USE OF A PLASMA REACTOR WITH A THREE-JET MIXING CHAMBER FOR PROCESSING OF LIQUID TOXIC WASTE MATERIALS

A. L. Mossé, D. Hebecker, and G. N. Kuznetsov

We present a brief review and show the outlook for processing of toxic waste materials by a plasma method. We carried out experimental investigations of the processing of liquid toxic organic and organochlorine waste materials in a plasma reactor with a three-jet mixing chamber.

One of the most serious ecological problems facing many industrially developed countries is pollution of the environment by communal and industrial waste materials that in the majority of cases have such undesirable properties as toxicity, carcinogenicity, mutability, corrosiveness, reactivity, and fire hazard. Radioactive and medical waste materials occupy a special place in this series. The accumulation of untreated hazardous waste materials on dumping and testing grounds, burial in the earth and at sea cannot be considered an appropriate means for neutralizing their harmful influence on the environment, since there is always a high risk of contamination of soil, ground and surface water, and air by hazardous substances. And this risk could persist for a long time. This presents a grave threat to the life of people, animals, vegetables, i.e., to the normal existence of the entire ecological system.

A very strong argument against the well-known and relatively cheap means of storing and placing waste materials is that in a number of cases, with a better understanding of the effect of chemical substances contained in waste on nature, it has been found that there is a greater danger from waste materials whose burial was not expected to cause ecological problems. This can be seen by the example of waste materials containing phenol-formaldehyde resins and pesticides.

Despite strict standards and rigorous requirements introduced in industrially developed countries on the siting and equipping of testing grounds, the burial and storage of hazardous waste materials, and their composition, preference is given to technological methods for neutralizing waste [1, 2], which include decontamination, reuse, and reduction of the volume of waste to be buried, despite the fact that technological methods for processing of waste materials require significant energy expenditures.

The technique most widely used for processing of liquid toxic waste materials is burning, pyrolysis, and thermal decomposition. Industrial furnaces and boilers are used only when the liquid waste materials have moderate or high calorific values and a minimal chlorine content. Low ecological indices and the very narrow range of organic waste materials that can be burnt in industrial furnaces made it necessary to develop special technologies for processing of toxic waste, some of which are already being applied, while others are at the stage of investigation. These include a combustion chamber with burners for liquid fuel injection, rotating roasting furnaces, electric infrared furnaces, fluidized-bed circulating furnaces, and combustion chambers with oxygen-enriched burners.

Unfortunately, all the above and other means for burning of liquid toxic waste have a substantial drawback. The thing is that in the burning of chlorine-containing organic substances at insufficiently high temperatures, in addition to nitrogen and carbon oxides, phosgene, dibenzofuran, dioxin, benzopyrene, and other ultratoxic products in amounts exceeding the maximum permissible concentrations (MPC) can be formed.
An alternative approach to the existing and new technologies of low-temperature combustion of liquid toxic waste materials is their burning in a low-temperature plasma, i.e., high-temperature combustion. The use of electric-arc, high-frequency, and other means for producing plasma with mean mass temperatures of the order of 5000 K allows one to destroy organic and inorganic compounds at very high rates and with a high degree of conversion. Moreover, complex compounds can be destroyed very efficiently in a plasma in the absence of oxygen. It is also possible to effect such an important factor of thermal processing of waste as good mixing of the reacting components, resulting in an increase of the degree of conversion.

A considerable effort is currently devoted in many countries to the development of plasmochemical methods for processing of toxic waste, mainly organic compounds of chlorine and other halogens. Thus, in Russia investigations of the process of pyrolysis of organochlorine waste in a low-temperature electric-arc plasma were carried out with a view toward obtaining secondary raw material that can be reused in organochlorine synthesis [3, 4]. Hydrogen or methane was used as the plasma-forming gas. Subjected to processing were liquid, resin-like, and solid waste materials in the production of organochlorine substances. After purification, such products of pyrolysis as CO, C, C2H2, C2H4, CH4, and HCl are again suitable for the synthesis of organochlorine compounds.

A plant for decontaminating chlorobenzene and dichloroethane in an electric-arc air plasma is described in [5]. It is noted that the presence of chlorine in waste gases seems to be due to excess air (oxygen), since the initial products contained sufficient hydrogen for chlorine bonding to obtain hydrogen chloride. Quenching and cooling were performed using an adiabatic flash tank and sprayed water. Gaseous chlorine was removed, while the weak solution of hydrochloric acid obtained from hydrogen chloride was neutralized by alkali.

One of the laboratories of the United States Environmental Protection Agency has developed a mobile plasma plant for processing of toxic waste materials [6]. The latter work cites test data on processing of carbon tetrachloride mixed with methyl ethyl ketone, ethanol, and water, as well as with methyl ethyl ketone and methanol. The results of investigations showed that in both cases the decomposition degree of CCl4 attained 99.9999%. Analysis of the final products for toxic substances showed that the concentration of CO and NOx was 0.01 vol.%.

Tests for dioxins and furans revealed only traces. A similar plasma plant for processing of polychlorides of diphenyls was employed by the Westinghouse Corporation [7]. The results showed that the degree of diphenyl decomposition was 99.99%. The final products contained carbon monoxide, which was later burned out. No dangerous toxic substances (dioxins, dibenzofurans) were observed in the waste gases.

Another work, also conducted in the USA, [8] presents investigations of the decomposition of organic and organochlorine waste materials in a countercurrent plasma reactor. The power of an Ar-operated plasmatron was about 14 kW. Two types of raw material were used: 1) hydrocarbons: acetone, gasoline, methyl ethyl ketones (MEK), and special thinners. The final products were CO2, H2O, CO, H2, and O2; 2) chlorinated hydrocarbons: chloroform, dichloromethane, carbon tetrachloride (CCl4), and polychlorinated biphenyls (PCB). The final products were Cl2, C, CO, H2O, H2, HCl. The consumption of raw material varied, but for PCB it was equal to 5 ml/min; the conversion degree was more than 99%.

One other work on thermal processing of chemical waste by the plasma method was carried out by an English company EA Technology [9]. They used a plasma reactor with three electric-arc plasmatrons operating on three-phase alternating current with a frequency of 50 Hz. The total rated power on an arc was 50 kW. The reactor was steel, water-cooled, lined with alumina, and separated inside by partitions into several sections. The plasmatrons were installed in the first section of the reactor. The raw materials used were model chemical substances simulating harmful chemical waste, ethanediol, 1,1,1-trichloroethane, benzene-alcohol, 1,2-dichlorobenzene, oil refining waste, and polychlorinated biphenyls. Various technological regimes of the process were investigated, including steam supply to decrease soot formation. The raw material capacity of the plant was from 1.7 to 6.5 kg/h, energy expenditures ranged from 3.1 to 16.9 kW·h/kg, and the conversion degree was 99.9%. It is noted that the process of pyrolysis in the presence of steam is very efficient for the destruction of organochlorine compounds.

Concluding this survey of works, note should be made of the technological process PLASKON developed by the Australian company XIRO for processing of liquid toxic waste [10]. Unlike Westinghouse, which makes use of burners, PLASKON employs a plasmatron that operates on argon. The power of the plasmatron is 150 kW, and