USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Fate and Transport of Virus and Bacteria in Groundwater: A Mass Balance Approach

Focus Categories: (1) groundwater (GW), (2) wastewater (V;W), (3) water quality (MET)

Keywords: viruses, Bacteria, Soil Cores, Hydrological Methods, Bacteria, Bioindicators, Contaminant Transport, Groundwater Hydrology, Groundwater Modeling, Groundwater Quality, Groundwater Management, Septic Tanks, Saturated Flow, Unsaturated Flow, Wastewater

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Federal Funds Requested: $51,299

Non-Federal funds: $102,599

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Congressional District: First

Statement of Critical Water Problem: Over 70% of disease outbreaks traced to the consumption of untreated groundwater are attributed to domestic sewage sources (Keswick and Gerba, 1980; Mosley, 1959; 1975; Taylor et. al., 1966; and Yates and Yates, 1989). In children in developed countries enteric viruses are responsible for 53% of severe enteritis, bacteria 13', parasites 1.0%, and unknown etiology, 33% (Bishop, 1995). Recognizing the inadequacy of existing regulations (based solely on data from indicator bacteria) to protect public health from water-bome diseases, Congress passed the 1986 Safe Drinking Water Act. As a result, Federal, State, and Local agencies are trying to revise current rules, and where appropriate, formulate new regulations and procedures to protect our groundwater from viral and bacterial pathogens of humans. However, this process has been hampered by limited data on the movement and fate of pathogens in groundwater at the field scale. Another major limitation of existing field and laboratory studies is that they only address the virus or bacteria in the aqueous phase at the time of sampling and have ignored the bound microbes, which often are over 90-99% of the total microbes in a contaminated system. This vast majority of bound microorganisms thus represents a major source of pathogens for continued contamination of the groundwater supply. Data clearly show that pathogens, whether bacterial or viral, that are adsorbed to the solid phase have slower die-off or inactivation rates than. pathogens in the groundwater (Hurst et al., 1980). It has also been demonstrated that these pathogens can be remobilized into the groundwater if conditions change in the subsurface (Bales et al., 1995). Thus, these bound vital and bacterial pathogens represent a persistent risk to the public health, especially in light of the fact that depending on the organism, one infectious dose can be as little as one to a few viruses or bacteria. The development of equitable rules which will protect public health and safety can be only accomplished by taking into account the presence of both unbound and bound infectious pathogens in our aquifer systems.

Sufficient data on the fate of pathogens using a mass balance approach (i.e. total numbers of virus or bacteria added = fraction bound + fraction free + fraction dead or inactivated) though more easily obtained in the laboratory, have yet to be acquired in the field. Without field scale mass balance data, regulatory agencies will lack sufficient information to accurately assess risks and formulate appropriate protective regulations. We propose to generate much-needed mass balance data by conducting a bacteria and virus seeding experiment using novel isotopic labeling and soil coring techniques as well as standard groundwater sampling techniques that will allow measurement of both bound and unbound microbes. The USEPA which is responsible for formulating national rules, The Montana Department of Environmental Quality, other State departments of Environmental Protection, local City and County Health Departments, and municipal and private water companies utilizing groundwater will all benefit from the proposed research.

Statement of Results or Benefits: Based on our current research examining the fate and transport of viruses and bacteria, a large percentage of viruses and bacteria (>90%) introduced into groundwater are bound to sediment particles at any one time. During the movement of pathogens through the groundwater system, the sediments within the flowpath will continue to adsorb passing pathogens. These adsorbed pathogens survive longer than free pathogens and some are constantly desorbing back into the groundwater. This fact is an important consideration for public health, especially since changes in the groundwater chemistry or hydrology can remobilize the surviving bound pathogens in larger numbers long after the initial contaminating event (Bates et al., 1995). Our proposed seeding experiment using standard monitoring techniques, novel non-radioactive (13C) isotopic labeling of marker organisms, and intensive soil coring to sample the solid phase, will provide a more complete picture of the fate of pathogens and provide valuable data needed to establish appropriate protective regulations for our aquifers. A second research result will be the determination of field inactivation rates for the seeded microbes. To date, inactivation rates of viruses and bacteria under field conditions have been estimated from laboratory experiments with viruses and/or bacteria held in groundwater or groundwater/sediment mixtures at various temperatures (Jansons et al., 1989a; Hurst et al., 1980; and Yates et al., 1985). These experiments by their confined "test tube" nature may not accurately simulate the natural system where new chemical, physical and biological components are constantly interacting with bound and unbound pathogens. Our experiments will provide field data on bound-microbe inactivation rates by allowing direct examination of both free and bound viruses and bacteria. Such rates have not yet been accurately measured in the field due to the free-flowing, unrestricted nature of the natural sites, the logistical considerations associated with solid phase sampling, and the presence of background levels of microorganisms.

In the proposed experiments the combination of traditional monitoring of unbound microbes in the groundwater with sediment core measurement of bound virus and bacteria will provide a more unified and complete representation of pathogen fate and migration patterns in ground water systems. These data will strengthen our predictions of appropriate setback distances for dfiriking water wells both in terms of distance and/or time of travel. A major attribute of the proposed research is that it will provide valuable information on the transport of viruses AND bacteria in a single system in a single experiment. Thus, important similarities and differences in transport of viral and bacterial particles can be determined.