EVALUATION OF BIOSORPTION OF TOXIC AND INHIBITOR AGENTS IN ORGANIC WASTES

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Abstract

Generally, biological utilization of organic wastes results in certain removal of contaminants as well, which become concentrated in the microbial biomass and is not degraded necessarily. However, controlled biosorption processes may be used for detoxification of the potential contaminants. Most research on microbiological degradation of chemical and biological contaminants has been performed in laboratory scale. There is a need to extend such studies to pilot scale as well as full-scale field applications.

Key words: organic contaminants, biosorption, kinetics.

INTRODUCTION

Contamination of the environment with potentially toxic chemical and biological agents is one of the major problems the industrialized nations face today. For example, petroleum industry produces high amounts of hydrocarbons and their derivatives thus it can be considered responsible for some air, soil, surface and underground water contamination. Many methods such as oxidation, precipitation, ion exchange, solvent extraction, enzyme treatment and adsorption have been used for removing both organic and inorganic materials from aqueous and non-aqueous solution. Organic compounds can be modified by either physico-chemical or biological processes. Diverse metabolic capabilities of microorganisms have been applied in many ways in the biodegradation of waste materials. (Okpokwasili et al., 1986).

The potential of microbes as detoxification agents for certain toxic compounds, thus indicates a major promising alternative as biological treatment to attenuate environmental impact caused by pollutants (Nwaeke and Okpokwasili, 2003). Many scientific approaches have been used in the *in situ* and *ex situ* bioelimination of organic contaminants. However, the extent of elimination is critically dependent on salinity, temperature, pH, heavy metals, surfactants, nutrients and the presence of readily assimilable carbon sources (Amanchukwu et al., 1989; Okpokwasili and Odokuma, 1990; Okpokwasili and Nnubia, 1995).

A variety of microbial growth and biodegradation kinetic models have been developed, proposed and used by many researchers (Simkins and

Alexander, 1984, 1985; Schmidt et al., 1985). Such models allow prediction of concentrations of potential inhibitors that sometimes remain present, calculation of time required to reduce chemicals to a certain concentration at a certain point (e.g. in case of aquifer, soil or surface water), and design of *in situ* or *ex situ* bioelimination schemes to remove toxic or inhibitor agents to a required concentration. On the other hand, it can be used to predict the amount of biomass production achievable at a given time.
This review gives an overview of the kinetic models applied in the prediction of microbial growth and degradation of organic substances. Interactions such as substrate inhibition through biosorption during organic waste degradation are also discussed.

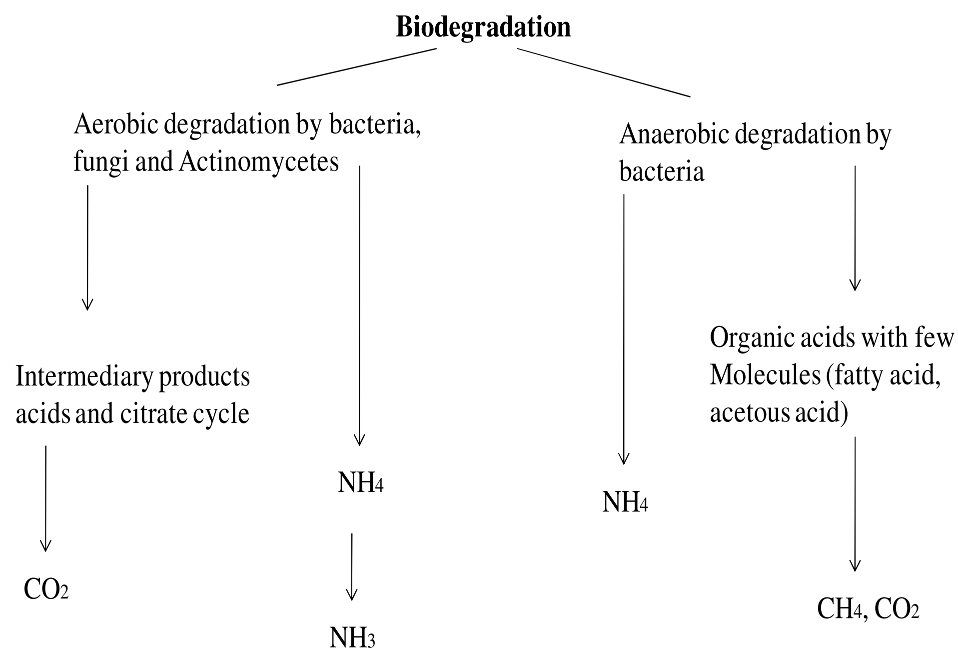

Fig. 1. Scheme of biodegradation (Kocsis, 2005)

MATERIALS AND METHODS

The chemistry compounds applied to the inhibition of the mycotoxins in the past years have brought up different scruples, as a result of which the examination of the obstructive effect of the natural compounds began. Among the examined natural substances we can find e.g. (yeast cell wall, lemon seed abstract). (Oppenheim and Chet 1992, Nguyen-the and Charlin 2000, Kraus and Johanson 2000) Reflecting on these facts I sum up a scientific point of view dealing with the topic in some decades.

DISCUSSION

Apart from fungal and fungoid artefacts, application of bacteria – *Bacillus thuringiensis, B. subtilis, Pseudomonas sp.* – is also being tested in outdoor growing (Goldman et al.,1994; Thomashow, 1996; Bacon et al., 2001).

In case of certain vegetables or fruits for the inhibition of reproduction of human pathogen bacteria (*Salmonella spp., Listeria spp.*) application of lactic acid bacteria appears to be a suitable solution, since they are among the constituents of the natural microbiota of much food , several pathogens are successfully inhibited by them and they have a favourable effect on the human organization, as well. (Leverentz et al., 2003). The inhibitory effect mechanism of yeasts is often explainable with the competition over nutrients and habitats. It is supported by an observation in which the cells of yeast fungi proliferate rapidly on the surface of the injuries (Petersson, 1998), so that they can occupy the place preceding other microorganisms. Additionally, more authors report that there is relation between the concentration of yeast cell and its inhibitory efficiency: in case of high cell count (10^7-10^8 cells/ml) yeast suspension, inhibition may be experienced to a larger extent. (McLaughlin et al., 1990; Piano et al.,1997).

Newer research area is the examination of killertoxin inhibitor effect of yeast in mold fungi (Petersson, 1998; Björnberg and Schnüre, 1993). According to the observation of Walker and his colleagues (1995) Saccharomyces cerevisiae and Pichia anomala species had an antifungal effect on more plant and human pathogenic fungi.

Nevertheless, toxicity measurements require bioassays, which are always very difficult and tedious. Therefore, efficacy of biodegradation is based on chemical measurements, e.g. disappearance of parent molecule, appearance of mineralization products or disappearance of other compounds used stoichiometrically during biodegradation of a compound, for instance, electron acceptors. There are several scenarios by which a compound can be transformed biologically. This includes when the compounds serve as:

(1) Carbon and energy source
(2) Electron acceptor
(3) Source of other cell components.

Other scenarios are the transformation of a compound by non-growing cells (the compound does not support growth) and the transformation of a compound by cometabolism, that is; transformation of a compound by cells growing on other substrate.

The simplest case is where the compound serves as source of carbon and energy for the growth of a single bacterial species. The compound is assumed to be water-soluble, non-toxic and other substrates or growth factors are limiting. In the case of single-substrate limited process, the Monod equation is often used to describe microbial growth and biodegradation processes.

$$q = \frac{q_{\max} S}{K_S + S} \qquad \mu = \frac{\mu_{\max} S}{K_S + S}$$

where μ = specific growth rate, q = specific substrate utilization/removal rate, and μ = Yq, with Y = true growth yield [mass of biomass (X) synthesized per unit of substrate (S) utilized or removed], S = aqueous phase concentration of the compound, Ks = affinity constant or half saturation constant for the compound (meaning the concentration of compound when m or q is maximum).

The hyperbolic equation proposed by Monod was modified by Lawrence and McCarty (1970) to describe the effects of substrate concentration (S) on the rate at which a given microbial concentration (X) removes the target substrate (-dS/dt). Alternatively, Monod equation can be written in terms of microbial growth by incorporating the net yield coefficient (Y).

$$\frac{dS}{dt} = \frac{q_{\max} SX}{K_S + S}$$

$$\frac{dX}{dt} = -Y\frac{dS}{dt} = \frac{Yq_{\max} SX}{K_S + S}$$

The Monod equation has frequently been simplified to an equation, which is either zero or first order in substrate concentration and the kinetics, has been widely used to describe biodegradation of organic contaminations in aquifer systems (Alvarez et al., 1991, 1994; Borden and Bedient, 1986; Chen et al., 1992; Widdowson et al., 1988). The versatility of Monod's equation is attributed to its ability to describe biodegradation rates that follow zero- to first-order kinetics with respect to the concentration of the target substrate. Moreso, Monod's model describes the dependence of biodegradation rate on the concentration of biomass.

CONCLUSIONS

This review highlighted microbial utilization of, and growth on, organic chemicals. It examined the various kinetic models applied in the prediction of microbial removal of organic contaminants from the environment. It shows that the success of any treatment protocol depends on optimization of several controlling factors and this is only possible through modelling of the factors that determine process rate. The ability to model these processes is desirable in order to facilitate understanding and management of contaminated sites and industrial effluents.

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