

Environmental Conditions and the Fate and Transport of Microorganisms in Biosolid- Amended Soil

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ABSTRACT

The treatment of human wastewater is intended to prevent/reduce the dissemination of contaminants into the environment and preserve the quality of receiving surface and ground waters. The solid product of wastewater treatment is termed biosolids, which contains any residual toxic chemicals and pathogenic microorganisms. Methods of biosolids disposal include incineration, landfill deposition, and land application as a soil amendment. Although amending soil with biosolids provides nutrients for agricultural production, the process also potentially releases pathogenic bacteria, viruses and parasites into the environment. Assessing the health risk associated with amending soil with biosolids would require characterizing the pathogen occurrence and exposure profile through determining the fate and transport of the pathogenic microorganisms released into the environment. In the effort to understand the potential risk, indicator organisms (specifically *Escherichia coli* 11775, *Clostridium perfringens* 12917 and bacteriophage virus Φ X174) for pathogenic microorganisms were seeded into soil amended with biosolids in the controlled environmental conditions of a combination windtunnel lysimeter to monitor the fate and transport of the indicator organisms through the soil, water and air. The soil was irrigated with 2.5 cm of water at 2-day intervals and lysimeter soil and windtunnel air were sampled the subsequent day. Lysimeter samples were extracted with a soil core at 5-cm depths and analyzed for microorganisms and soil moisture content. The windtunnel air velocity was increased from 40 m³/min (~1.5 mph) to 100 m³/min (~4.0 mph) and air samples to be analyzed for microorganisms were taken with aerosol impinger samplers. Comparing the analytical results with the meteorological data indicated that the air temperature and relative humidity effect on the soil temperature and water content affects the viability and transport of the microorganisms. No microorganisms were detected in the air which indicated that due to the meteorological effects the aerosols contained no viable microorganisms or the environmental conditions were not suitable for creating bioaerosols.

INTRODUCTION

The treatment of human wastewater, intended to prevent/reduce the dissemination of contaminants into the environment and preserve the quality of receiving waters, produces biosolids which contains any residual toxic chemicals and pathogenic microorganisms removed from the wastewater. Land application as a soil amendment is a method of biosolids disposal which can provide nutrients for agricultural production; however, the process also potentially releases pathogenic bacteria, viruses and parasites into the environment. The health effects of occupational exposure to the pathogenic microorganisms in biosolids produces symptoms of fever, malaise, and upper respiratory irritation called "sewage workers syndrome". Although information exists on the environmental effects of biosolids, there remains a limited amount of research on the fate and transport of pathogenic microorganisms in biosolids applied to land.

HYPOTHESIS

If soil is amended with domestic biosolids containing indicator microorganisms for potential pathogens in controlled environmental conditions then will the microorganisms remain viable and be transported through the soil and air.

OBJECTIVES

•Compare the soil and meteorological data with the detected quantities of microorganisms in the biosolid-amended soil to determine the environmental effects on microorganism viability.

•Compare the soil and meteorological data with the detected quantities of microorganisms in soil and air samples to determine the environmental effects on microorganism transport through the soil and air.

MATERIALS AND METHODS

WINDTUNNEL LYSIMETER

Windtunnel lysimeter tests included experiments to assess the potential to aerosolize microorganisms and sample the bioaerosols. The windtunnel lysimeter configuration consists of an aerosol chamber (2.4 m x 0.8 m x 1.2 m) above the lysimeter (0.5 m² surface area and 0.8 m depth) with a 350 m³/minute capacity high-velocity air circulation fan (FIGURE A).

SOIL AND AEROSOL SAMPLES

Point source experiments consisted of spraying 1.0-liter solution of artificial irrigation water containing *Escherichia coli* 11775, *Clostridium perfringens* 12917 and bacteriophage Φ X174 aerosolized at 120 ml/minute inside the windtunnel with an average air velocity of 85 m/minute. The air impinger sampler was positioned 90 cm below and 3.0 m downstream of the point source solution discharge and aerosolized microorganisms were collected in a 20-ml volume of impinger solution with an AGI-30 glass impinger at a sampling rate of 12 l/minute for 10 minutes at the discharge of the windtunnel aerosolization chamber.

After the initial point source test, the windtunnel lysimeter testing began with the microorganisms seeded into the lysimeter at 15-cm depth containing ~85 Kg loam soil (volume of 7.5x10⁴ cm³) amended with 1.0% w/w biosolids seeded with indicator microorganisms. An irrigation volume of 2.5 cm of water was applied on days 1, 3, 5, 8, 10, 12, 15, and 18 with the soil and aerosol sampling occurring the subsequent day. The windtunnel fan operated at 40 m³/minute (~1.5 mph) continuously to maintain comparable environmental conditions inside the aerosol chamber and at 100 m³/minute (~4.0 mph) during aerosol sampling events. The aerosol chamber was sampled for microorganisms with the AGI-30 glass impinger using protocols previously established during the point source experiments. Aerosol samples were collected at 0, 60, and 120 minutes with 0 minutes corresponding to the initiation of the increased air velocity in the aerosol chamber. The lysimeter soil was core sampled at 5-cm depths.

SAMPLE ANALYSIS

The aerosol and soil samples were promptly analyzed for the microbiological and physical characteristics. The aerosol samples were not concentrated but the impinger solution was analyzed for microorganisms with the appropriate detection methods. Point source microorganism aerosol data were analyzed with a Gaussian dispersion model to verify windtunnel aerosol and dispersion capability (FIGURE B). The soil samples were analyzed for soil moisture content by gravimetric methods and for microorganisms with the appropriate detection methods.

RESULTS AND DISCUSSION

•**Point Source Aerosols:** Comparing Impinger sampling and Gaussian Dispersion model results from microorganism point source aerosols indicate the windtunnel conditions are suitable for aerosolizing and sampling microorganisms from a point source (FIGURE C).

•**Lysimeter Area Source Aerosols:** No viable microorganisms were detected in aerosol samples generated from the lysimeter as an area source for aerosols.

•**Environmental Conditions:** A comparison of results from air- soil conditions and microorganism viability indicate air temperature affected the soil temperature and moisture content which influenced the viability of the microorganisms in the soil. These conditions may have affected the ability to aerosolize microorganisms from the lysimeter soil as an area source for bioaerosols (FIGURE D).

•**Soil Microorganism Transport:** The results indicate the microorganisms did not infiltrate greater distance than the initial seeding depth of ~15 cm. This may be due to an insufficient amount of water being applied to the soil surface. An observation can be made about the detected quantity of each type of microorganism and soil moisture content. For example, the quantity of *E. coli* fluctuated with the soil moisture content while the quantity of bacteriophage Φ X174 progressively decreased regardless of the soil moisture. This may be due to regrowth and die-off of *E. coli* when compared to the die-off of Φ X174 which would not replicate without a host organism (FIGURES E,F,G).

•**Future Research:** Additional research will be required to determine if altering environmental conditions such as different soil, increased irrigation rates, and increased air velocities will increase the potential to maintain microorganism viability and potentially transport microorganisms in the soil and air.

Windtunnel Lysimeter

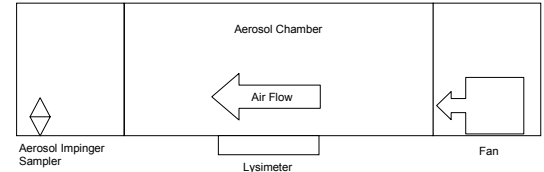


FIGURE A

Gaussian Dispersion Model

$$\chi = \left(\frac{bQ}{2\pi u \sigma_y \sigma_z} \right) \left[\exp\left(-\frac{y^2}{2\sigma_y^2} \right) \right] \left[\sum q_i \exp\left(-\frac{(H - V_{zi} x)^2}{2\sigma_z^2} \right) \right] \exp(-\lambda x)$$

FIGURE B

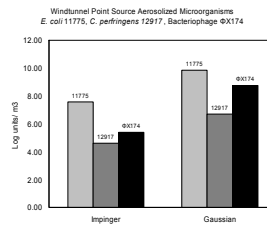


FIGURE C

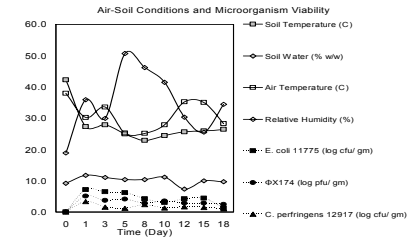
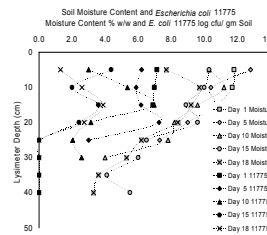


FIGURE D



FIGURES E,F,G

