total carbon and of CO were both reduced through the use of MBM, while the ash tends to be more completely combusted when MBM is used.

Available equipment for accepting and conveying sewage sludge can often be used for MBM as well.

Tests to date have only covered MBM, there is as yet no experience with tallow as a support fuel in coal-fired power stations.

<u>Delivery and storage</u>

The following methods for accepting MBM are known:

If equipment for sewage sludge is available, the MBM is delivered by lorry and pressed into a form which is closed on 3 sides. It is then conveyed on a belt to the mixer, where it is mixed with coal and fed into the furnace through a mill. There appear to be no problems with escape, as the MBM is not fine grade, nor is it stored, but incinerated very soon after arrival. As a provisional measure at some test sites, the MBM was tipped onto the coal and mixed there. Due to the hygiene risks (vermin) and the possibility of dust or odour emissions, this procedure would not normally be acceptable.

Further plans are for erecting silos to accept MBM delivered on silo lorries. It should be noted that only certain grades of MBM are suitable for silo storage and pumping, and this path may therefore only be possible for some MBM. As well as the problem of pumping, the problem with escaping gas (dust and odour) when silos are filled, as well as the risk of spontaneous heating or even combustion must both be dealt with.

In general, human contact with MBM is avoided by automating delivery and conveyance. If an accident makes this unavoidable, disposable protective suit, gloves and dust masks are used.

Conveyance and incineration

In tests to date on pulverised-coal furnaces and slag-tap furnaces, the MBM is either added to the coal after the mill or fed together with the coal into the mill and then into the furnace. The current results show that MBM can be used as a support fuel in these furnaces. No negative effects on the combustion process have been observed yet.

Other tests have been conducted on feeding MBM into the furnace through a separate dust burner. Technical tests by burner manufacturers have shown that this is possible in principle. However, there is little experience of large-scale use of this technology and much more research is needed. The restrictions mentioned above should apply to pneumatic conveyance of MBM.

Combustion temperatures in pulverised-coal furnaces are 1600 to 1700 °C, with gas temperature equal to solid temperature.

The composition of MBM makes the following effects on combustion possible:

- slag-tap furnace: changes in the slag behaviour due to high calcium and phosphorous content in MBM
- greater soiling of the boiler due to high phosphorous content in MBM
- fears of increased boiler corrosion due to MBM's high chlorine content. The available analyses of coal ad MBM are inadequate for a final judgement.

The authors are unaware of any large-scale experience with stoker-fired furnaces

Emissions

Commercial-scale tests to date have shown no recognisable effects on emissions from coal-fired power stations. This is backed up by experiences with MBM and tallow as support fuels in England [15, 17], although the inputs of MBM were relatively small and the experience is still limited. Potential effects on emissions are listed below:

- Higher NO_x emissions due to higher nitrogen content in MBM fuel.
- Higher chlorine emissions due to higher chlorine content in MBM can be ruled out, as desulphurisation removes chlorine first.
- Negative impact on exhaust gas purification (especially High-Dust SCR) due to higher phosphorous content in MBM.

More research is needed, as there is little experience on a commercial scale.

Products and residues

Available tests on slag-tap granulate reveal no effects from MBM incineration, nor do tests on FGD gypsum. The relatively small amount of experience to date has indicated no practical effects on products and residues (slag-tap granulate, boiler ash, fly-ash, FGD gypsum). Some English tests on MBM as a support fuel have revealed residual amino acids in the ash [17] (proteins, and therefore prions, consist of chains of amino acid), however, all the chains were incomplete, allowing one to conclude that no prions were present.

In view of the high levels of calcium, phosphorous and sodium in MBM, effects on ash and FGD gypsum are possible. Here too, research is needed, because the use of MBM in coal-fired power stations would have to be ruled out if the aforementioned products were made unusable.

The fly-ash from many furnaces with dry ash removal is used in concrete. Building licensing regulations would scarcely permit the use of fly-ash from MBM incineration at present, and considerable quantities of fly-ash would therefore end in landfill. For economic reasons, MBM can therefore only be used as a support fuel in these power stations if the appropriate tests permit licensing this fly-ash for concrete production.

Pricing

Reliable prices for treatment cannot be given at present, as the market for MBM as a support fuel in coal-fired power stations has not yet established itself. One operator expects prices to be around c.100,- to 200,- DM/Mg.

Capacity

The possible capacity for MBM input to coal-fired power stations cannot yet be determined, as there is no certainty about the maximum possible MBM content. However, in view of the vast fuel inputs to these stations, using even small proportions of MBM would represent a useful disposal path.

C. 40 Mil. Mg/a of coal are currently used in German coal-fired power stations, not including industrial power stations. Lignite consumption is currently c. 170 Mio Mg/a. If only 1% of coal were substituted with MBM, this would produce an incineration capacity of 1.5 Mil. Mg/a MBM in terms of calorific value.

Even if only major slag-tap pulverised-coal furnaces were used for 1000 hours at full capacity, a total of 300,000 Mg/a MBM could be incinerated with 1% input, in terms of calorific value.

4.2.5 Cement works

German cement producers are currently examining the use of MBM and tallow as a support fuel in their factories. Appropriate technologies are being developed to meet the special workplace safety, environmental and public health requirements, as well as ensuring that product quality does not suffer and the burning process is not impaired.

Thermal recycling of MBM and tallow is seen as useful by the cement industry, because the thermal process where cement clinker is burnt has good conditions for complete combustion in terms of the temperature and the time spent in the oven, as required in the 17^{th} BImSchV. At the same time, substituting primary fossil fuels (coal and lignite) has environmental and economic advantages.

See the source materials for the VDI guidelines on air quality [32] [33] [34] for available techniques in cement works.

In general, the following technical characteristics of clinker burning are crucial for the use of secondary fuels [33] [34]:

- Gases remain in the rotary oven for some 8 seconds at over 1,200 °C
- Gases remain in the second firing for over 2 seconds at over 850 °C
- Gaseous components like HF, HCl, SO_2 are adsorbed by alkali reactants and particulate heavy metals are strongly bound
- Fuel ash is used as an ingredient for the clinker - simultaneous material and thermal recycling
- Trace elements are bound into the clinker chemically and as minerals

Like all raw materials and fuels, the secondary fuels used for clinker must be easy to dose.

Combustion conditions in rotary ovens ensure low emissions of PCDD/F (dioxins/furane). Waste which could contain significant impurities of persistent organic substances (e.g. waste oil containing PCB), are fed in during the main firing [33].

See also the notes on the use of waste in the cement industry in the published draft VDI guideline "Emissionsminderung Zementwerke“, March 2001 [34].

<u>Delivery and storage</u>

The material is delivered in silo lorries, and can be pumped from the vehicles without much difficulty, although there is a risk of compaction during transport, in which case the MBM must be shaken and loosened in the lorry.

Narrow silos are unsuitable for storing MBM; short, squat silos are better. The higher the fat content, the more MBM tends to compact, sticking together to form a gluey mass.

Problems with flow cannot be solved with compressed air, although shock blowers are used to clean the corners of flat-bottomed silos and to remove bridges.

The silo's filters must be cleaned and maintained continually. Hoses made of uncoated or natural fibres can become blocked when fat content is high, and natural fibres are susceptible to attack from bacteria.

Open storage of MBM is avoided. The cement industry can exploit its experience with delivery and storage of heating oil when dealing with tallow, which can be stored in the appropriate tanks (e.g. fitted with heating and stirring equipment).

Conveyance and input

Pumping between the storge silos and the burner becomes more difficult with higher fat contents, as bends in pipes can become blocked.

Mechanical conveyance can be achieved without problems using plate or chain conveyors, extraction screws and bucket elevators. The latter require regular cleaning in the corners, to avoid residues rotting.

In the schemes pursued up to now, MBM is blown separately into the oven system, while tallow is fed into the rotary ovens in similar way to heating oil.

Effects on incineration

Owing to the chlorine input, the quantities of MBM entering the oven system may need to be restricted, as the chlorine in raw materials and fuels reacts to alkali chlorides, which evaporate almost completely in the sintering zone, condense onto the fuel in cooler areas, and are thereby returned to the oven system. This cycle between the rotary oven and the economiser can lead to an accumulation of deliquescent alkali compounds in the hot dust. If this becomes excessive, cleaning becomes more difficult and operation can be disrupted, including blockages. This is well-known in the use of other secondary fuels, and can be controlled either by restricting chlorine inputs or breaking the chloride cycle. Depending upon how much chlorine is contained in the raw materials and fuels, cement industry ovens may be fitted with suitable bypass or dust removal systems.

Emissions

Manufacturers find the effects of MBM as a support fuel on emissions from cement production to be minimal, because the content of trace elements in MBM and tallow is comparable to that in regular fuels, if not significantly lower. This has now been confirmed by measurements in rotary oven plant. However, MBM contains nitrogen compounds, so that NO could theoretically be formed in the fuel. Since the level of nitrogen oxides emissions is determined principally by thermally formed NO, it can be assumed that total emissions will remain unchanged, or that legal limits will not be exceeded. It should also be noted that the majority of nitrogen in MBM is in the form of amino acids which can, like other organic nitrogen compounds, form NH_2 radicals, thereby reducing nitrogen oxides emissions.

Products and residues

In order to assess the use of a fuel in clinker production, material properties are as important as energy, as the fuel's components are bound into the clinker during burning. The phosphorous content in MBM is therefore significant. There are indications in the literature that increased phosphorous can increase the setting times for Portland cement clinker. However, other authors assume that phosphate is bound into clinker as calcium phosphate, which would have no effect on the setting times of the cement produced. Available experience and studies by the German cement industry show that the use of MBM presents no risk to product quality. The phosphate input from MBM will be examined on a case by case basis, and compared with the input from other sources, mainly raw materials.

Capacity and pricing

Capacity for using MBM as a support fuel in German cement works is put at 300,000 to 400,000 Mg/a, at a cost of c. 200 DM/Mg. Further capacity is available for tallow.

4.2.6 Gasification plants

The only large waste gasification plant In Germany is the Schwarze Pumpe SVZ recycling centre, which has many years of experience in handling MBM and tallow.

Delivery and storage

MBM is used in three forms:

Pellets:

MBM can be delivered loose in pellet form, preferably 16 mm diameter.

Loose:

MBM can be delivered loose, in which case it is mixed with sewage sludge and turned into pellets on site.

Greaves:

Greaves are also delivered loose.

In all three cases, the MBM is fed directly into a closed automatic system, without temporary storage. At present, no MBM from special risk material (SRM) is used.

Where possible, the plant is run so that no aggregate which has come into contact with MBM remains when the plant is shut down. In case of a malfunction, the plant is cleaned with steam jets. There are similar rules for handling MBM and tallow

Tallow containing < 1 % water is delivered in liquid form (T > 50 °C) and fed into the dust-pressure gasifier through a closed system. Fat from SRM and normal fat are treated differently, but both can be gasified.

Gasification

The operator has reported no problems in gasifying MBM or tallow. The fixed-bed pressure gasifier (for MBM) is operated at a reaction temperature from 800 °C to 1300 °C, at a pressure of 25 bar. The dust-pressure gasifier (for tallow) splits the input chemically at a temperature of 1600 °C to 1800 °C, producing a synthetic gas containing principally hydrogen and carbon monoxide.

Products and residues

The operator claims that the quality of the product (methanol) and the slag is not harmed by the input of MBM and tallow.

Emissions

Gasifying MBM and tallow has not had any influence on emissions, according to the operator, and chlorine content in MBM is not an issue, since the plant can accept material with up to 10% chlorine.

Capacity

The plant's capacity for MBM is c. 70,000 Mg/a, and greater capacity is planned. Capacity for tallow is c. 60,000 Mg/a. The plant could currently process another c. 160 Mg/d tallow (water content < 1% delivery temperature > 50 °C).

Pricing

Prices for gasifying MBM are c. 165,- to 200,- DM/Mg, and prices for tallow vary widely. There are currently competitors who accpet tallow virtually free of charge. Recycling methods in the chemicals industry still appear to be exploited.

4.2.7 Other thermal processes

Alongside the aforementioned processes, it is conceivable that MBM and tallow be used in other thermal processes. The following mentions a few examples of these processes:

- Steel production
- Residue incineration in paper factories
- Power generation (Oil-fired power stations)
- Biomass plants
- Thermoselect processes
- Asphalt mixing
- Pyrolyse plants

As yet there has been no experience with the use of MBM in steel production. Where fluidised bed combustion is used to incinerate residues in paper manufacture, the situation is more or less as described in Ch 4.4. However, it cannot automatically be assumed that paper factories have experience with handling materials where there are hygiene problems.

An application has also been made to test the use of MBM in lignite-fired asphalt mixers. Since the maximum temperature reached is only 350 °C, compliance the 17th BImSchV is not possible, and permission is therefore unlikely to be granted.

There has been more experience with using tallow as substitute for heating oil, for example in a power station. Tallow is delivered, stored, conveyed, input and burnt similarly to the primary fuel. Its consistency, pollution content and calorific value are not significantly different to those of heavy oil, and are in fact somewhat better. Previous commercial experience has revealed no negative effects on combustion, emissions or products and residues.

Nothing certain can be said about the costs for using MBM to substitute heavy oil (see also Ch. 4.2.6). It is unlikely that the use of tallow as a heating oil substitute will increase, as tallow is still used as a material in industrial production.

Thermoselect has not yet had any experience with MBM.

4.3 MBM incineration in neighbouring countries affected by BSE

4.3.1 UK

It should first be noted that high-pressure sterilisation, required in Germany, is not used in MBM production in the UK. In view of the existing feedstuffs ban, this is not considered necessary.

Glanford power station in Flixborough has been incinerating MBM exclusively since 1999, with an annual input of 85,000 Mg. It had previously run on chicken manure, and was adapted for MBM. It is a stoker-fired furnace. The MBM is delivered into a closed warehouses and transported to the furnace on closed conveyor belts. SRM is not incinerated. The licensing authority was informed that the MBM is exposed to a temperature of 850 °C for at least 2 seconds.

Dedicated ovens for incinerating MBM have been operating in Widnes and Wyminton for some time, with a joint capacity of 60,000 Mg/a.

A further plant for incinerating only MBM is currently being built at Fawley, a fluidised-bed incinerator with a capacity of 60,000 Mg/a which should come into operation in April 2001. The UK's total incineration capacity is therefore 200,000 Mg/a, although no SRM is burnt. In addition, c. 3,000 cattle carcasses are incinerated directly.

Trials of MBM as a support fuel in coal-fired power stations were conducted in the UK in 1996 and 1997, and were apparently successful [15], although the practice has not become established in UK power stations. Operators were hesitant as to possible risks and special requirements when processing MBM, which would have made this method of disposal uneconomic. There are no comprehensive reports on these trials.

There are no reports of waste incinerators using MBM as a support fuel. Since UK waste incineration plants do not feed grate losses back into the furnace, they are presumably considered unsuitable [13]. There is also no information on the use of MBM in cement works.

Current installed incineration capacity is insufficient for thermal treatment of the MBM arising. In June 2000, c. 460,000 Mg MBM were stored, either in warehouses or special landfill sites. In Lincolnshire, a former hangar is being used to store 100,000 Mg MBM.

4.3.2 Switzerland

In Switzerland, 45,000 Mg MBM, 20.000 Mg bone meal and 20.000 Mg fat arise annually. Storing organic or chemical waste has been banned since 1/1/2000, and cannot therefore be an option for MBM.
Only incineration is an option, and the situation is as follows [26]:

- Waste incinerator capacity is overstretched with regular waste, and this is not therefore considered a serious option for large quantities of MBM.
- Cement works burn some MBM and tallow arisings as support fuel. For technical reasons, the total arisings cannot yet be processed here.
- There is a fluidised-bed furnace (RENI in Niedergösgen) which processes large quantities of bone meal, but cannot meet demand.
- Hazardous waste incineration plants are either overstretched or too expensive.

For energy reasons, prior fermentation is considered an interesting alternative.

Since incineration capacity is currently insufficient, and storage is associated with health and safety risks, Switzerland is seeking to export unburnt MBM (but not from SRM) to its neighbours, e.g. to German power stations, under the condition that thermal treatment abroad is environmentally friendly and uses BAT.

4.3.3 France

France produces c. 850,000 Mg MBM and c. 150,000 Mg tallow annually. Some 130,000 Mg MBM and 40,000 Mg tallow is from SRM, which has been collected separately, processed and completely incinerated by the cement industry since 1996 [49,50].

In future, the remaining MBM will also be incinerated in cement works and power stations. Capacity in the cement works is currently c. 200,000 Mg/a, and is to be extended to c. 450,000 Mg/a. Incineration in coal-fired power stations is still undergoing tests. It is planned to recycle tallow as a support fuel.

BSE-infected animals are ground to MBM, for disposal in hazardous waste incineration plants. This amounts to c. 30 Mg/a from 150 Mg infected animals.

Waste incineration plants have as yet been little used, as there are no plans to do so.

A large amount of MBM is still stored in warehouses or sent to landfill, c. 400,000 Mg in 2001.

An advice paper on MBM and tallow incineration has also been produced in France [21].

5.0 Requirements and recommendations

5.1 Legal framework

There are no specific regulations on incinerating MBM and tallow or mixed animal feed in incineration or gasification plants. In view of the large quantities of material to be disposed of in thermal treatment plants and the BSE pathogens it may contain, however, some advice and guidance should be noted:

Regardless of which laws are applied to the MBM, tallow or mixed animal feed to be burnt (see Ch. 4.1), the material can only be accepted for incineration by treatment plants where this is explicitly permitted or not explicitly prohibited in the plant's licence. If the plant has no licence to incinerate these materials, the operator must apply for an extension to the licence or give notification, under the Federal Pollution Control Act (§ 16 or § 15).

The operator should clarify the position by contacting the responsible licensing authority.

The incinerator must also comply with requirements in the ordinance on incineration plants for waste and similar combustible material (17^{th} BImSchV), in particular the technical requirements on firings under § 4 (minimum temperature 850 °C for a minimum of 2 seconds, minimum oxygen content 6 % by volume, see 5.2.1.1), as well as emissions limits and supplementary protective measures for dust.

There are no fundamental objections under pollution control law to incinerating MBM or tallow in waste incineration or other industrial incineration plants. This applies to all types of MBM or tallow, including materials which were not produced in compliance with current regulations (§ 5 TierKBAnstV or 90/667/EWG), or which contain SRM. Indeed, this problematic material should be disposed of in plant with a licence for the thermal treatment of waste.

Nonetheless, occupational health and safety requires protective measures to be taken when incinerating MBM. Special measures should also be taken to monitor and ensure the quality of products and residues. Operational experience to date at various types of plant has provided much proven advice on safe and proper operation when using MBM and tallow as support fuels, which can be found in Ch. 5.2.

Even though there is in principle no special hazard associated with incinerating MBM or tallow, when the occupational health and safety regulations specified in the licence are complied with, especially those relating to handling biological or dusty materials, additional safety measures should be introduced, firstly for delivery, and secondly for storage handling. In the recommendations set out in the following Ch 5.2, the authors have oriented themselves above all around the decisions of the Committee for Biological Working Materials (ABAS) on special measures to protect employees from infection by BSE pathogens (No. 602, 21/12/2000, amended 6/12/2000 [12]).

5.2 Procedural and operational requirements

5.2.1 General requirements

The following recommendations apply to emissions, residues and occupational safety at every type of MBM or tallow incineration, regardless of the plant.

The only thermal plants which could treat MBM and tallow are those with a licence under the 17th BImschV, and the processes used should be up to date. The VDI guide on air quality provides details of available techniques, for example VDI guideline 3460, "Emissionsminderung Thermische Abfallbehandlung“ [32]. The VDI commission on air quality (KRdL) and DIN have informed the authors that an updated draft [33] and a further draft VDI guideline 2094, "Emissionsminderung Zementwerke“ [34] have been completed, and will be published in March 2001.

5.2.1.1 Emissions

The 17th BImSchV applies to emissions from plants which burn waste, either exclusively or along with other materials. The authors see no reason to require different limits or other changes to these regulations when MBM is incinerated or used as a support fuel. Note again that firing conditions must comply with § 4 (2) 17th BImSchV (minimum temperature 850 °C for a minimum of 2 seconds, minimum oxygen content 6 % by volume, [39] and [42]). The new EU guideline on incineration of waste (4th December 2000, [43]) has no requirement on oxygen content, and this guide therefore more than complies with the EU guideline in this respect.

When delivering and storing MBM, emissions of dust into the environment must be ruled out or at least minimised (e.g. by pumping out the air and using it to feed the furnace). If MBM is stored in silos, emissions occur during filling, and TA Luft guidelines apply. New plants should use up to date technology.

Closed warehouses for temporary MBM storage should be kept at below external air pressure, to avoid emissions, and suitable air purification should be used here too. See also VDI guideline 2590 [35] and the odour pollution guideline (GIRL, [37]) used in many *Länder*.

5.2.1.2 Residues and products

In all cases, the extent to which the MBM has been destroyed should be tested by analysing the protein content of residues and products. A guideline on the type and frequency of sampling and the analysis method has been issued by the UK Environment Agency [13].

There is currently no validated standard method in Germany for determining the protein content in incineration residues and products. The authors recommend that a qualified institution begin work immediately on developing such a guideline, possibly with reference to the UK recommendation.

BSE tests (e.g. ELISA, Prionics) on the concentration of prions are not considered suitable for assessing the residues from MBM incineration, according to the Federal Research Institute for Viral Illnesses in Animals [40]. The tests currently have a detection limit of up to 0.1 % prion concentration in the brains and spinal cords of clinically infected cattle [25,36]. It must be assumed that, even applied to MBM from non-SRM material, the test would be unable to identify prions. However, there are opinions that the use of these tests should be considered, so long as no standard method exists for identifying proteins in residues or products. The authors therefore also recommend that a qualified institution examine the applicability of these tests in the short term.

Since there are currently no residue analyses from German incinerators using MBM, these would appear necessary. When more comprehensive analyses of proteins become available, it will be possible to determine specific values to use in monitoring residues and products from plants, if the analyses show this to be necessary.

5.2.1.3 Occupational health and safety

The decision No. 602 by the Committee for Biological Working Materials (ABAS) (21/12/2000, amended 6/12/2000 [12]) should be noted when handling MBM. The German text of this decision can be found on the internet (see Ch. 6, Literature and Sources), and it assumes that the MBM production process required in Germany can ensure, as far as current knowledge permits, that potential BSE pathogens are inactivated.

There is disagreement as to whether high-pressure sterilisation guarantees complete destruction of BSE pathogens (see e.g. [20, 22]). A Dutch study [24] measured an inactivation by a factor of 160 - 1000 under steam pressure of 3 bar at 133° C for 20 minutes, leaving a residual infectiousness of 0.1 - 0.6 %. It is therefore certain that high-pressure sterilisation considerably reduces the risks in handling animal products.

A risk assessment by the UK Environment Agency [17] assumes that the risk of infection is reduced by at least a factor of 50 during MBM production (note that high-pressure sterilisation is not used in the UK). The study concludes that the disposal options under examination expose humans to extremely low risks of infection by BSE pathogens. It should also be noted that no link has been found in the UK between exposure at work (e.g. meat processing employees) and the occurrence of nvCJD [1].

The core points of the ABAS guidelines are as follows:

§ 3.5 (1): *The MBM production process prescribed in Germany (§5 TierKBAnstV) ensures, as far as can be known today, that potential BSE pathogens are inactivated. The thermal recycling (incineration) of properly produced MBM therefore requires no additional protective measures beyond the current (occupational health and safety) regulations. Note the general requirement to minimise dust, and the risk of pest and vermin, attracted by the large amounts of nutrients and moisture remaining in the MBM during storage.*

§ 3.5 (2): *§ 1 applies also to imported MBM which can be proven - e.g. through certification - to have been produced with the minimum process as prescribed in Germany under § 5 TierKBAnstV.*

§ 3.5 (3): *When incinerating imported MBM without the proof described in § 2, it should be ensured that employees are not exposed to the material.*

§ 3.5 (4): *Where the incineration process permits, MBM should be used in pellet form. Loose goods should be used only when packaged in (sealed) sacks (which should also be burnt) or in closed systems.*

The ABAS decision can be considered as providing the minimum requirements for handling MBM.

The amendments to guideline 602, published by decree of the Lower Saxony Ministry for Women, Employment and Social Affairs, should also be noted [38], as should the technical rules for biological working materials (TRBA 500: "Allgemeine Hygienemaßnahmen: Mindestanforderungen“) of March 1999. [45]

5.2.2 Specific protective measures

This section describes specific recommendations for the delivery and storage of MBM, additionally to the general requirements above. Regardless of the type of plant, this is the stage during which employees could come into contact with MBM, and this requires special procedures. A complete list of all relevant aspects is not possible in this guide - which is not intended to replace careful examination of each case - and the authors refer readers to the guidelines and regulations cited here.

The following properties of MBM should all be noted during delivery and storage:

- Apart from the potential risks from BSE pathogens, the storage and composition of MBM may entail risks from pests, vermin, bacteria and fungi. To minimise these risks, an increase in the water content should be avoided during storage.
- If the storage temperature is allowed to exceed certain levels, MBM may heat up and spontaneously combust.
- MBM may harden if stored over long periods.
- Standard disinfectants provide no guarantee that any BSE pathogens will be inactivated.
- Certain grades or distributions of grades can bring a risk of explosion.

Depending on the quality of the MBM, especially

- grade (greaves/pellets/loose),
- fat content,
- water content,

It can be delivered in normal vehicles, either loose or packaged. Loose delivery is best suited for greaves or pellets, which must be transported in covered, dust-free vehicles. Loose MBM should only be used where the appropriate technology (silos, pumps, etc.) creates a closed system.

Staff should be informed of the risks, especially when working in waste bunkers and warehouses, and given training in the required protective measures, including hygiene.

After being emptied, and at the end of each working day, delivery vehicles and transport skips must be wet-cleaned and disinfected with sodium hydroxide or chlorine bleach (sodium hypochlorite). For concentrations and application cf. ABAS decision 603 [46]. Washwater must be collected and inactivated on site (e.g. fed into the incinerator).

Silo lorries should only be used for MBM which can be pumped, i.e. ground MBM with a water content < c. 5 % by weight and fat content max. 10 - 13 % by weight.

Transport containers and vehicles may not be used for foodstuffs after transporting MBM.

In waste and hazardous waste incineration plants, MBM can be tipped into waste bunkers as usual, provided at least one combustion line guarantees air extraction. Increased dust emissions should be avoided during trimming (mixing MBM with other waste). In general, a dust mask of category FFP3 is recommended where contact with dust containing MBM cannot be ruled out.

MBM should be delivered to bunkers in quantities which ensure that it is processed and incinerated on the day of delivery, where possible. On the other hand, care should be taken to ensure that the composition of the waste remains as constant as possible.

When silos are used, a steady flow of MBM should also be used to ensure that storage times are as short as possible, to avoid pest and vermin or spontaneous overheating or combustion. Odour emissions should be avoided through appropriate air filters. When filling silos pneumatically, the air temperature should be kept below 40 °C, to minimise the risk of overheating.

The temperature of the MBM should be controlled in larger silos or warehouses. Note that longer storage periods can lead to oxidation of the fat in MBM, which increases the risk of overheating. Silos should not be more than 7 m high, and should be broad. The water content of MBM must not be allowed to increase, to minimise attack from pests, vermin, bacteria or fungi, and the risk of hardening. Detailed recommendations for storing MBM in silos or warehouses should be taken from the French guideline [21].

Storing MBM in open piles is not permissible. Long storage times should be avoided for loose MBM (bunkers, warehouses), as this is associated with secondary growth of biological materials, possible pest or vermin attack and odour. Adequate airing and regular monitoring of temperatures must be ensured.

MBM should only be pumped when the MBM is fine grade, with a water content below 5 % by weight and a fat content below c. 10 - 13 % by weight.

The VDSI working group on thermal treatment of waste has produced recommendations on implementing the Biomaterials Ordinance in thermal waste recycling plants [11], referring to risks from working with biological materials in waste recycling plants in general, and not specifically with MBM. The recommendations were published in VDSI-Informationen 1/2001 on 06/02/2001, and the ABAS was not consulted. Further guidance based on this publication is given in the following:

Delivery

- Avoid dust. Air should be continually extracted from waste bunkers via the boiler's combustion air vent. Corresponding forced ventilation should be used in warehouses
- Direct skin contact with MBM should be avoided
- Washing facilities to be provided at the delivery area, or at least for the rest rooms
- Working clothes should be kept separate from casual wear
- Working clothes should cover the entire body
- Employers should change and clean working clothes every week
- No eating, drinking, smoking or sneezing in work areas
- Work areas should be cleaned regularly
- Control rooms and cabins in machinery should be regularly wet-cleaned
- Category FFP3 dust masks should be worn when supervising tipping
- The above rules should be collected in an operating instructions manual

In principle, the protective measures taken in the waste bunker should also be taken in all areas directly surrounding the bunker, such as the brace, hopper, etc.

Activities in waste bunkers and warehouses

- Avoid increased dust deposition through regular cleaning
- Disposable dust suits and masks (class P3 or FFP3) should be worn and disposed of immediately after use (e.g. in waste sacks)
- Protective clothing should be disposed of (e.g. in waste sacks) or cleaned, to prevent germs (biomaterial) being transmitted from the bunker area
- Shower facilities for employees who have just spent long periods in the waste bunker

- Areas adjoining the waste bunker, e.g. crane cabin, gantries, stairs, etc. should be regularly wet cleaned

Note also the UK guidance cited above [1], which contains requirements for transporting, storing and handling MBM. There is also a corresponding French guideline, which applies particularly to the storage of MBM [21].

5.3 Concluding remarks on the suitability of processes for MBM incineration

The processes dealt with in Ch. 4.2.1 to 4.2.7 can be considered fundamentally suitable for MBM incineration, provided that they comply with the 17th BImSchV and use up to date techniques. The residues and products should be analysed, however, and since there is as yet no standard German guideline (see the remarks in Ch. 5.2.1), a qualified institution should examine whether the UK guideline [13] can provisionally be used in Germany.

The following remarks can be summed up for each plant type:

- The main restriction on MBM input to waste incineration plants is its influence on the composition of the slag. Where too much MBM was fed in, residues of it were found in the slag, but no analysis has been conducted. A further restriction is the comparatively high calorific value of the material.

- The issue of slag composition is less critical in hazardous waste incineration plants, but must not be ignored. The maximum ratio of MBM to other waste is also restricted by slag quality and calorific value. Owing to the existing experience these plants have with handling hazardous materials, the conditions are good for incinerating MBM from SRM.

- Using MBM as a support fuel in coal-fired power stations may have a negative impact on the quality of residues and products, and more research is needed here.

- The input of MBM in sewage sludge incinerators is generally restricted by its high relative calorific value. Apart from this, a fluidised-bed furnace is eminently suitable for MBM incineration.

- MBM input in cement works has the advantage of the especially high process temperatures in the primary firing (>1200 °C), while temperatures of >850 °C are maintained in the secondary firing. As far as can currently be ascertained, negative effects on the process and clinker product can be avoided by restricting and monitoring the input loads of pollutants (Cl, P).

- The SVZ gasification plant has many years experience in handling MBM and tallow. There are no known restrictions or problems with the process.

Hazardous waste incinerators are considered preferable to the other plant types for handling MBM from SRM. This recommendation is based more on the experience such plants have with handling hazardous material than on the process itself. Where MBM from SRM is used in ordinary waste incineration plants, power stations, sewage sludge incinerators, cement works or gasifiers, care must be taken to educate employees and ensure the safety of the workplace.

5.4 Additional Recommendations

The authors recommend stable relationships between individual operators of rendering works and of thermal treatment plants, to enable the best possible cooperation between them. Operational requirements can then be adapted to suit specific conditions, and organisational issues can be clarified consensually.

In addition, a full and comprehensive information policy for employees and the general public is strongly recommended. Employees should be continually informed and trained as new information becomes available or the operational conditions change.

6.0 Literature and Sources

(hyperlinks to any online versions of the documents, where possible in English, or to the authors' homepage are given in parenthesis)

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