USE OF HIGH ENERGY RADIATION IN DECOMPOSITION AND REMOVAL OF ORGANIC WATER POLLUTANTS

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The present review deals with the radiation chemistry of dilute aqueous solutions of organic substances emphasizing the possibility of use of high energy radiation in wastewater treatment. Effects of radiation on biodegradability, toxicity to water organisms and changes in molecules of solutes showing resistance to biochemical degradation and toxicity to water organisms are discussed.

Introduction

Many difficulties arising in wastewater treatment are caused by the presence of biologically hardly decomposable and toxic substances decreasing the efficiency of biological treatment. Solution of these problems by chemical pretreatment of wastewaters is often unsatisfactory and therefore other, although more expensive, ways of pretreatment or supplementary treatment of wastewaters are necessary to find. One of these ways is the use of high energy radiation (gamma-radiation, accelerated electrons).

The present review deals with the radiation chemistry of dilute aqueous solutions of organic substances and underlines the possibilities of use of high energy radiation in wastewater treatment.

Effect of high energy radiation on dilute aqueous solutions

During irradiation of aqueous solutions by high energy radiation a nonselective absorption of radiation takes place; the radiation interacts practically with all bound electrons of irradiated medium irrespectively of to which atoms the electrons belong. As a first approximation, we may state that the location of absorbed energy in individual components of the reaction mixture is proportional to their concentrations (mass fractions or electron fractions). Therefore, if a dilute aqueous solution is irradiated, the primary processes will predominantly be due to interactions of the
radiation with water molecules in which reactive intermediates $\cdot OH$, $H_\cdot$, $e^-_{aq}$ (in the presence of oxygen $H_2O_2$, $O_2$) and molecular products $H_2O_2$, $H_2$ arise. The effect of high energy radiation on dissolved substances is practically only indirect and caused by the action of reactive species formed in the radiolysis of water.

During continuous irradiation of a dilute aqueous solution at constant irradiation conditions, steady concentrations of water radiolysis species are formed (the rate of formation of active particles is equal to the rate of their decay). Thus, in first approximation, we may see the irradiated solution as a medium with constant concentrations of reactive particles reacting with the solutes. With gamma irradiation, concentrations of $\cdot OH$, $H_\cdot$, $H_2O_2$ radicals are currently in the range $10^{-7} - 10^{-14}$ mol · l$^{-1}$.

The choice of an energy source for the radiation treatment of wastewater is between a gamma-ray source of radioactive cobalt or cesium or an electron accelerator. An important characteristic of the gamma-rays from either $^{60}$Co or $^{137}$Cs is that they are highly penetrating. The half-value layer of water for $^{60}$Co gamma-rays is 27 cm, which means that a 27 cm layer of water decreases the intensity of radiation to one half. Practically, that means that at appropriate arrangement of irradiation facilities water stream of the thickness of 50–60 cm can be readily treated. On the other hand, the exponential character of the absorption process leads to the requirement of thick shielding for high-level gamma-ray facilities and concrete walls of 1–2 m thickness are commonly used. Electron accelerators in comparison with gamma-ray sources have several advantages ($10^6 - 10^7$ times higher dose rates, easier shielding possibility of immediate switching off, etc.) and practically one disadvantage, the very limited penetration of accelerated electrons (e.g., 10 MeV electrons have a practical limitation in thickness of water layer of about 3.5 cm). The high energy electrons are capable of producing chemical and physical effects similar to those produced by high energy rays.

Examples of changes in organic substances caused by irradiation of their aqueous solution

Selected organic substances described below, represent pollutants resistant to biodegradation and toxic to water organisms, respectively. Degradation and removal of such compounds from wastewaters is of great importance for the water treatment.

As the first example, the mechanism and products of radiolysis of aqueous benzene solution can be shown. Benzene is a biologically hardly decomposable substance and it is supposed that during biological degradation first of all its dihydroxylation must take place followed by oxidative opening of the aromatic ring. A study of irradiated aqueous benzene solutions showed that in reactions of benzene with $\cdot OH$ radicals...