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Project Summary

User's Manual for the Plume Visibility Model (PLUVUE II)

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This publication contains information about the computer programs for the Plume Visibility Model, PLUVUE II. A technical overview of PLUVUE II and the results of model evaluation studies are presented. The source code of PLUVUE II, as well as two sets of input and output data, are provided. This model is based on Gaussian dispersion assumptions, chemical reactions of plumes in nonurban atmospheres, light-scattering and absorption characteristics of aerosols and gases, and radiative transfer along different lines of sight. PLUVUE II differs from the original Plume Visibility Model (PLUVUE) in that it contains an improved treatment of multiple scattering of light by aerosols and it incorporates light absorption by carbonaceous aerosols. PLUVUE II is applicable to assessing visibility impairment due to pollutants emitted from well-defined point sources.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, 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

This report provides documentation of the Plume Visibility Model, PLUVUE II, developed by Systems Applications, Inc., for the U.S. Environmental Protection Agency (EPA). The model can be used to predict the effects of a single emission source on atmospheric visibility, such as reduction in visual range and atmospheric discoloration. PLUVUE II, a refinement of the original Plume Visibility Model, PLUVUE, now includes an anisotropic treatment of the multiple-scattered radiance field and light absorption by carbonaceous aerosols.

The user's manual presents a technical overview of the model, a summary of model evaluation results, and descriptions of the input and output data. In addition, a flow chart of the computer source code, a listing of the computer source code, and listings of input and output data for two sample simulations are provided.

Technical Overview

PLUVUE II is a computerized mathematical model that describes emissions of pollutants from a single point source, atmospheric transport and diffusion, surface removal, chemical reactions and transformations of pollutants, light-scattering and absorption characteristics of aerosols and NO_2, and radiative transfer along different lines of sight.

Transport, Diffusion, and Removal Processes

The plume rise and initial dilution of a plume from the top of a stack to the point of final plume rise are modeled according to the mathematical formulas developed by Briggs. The transport of the plume by advection is treated by means of a mean wind velocity that is constant with time. The wind velocity at plume height is either input or calculated by means of a power-law relationship from an input surface wind velocity. The turbulent diffusion of the plume material is described by means of a Gaussian model that uses either Pasquill-Gifford-Turner dispersion coefficients, TVA dispersion coefficients, or input dispersion coefficients. A constant mixing height is input to the model and considered in the vertical plume diffusion calculations. Surface deposition of gases and

gation of regulations and guidance at the federal level and in more than 20 states concerning the land application of municipal sludges and effluents. In addition it has, over the past ten years, led to the use of land application for treatment and disposal of municipal wastewater and/or sludge at more than 1000 sites each nationwide.

Workshop Highlights

Significant developments in land treatment since 1973 and future research in each workshop are briefly identified below.

Engineering Systems

- Land Application is a viable, environmentally sound, and cost-effective technology for both wastewater and sludge disposal. More than one-thousand wastewater land treatment systems are currently in operation; a similar number in various stages of planning are expected to be in operation within the next decade.
- Land treatment is not just a disposal process, but rather a component in the total treatment system. This total systems approach allows rational engineering designs to include appropriate provision for pollutant removal within the soil-plant ecosystem. Wastewater treatment is the primary goal of a land treatment system.
- When properly designed and operated, the reliability and peformance of municipal land treatment systems are equal to or greater than other conventional practices. They are dependable in all climates and geographical areas of the nation.
- Information developed since 1973 permits the design of systems that meet existing water quality criteria.
- Major information gaps exist in the following areas: post-construction performance evaluations and cost documentation of existing land treatment systems; design criteria for application of municipal wastewater and sludge to forest ecosystems; and heavy metal loading criteria in terms of regional considerations and long-term sludge loadings.

Management Considerations in Wastewater Use

- Land treatment systems are now being successfully operated throughout the world. Infiltration rates, nitrogen leaching and crop response, and runoff, among other potential problems, can be controlled through proper engineering operation and management.
- Soils and climates have been characterized as to their suitabilities for various land treatment systems.
- Adequate information is available for slow rate systems to assess crop selection, response, and management; erosion control; loading rates; heavy metal, suspended solids and phosphorus retention; quality criteria for irrigation use; and decomposition of most of the organic materials in the wastewater. (Some synthetic organics are exceptions.)
- Adequate information is available for rapid infiltration systems to determine retention of suspended solids, reduction in biochemical oxygen demand and heavy metal loadings.
- There is a general need for more technology transfer and the training of managers of land treatment systems.
- Mathematical models of slow rate and rapid infiltration systems have been developed but must be verified by field data so that they can be used to maximize efficiency and reliability of wastewater treatment systems.
- A major research need is the risk assessment of potential pathogens associated with land treatments, as opposed to risks associated with conventional municipal wastewater treatment systems. Also required are long-term studies of ecosystem dynamics both on-site and off-site, of renovative efficiency in relation to site aging; and of ecosystem collapse and recovery in a system not properly operated.

Management Considerations in Sludge Use

- Guidelines have been developed to enable the environmentally safe use of sewage sludge containing median concentrations of metals and organics when the sludge is applied at agronomic rates based on nitrogen or phosphorus utilization rates by crops. Sludge can be successfully used as a substitute for conventional fertilizer, especially phosphorus and, to a lesser extent, nitrogen.
- Current guidelines for the cumulative application of copper, zinc and nickel are safe but should be re-assessed to account for regional differences in soil characteristics.
- Concentrations of synthetic organics in sludges are generally low but high concentrations may exist in some sludges. Most synthetic organics decompose in soil. Current federal regulations for PCBs in sludges are adequate to protect animal health.
- Groundwater monitoring for nitrate-nitrogen is not needed where sludge nitrogen additions do not exceed fertilizer nitrogen recommendations for the crop grown.
- Utilization of sludge for reclaiming disturbed land at rates higher than those for agricultural land, when properly implemented and managed, does not degrade the quality of soils, groundwater or vegetation.
- Major information needs for the agricultural use of sludge include: determination of the availability of metals to plants following termination of sludge applications; development of models to predict and further refine nitrogen behavior in sludge-amended soils with emphasis on ammonia volatilization, organic nitrogen mineralization and denitrification; and, for organic chemicals, determination of the factors affecting their decomposition, mobility, fate, and potential accumulation in plants and animals.
- Major information needs for the application of sludge to forest land include: the quantitative determination of nitrogen cycling in forest ecosystems; development of data required to establish criteria for site selection, metal limits, and for runoff leachate quality. Improved application and management techniques are also needed.
- For land reclamation, methods are needed to maintain vegetative cover and to identify the plant species that are most responsive to relatively high loading rates of sludge and tolerant of adverse conditions of disturbed land.

Public Health and Risk Assessment: Pathogens

- With proper management and safety allowances based on research data, land application is a safe, beneficial and acceptable alternative for municipal wastewater and sludge.
- As of the time of the workshop, in the U.S. there were no known outbreaks of infectious disease attributable to

land application of wastewaters and sludges.

- Major improvements in monitoring methods, especially in the virus area, have been achieved. Data generated since 1973 provided the scientific bases for criteria at the federal level.
- In terms of current detection capability, federal sludge disposal criteria are adequate to protect public health from pathogenic microorganisms. Data currently being generated will provide guidance to any consideration for relaxation of the ciriteria. Criteria and management guidance based upon geographical considerations is warranted.
- Although some major research needs identified in 1973 are still pending, research priorities have changed. For example, epidemiological studies no longer remain a high-priority research need.
- For bacteriology, information needs include: survival and growth of pathogens, improvement of detection methodology and virulence assessment, effectiveness and mechanisms of treatment processes, relevance of current indicators and movement through soils.
- For parasitology, the needs include: pathological effects of repeated, low-level ascarid infections; virulence of swine vs. human ascaris; potential pathological significance of naegleria and similar organisms in waste-treated soils, and survival of ascaris ova in sludge-treated soils.
- For virology, the needs include: site monitoring studies of survival and movement of viruses in a wide range of climatic, hydrologic, and waste conditions; effectiveness of sewage treatment processes before and during land application, and methodology to detect hepatitis A, Norwalk agent and rotaviruses.

Public Health and Risk Assessment: Organics and Inorganics

- No longer are there serious gaps in knowledge of the human health impact of organic and inorganic contaminants in municipal wastewater and sludge applied to land.
- At annual application rates of less than 15 mt/ha of sludge of medium composition, where reasonable drainage and a cyclic establishment of sustained aerobic soil conditions occur, and where groundwater remains deeper than 0.3 to 0.7 meters from the soil surface, leaching of metals and organics should pose little or no threat to groundwater resources. However, adjustments may be necessary because of site-specific conditions.
- Wastewaters should not be chlorinated before high rate application to land, since precursors to halogenated organics may form.
- Except for cadmium, heavy metals are not expected to create a human health problem in sludge-amended soils.
- In view of the substantially better data base today, an international panel should re-evaluate 1972 recommendations of the WHO/FAO on limits for cadmium intake by humans.
- More research is needed on the factors affecting migration of organics through various soils and their decomposition in groundwater.

Political and Institutional Constraints

- Research conducted in the past decade has provided information needed to establish federal, state, and local guidelines and regulations; to identify and resolve design problems and operational constraints and to identify and resolve general concerns.
- Land treatment information should be provided to the general public in an understandable form to allay health fears.
- Unqualified assurance of no risk cannot be provided, but assuming good management for a given situation, assurance can be given that land application of sludges and wastewaters can be accomplished with minimum risk.
- Federal regulations should contain minimum standards for key health parameters, require public notification of noncompliance as well as good management practices, require consideration of reasonable alternatives for management of wastewaters and sludges, and provide sufficient flexibility to permit state and local agencies to combine environmentally sound and socially acceptable management practices for their own unique social, political, and physical situations.
- Public acceptance can be improved by involving elected officials and opinion leaders in decision making, and continuing education and communications programs for all affected groups and individuals.
- Major research needs include: risk assessment data for pathogenic organisms and organic contaminants in wastewater and sludges; land treatment system case studies and follow-up studies; a need also exists for a federal interagency sludge task force and for better communication between universities and municipalities.

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