Microwave induced pyrolysis of sewage sludge

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ABSTRACT

Sewage sludge contains, similarly to most organic waste a considerable proportion of degradable substances and thus it is a valuable source that may be recovered in the form of a valuable product. This paper deals with microwave pyrolysis as technology which features considerably time and energy savings compared to conventional pyrolysis and achieves results comparable with conventional pyrolysis. Sewage sludge microwave-induced pyrolysis reduces its volume by up to 80 %, the resulting product is a porous carbonaceous product (BICOAL-BIOCHAR), fuel gases and liquids.

Sewage sludge is waste produced inevitably during wastewater treatment. Sludge forms approximately 1-2% of the volume of treated wastewater, which, however, concentrates up to 50-80% of the original pollution and the costs of operating sludge management systems total 50% of the total operating costs of wastewater treatment plants. The total volume of produced sludge depends on the volume of treated, and the method of wastewater treatment and the type of sewerage. The amount of produced sludge depends on the technological process of sludge treatment. The volume of sludge is also affected by iron and aluminium salts, lime, polymers etc. which are added to the process of wastewater treatment or sludge treatment. Methods of sludge treatment depend on the local conditions in the relevant locality, the physical, chemical and biological properties of the sludge and the possibility of a final disposal solution. Currently, there are three ways the final sludge disposal available: application in agriculture and for land reclamation, thermal treatment and landfilling. Trends set in Europe clearly show that the ban on landfilling biodegradable waste is gradually implemented and the value of sludge as a fertilizer for agricultural use is significantly reassessed. The precaution principle dictates that the reintroduction of sludge into the environment must be rejected. Sludge containing residues of drugs, antibiotics, additives, detergents and cosmetics is a source of micropollution. Furthermore, the transfer of heavy metals contained in sludge into agricultural land is not zero and it is uncertain whether this sludge can be used in agriculture due to the possible presence of BSE prions.

One of the breakthrough technologies in the context of depolymerisation, pyrolysis, was developed in the late 1950s. Pyrolysis is a step further away from carbonisation and it also takes place with the lack of oxygen. Pyrolysis is understood as thermal decomposition of organic materials in the absence of oxygen containing media. Pyrolysis is based upon heating the material above the limit of thermal stability of the present organic compounds, leading to their splitting down to stable low molecular weight products and solid residues. Most currently operated pyrolysis systems are based on thermal decomposition of waste in a rotary furnace heated externally by flue gases produced during the pyrolysis gases combustion in the so-called “thermoreactor”. The so-called “fast pyrolysis” is one of the modern and highly promising processes in a group of technologies that transform biomass in the form of wood and other waste materials to higher energy level products such as gases, liquids and solids. The by-products of this fast pyrolysis is pyrolysis coke (BIOCOAL-BIOCHAR) (15%) and pyrolysis gas (up to 51%) which are usually used in the actual pyrolysis process to produce heat. Fast pyrolysis processes have been developed around the world by a number of institutions and manufacturers in particular over the past 10 years and they are also used as the basis of the concept of “biorefineries” which are one of the most promising ways to make use of biomass for the production of liquid fuels. Bio-oil produced through the fast pyrolysis processes may be used after further purification and treatment in chemical engineering and for mobile diesel engines or directly as heating oil for boilers and as fuel for electricity generation in internal combustion engines and combustion turbines.

While the heating effect of microwaves was discovered accidentally in 1946, science has not demonstrated too much interest in the application of microwaves in chemical reactions until recently. However, over the last 10-15 years, a large number of scientific studies have begun to explore the use of microwave heating, including in the field of biomass. Most of these advantages are highly energy efficient, fast inside out heating and the selectivity of microwave agitation based on molecular electrical properties that have a greater effect than simple heating. At surface temperatures around 300-350 °C, the combined effects of pulsed microwave radiation, activated carbon particles and catalyst result in the cracking of hydrocarbon molecules in the feedstock into smaller, more volatile molecules and evaporation. The resulting fuel product can be further improved to meet the fuel standards through typical petrochemical methods. The solid residues remain in the reactor, all the contained oils evaporate. A highly calorific product is produced as the second valuable product of the process of microwave pyrolysis. An examples of newly developed equipment for microwave pyrolysis is the BionicFuel reactor currently tested in AdMaS centre laboratories. Most parts of the equipment combine standard tools and off-the-shelf components with the reactor which has been designed by BIONIC to achieve the best possible results in the microwave application. The microwave equipment is made up of 90% standard components fitted with bionic technology and control software. The pyrolysis product is a liquid fuel, biocoal (BIOCHAR), gas, water, sulphur and inorganic waste. The liquid fuel can be used directly in the production of electricity or, following treatment, for standard heating and as a fuel. Biocoal (BIOCHAR) is of high carbon purity for most types of feedstock with a calorific value comparable to a high quality coal. Besides the use for heating purposes, it can also be applied in other fields. Gases are a mixture of methane, propane or pentane and other highly volatile organic compounds in the reaction mixture in the initial stage of heating.

Wet sewage sludges from different waste water treatment plants were dried and pyrolyzed at pilot scale, using a BIONIC microwave pyrolysis unit. The gases obtained from these pyrolysis experiments were analysed and compared with those from a conventional pyrolysis employing an electrical furnace. The results help to explain the complex mechanisms that take place during the pyrolysis of sewage sludge. This process produces a considerable amount of gases with potential value as fuels due to the fact that they have relatively high calorific values. Upon comparing the two pyrolysis processes, it was found that microwave pyrolysis takes a much shorter time than when using the electrical furnace. It was also found, that microwave pyrolysis generates different composition of gas than conventional pyrolysis.