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Report No. 29217 “Status of Alternative Techniques for Thermal Waste Treatment”

Summary

Concerning both number and capacity of installations, incineration is the dominating process for thermal treatment of waste. Around the world, about 255 million Mg of waste are incinerated per year in approximately 2,200 installations.

Besides this established method for waste treatment, waste pyrolysis and waste gasification are offered on the market as additional thermal treatment processes. These processes – also called “alternative” thermal treatment – have been on the market since the 1970ies, presented by changing providers under different labels. Alternative processes are characterized by comparatively complex systems engineering. Suppliers state that in comparison to waste incineration, alternative processes show the advantage of higher electrical efficiency and/or produce higher quality conversion products, like liquid energy carriers to substitute other fuels or vitrified slag of very low leachability.

Marked by setback experiences, alternative thermal processes are not relevant in the Federal Republic of Germany. In other countries, though, discussion has intensified in the recent years, with lobby groups and some decision makers explicitly calling for application of these technologies. Supporters refer to long-term operating experience of installations in Asia, especially in Japan. Yet, general conditions there are completely different from those in Europe or North America. In particular, treatment costs are significantly higher whereas annual operation time is much shorter.

Practical experiences mentioned above mainly refer to gasification and pyrolysis plants. Besides these “classic” alternative thermochemical processes, there have been further alternative processes pushing into the market in recent years. Plasma processes (realized as plasma gasification) convert waste respectively its carbonization products by contact with plasma at temperatures of at least 2000 °C (partly ionized gas). According to suppliers this leads to low gaseous emissions and high quality conversion residue at the same time. Another alternative thermochemical process variation, (catalytic) liquefaction is supposed to convert waste to liquid carbohydrates, usually in a single-stage process frequently using catalysts. It is intended to obtain a product with fuel-like characteristics which can then be used to substitute diesel. The so-called HTC-processes (hydrothermal carbonization) are preferably used to treat (wet) biodegradable waste and (sewage) sludge. The input material

is converted to carbonization product under pressure and in liquid aqueous phase. The product is meant to allow optimized energetic or material utilization.

There is little reliable data available on operating experiences from plasma and liquefaction processes, which are currently subject of intense discussion, as well as for hydrothermal carbonization, which is on the verge of being introduced to the market. For some of the discussed technologies, even mass and energy balances are not available. Treatment of problematic secondary material flows is often still on a conceptual level and not tested in practice.

The report „Status of Alternative Techniques for Thermal Waste Treatment“ aims to provide and evaluate information on the state of the art of alternative thermal processes for the treatment of mixed municipal solid waste.

Subject of this report are only processes for which a relevant time span of continuous operation could be proved. Technologies currently not in operation, but with demonstrated practicability in the recent past, have been included. In addition, some newer developments have been considered which are - according to suppliers - about to be available on the market. Yet, a certain minimum stage of development was applied as criterion for inclusion.

Besides technological maturity of waste treatment technologies, the local legal and (socio-) political framework is crucial for success or failure of new technologies. For example, the widespread use of alternative thermal processes in Japan cannot be understood without knowledge of the local situation. Therefore country specific conditions are also outlined and discussed in this study.

Information for this report was gathered from different sources. Basis is a comprehensive literature review. Information gathered here was supplemented and verified by questioning of operators. Technologies currently in operation in Germany or – due to development stage – presumably relevant for the market were subject to more detailed examination by visitation of installation sites. Basic process information and parameters as well as environmentally relevant indicators like emissions, energy demand or quality of recyclable materials reconditioned within the process were investigated. Were available, economic data and treatment costs were included. Literature was researched in the English, French, Japanese and German language area. Current developments and established processes currently in operation were considered as well as those “historic” processes which were in long-term operation on an industrial scale in the recent past and therefore also represent state of the art.

Based on gathered information, processes were classified respectively evaluated considering the following aspects:

- Development status of technology (classification according to VDI Guideline 3460)
- Necessary (pre-)treatment effort
- Nature and quality of products (eventually as input for follow-up process)
- Complexity
- Economic viability

The evaluation of alternative thermal waste treatment technologies shows a clear picture:

Of the many types of alternative waste treatment methods analyzed, some upstream facilities jointly operated with other thermal processes can be looked at as potentially reasonable and economic alternatives, even under European legal and market conditions. Alternative processes coupled to power-, cement- or lime plants allow direct utilization of generated products (gas, eventually coke) under optimized conditions (e.g. higher electrical efficiency in power plants).

Also, processes can be relevant that allow treatment of specific waste fractions like highly toxic, chlorine contaminated or low calorific value materials (e.g. contaminated soils) which are not combustible independently. The ecological necessity of high-grade treatment of these hazardous waste materials may justify higher treatment efforts as for example in plasma processes. Here, legal requirements are decisive.

Processes that do not achieve complete inertization of products must be assessed critically. According to the valid BREF-Document on waste incineration, only those alternative thermal treatment methods can be state of the art, which are either equipped with a consecutive combustion stage with energy utilization or which recover or dispose products. This requirement is not met by methods that generate coke or residue with high ignition loss as "product" without a specified subsequent use. These processes frequently lead to high follow-up costs for product disposal. Given these conditions, profitable operation hardly seems possible.

Especially comparably simple processes (e.g. low-temperature pyrolysis or direct liquefaction) provoke high efforts for product processing (be it gas treatment after pyrolysis/gasification or fuel refinement after direct liquefaction). The alleged simplicity of the main process is generally at the expense of higher complexity in product post-treatment. Accordingly, post-treatment frequently is the weak point of these processes. In many cases, these problems are not considered during process development.

It must be emphasized that all alternative thermal processes considered in this study require significantly higher treatment effort than classic waste incineration. In general, a high effort for processing and conditioning of input material is mandatory. At least size reduction is necessary, often also fractionation and removal of metals and inert materials. Some processes even require pre-drying or pelletizing (briquetting) of input materials. Those few Japanese melting processes which – according to suppliers –can be operated without pretreatment of waste (but still with restricted particle size) are especially intricate to operate. Addition of coke and insertion of oxygen are common in these processes.

Operating efforts of complex alternative treatments cannot be reduced significantly with increasing experience in long-term operation. This can be learned from examples in Japan or the Secondary Raw Materials/Recycling Centre Schwarze Pumpe (SVZ). In Europe, sometimes the opinion is held that alternative treatment technologies are not on par with classic waste incineration only because of the latter's technological maturity. The conclusion that increasing operating experience and optimization could improve alternative processes leading to comparability with incineration therefore does not seem to be tenable.

In conclusion, it can be stated that alternative thermal processes are only operable and economically viable when the following requirements or conditions apply:

- Compliance with legal requirements
  (e.g. melting processes Japan)
- Attainment of special product properties
  (e.g. vitrified slag, low pollutant content)
- Treatment of special fractions
  (e.g. highly toxic or chloride containing materials,
  fractions with low calorific value)
- Operation of pre-treatment facilities to substitute fossil fuels
  (e.g. in power generation, cement and lime plants)

Hence, waste incineration is still state of the art to treat mixed municipal waste. None of the alternative processes has proved to be comparable in performance and flexibility. There are no alternative thermal processes available which are capable to compete with waste incineration considering both economic and ecological aspects. Because of their higher complexity, it is currently not to be expected that alternative methods can bridge this gap. In principle, treatment of mixed municipal solid waste should be reserved to established incineration processes, designed and well-tried for this purpose.

Table 0: Development status of thermal waste treatment processes according to [VDI 3460] (simplified)

Devel.	Status Regarding	Minimum Requirement

Status		
1	Plant/Process	bench-scale tests, mass and energy balance of core plant
	Input/Output Materials	descriptive analysis of input and output materials (quality, quantity)
	Market Potential	assessment of market potential of a full-scale plant based on bench-scale test results
	Scale-up	description of risks and opportunities of a scale-up, design of a pilot plant
2	Plant/Process	steady-state operation of a pilot plant, mass and energy balances of a core plant
	Input/Output Materials	analysis of input and output materials (quality, quantity); discussion of opportunities and limitations of input materials
	Market Potential	prediction of market potential of a full-scale plant
	Scale-up	description of technical conditions for a scale-up, further unit operations needed for material feeding and discharge, design pilot plant
	Operation	assessment of potential operating problems (corrosion, erosion, scaling…)
3	Plant/Process	steady-state operation of a pilot plant over a prolonged period, measurement of emissions
	Input/Output Materials	testing of the process-specific products concerning their environmental relevance and utilization options
	Market Potential	description of the market potential of a full-scale plant
	Scale-up	technical and economic interpretation of measurement and analysis results related to a full-scale plant, size of equipment, materials, expected construction and operating costs of a full-scale plant, costs per Mg of waste
	Operation	assessment of the expected run time, plant availability and service life a planned full-scale plant
4	Plant/Process	normal operation of full-scale plant over a period of one to two years, confirmation of mass and energy balances, emission values
	Input/Output Materials	demonstration of the suitability of the plant for then planned input materials, marketing potential of typical products generated by the process
	Market Potential	validation of capital and operating costs (business plan)
	Operation	demonstration of availability and runtime
5	Plant/Process	normal operation of full-scale plant over several years, assessment of environmental relevance of the process and plant
	Input/Output Materials	demonstration of disposal of input materials, demonstration of the

		marketing of process-specific products
	Market Potential	traceable description of capital and operating costs over several years
	Operation	optimization efficiency, availability, runtime

Project Organization

This report was subject to a public rendering process by the Umweltbundesamt, the German Federal Environmental Agency. Contractor is the Unit of Technology of Fuels (TEER) at the RWTH Aachen University.

The following table shows project partners involved in carrying out the research. Project manager was the Unit of Technology of Fuels.

Table 1: Project management and project partners

Institution	Editor
Project Management	
RWTH Aachen Unit of Technology of Fuels TEER	Prof. Dr.-Ing. Peter Quicker Dipl.-Ing. Yves Noël Dipl.-Ing. Florian Neuerburg Adrianna Huras B.Sc.
Project Partners	
Japan Consult	Dipl.-Volksw., Dipl.-Geogr. Ralf Georg Eyssen
Karlsruhe Institute of Technology Institute for Technical Chemistry	Prof. Dr.-Ing. Helmut Seifert Dr. rer. nat. Jürgen Vehlow
TK Verlag Karl Thomé-Kozmiensky	Prof. Dr.-Ing. Karl Thomé-Kozmiensky

Overview and Classification of Thermochemical Processes

As shown in figure 2, basic thermochemical processes can be classified regarding heat supply and reactant, distinguishing between

- Processes with external heat supply (pyrolysis)
- Processes with oxygen as reactant (autothermal gasification and combustion)
- Processes with water as reactant (allothermal steam gasification, hydrothermal processes)

- Processes in which a partly ionized gas of high temperature is generated by applying electrical voltage (plasma processes)

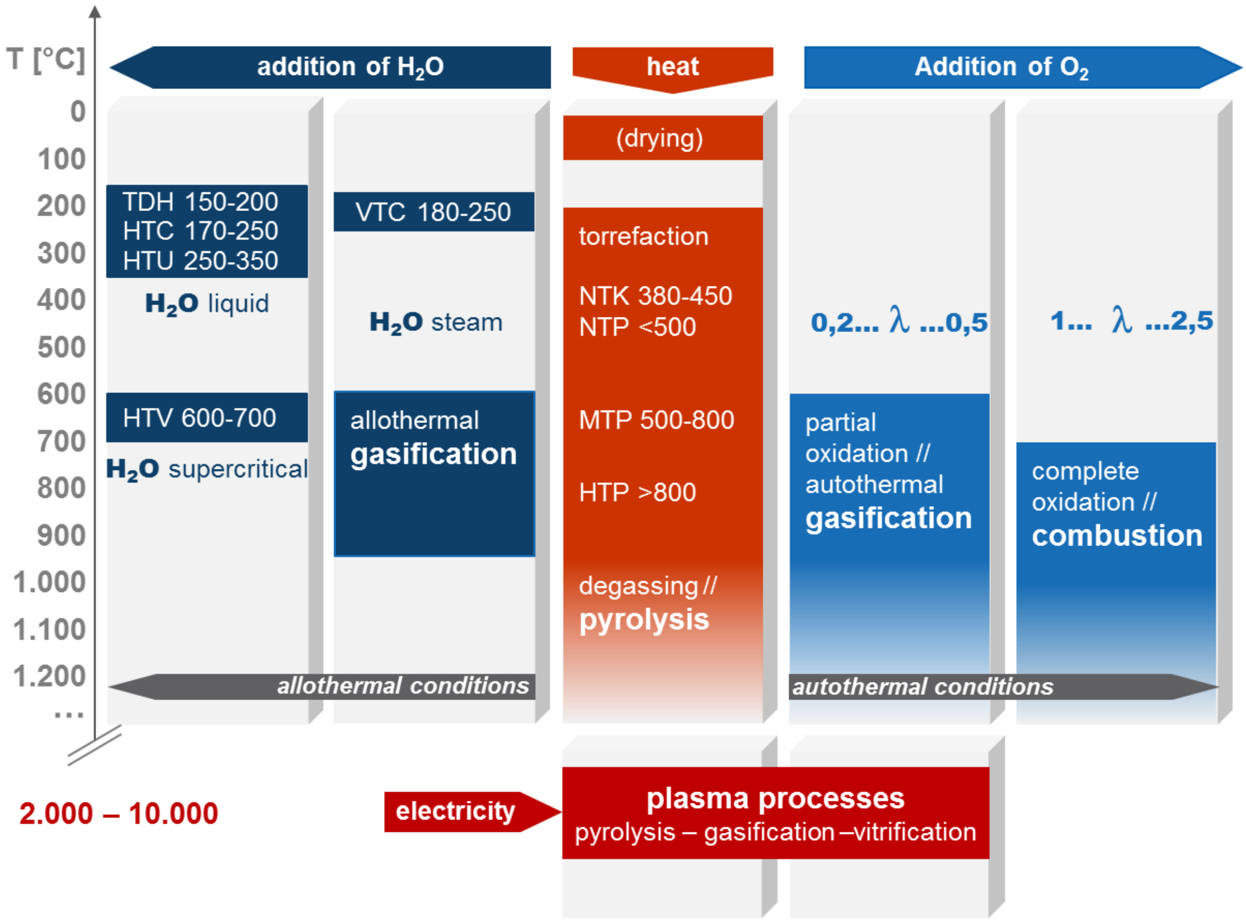

Figure1: Overview of thermochemical processes (see annex for abbreviations)

Conclusion

Attempts to recover reusable material from waste are as old as waste management itself. Especially the idea to generate energy carriers of higher value and quality, if possible even fuels conforming to standards, seem to exert particular fascination.

The fact remains, however, that so far in the history of waste management - starting with first attempts at the beginning of the 19th century until now - so-called alternative thermal processes as singular waste treatment process could only be operated permanently when this was enabled by the particular political or societal framework as is the case in Japan for high-temperature processes (legal requirements) or the pyrolysis plant in Burgau (funded pilot project).

Of the many variations of alternative thermal waste treatment processes considered in this report, only upstream pre-treatment processes operated in a plant network with other thermal processes (power plants, cement or lime plants) that allow for direct utilization of generated products (gas, eventually coke) under optimized conditions (e.g. higher electrical efficiency of power plant) can be considered as potentially reasonable and in part as actual economic alternative for thermal waste treatment under European conditions.

Of further interest are also those processes that allow treatment of special fractions like for example highly toxic or chlorine contaminated substances or materials of low calorific values not allowing auto-thermal combustion, e.g. contaminated soil. The ecological necessity of a high quality treatment of such problematic waste materials justifies costly treatment processes, including energy-intensive plasma processes in specific cases. Here, legal requirements are vital.

Stand-alone processes that do not achieve complete inertization of products are problematic. Generation of not marketable pyrolysis coke for example leads to additional follow-up costs for product disposal. Economic operation hardly seems possible under such conditions. What is more, according to the currently valid Reference Document on Best Available Techniques in waste incineration, processes are only best available technique when they are equipped “with a subsequent combustion stage with energy recovery” or when they “recover or supply for use of the substances that are not combusted” [BREF 2005, chapter 5.1, No. 24a/b].

Especially when processes are designed in a rather simple way (e.g. low temperature pyrolysis or direct liquefaction), the conditioning of products requires significant effort, be it gas conditioning following pyrolysis/gasification or fuel refining following liquefaction. The alleged advantage of a simple main process is at the expense of higher complexity in product treatment. Accordingly, post-treatment often is the weak point of these processes, in some cases it is even ignored during development.

It has to be pointed out that all alternative thermal processes considered require higher treatment efforts than classical waste incineration. Generally, in-depth processing of input materials is mandatory. At least crushing of waste is necessary, often also comminution of waste and removal of metals and inert materials. Some processes even require pre-drying or pelletizing of input materials. Those few Japanese melting processes which may be operated without waste conditioning (still, piece-size is restricted) are intricate in operation. Addition of coke and oxygen is common in these processes.

As can be learned from examples in Japan or the SVZ Schwarze Pumpe, even operating experience of several years does not lead to a significant reduction in the extensive effort to operate complex alternative processes. With this background, the argument that is sometimes brought on in Europe that alternative technologies for thermal waste treatment are not on par with classic waste incineration only because of a lack of operating experience and the necessity for further optimization seems untenable.

In conclusion, it must be stated that waste incineration is state of the art for the treatment of residual waste. None of the so-called alternative processes has proved comparable performance and flexibility under comparable conditions.

Alternative thermal processes can only be economically successful under specific circumstances respectively requirements which are:

- Compliance with legal requirements
  (e.g. melting processes in Japan)
- Achievement of specific product properties
  (e.g. vitrified slag, low contaminant content)
- Treatment of special fractions
  (e.g. highly toxic materials, materials containing chloride,
  fractions with very low calorific value like contaminated soils)
- Upstream processes
  (e.g. in power plants, cement or lime plants) to substitute fossil fuels

There are currently no alternative thermal processes available that can be used to treat mixed municipal solid waste under comparable economic and ecological conditions as is the case for waste incineration. Due to the higher complexity of alternative processes, this can also not be expected in future. Therefore, treatment of mixed municipal solid waste should generally be reserved to incineration processes that have been developed and approved for this application.