MANAGEMENT OF COMBUSTIBLE WASTE

A. Buekens
Department of Chemical Engineering – CHIS 2, Vrije Universiteit Brussel, Belgium

Keywords: Chlorinated Waste, Destruction and Removal Efficiency (DRE), Hazardous Waste, Hospital Waste, Industrial Waste, Municipal Solid Waste (MSW), Principal Organic Hazardous Pollutants (POHC), Sewage Sludge

Contents

Summary

After referring to some general principles in waste management the genesis of comprehensive centers for industrial waste treatment as well as scope and possibilities of incineration are situated. A survey is given of various types of waste, eligible for incineration.

1. Some Principles in Waste Management

1.1. The Polluter Pays

In consumption society consumers are incited to buy goods that after some short usage are thrown away. Such standards of living rapidly deplete primary resources, converting these into pollution.

Transforming our society from wasteful to responsible attitudes was attempted ever since the 'Golden Sixties'. In a cyclic society, waste is collected at all stages of production and consumption and its materials and energy content are put to good use. Today, both producers and consumers need to sort their waste at the source, confronting them with these issues.

The principle ‘the polluter pays’ is valid in almost all industrial countries. Producers are confronted with take-back obligations at the End-of-Life stage (cars, tires, batteries, packaging, etc.). The waste generator remains responsible for the waste until it is handed over to a recognized waste disposal firm or center. Sometimes liability can go even further, e.g. joint and several liabilities (USA).
The **“Ladder of Lansink”** is often applied in the European Union for establishing priorities in Waste Management. The highest step is **Prevention**, i.e. avoidance of waste, by adopting thrifty consumption patterns, reviewing operating procedures in acquisition, managing inventories, etc. Non-Waste Technology is introduced to avoid or alleviate the generation of wastes or to reuse the wastes as secondary raw materials in other processes. Thus, distribution and application in bulk of e.g. cement, flour, or sugar eliminates the need for packing, and the concomitant packaging waste. **Reduction** is based on a lesser use of materials, e.g. designing lighter packaging. **Reuse** involves a second use of equipment or goods, e.g. second hand cars, or dresses passing from older to younger sisters. In most industrial countries waste exchange programs are organized. **Recycling** involves the recovery, collection, separation, grading, and grouping of secondary raw materials that can reintegrate the economic cycle. Scavenging waste employs a fraction of the poor in numerous countries. Private industry organizes the recovery of metal scrap, paper, board, plastics, glass, spent solvents, waste oils, which can be recycled economically. Compulsory legal measures (e.g. a 'take back' obligation), rising disposal costs, and other economic incentives (landfill levies) are designed for stimulating reuse and recycling. The lowest steps of the Ladder of Lansink are incineration, preferable with heat recovery, and safe disposal. The E.U. has promulgated a ban on landfilling combustible waste.

1.2. Types, Origins and Quantities of Wastes

Waste can be subdivided according to a number of different criteria, e.g.

- **Activity of origin** (agriculture, forestry, mining, etc.),
- **Physical properties, condition, shape** (e.g. blocks, lumps, paste, grains, sheet, dust, sludge, slurries, brines, vapors or smokes),
- **Disposal method** preferred or required (combustible, compostable, recyclable),
- **Hazardous properties** (e.g. radioactive, toxic, carcinogenic, flammable,

corrosive), and

- **Collection responsibility**, i.e. either the municipality or private contractors, hired by the waste generator.

The Waste Management Policy Group of **O.E.C.D.** (Organisation of Economic Cooperation and Development) defined waste as a material intended for *disposal*, for reasons specified in a Q-list. Disposal operations were defined in a D-list (final disposal) and an R-list (recovery). A second step was defining a core-list of wastes to be controlled. This list of Y-codes was based on origin (Y1 to 18), specific constituents (Y 19 to 45) or hazard characteristic H.

The collection and disposal of **municipal solid waste** (MSW) is the responsibility of' Public Authorities, who organize cleansing activities or tender these services periodically to private contractors, whereas industrial and trade wastes are a private responsibility. Municipal waste consists of e.g. household refuse, bulky waste, street sweepings, market waste, building waste and debris, hospital waste, animal corpses, cesspool waste, and abandoned cars and vehicles.

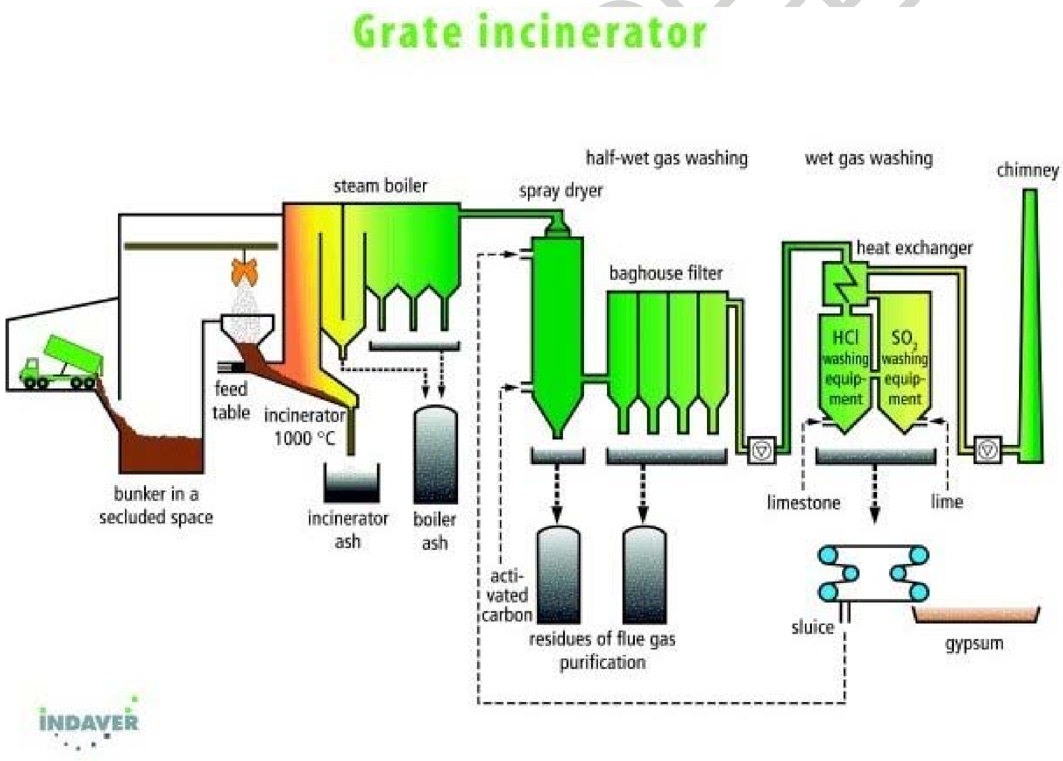

Figure 1: Municipal Solid Waste Incinerator Plant (Beveren/Antwerp).

Industrial and trade wastes are much more versatile in composition, condition and shape. Some trade waste is assimilated to household refuse, consisting mainly of garbage, packaging materials and other common and inoffensive matter. Other industrial waste is termed **hazardous, pathogenic** (e.g. manure, slaughterhouse waste, containing contagious germs), **toxic** (containing e.g. heavy metals) or **persistent** (chlorinated pesticides). All these terms are often used loosely, but must be defined in legal codes to ensure appropriate management and handling of waste. Industrial waste is subdivided into:

- general waste, assimilated to MSW,
- production waste, specific for each type of industrial activity.

1.3. Elimination of Industrial Waste

In the early seventies, there was a hopeless situation regarding waste: amount and composition were essentially undocumented, high-level elimination methods and incentives to use these almost non-existing, and easy routes out, such as dumpsites and waste tourism amply available. Since these days, much has been changed.

Statistical data on waste generation can be presented in many different fashions. In Baden-Wurttemberg once it was split in 53 industrial sectors. For a survey by Dutch industry S.V.A. (the Netherlands) prepared a classification grouping industrial waste according to the most appropriate method of disposal. The same classification principle was used for reporting in the waste treatment center of Schwabach (Germany).
Since the 1960s several large companies (e.g. BASF; Ford Motor) operate their own disposal centers. Most small companies, on the other hand, have neither the expertise not the amount of waste to justify local disposal. This has led to the establishment of a number of waste disposal centers, where private industry can deliver its wastes at a certain charge. Public bodies in the Netherlands, Denmark and Bavaria have established centers. In the USA, UK, Belgium and Ruhr private companies did this job.

One of the first large scales public initiatives was launched in 1963 by the City of Rotterdam. After a brief study incineration was selected as the disposal method. The required capacity was estimated after an enquiry on present and future disposal needs. The plant was constructed at Botlek with impressive total capacity and elaborated provisions for heat recovery. Revenues for the project were to be generated by a disposal fee and by the sales of power, distilled water, ferrous metal and slag. The plant started up in 1971 but was unable to attract sufficient wastes. It operated at a fraction of its nominal capacity and accumulated heavy financial losses.

In Bavaria the “Gesellschaft zur Beseitigung von Sondermüll” was founded in 1970 in view of the safe and orderly disposal of about 300,000 tons of special waste generated annually. Final treatment was centralized in disposal plants. In order to induce industry to deliver their special wastes, the initial disposal conditions were made as attractive as possible. The disposal fee included transportation from the collection to the disposal point and was constant throughout Bavaria. A collection network, consisting of about 20 collection points has been organized for reducing over-all treatment cost; these collection points are not only provided with storage, but also with volume reduction facilities, such as emulsion breaking and neutralizing tanks and sludge thickeners. Sometimes part of the wastes can be incinerated locally in municipal incinerators.

Kommunekemi A/S, founded in 1971 by the Danish Municipalities, followed a somewhat similar approach. The industrial companies were compelled to deliver their special unless they could prove themselves capable of properly disposing of such waste.

The wastes were delivered to a network of 20 collection centers, with provisions for receiving and stationing trucks and wagons. A central disposal plant has operated since 1975.

In France, waste generators received financial support from the Authorities under the form of a regressive contribution of 50 to 30 percent to the disposal cost during 10 years.

In Belgium several enterprises gained formal recognition for acquiring and exporting waste, e.g. to incinerator ships anchoring in Antwerp, to disposal companies in France or the U.K., or German salt mines. In 1985 Indaver was founded as a result of official and industrial initiative. Such a public + private participation has been hailed for a number of advantages:

- Public authorities provide a moral caution that elimination will proceed in an orderly and legal manner and some mild pressure is exerted to supply waste to the center,
- Private enterprise shows sense for responsibility. (cf. Responsible Care, launched by chemical industry)

In one study dealing with 33 most important chemicals it is concluded that the rate of waste generation will decrease, mainly as a consequence of changes in the manufacturing process.

The Federal Acquisition Regulations System compiled a list of 63 American companies collecting, transporting and disposing of wastes, together with the wastes accepted and the disposal methods used.

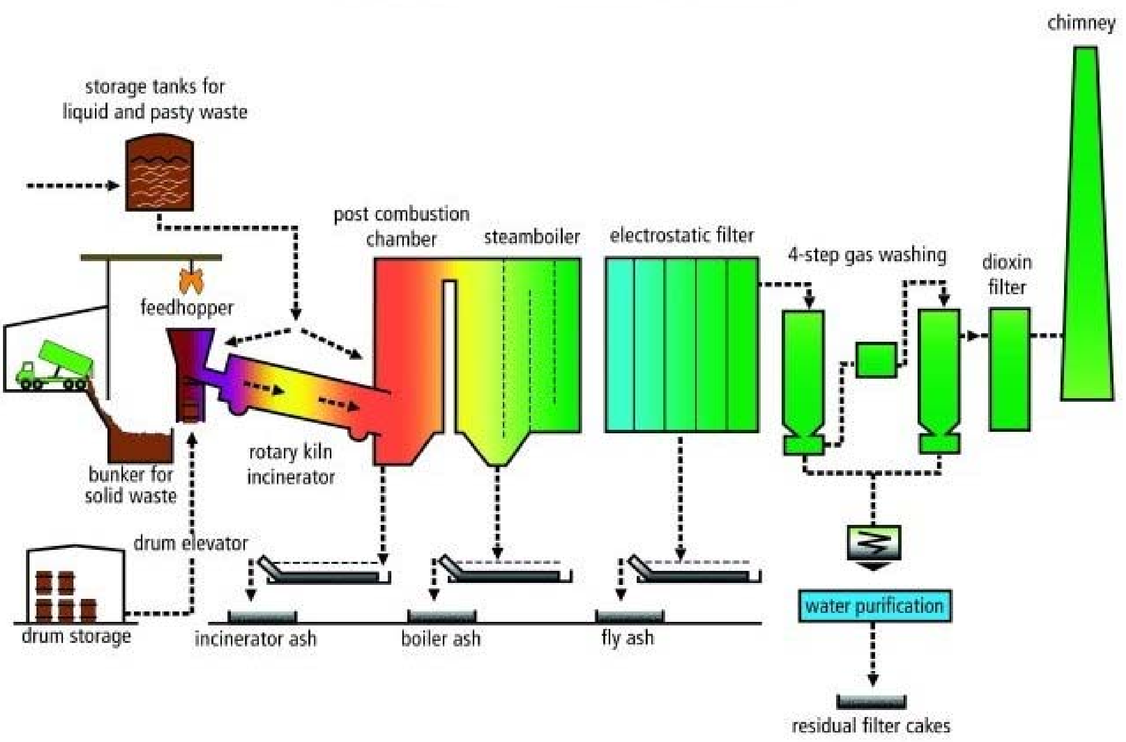

Figure 2: Industrial Waste Incinerator Plant (Antwerp).

2. Selection of Disposal Methods

For several decades, increasingly stringent environmental protection measures have been enforced. All effluents must conform to specifications, prior to their discharge or emission. Solid residues must be rendered biologically and chemically inert, hazardous and persistent materials thermally or chemically decomposed. The 'lowest cost' criterion is replaced by a 'lowest environmental damage' rule.

Waste disposal methods can be subdivided into the following categories:

a) **Direct disposal methods** involve sanitary landfill, lagooning, disposal into surface waters, in deep wells, or at sea. The use of direct disposal methods at present is restricted to well-engineered sites and selected categories of non-objectionable wastes. Some inert wastes, however, such as building wastes and debris, dredging spoils, colliery and other mining wastes, slag and cinder, generally can only be disposed of by sanitary landfill, land reclamation or disposa1 at sea, as long as no system and markets have been developed for reuse or recycling. Much work is underway to recycle huge quantities of mineral and metallurgical waste and develop non-waste-technologies. Brines are discharged into the sea or brackish surface waters. Deep well disposal of liquid wastes in porous underground layers, storage of cyanide hardening salts in salt mines and permanent storage of high-level radioactive wastes are technically interesting but also controversial disposal methods. The economic advantages inherent to the low cost of direct disposal are more and more offset by supplemental costs related to administrative and technical measures, levies and taxes and analytical monitoring. It is a general tendency to develop suitable uses for bulk materials such as slag, foundry sand, and demolition waste, landfill gradually becoming unaffordable.

b) **Mechanical, physical and chemical treatment methods** are applied in different branches of industry. Solid waste, such as wastepaper, metal scrap and refuse, can be baled, cars, white goods, and bulky wastes shredded, electric and electronic equipment dismantled. Mechanical sorting of refuse, mainly based upon ore beneficiation technology, was tested in several countries. At present practical application is limited, and recyclable packaging waste, wastepaper and plastics are mostly hand sorted, albeit at a high cost, by far exceeding the value of the recovered materials. Unfavorable economics are compensated by subsidies from producers or distributors, assuming full responsibility for their products, including end of life recovery, treatment and disposal. Hazardous waste is either detoxified, or immobilized, i.e. leaching is impeded by barriers or conversion into insoluble chemicals or glassy materials. Wastewater and liquid waste is treated by settling, filtration, flotation and other solid/liquid separation methods, possibly after colloids coagulation and heavy metal precipitation. Other impurities are removed by adsorption or extraction, or destroyed by oxidizing or reducing chemicals. Solvents are distilled and dried, waste oil treated by dewatering, fractionation, and adsorptive treatment.

c) **Biochemical disposal methods** include activated sludge or trickling bed treatment of wastewater, aerobic stabilization or anaerobic digestion of sludge and concentrated liquors, or composting. These methods are based on an accelerated biological breakdown of biodegradable waste and are often preferred for the disposal of vegetal and animal waste having high moisture contents. Decentralized disposal with local recovery of fermentation gas, compost, fodder, or even proteins is possible, presuming that heavy metals, pesticides and other pollutants are largely absent.

d) **Thermal treatment methods** encompass incineration, gasification and pyrolysis, wet oxidation, and freezing (of sludge). High temperature disposal methods are faster than any other method and convert combustible wastes into low volume, sterilized residues. Heat recovery is often possible, but the presence of tacky fly ash or corrosive gases and salts may decide against the presence of a waste heat boiler or limit its operating conditions to low pressures.

3. Properties of Combustible Wastes

Combustible wastes can be characterized by:

- Higher and lower heating value (HHV, LHV),
- Short or proximate analysis, i.e. a determination of their moisture, ash and combustible content, further subdivided into volatile matter and fixed carbon.
- Ultimate analysis, i.e. element analysis of the combustible fraction and ash.

Other important properties are:

- Form and size, physical and bulk density, flammability and putrescence of **solid waste.**
- Vapor pressure, boiling point, density, viscosity, explosion limits, flash point, self-ignition temperature, corrosiveness, toxicity, and gas evolution or decomposition during preheating, possible auto-oxidation, polymerization or other incontrollable, exothermic or dangerous reactions of **liquid waste.**
- Density, explosion limits, toxicity and corrosiveness of **off-gases.**

Heating values determine whether waste is highly, moderately or almost not combustible. Heating values are required to establish the capacity and heat balance over the furnace, the combustion air requirements, and to decide whether heat recovery, combustion air preheating, or disposal in combination with other wastes are desirable.

The proximate analysis defines the amount of moisture to be evaporated prior to combustion and the required size of ash handling equipment. Moist waste, such as garbage, sewage sludge and aqueous solutions, burns only after at least superficial evaporation of the moisture contained. Hence, fast drying should be stimulated by adequate measures, such as exposure to radiant heat or contact with easily ignitable waste.

From the chemical analysis of combustibles the amount and composition of the flue gas can be estimated at a given excess of air. In a first approximation, the S-, Cl- and (much less so) N- content during combustion will be converted into SO_2, HCl and NO. Their concentration determines whether wet scrubbing of the flue gas is required. When the flue gas is cooled slowly and in the presence of catalytic fly ash, SO_2 can be further oxidized to SO_3, and HCl to Cl_2. Some part of SO_2/SO_3 and HCl is removed by adsorption on fly ash. NO formation is lowered by staged combustion, i.e. when the combustion is conducted in two steps: the first under reducing conditions, the second at moderately low temperatures.

Chemical analysts and dedicated testing of ash inform on its softening and melting behavior and hence about its tackiness and possible attack on refractory. Sodium and potassium compounds decrease the melting point, in particular when present as persulfates, vanadates and borates. The presence of volatile elements, such as mercury, thallium, cadmium, arsenic, antimony, etc. makes waste improper for incineration in conventional units, unless their air pollution controls are adapted.

Some properties are vital for selecting and specifying adequate storage, handling and feeding facilities and safety provisions. Information is also required on frequency and timing of deliveries, kind of containers and packaging, etc.

-
-
-

Bibliography

[1] A.G. Buekens and J. Schoeters (1986). European experience in the pyrolysis and gasification of solid wastes. *Conservation & Recycling* **9** (3), 253 - 269. [Reviews early efforts in innovative thermal techniques in waste treatment].

[2] A. G. Buekens, J. Schoeters, D. Jackson and L. Whalley (1986). Status of RDF-production and utilization in Europe, *Conservation & Recycling* **9** (3), 233 - 252. [Reviews early efforts in producing and firing Refuse-Derived Fuels]

[3] *Environmental Management of Urban Solid Wastes in Developing Countries, a Project Guide* (1982), Washington D.C.: The World Bank. [A well-known guidebook destined for a wide, non-technical public]

[4] http://ecb.jrc.it/classification-labelling. [The website of the European Chemicals Bureau (EBC) lists 7000 hazardous substances, classified on EU level. Classification and labeling involves an evaluation of the hazard according Directive 67/548/EEC]

[5] http://www.cefic.be/Files/Publications/RCreport2003.pdf. [Product stewardship, the responsible and ethical management of the health, safety and environmental aspects of a product throughout its total life cycle, is sponsored by Chemical Industry.]

[6] http://www.epa.gov/epaoswer/osw/hazwaste.htm. [This website provides excellent entries to the themes, relevant in Hazardous Waste Identification and Treatment, Subtitle C of RCRA]

[7] www.epa.gov/osw. USEPA "*Risk Burn Guidance for Hazardous Waste Combustion Facilities*", EPA530-R-01-001, July 2001 [Analyzes the procedures for performing test burns on hazardous waste].

Biographical Sketch

Alfons Buekens was born in Aalst, Belgium; he obtained his M.Sc. (1964) and his Ph.D (1967) at Ghent University (RUG) and received the K.V.I.V.-Award (1965), the Robert De Keyser Award (Belgian Shell Co., 1968), the Körber Foundation Award (1988) and the Coca Cola Foundation Award (1989). Dr. Buekens was full professor at the Vrije Universiteit Brussel (VUB), since 2002 emeritus. He lectured in Ankara, Cochabamba, Delft, Essen, Sofia, Surabaya, and was in 2002 and 2003 Invited Professor at the Tohoku University of Sendai.

Since 1976 he acted as an Environmental Consultant for the European Union, for UNIDO and WHO and as an Advisor to Forschungszentrum Karlsruhe, T.N.O. and VITO. For 25 years, he advised the major industrial Belgian Bank and conducted more than 600 audits of enterprise.

Main activities are in thermal and catalytic processes, waste management, and flue gas cleaning, with emphasis on heavy metals, dioxins, and other semi-volatiles. He coordinated diverse national and international research projects (Acronyms Cycleplast, Upcycle, and Minidip). Dr. Buekens is author of one book, edited several books and a Technical Encyclopedia and authored more than 90 scientific publications in refereed journals and more than 150 presentations at international congresses. He is a member of Editorial Boards for different journals and book series.

He played a role in the foundation of the Flemish Waste Management Authority O.V.A.M., of a hazardous waste enterprise INDAVER, and the Environmental Protection Agency B.I.M./I.B.G.E. He was principal ministerial advisor in Brussels for matters regarding Environment, Housing, and Classified Enterprise (1989). Since 1970 he has been a Member of the Board of the Belgian Consumer Association and of Conseur, grouping more than a million members in Belgium, Italy, Portugal, and Spain.

He is licensed expert for conducting Environmental Impact Assessments (Air, Water, Soil) and Safety Studies regarding large accidents (Seveso Directive).