Mechanical biological pretreatment and energetic recovery of RDF fractions in germany: Processing and costs

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1 Introduction: Substance-specific treatment of residual waste within the contradictory area of the basic legal framework

In spite of all efforts to avoid waste and to recover valuable substances to a large extent, a certain inevitable residual waste which has to be disposed also remains in the circulation industry. Therefore, an environmentally suitable disposal shall be provided, though with regard to that significant design uncertainties exist at this moment - such as the prognosis concerning the further development of quantities and composition of the residual waste which i.a. depends on the avoidance - and on the utilization rate achieved. The damage potential on the one hand and the cost relevance of waste economical measures on the other hand become obvious in view of the environmental impacts caused by old deposits and in view of long-term capital commitments relevant for investment decisions (Hupe et al., 1998). With this background, demands on the qualities of waste to be deposited are fixed in the German "Technical Instructions on Waste from Human Settlements" (Technische Anleitung Siedlungsabfall: TASi, 1993) to guarantee especially the environmentally suitable treatment and deposition of non-utilizable waste - apart from utilization. Especially the assignment criteria for landfills (TASi, appendix B) are a subject of the waste-political controversy in the field of the pretreatment of residual waste to be deposited. The establishment of maximum values for the organic part of the landfill material results in a one-sided preference of the thermal treatment: ignition loss and total carbon content are taken into consideration as parameters whereas a differentiation with regard to biodegradability is not taking place (Turk et al., 1998). The objective – to reduce the emission potential of the landfill body – refers to the biodegradable part of the landfill material. However, the inertization of a partial flow of the residual waste is also achieved by alternative methods for waste combustion – especially by the mechanical - biological pretreatment (MBP) which at this moment is examined within the scope of a proof of equivalence according to paragraph 2.4 of the TASi in several territorial authorities liable to dispose (Fricke et al., 1998).

During the last years, the application of the basic legal framework led to additional uncertainties followed by an investment- and a decision pile-up – disadvantageous for a waste disposal environmentally acceptable. Therefore, the requirements on a lasting environmentally acceptable development by means of integrated waste management concepts shall be taken particularly into account. Disposal security and environmental compatibility are to the fore but the economical aspects are inseparably involved. With regard to that, the substance-specific treatment of residual waste has got a key position. Basically, the residual waste can be divided into the substance groups valuable substances, organic substances, light fraction, heavy fraction as well as disturbing substances. Corresponding to that, the mechanical pretreatment is to skim off the remaining valuable substances for the material utilization and to filter problematic substances. The heavy fraction which also is to be separated mainly includes mineral components which can directly be put to deposition if need be. In this case, corresponding examinations would be necessary to prove that the assignment values of landfill class I (inert substance landfill) can be followed.

By means of combinations of shredding aggregates, of classification in drum screens (different sizes) as well as by air separation a high caloric fraction can be obtained as a screen tailings respectively as light fraction. This fraction mainly consists of paper/paperboard as well as of plastic material (foil residues) and of composites and can be considered as well suitable for combustion. As an option a production of RDF and a following energetic use can be taken into consideration if the quality is appropriate (Leikam et al., 1996). As the significance of this topic is increasing, it will be dealt with the subject secondary fuels in a special chapter. The costs of the thermal utilization of the high caloric partial fraction will also be discussed.

After the separation of biologically hardly available or even unavailable waste fractions such as plastic material or newspapers in the screen tailings, mainly biodegradable residues remain as underflow respectively as heavy fraction. These are for example vegetable residues or organically dirtied paper (e.g. napkins). The biological treatment is carried out by aerobic and anaerobic processes as well as by a combination of these. The objective can be the biological drying (short treatment period) as well as the controlled degradation of the native organic substance (longer treatment period). The main influencing factors on the treatment costs shall also be discussed for this fraction.

The part of the landfill as a permanent deposition of waste respectively of treatment residues to be removed will not change in the medium-term in the circulation industry. However, by means of the substance-specific pretreatment of residual waste a landfill material can be produced which facilitates the decrease of emissions to a large extent and a significant reduction of the after-care measures of landfills (Hupe et al., 1998).

2 Costs of the substance-specific treatment of residual waste

2.1 Costs of the mechanical treatment

The mechanical treatment is the central part of a substance-specific treatment of residual waste in which the waste is separated according to kind and quality. The objective is to separate a RDF fraction of high calorific value for the thermal utilization as well as the selection of further valuable- and disturbing substances. The remaining partial flow of low calorific value - enriched by bioavailable organic substances - is supplied to biological treatment.

There are different variants of mechanical treatments in the existing plants and in the plans and conceptions for further plants so that a theoretic examination of the costs of this step shall take place (Bilitewski et al., 1998): a mechanical treatment step constructed for 30.000 Mg/a is examined for which – depending on the objective of the treatment - different aggregates are applied (Table 1).

Table 1 Costs of the mechanical treatment for different variants (price basis 1997) (Bilitewski et al., 1998)

Plant module	Variant I	Variant II	Variant III
Flat bin	X	X	X
Pre-shredding	X	X	X
Magnetic separation		X	X
Sieving (100 mm)		X	X
After-shredding			X
Sieving (40 mm, if need be after the rot)			X
Specific costs of the mechanical treatment [Euro/Mg]	24	27	33

All variants have a flat bin. In variant I the residual waste is only pre-shredded while in variant II and III a substance-specific treatment of the residual waste is carried out. Variant III also includes an additional preparation of the rot material after the biological treatment. The specific costs of the mechanical treatment for this example with an output of 30.000 Mg/a are between 24 to 33 Euro/Mg. These amounts - compared to the total costs of the mechanical and biological treatment at the moment - are considered to be rather high and thus would probably not be realizable.

2.2 Costs of the mechanical – biological treatment

When examining the costs of the mechanical – biological treatment it has to be taken into consideration that the existing MBP plants are equipped and operated in different ways – depending on the objective of the treatment. Plants operating at the moment are mainly working with the objective of a late disposal of the treated residual waste. Concerning the plants which are planned and constructed now, the substance-specific treatment including the material- and the energetic utilization like the thermal disposal becomes more and more important. This evolution is also reflected in the complexity of the applied plant- and process technology.

In the following, special emphasis shall be placed on the examination of plants which use a costly technological equipment for preparation and treatment as these plants are more and more employed in the interest of a control of the treatment process and of the controlled recording and treatment of the emissions. Plants of this category show the following characteristics (Bilitewski et al., 1998):

- high degree of automation
- costly process- and site engineering, i.a. indoor for areas relevant for emissions
- costly recording and treatment of the exhaust air

The following price indications are mainly referred to the processing concepts of market leading suppliers (Turk et al., 1998). The basis are the results of invitations of tenders according to VOB-invitations of tenders of the government. It should be taken into account that every invitation for tenders includes individual conditions which do not allow an exact comparison but show the general direction of the costs. Furthermore, it should be taken into consideration that the number of completed plants for the treatment of residual waste is not very high at this moment. On the other hand, the experiences with the biowaste composting can be used under reservations for the examinations.

Additional location-specific costs (such as for example infrastructure, building site) which may lead to significant extra costs are not taken into consideration.

2.2.1 Investment costs

Investments can be divided for example into the following four sections (Turk et al., 1998):

- structural plant groups (S part),
- mechanically engineered plant groups (M part),
- electronic plant groups (E part),
- other investments.

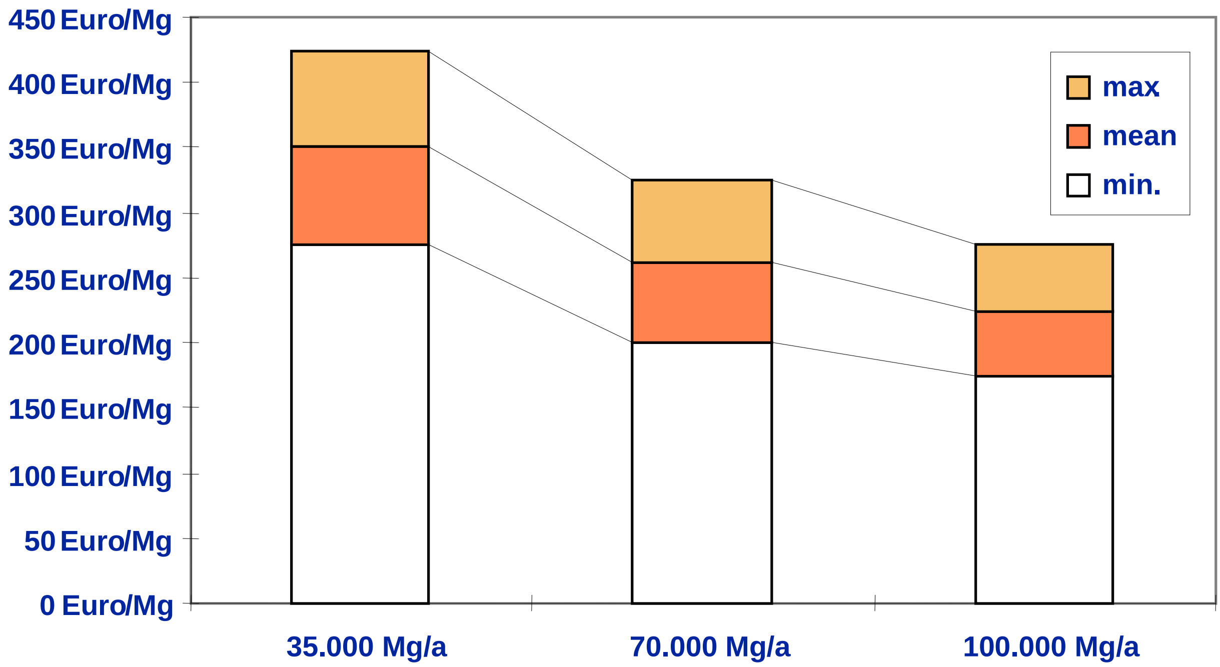

Figure 1 Specific need of investment – total investment (manufacturer details of market leading bidders after evaluation of invitation of tenders, year of reference: 1997/1998) (Turk et al., 1998)

The specific investments are the investment costs per ton input. Figure 1 shows the specific total investments in dependency on the output of one year of "standard plants" (analyses of invitations of tenders, inquiry of producers).

The expression "standard plant" refers to the following basis of the process engineering (Turk et al., 1998):

- treatment of household-, trade- and industrial waste
- capsulation of the delivery – and preparation hall including active deaeration
- a complete capsulation of at least 5 weeks of the biological treatment including active aeration and exhaust air recording
- aerobic biological treatment
- exhaust air treatment by scrubber and biofilter
- separation of a fraction of high calorific value within the scope of preparation (approx. 30 % of the input)

- production of a rot end product which meets the following requirements: TOC in the eluate about 250 mg/l, respiration activity AT_4 about 5 mg O_2/g DM
- container loading for the residual substances (fraction of high calorific value, rot end material, Fe-scrap
- buffering capacities approx. 1 d – that means an almost regular delivery of the waste and disposal of the residual substances
- additional construction costs about 10 % of the total investment.

On average, the specific investment costs (total investment) for about 35.000 Mg/a and an average of about 350 Euro/Mg are in a range between 270 to 430 Euro/Mg treatment capacity (Turk et al., 1998). For 70.000 Mg/a, the average is reduced to 265 Euro/Mg input for a range of 200 to 330 Euro/Mg. By a further increase of the output capacity further reductions of the specific investment costs are possible – but it has to be taken into account that according to the chosen method these costs may increase again from a certain scale on as the plants have to be operated in several lines then. 100.000 Mg/a would come up to an average of about 225 Euro/Mg input for a range of 175 to 275 Euro/Mg. The specific investment costs have to be adjusted in dependency on the different locations (e.g. higher resp. lower degree of capsulation). These costs do not include:

- costs for the site
- supply point / grid point (electricity, water, waste water) to the site boundary
- access to roads
- special foundation measures

An examination of the relation between investigation costs for the construction and for the M + E part shows that the structural part needs about 40 and 70% of the total investment. Concerning this, the different processes show significant differences. This fact can be of great importance for the examination of the overhead expenses for the whole running period of a plant as the tax write-off periods for the construction group are differing from each other (e.g. structure part 20 years, M + E part 10 years) and thus the annual interest payments are different with similar investigation costs. This is why the different cost classifications have to be taken into consideration when comparing offers with regard to the costs to facilitate a differentiated cost comparison.

Comparing the necessary investment costs for aerobic biological treatment processes with anaerobic/aerobic combination solutions, it can be ascertained that in general the combination solutions require higher investments. Nonetheless, the higher investment costs can lead to lower overhead expenses in dependency on site conditions (e.g. use of synergy effects with regard to gas accumulation/ -utilization at landfill sites) and on the further development of energy costs.

2.2.2 Overhead expenses

The overhead expenses cover all annual costs necessary for the operation of a plant – especially the costs for personnel, maintenance, repair, and keep of the plants and machines, insurance as well as the changed costs for energy, waste water disposal and disposal of residual substances directly depending on the output. In addition to that, the investment is taken into account in the overhead expenses via the annual lost in value (tax write-off) and the payment of interest.

In this connection the significance of the underlying tax write-off period as well as of the chosen kind of financing (interest rate, subsidies) becomes clear which are to be given to the manufacturers in procedures of invitations of tenders respectively in process comparisons.

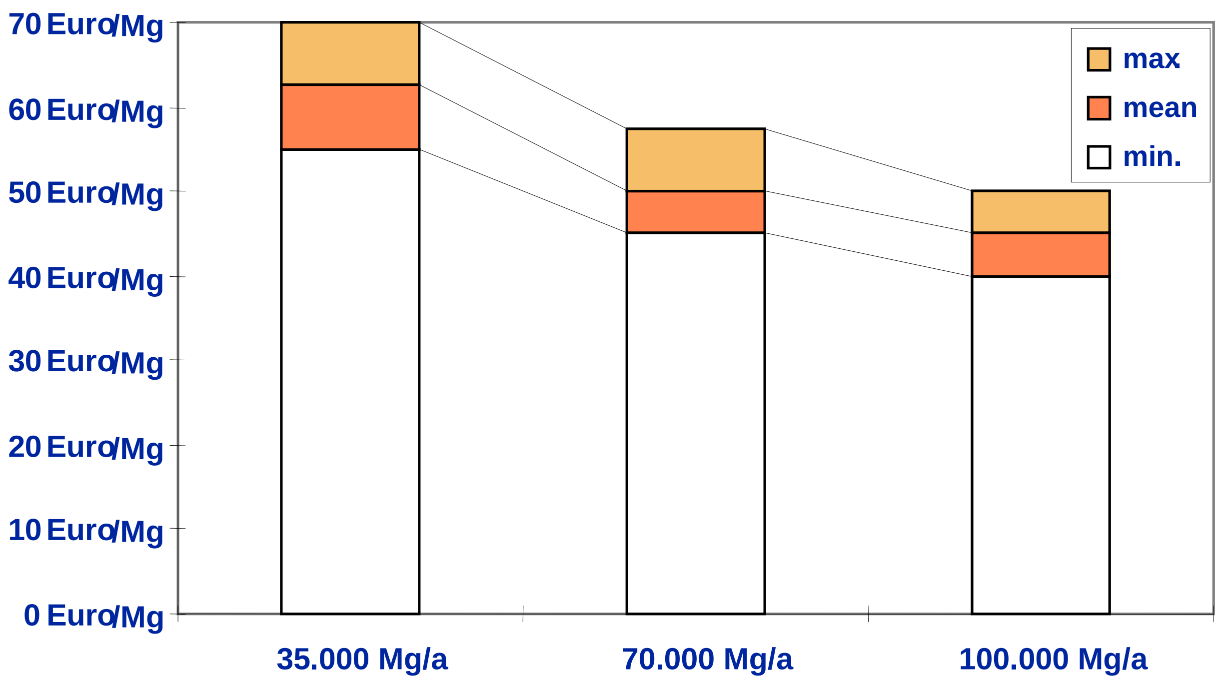

Figure 2 Specific overhead expenses (manufacturer details of market leading bidders after the evaluation of an invitation of tenders, year of reference: 1997/1998) (Turk et al., 1998)

Figure 2 shows the specific overhead expenses per ton input according to manufacturer details for an output of 35.000, 70.000 and 100.000 Mg/year. In this connection it can be ascertained that these costs are reduced with an increase of the plant output. On average, the specific overhead expenses for 30.000 Mg/a are at 62 Euro/Mg – for 70.000 and for 100.000 Mg/a this value is reduced to 50 respectively 45 Euro/Mg input (Turk et al., 1998). As already mentioned in connection with the investment costs, the overhead expenses are also subject to significant fluctuations of course because of different basic conditions (such as location conditions or immission situation).

For the MBP plants with a higher technical standard operating at this moment in Germany, specific treatment costs (overhead expenses) of 50 to 85 Euro/Mg are indicated - partly utilization and disposal of the remaining partial flows are already taken into account (Bilitewski et al., 1997). Apart from the regionally different landfilling prices, specific plant configurations are the basis of these details. This is why the costs are only comparable to a certain extent. The costs of the biological drying over a period of 10 days are significantly lower for the biological step than the costs of a biological stabilization with a rot duration of about 12 weeks.

A further factor of influence on the cost development is the degree of capacity utilization of a plant. The prices quoted up till now are mainly basing on the full utilization. Half-capacity utilization leads to significant increases of the specific treatment costs - as the fixed costs have to be covered anyway: with a capacity utilization of 80%, the specific treatment costs can increase by 10 to 20%, with 60% capacity utilization by 50% and after all – may double with a capacity utilization of approx. 40% (Bilitewski et al., 1998).

2.3 Costs of the thermal treatment

The thermal processing step can be applied for the energetic utilization of the RDF fraction of high calorific value but also for the removal of the biologically pretreated fraction. Industrial users with a high need of heat and energy are of interest concerning the application of the RDF partial flow if a fossil energy source (oil, coal, gas) can be substituted by the RDF as substitute fuel. The RDF portion referred to the whole waste flow often varies between 20 and 50% in dependency on the mechanical preparation modules applied and of the secondary utilization- respectively disposal plants. In exceptional cases it can be only 12 – 16% but also up to 67% (Leikam et al., 1996). The composition, the calorific value and the pollutant content are correspondingly different. To achieve favorable landfill qualities for the treatment residues of the biological pretreatment (i.a. high emplacement density, low permeability, low spring effects) it is imperative to separate the RDF portion before or after the biological treatment.

The RDF can be added directly to the production process as it is done in the cement industry or it can be used for the production of energy and heat via thermal processes. It depends on the regional boundary conditions (existing branches of industry, license requirement etc.) which of these possibilities is realized. This also finds expression in the costs of the energetic utilization and this is why the costs for preparation- and utilization are varying in specialist literature (Table 2).

Table 2 Preparation-/conditioning costs – respectively utilization costs for the application of RDF in different branches of industry (according to Fricke et al., 1998)

Plant	costs in Euro/Mg including preparation	costs in Euro/Mg not prepared
Power stations (recommended prices for dried and processed MSW incl. preparation and delivery free of charge)	120	
Cement works (recommended prices for Trockenstabilat incl. preparation and delivery free of charge)	100 – 150	
Cement works (utilization without preparation)		15 - 25
Cement work Rüdersdorf (fraction of high calorific value not prepared and delivery free of charge)		40
Coal gasification SVZ Schwarze Pumpe (Mixed calc. with further substances of high calorific value, delivery free of charge)	100 – 110	

In a further invitation of tenders for a fraction of high calorific value > 100 mm of the mechanical preparation of residual waste (quantity about 10.000 Mg/a) suppliers asked for extra prices of 60 to 110 Euro/Mg for the energetic utilization (Franke, 1998). For a fraction of high calorific value > 80 mm of the mechanical preparation of residual waste and for the rot output of the biological treatment step (total quantity approx. 23.000 Mg/a) extra costs of 80 to 120 Euro/Mg were indicated (Fricke et al., 1998).

To draw a comparison, the actual price margins for waste incineration plants (WIP) are shown in Table 3.

Table 3 Net prices of the waste incineration in waste incineration plants in Germany (price basis June 1998) (EUWID, 1998)

Land of the Federal Republic of Germany	Net prices in Euro/Mg long-term contracts	short-term "spot market"
Baden-Württemberg	90 – 345	90 – 200
Bavaria	85 - 375	75 – 375
Berlin	140	-
Hessen	160 - 315	75 – 275
Lower Saxony and Bremen	70 - 135	40 – 135
North Rhine-Westphalia	60 - 370	40 – 175
Saarland and Rhineland-Palatinate	100 - 205	70 – 100
Schleswig-Holstein and Hamburg	85 - 215	60 – 150

They are arranged for residual waste from households and industry with reference to the different Lands of the Federal Republic of Germany which have waste incineration plants. The incineration prices for long-term contracts are significantly higher than the prices at the "spot market". Mainly industrial waste for thermal utilization is concerned in these short-term orders with a price margin from 75 to 150 Euro/Mg. The lower price indications refer to fractions which in particular are of high calorific value and which are comparatively type-specific.

In total, the prices for the utilization of RDF are varying a lot so that reliable cost indications can only be given for the individual case. However, it can be stated that in general the total production-, formulation- and utilization costs of RDF from a mechanical-biological pretreatment plant (e.g. in cement works or power stations) are not lower than those of a utilization in a waste incineration plant (Fricke et al., 1998). The objective of the waste producers to achieve proceeds for RDF as substitute fuel will hardly be realizable under the actual basic conditions.

3 Action recommendations and outlook

In the year 2005 - after the deadline of the period of transition conceded by the TASi - the deposition of waste is exclusively possible after an extensive mineralization. At this moment, the capacities in many regions are not sufficient for the mechanical-biological treatment and for the thermal treatment of the total residual waste. Due to the legal position not clarified, the investors are hesitating to plan new plants. As it takes extremely long periods anyway to find a location, to get the license and to realize everything, measures for the creation of a corresponding disposal security should already be taken at this moment. Another consequence of this interim arrangement is the effort of the landfill operators to guarantee the closure until the year 2005 and if possible over and above that. In this respect the necessary re-financing of existing investments leads to a market failure: the low price level of landfills with a bad technical equipment drive out disposal processes which correspond to state-of-the-art-technology and thus produces the false impression of overcapacities (Stegmann et al., 1997).

The details for the conception of the residual waste treatment clearly show which cost relevance the fixing of the plant configuration has. The plant modules for mechanical, biological and thermal treatment have to be in tune with each other. With it especially the first step of the mechanical preparation has an important influence on:

- partial flow quantities and –distribution
- quality of the partial flows
- necessary capacities of the on-leading treatment steps
- costs and proceeds of the on-leading treatment and utilization of the partial flows

To come to a decision within the frame of a comparison of offers it is imperative to present binding conditions to the suppliers. These are i.a. for MBP plants (Turk et al., 1998):

- location specifications – e.g. with regard to the structural foundation
- supply and disposal
- emission-minimizing measures (e.g. total / part capsulation)
- basis information for the bin dimensioning
- operational basis information (effective working hours etc.)
- machine technology, structural engineering (e.g. corrosion prevention)
- tax write-off periods for machines, structural and electronic plants, finance plan.

The costs of the single treatment steps may not be examined separately as they are relied due to manifold interactions. For a decision, the costs of the whole concept have to be examined and assessed. In addition to that the further boundary conditions of the disposal region have to be taken into consideration:

- settlement structure, population density, economic development
- variations of waste quantities and - composition (depending on the season, on tourism etc., prognosis of the development)

- planned and existing treatment capacities (thermal utilization and disposal, transportation distances, contracts with external plants, disposal combine with central and decentralized concepts)

This list once again shows that individual solutions have to be developed for each disposal region if only because of the costs. The proper selection of disposal pathways has to be geared to the substance qualities of the residual waste as well as to the structural conditions of the disposal region. In the integrated waste management concepts, the mechanical-biological processes are an important building block of the pretreatment of residual waste apart from thermal processes: they open up an additional degree of flexibility to be in the position to follow economical and environmentally acceptable disposal pathways in the development of waste management in spite of incalculability and so many uncertainties.

REFERENCES

Bilitewski B., Heilmann A. (1997) Wirtschaftliche Kenndaten der Restabfallbehandlung; in: Stegmann, R., Bilitewski, B. (eds.): *Mechanisch-biologische Verfahren zur stoffspezifischen Abfallbeseitigung*. Beiheft zu Müll und Abfall, Heft 33, Erich Schmidt Verlag Berlin

Bilitewski B., Heilmann A. (1998) Kosten der mechanisch-biologischen Abfallbehandlung im Vergleich zur thermischen Behandlung, *Entsorgungspraxis* 10/98, pp. 26 - 31

EUWID (1998) Verbrennungspreise in Deutschland. Europäischer Wirtschaftsdienst GmbH, *Recycling und Entsorgung*, N. 29

Fricke, K., Müller, W., Bidlingmaier, W., Stegmann, R., Friedrich, R. (1998) Methodische Ansätze zum Gleichwertigkeitsnachweis nach Ziffer 2.4 TASi für den KAEV Niederlausitz. In: *Entwicklungstendenzen in der Deponietechnik*, Hamburger Berichte 12, eds.: R. Stegmann, G. Rettenberger, Economica Verlag Bonn (Verlag Abfall aktuell, Stuttgart)

Fricke, K., Franke, J., Jager, J. (1998) Kosten der BRAM-Herstellung und Verwertung. In: *BRAM – Brennstoff aus Müll – Lösung für die Zukunft*, eds.: R. Stegmann, B. Bilitewski, G. Rettenberger, Verlag Abfall aktuell, Stuttgart

Hupe K., Leikam K., Heyer K.-U., Stegmann R. (1998) Auswirkungen der mechanisch-biologischen Vorbehandlung von Restabfällen auf die Deponietechnik; in: *Müll und Abfall* N. 3

Leikam, K., Stegmann, R. (1996) Ergänzungsparameter und Richtwerte des BWK zur Öffnung der TA Siedlungsabfall. Tagungsunterlagen zum VDI-Seminar *"Planung von biologisch-mechanischen Restabfallbehandlungsanlagen (MBA), Betriebserfahrungen, Risiken*. 10./11.06.1996 in Düsseldorf

Stegmann, R., Bilitewski, B. (eds.) (1997) Mechanisch-biologische Verfahren zur stoffspezifischen Abfallbeseitigung. *Beiheft zu Müll und Abfall*, Heft 33, Erich Schmidt Verlag Berlin

Turk, T., Fricke, K., Hake, J. (1998) Investitions- und Betriebskosten – Restabfallbehandlung – Gekapselte Anlagen. Mitteilungen der Ingenieurgemeinschaft Witzenhausen (IGW), Fricke & Turk GmbH