Wastewater Sludge as a Resource

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Evaluation of the potential for bioaerosols from land applied biosolids

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Abstract. The overall objective of this study was to quantitatively and qualitatively document the potential hazards of biological aerosols derived from land applied biosolids, and ultimately develop risk assessment models and land-management strategies for safe, effective use of biosolids. The specific objectives were: i) Quantify bacterial and viral microorganisms emitted as bioaerosols from point sources of biosolids, and area (land-applied) sources of biosolids; ii) Develop risk assessment models based on a) hazard identification, b) dose response, c) exposure assessment; d) risk characterization. Research has consisted of laboratory studies at the University of Arizona and field studies at several regional U.S. locations. Bioaerosol samples have been collected via "Impingement" using SKC biosamplers. The biologicals monitored for included: i) viruses: enteroviruses, calciviruses; ii) phage e.g., MS2; iii) *E. coli*; iv) *Salmonella*; v) total coliforms; vi)*Clostridium perfringens*; vii) *Aspergillus spp.*; viii) Endotoxin. Air samples were collected at discrete distances from both biosolid piles (point sources), or land applied biosolids(area sources).
Keywords: Bioaerosols, biosolids, land application, pathogens

Introduction

Approximately 65% of all processed sewage is ultimately land applied as biosolids in the United States. Biosolids are generally classified with increased treatment processing as "Class B" or "Class A." Of these categories, "Class A" biosolids can be reused with few restrictions. For "Class B" biosolids, which normally contain human pathogenic microorganisms and heavy metals of variable concentrations, there are usually site restrictions placed on biosolid-amended soils, depending on the proposed future use of the site e.g., grazing or agriculture. However, clearly the potential exists for biological aerosols and odors to be emitted from biosolids that bypass site restrictions.

Because of the potential for disease transmission via aerosolized microbial pathogens, determining the risk associated with field-placed biosolids is important. An early study by Pahren and Jakobawski (1980) documented the relationships between land application of biosolids and aerosolization of pathogens. Recent studies by Dowd et al. (1997) and Pillai et al. (1996) have documented that under proper biosolid-management practices, the likelihood of airborne transport of microbial pathogens into population centers is extremely low.

Dowd et al. further assessed the potential bioaerosols in a later study using a modeling approach (Dowd et al., 2000). However, to date very few data are available on the incidence of human pathogens as aerosols, particularly enteric viruses.

The overall objectives of this study were to quantitatively and qualitatively document the potential hazards of biological aerosols derived from biosolids, and ultimately develop risk assessment models and land-management strategies for safe, effective use of biosolids. Specific objectives are: i) Quantify bacterial and viral pathogens emission rates of bioaerosols during land application of biosolids; ii) Characterize fate and transport, and perform risk assessment analyses; iii) Analyze emission rates from different land application methods, including spraying, spreading and slinging. The information gained with respect to aerosolization will be used to minimize emissions through management practices.

Materials and Methods

Sites and land application procedures

i) Marana and Eloy, Arizona. Spraying method: Bioaerosols were sampled during operation of a Betterbuilt© spray tanker with a carrying capacity of 4250 gallons. The tanker was operated at a continuous speed of 3 mph. Class B anaerobically digested liquid sludge was sprayed at a height of 3' off the ground approximately 6' into the air with a 13.5' width spray. On average the biosolids were between 6 and 7.5 % solids. Spray operations were conducted on cotton fields in Marana, AZ and Eloy, AZ.

ii) Mohave County, Arizona. Slinging method: Bioaerosols were sampled during operation of a Pro Twin slinger. The slinger was loaded with Class B biosolids (20–25% solids) using a front end loader. The slinger flung the biosolids in small clods approximately 100 feet at a height of approximately 50 feet. Slinging operations were conducted on cotton fields in Mohave County, Arizona.

iii) Solano County, California. Spreader method: Bioaerosols were sampled during operation of a manure spreader in Solano County, CA. The manure spreader was loaded with Class B biosolids (20-25% solids). The spreader flung the biosolids in large clods approximately 15 feet in each direction, behind the path of the truck at a height of approximately 3 feet. Spreading operations were conducted on cow pasture in Solano County, California.

Bioaerosol sampling procedures

AZ samples. For emission rate and transport studies, sampling was carried out while the spray tanker truck was in operation, beginning approximately 2 min prior to exposure to biosolids applied from the tanker truck. There was then a 15–20 sec exposure from the tanker truck followed by 17.5 min of downwind sampling for a total of 20 min. Bioaerosols were impinged into 0.1% peptone amended with antifoam agent using six SKC Inc Biosamplers ©. Samplers were placed at a height of 1.5 m corresponding to the average human breathing height. All samplers were calibrated to be operated at a continuous rate of 12.5 L/min using SKC Inc Vac-U-Go © sampling pumps. The samplers were placed parallel to the truck spray path at a downwind distance of 1.8, 3.2, and 10 m from the sprayed area. For aerosol emission rates, samplers were placed 2m from application sites at heights of 1 or 2 m. Background samples were taken prior to the land application process, or at a site off field following land application. Following the sampling procedure, each sample was sealed, placed in an ice cooler, and transported back to the laboratory for subsequent analysis. All assays were conducted within 8 hours of sampling. Atmospheric conditions were also observed including relative humidity, ambient temperature, and wind speed.

Mohave, Arizona and Solano County, California samples. Sampling was carried out during operation of the slinger, and the hopper respectively, beginning approximately 2 min prior to exposure. Two trios of samplers were placed parallel to the spreading path at downwind distances of 2m and 5 m from biosolid terrain impact. Downwind samples were also collected during operation of the front-end loader and during dump-truck unloading. These samples were collected at distances of 2m and 20m downwind of these activities. Along with downwind samples, background and upwind samples were also collected with background samples being collected off site. All samples were placed in ice coolers and shipped overnight on ice to the laboratory for subsequent analysis. All assays were conducted within 24 hrs of collection.

For emission rate studies, six samplers were utilized 2m from the application site. All 6 samplers were placed at either 1m height or at 2m height.

Assays

Detection of organisms.

1. Coliphage was detected using the standard plate overlay method using *E. coli* 15597.
2. Total Coliforms and *E. coli* were detected using the Colilert system.
3. *Clostridium perfringens* was detected using m-CP media and Sheep Blood Agar for presumptive confirmation.
4. *Staphylococcus aureus* was assayed on Sheep Blood Agar plates. Isolates that were gram positive cocci, catalase positive, coagulase positive, slide coagulase positive and resistant to polymyxin B would be considered as *S. aureus*.
5. Heterotrophic Plate Counts (HPC) were assayed using R2A agar employing the standard spread plate method.
6. *Aspergillus* spp. were detected using Sabaroud's Dextrose agar and Czapek Agar amended with chloramphenicol followed by microscopic identification using lactophenol blue tape mounts.
7. Viruses including Norwalk-like Virus, Hepatitis A Virus, and Enteroviruses are being analysed via Polymerase Chain Reaction.

For emission rate studies, assays for organisms present in the biosolids at the highest concentrations were used i.e., total coliforms on m-endo media; coliphage and heterotrophic plate counts.

Results and Discussion

Summary figures of emission rates from all three sites are shown in Figures 1 and 2.

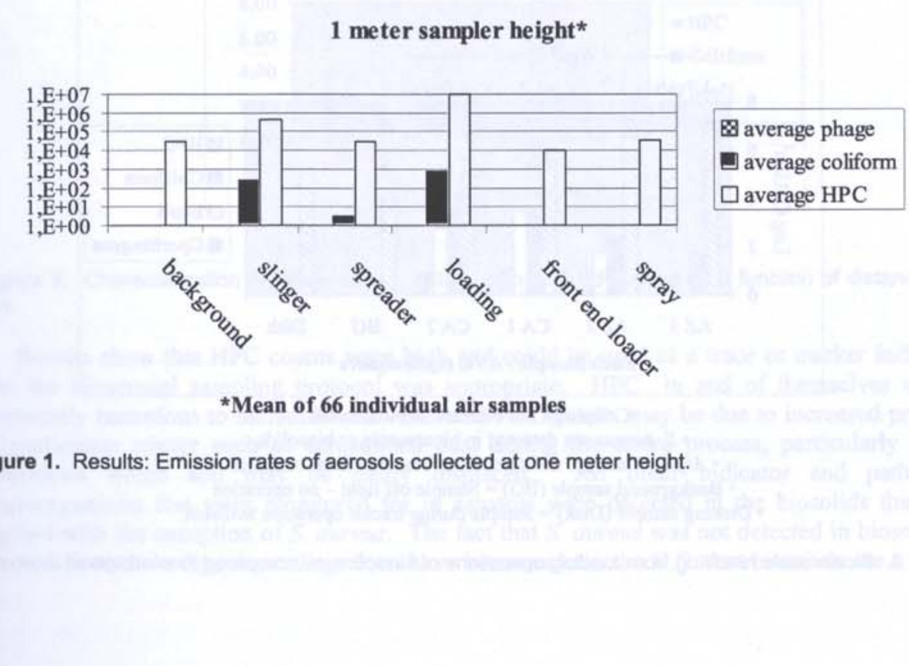


Figure 1. Results: Emission rates of aerosols collected at one meter height.

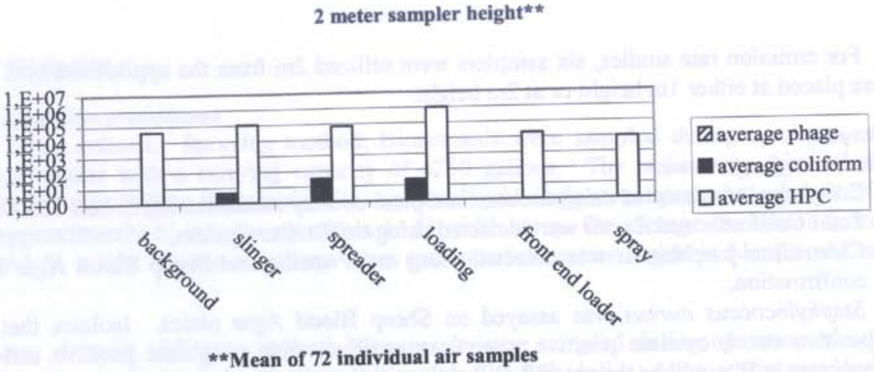
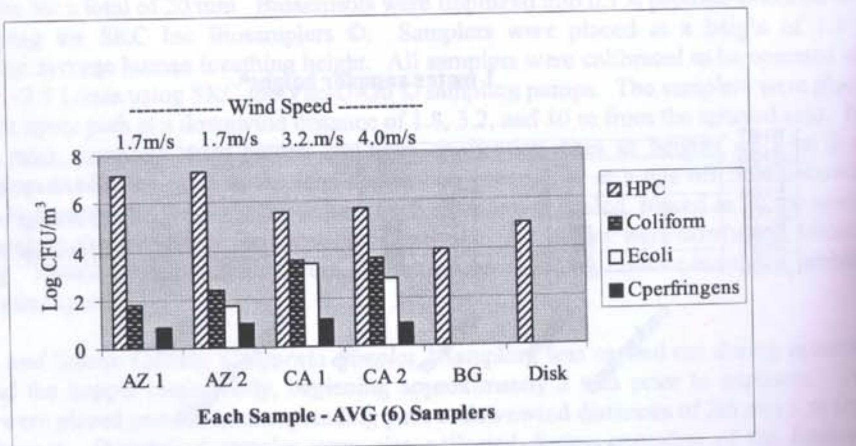


Figure 2. Results: Emission rates of aerosols collected at two meters height.

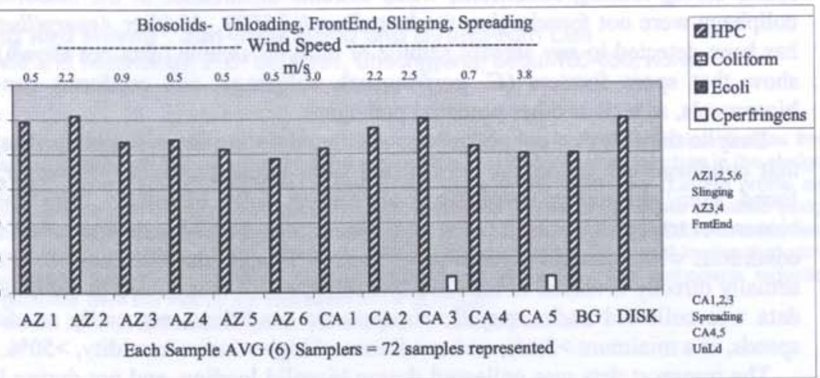
Results show that HPC counts were high and could be used as a trace or marker indicating that the bioaerosol sampling protocol was appropriate. It appears that HPC bacteria are the most commonly aerosolized bacteria, most likely due to normal dust from the tractor operation. Total coliform counts were occasionally elevated, approaching 10,000 coliforms per cubic meter of air for some samples. Coliphages were not detected using the host *E. coli* 15597. To date, the data suggest that HPC bacteria are at least three orders of magnitude greater than coliform bacteria during land application. Thus, the overall rate of aerosolization is based mostly on these microorganisms which generally do not cause adverse human health effects. Eventually, the data will be used for environmental modeling.

Data on fate and transport studies are shown in Figures 3, 4, and 5.



•Coliphage not detected in bioaerosols
• *S. aureus* not detected in bioaerosols or biosolids
• *Aspergillus* spp. not detected in bioaerosols or biosolids
• Background sample (BG) = Sample off field – no operation
• Disking sample (Disk) = Sample during tractor operation w/disker

Figure 3. Bioaerosols resulting from loading operations of biosolids as compared to wind speed.



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• Disking sample (Disk) = Sample during tractor operation w/disker

Figure 4. Bioaerosols resulting from biosolid slinging, front end loading, spreading and unloading operations.

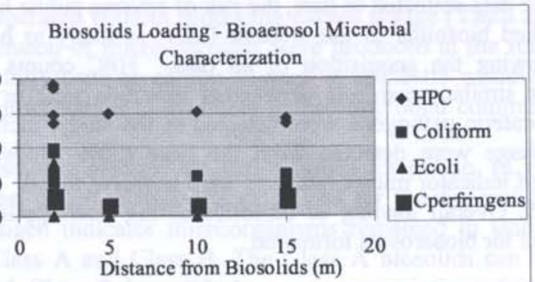

Figure 5. Characterization of bioaerosols resulting from biosolid loading as a function of distance from site.

Results show that HPC counts were high and could be used as a trace or marker indicating that the bioaerosol sampling protocol was appropriate. HPC in and of themselves are not commonly hazardous to human health. Elevated HPC counts may be due to increased presence of particulate matter such as aerosolized dust during the entire process, particularly during conditions where soil may be easily displaced. All other indicator and pathogenic microorganisms that were monitored for in aerosols were detected in the biosolids that were applied with the exception of *S. aureus*. The fact that *S. aureus* was not detected in biosolids or aerosols is noteworthy, since allegations have been made in the U.S. that biosolids are a source of *S. aureus*. Total coliform counts were occasionally elevated as was *E. coli,* but were only found during loading conditions, when extreme disturbance of the biosolids occurred. MS–2 coliphage were not found using the host *E. coli* 15597. Neither *Aspergillus* spp. nor *S. aureus* has been detected in any aerosol sample or biosolid sample (data not shown). To date, the data show that spore formers (*C. perfringens*), coliphage, and coliforms can be transported as bioaerosols, as well as other potential pathogens.

Despite the fact that coliphage was not found during these sampling dates, data in AZ show that coliphage can indeed be aerosolized from liquid biosolids. However, no coliphage was found from procedures involving high percent solid biosolids. The data also shows that bioaerosol transport can take place at distances including 15m downwind of the biosolid loading conditions which functioned as a point source. Despite the fact that this biosolid loading is not actually directly involved in biosolid spreading, it still is involved in the overall operation. This data was collected under specific atmospheric conditions, especially conditions of high wind speeds, at a minimum >2m/s, and conditions of high relative humidity, >50%.

The transport data was collected during biosolid loading, and not during biosolid application or unloading. It is worthy to note that a consistent wind speed has resulted in aerosolized particles being carried downwind and that despite conditions that would enhance aerosolization, detection of indicator microorganisms was rarely achieved. Therefore, as of now, the biosolids application risk appears to be minimal to the general public. Enteric viruses and Norwalk Like Virus have not yet been detected in any of the bioaerosol samples, through the use of Reverse Transcription Polymerase Chain Reaction (RT-PCR).

Conclusions

Based on the data collected to date, the risk of adverse public health effects from bioaerosols from land applied biosolids in the western USA is likely to be low. Actual risks will be calculated following the acquisition of all data. HPC counts that resulted due to tractor operations were similar regardless of whether biosolids were or were not land applied. No known human enteric pathogens were detected in the study, including human enteric viruses. Likewise no phage were detected from the cake (20% solids) biosolids. Relatively low concentrations of indicator microorganisms were however found. Low windspeed was found to reduce transport. Overall loading of biosolids during land application appeared to create the greatest potential for bioaerosols formation.

References

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