DRYING AND INCINERATION

Introduction

Drying and incineration are thermal processes employed in several food industries. Drying in general is used to increase the shelf life of the prepared food and even employed in solid waste management. Incineration is considered as a best method and only option for removal of few solid wastes.

Let us understand both the topics in this session in the following headings

1. Evaporation
2. Drying
3. Thermal conversion
4. Incineration
5. Cleaning out Flue Gas and solidify outputs

1. EVAPORATION

Evaporation is a method used to concentrate non-steam-volatile wastewater components. The evaporation plant contains a vapor condenser by which vapor and steam-volatile compounds are separated from the concentrate. While the concentrate is then recycled into the evaporator, the exhaust steam can be used for indirect heating of other evaporator stages.

The degree of concentration of the wastewater components depends on different factors, for example

- Reuse of the concentrate (e.g., reuse in production, use as fodder, recovery of recyclable material);
- Type of disposal of the concentrate (e.g., incineration, landfill)
- Properties of the concentrate (e.g., viscosity, propensity to form incrustation, chemical stability).

Advantages of this method include:

- The residue (dried oil wastes) can be reused as fodder and fertilizer;
- Only a small area is needed;
- Exhaust steam can be reused as energy;
- Considered state of the art in the food industry

Disadvantages are:

- The exhaust steam from evaporation is organically polluted and needs treatment;
- Rather high operation and maintenance costs;

2. DRYING

Drying of a food material occurs when water vapour is removed from its surface into the surrounding space, resulting in a relatively dried form of the material. Drying, differs from the dewatering process, in dewatering, liquid water is ‘drained’ or ‘squeezed’ out of the material. During drying, the heat can be supplied in different ways: convection, radiation, conduction, microwave, radio-frequency, or even Joule heating.

The principle of drying, no matter what drying mechanisms are involved, can be generally expressed by the following surface vapour flux equation:

$$N''v = hm \cdot (\rho v,s - \rho v,\infty)$$

where $N''v$ is the vapour (or drying) flux (kg m^{-2} s^{-1}); hm is the mass transfer coefficient (m s^{-1}); $\rho v,s$ is the interfacial vapour concentration at the moist material surface (kg m^{-3}) and $\rho v,\infty$ is the vapour concentration in the surrounding space that the vapour travels into (kg m^{-3}). hm is determined by the flow field around the material being dried (m s^{-1}), which may be viewed as a velocity of mass movement.

When this vapour concentration difference is positive, vapour leaves the material and thus drying occurs. The reverse is the wetting/humidification process. The drying process as a whole has to involve the generation of vapour (transforming from the liquid phase inside the moist material to gaseous phase) on and within the moist material being dried, and the transport of the water phases outwards of the material. Some debates are around how liquid water may move within the material structure.

The micro-structure of the food materials is particularly relevant to drying, as both liquid water and water vapour move within the structure. The micro-structure, as far as the transport of heat and chemical species is concerned, is mainly made up of compounds such as protein, fat, carbohydrate, minerals and air. Porosity and tortuosity are usual characteristics. The material’s composition and its affinity to water (sorption characteristics) play a key role in water holding capacity and local evaporation rates.

Drying also creates a new micro-structure as it progresses and the spatial distribution of the micro-structure characteristics, density included is important in texture perception of the product and affects how it may be used as an ingredient for mixing into other foods (for instance, the reconstitution properties for food powders created by spray drying). For instance, microencapsulation is employed to protect the active and beneficial ingredients, such as probiotic bacteria, during drying. Drying is also preferably done at the lowest temperature possible, for the same purpose of achieving higher retention of bioactivity.

Bacterial cells or microorganisms are vulnerable in the drying process, especially when a high temperature environment is encountered. Drying may be viewed as a thermal processing stage. One the other hand, as mentioned above, preservation of the activities of the good beneficial bacteria – such as probiotic bacteria – becomes important when the drying process can be detrimental.

There has been much research effort spent on understanding the fundamentals of drying, and more complicated mathematical models published in the literature, but a concise introduction of drying still centers on the notion of three drying stages; a warming up/cooling down period, a constant rate drying period and a falling rate drying period.

The maintenance of the constant drying rate period (at the end of it) may be due to two reasons: one is the increasing temperature at the air–product interface (increasing the interfacial vapour concentration even though the relative humidity might have gone below unity); the other is due to the material's surface nature, where relative humidity can be kept constant for quite a long time.

There have been a large number of studies published in the past two decades on the drying of food and biological materials. In these papers, drying rates are represented using empirical models of explicit time-dependent functions. In particular, the *Page* model (1949) appears to be the one that is the most successful in describing the weight loss versus time data obtained in a constant environment for drying (constant temperature and humidity of the drying medium).

3. THERMAL CONVERSION

Thermal conversion of solid waste includes transformation of wastes into gaseous, liquid, and solid conversion products. The process also generates energy due to burning of waste materials, Thermal processing also results in waste volume reduction, Combustion or incineration, pyrolysis, and gasification are the techniques commonly employed for thermal conversions.

A waste treatment technology, which includes the combustion of waste for recovering energy, is called as “incineration”. Incineration coupled with high temperature waste treatments are recognized as thermal treatments. During the process of incineration, the waste material that is treated is converted in to gases, particles and heat. These products are later used for generation of electricity. The gases, flue gases are first treated for eradication of pollutants before going in to atmosphere.

Thermal treatment

In spite of the wide range of approaches to waste treatment in the food sector, in some cases thermal treatment is the most effective or the only one applicable. Compared to other disposal methods it has a number of advantages, such as:

- Short time of treatment (in the case of land filling, it may take decades for the waste to decompose);
- Possibility of treating hazardous waste (as for example in the case of animal carcasses contaminated by a dangerous contagious diseases);
- Possibility of off-gas control (abatement of environmental impacts);
- Possibility of utilizing heat released by the oxidation process (waste-to-energy).

Thermal treatment may be used for a wide spectrum of waste from solid to gaseous. The choice of suitable thermal treatment technology is then based on the type of treated waste and its characteristic properties. Examples described below include completely different technologies, applicable to different type of waste:

- Incineration of solid residues with relatively low water content and free of hazardous properties may be performed in units very similar to biomass boilers (a typical example is provided by peach and olive pits). Due to the character of this waste it is not necessary to equip the units with complicated flue gas cleaning systems.
- Another example of solid waste is sludge (namely WWTP sludge). In contrast to the latter example, high water content may be expected, thus requiring completely different approach and technologies. One possibility is sludge co-firing after drying. One suitable

process is cement and burned lime production, where an alternative fuel (sludge in this case) can be fed using a special feeder directly into a rotary kiln. In some cases however, it is, necessary to apply special sludge incineration technology. This is very often based on a multiple hearth combustion chamber.

- For hazardous waste like some types of meat and bone meal, thermal treatment is the only alternative. In such cases, systems based on a rotary kiln and secondary combustion chamber is preferred.

4. INCINERATION

Incineration as a disposal method involves burning the trash. Sometimes this is simply referred to as thermal treatment, as a general category of high temperature treatment of trash material. This method can be used to transform waste into heat, gas, steam and ash. One of the advantages of incineration is that with this method, refuse volume can be reduced by half or more and it requires little usage of land. An incineration facility can be built in a small area to process huge amounts of waste. It definitely saves a lot of space compared with using a landfill only. This method is popular in countries like Japan where space is limited.

Incineration of waste materials converts the waste into ash, flue gas, and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas.

Some incinerators generate energy from the burning of waste; these plants are called waste-to-energy plants. Incinerators reduce the volume of waste by about 90 percent and weight by 75 percent. There are eight types of incinerators, fixed-hearth incinerators, rotary kiln, plasma arc, liquid injection, fluidized bed, multiple hearth, catalytic combustors, and static heart incinerator. In 1885 the U.S. Army created the first garbage incinerator in New York Harbour.

Rotary Kiln

The rotary kiln hearth system has been used for several hundred years in the pyroprocessing industry. The rotary kiln concept accomplishes two objectives simultaneously: moving solids into and out of a high-temperature combustion zone and mixing and stoking the solids during combustion. In its classical embodiment, a kiln is comprised of a steel cylindrical shell lined with abrasion-resistant refractory to prevent overheating of the metal. A kiln is generally inclined slightly toward the discharge end, and the movement of the solids being processed is controlled by the speed of rotation.

In some instances, special provisions have been made for air cooling or water cooling the kiln shell, thus eliminating the use of refractory. For example, a steel kiln cooled with external water sprays known as the Lantz Converter was developed for pyrolysis applications in the mid-1960s. In the late 1970s, a new kiln technology emerged involving a water-cooled kiln cylinder fabricated of steel boiler tubes welded together and manifolded for the introduction of feed water and withdrawal of steam.

Plasma gasification

Plasma gasification is another form of waste management. Plasma is a primarily an electrically charged or a highly ionized gas. Lighting is one type of plasma which produces temperatures that exceed 12,600 °F. With this method of waste disposal, a vessel uses characteristic plasma torches operating at +10,000 °F which is creating a gasification zone till 3,000 °F for the conversion of solid or liquid wastes into a syngas. During the treatment solid waste by plasma gasification, the waste's molecular bonds are broken down as result of the intense heat in the vessels and the elemental components. Thanks to this process, destruction of waste and dangerous materials is found. This form of waste disposal provides renewable energy and an assortment of other fantastic benefits.

Plasma arc incinerators ionize inert gases via an electric arc between two electrodes. This plasma creates an extraordinary amount of heat, ranging from 3000-7000˚ Celsius. The extreme heat can easily break down organic compounds into their basic atoms, which later recombine to form gases such as CO_2. Inorganic material is left as a stable, leach-resistant slag. Concerns surrounding plasma arc incineration include ensuring that gas emissions are minimal and cleaned before being released to the atmosphere.

Fluid Bed Systems

The fluid bed (FB) incineration systems relative to bubbling fluid bed (BFB) applications in burning biological wastewater sludge and circulating fluid bed (CFB) applications in burning hazardous wastes are widely employed. These two waste management areas were the dominant applications of fluid bed technology in the United States at the beginning of the 1990s, but several applications for municipal solid waste could be found in Japan and Europe.

In order to provide a feed with relatively homogeneous composition and size, almost all solid wastes fired in BFB or CFB units are preprocessed or, at least, made somewhat more homogeneous through waste separation at the point of generation (e.g., in Japan). Both BFB and CFB furnaces can accept other fuels such as wood chips, coal, or chipped tires. By acquiring these relatively clean, alternate energy sources when the prices are favorable, energy revenues can sometimes be increased significantly with little increase in maintenance and operating cost.

Stationary Hearth

Those incinerator furnace systems that operate without grates include the stationary hearth, rotary hearth, and rotary kiln. The stationary hearth is usually a refractory floor to the furnace, which may have openings for the admission of air under slight pressure below the burning material on the hearth, in the manner of the blacksmith’s forge. In the absence of under fire air ports, air is admitted along the sides or from the top of the furnace, and combustion proceeds in the same, surface-burning manner as in a bonfire, but with improved conditions due to the reradiation of heat from the surrounding furnace walls and roof. Unless the refuse being processed provides a porous burning mass (as may be the case with bulky refuse), it is necessary to provide manual stoking with slice bars to stir the mass of refuse in order to achieve a reasonable burning rate and degree of burnout.

Stationary hearth furnaces are used for most commercial and smaller industrial incinerators. They are also used almost exclusively in crematories and for hospital wastes. For the latter applications, auxiliary gas or oil burners are used to maintain the furnace temperature in the range of 650º to 900 ºC in the presence of adequate quantities of oxygen from air, well dispersed throughout the gas. In burning such high-moisture waste, primary chamber burners are needed to ensure complete oxidation of combustible solids and vapors for the elimination of smoke and odors. Confident smoke and odor control requires auxiliary fuel burners under automatic temperature control in a secondary combustion chamber.

Moving Grate

The incineration plant used for treating MSW is moving grate. This grate is capable for hauling waste from combustion chamber to give way for complete and effective combustion. A single such plant is capable for taking in thirty-five metric ton of waste every hour for treatment. Moving grates are more precisely known as incinerators of municipal solid waste. This waste is poured in the grate with a help of crane from and opening or throat. From here, the waste has to move towards the ash pit. Waste is further treated and water locks wash out ash from it. Air is then flown through the waste and this blown air works for cooling down the grate. Some of grates are cooled with help of water. Air is blown through the boiler for another time but this time comparatively faster than before. This air helps in complete burning of the flue gases with the introduction of turmoil leading to better mixing and excess of oxygen. In some grates, the combustion air at fast speed is blown in separate chamber.

European Waste incineration Directive is of the view that an incineration plant must be designed so that operating worker must know that flue gases are reaching the temperature of 850ºC within two seconds. This would ensure complete and required breakdown of toxins of organic nature. In order to achieve this every time backup auxiliary burners must be installed.

Systems analysis

The basic information used in the analysis of combustion systems can include tabulated thermochemical data, the results of several varieties of laboratory and field analyses (concerning fuel, waste, residue, gases in the system), and basic rate data (usually, the flow rates of feed, flue gases, etc.). Guiding the use of these data are fundamental relationships that prescribe the combining proportions in molecules (e.g., two atoms of oxygen with one of carbon in one molecule of carbon dioxide) and those that indicate the course and heat effect of chemical reactions.

5. CLEANING OUT FLUE GAS AND SOLIDIFY OUTPUTS

A number of processes are involved for the cleaning up of flue gas. The mixture of flue gas is collected by means of particle filtration and this filtration is conducted using electrostatic precipitators and baghouse filters. Baghouse are very effective for fine particles. The next step of the processing and cleaning of flue gas is processing of scrubbers, which are critical for the removal of hydrochloric acid, nitric acid, mercury, hydrofluoric acid, lead and residuary heavy metals. With the reaction of lime, sulfur is converted in to gypsum. The wastewater, which comes out of scrubbers, is then passed through wastewater treatment plant.

Desulphurization is a process that is used to remove sulfur dioxide with the limestone slurry injection directly in to flue gas. Nitric component or gases are reduced with catalytic reduction with help of ammonia application. Heavy metals are removed with the help of active carbon injection. Particles are the collected at filters.

Solidify Outputs

Flue ash and Bottom ash is produced with the processing of waste materials and settle at the bottom of the incineration plant. The ash, which is produced, is four to five percent of total weight of the waste processed while the flue ash makes up some ten to twenty percent of total weight of waste material. The heavy metals, which are contained in the flue or bottom ash, are lead, cadmium, zinc and copper. A small amount of furans and dioxins are also produced. It is to mention here that bottom ash seldom have heavy metals in it. Flue ash is hazardous while bottom ash is not that dangerous or injurious to health.

Conclusion

Incineration is considered to be best method of waste management over landfill, provided it helps in recovery of energy from the solid waste. Even though landfills is most commonly practiced form of waste management, its contribution to the pollution of ground water and air through leachates and even huge requirements of land has made incineration most suitable for management of selected solid wastes.