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Project Summary

Available Models for Estimating Emissions Resulting from Bioremediation: A Review

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The use of bioremediation processes to treat hazardous waste has increased in the last 10 years. Biological treatment offers the advantage of contaminant destruction rather than transfer to other media. There is concern, however, that significant amounts of organic pollutants are emitted to the air from biological treatment facilities before they can be degraded. To estimate the magnitude of emissions from these facilities, overall fate models that incorporate the effects of several competing removal mechanisms are needed.

This report focuses on the state-of-the-art in modeling air emissions from bioremediation processes. The biological treatment systems are described, as are the important pathways that affect the fate of organic pollutants in those systems. Currently available models are identified, described, and evaluated for each bioremediation process. Finally, some limitations of the models and the need for further research are discussed.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Biological treatment of organic pollutants offers the advantage of contaminant destruction rather than transfer to other media. Thus, biotreatment systems may provide the potential to reduce or eliminate the human health risks associated with the treatment and/or disposal of hazardous wastes. However, concern has grown in recent years that many volatile organic pollutants are emitted to the atmosphere from biotreatment facilities before they can be degraded. In response to the increased attention, a number of models have been developed that predict the fate of organic pollutants during specific bioremediation processes.

The full report focuses on the potential for bioremediation processes to transfer contaminants between the soil or water and the air. The intent is to identify, describe, and evaluate available methods and models for estimating atmospheric emissions from bioremediation processes used to treat hazardous waste. Models that consider only volatilization will tend to overpredict the magnitude of air emissions from bioremediation processes. Therefore, this report concentrates on models that incorporate the competing effects of biological activity, volatilization, and possibly other mechanisms, such as adsorption and transport, on the fate of organic pollutants. Models of some non-biological components of the treatment processes also are included. Bioremediation processes that are currently in use or in advanced stages of research are listed in the final report, where each process is briefly described in terms of its operation and component parts, the types of contaminants treated, advantages and disadvantages associated with its use, and the likelihood of air emissions.

An extensive literature search was conducted to locate models that simulate the fate of organic pollutants for each biotreatment process. Summaries of the models located during that search make up the bulk of this report. Models are summarized in terms of their theoretical basis, assumptions, and the mechanisms of transport and fate that are considered. Input requirements, output, previous model applications, resource requirements, ease of use, and model availability also are discussed briefly. Air emissions from some biotreatment processes have not been modeled. For those processes, the current status of research is discussed. In addition, the status of modeling two physical remedial processes (i.e., soil washing and soil venting) often used in conjunction with bioremediation efforts is briefly addressed.

A chapter in the full report describes the important pathways by which pollutants are transferred from a waste treatment site. Generally accepted theories associated with each pathway are briefly summarized. In addition, when *possible, methods* of estimating equilibrium and rate constants are presented.

Current efforts to model the fate of hazardous compounds at biological treatment facilities suffer from a number of limitations that should be understood by users of the models described in the full report. These limitations and the related need for further research are discussed in the final section of the full report.

Conclusions and Research Needs

In order to estimate the magnitude of emissions from biological treatment facilities, overall fate models that incorporate the effects of several competing removal mechanisms are needed. Although such models have been developed for some bioremedial processes, no models exist for other processes. The models that are available are of limited utility both because of limited laboratory and field data and because of the assumptions made in developing the models.

Conclusions drawn from this report are:

1) Models of bioremediation processes are empirical. Data are unknown or incomplete and the interrelationships of components and pathways are complex. Moreover, at wastewater treatment facilities, the concentrations of hazardous organics can vary by several orders of magnitude on a daily basis. Thus, the release of organics to the air or other media from bioremediation sites is difficult to estimate.
2) There is a correlation between operational experience with a biotreatment process and the state-of-the-art in modeling that proces. No models exist for some innovative new processes, such as the composting of hazardous materials. For some wastewater treatment processes, only models of substrate removal exist. On the other hand, many models have been developed to describe the fate of pollutants in some commonly used treatment processes, such as landfarming. Most of the models identified for this project are analytical models based on a mass balance approach. Some more complex numerical models also are reviewed.
3) Among the suspended-growth systems, a number of models have been developed to describe activated-sludge aeration tanks and surface impoundments. Biodegradation, adsorption, and volatilization and/or stripping are the removal mechanisms considered. Most of the models describe steady-state, completely mixed conditions. Few models of sequencing batch reactors or of powdered activated carbon treatment are available.
4) No models have been produced to simulate the emission of specific organic pollutants from fixed-film biologiical treatment systems. Most available models reflect a concern for substrate removal, in terms of biologocal oxygen demand (BOD). Under some conditions, estimates or measurements related to the mass transfer of oxygen can be used to approximate air emissions fom these systems.
5) Among soil-incorporation systems, land treatment facilities have been modeled most. The fate mechanisms included in the models include biodegradation, diffusion and volatilization, adsorption and solute transport. The models are non-steady-state and ouput is generated for specified times. No mathematical models exist to describe the composting of hazardous materials. One model simulates biodegradation of organic vapors in a soil treatment bed.
6) A number of models predict the fate of organic pollutants in the subsurface under natural conditions. The unsaturated-zone models are not designed to simulate *in situ* bioremediation, which often includes air sparging to stimulate microbial growth. While some of the saturated-zone models can be applied to *in situ* bioremedial efforts, they cannot be used to dirctly estimate air emisions. Pollutant vapors escaping from a contaminated aquifer must pass through the unsaturated zone. Thus, the likelihood and *magnitude* of air emissions from the saturated zone must be modeled using an unsaturated zone model with a pollution source term supplied at the water table boundary.
7) The biodegradation of organics in biological treatment facilities is poorly understood and limited data are available to estimate the biodegradation rate constants for compounds of interest. In addition, data generated in laboratories may vary greatly from field study data. Thus, reported values should be used with caution and experimentally verified when possible.
8) Suspended-growth system modeling results have been shown to be very sensitive to the values of the biodegradation parameters. Thus, when accurate information about biological activity is not available, modeling studies should use a range of values, including zero, for the biodegradation rate constant. By ignoring biodegradation, estimates of air emissions under "worst-case" conditions (e.g., periods of acclimation or of inactivity due to toxic shock) are obtained.
9) Most of the models summarized in this report have not been validated in the field. When predicted model results are compared to laboratory or field data, many authors report agreement within an order-of-magnitude. That level of agreement is generally considered adequate for screening purposes. Because of the many assumptions incorporated into the models, they should be used with caution for detailed site-specific studies.
10) To be able to adequately predict air emissions from biological treatment facilities, further research is needed in several areas. More collection of field data is needed, both in order to understand the severity of the problem and in order to aid in model development and validation. An improved understanding of the kinetics of biodegradation in multi-

component heterogneous systems is needed. For some processes, first-generation fate models have yet to be developed. For other processes, the capabilities of the current models could be expanded.

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The complete report, entitled "Available Models for Estimating Emissions Resulting from Bioremediation Processes:A Review," (Order No. 90-228 610/ AS;Cost: $31.00 subject to change) will be available only from:
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