Fate and Transport of Viruses in Groundwater Environments

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Groundwater contamination

Groundwater is widely used as drinking water supplies around the world, specifically in the developing economies. About 96 percent of all usable freshwater is found as groundwater, which globally provides 25 to 40 percent of the world's drinking water. Aquifers are the source of groundwater that is located subsurfaceis often connected with surface water systems and mostly recharge through rainwater infiltration and percolation and may discharge to surface water sources such as streams and lakes. Contamination of groundwater depends on the risk factors: 1) sensitive aquifers; aquifers in which viruses may travel faster and further than bacteria (e.g. limestone, lateritic or coastal plain sand aquifers, which are high in permeability; 2) shallow unconfined aquifers; 3) aquifers with thin or absent soil cover;4) close to surface water bodies; and 5) high population density areas.

Contamination of groundwater via chemical and pathogenic contaminants is a severe environmental problem that poses a significant threat to human health. Among the pathogenic contaminants such as viruses, bacteria, and protozoa, viruses are readily transported through soils, due to their smaller size compared to bacteria and protozoa. Studies have reported on the fate and transport of viruses in soils and aquifers are necessary to determine the vulnerability of groundwater to pathogenic contamination and to secure safe drinking water sources. However, only a handful of literature reports on the capacity of transport of viruses into groundwater.[1,2] Major processes that govern the subsurface transport of viruses are their rate of inactivation and their sorption into sediment particles. Inactivation of viruses as well as sorption to soil particles is controlled by the degradation of the viral capsid and by subsurface temperature. Included among the essential hydrogeological factors that can be used to evaluate viral transport are the flux of moisture in the unsaturated zone, the media through which the particles travel, porosity, the length of the flow path, organic matter, dissolved oxygen, presence of other microbes, groundwater chemistry and the time of travel.[2-4]

Sources of viruses in groundwater

It has been a well-known fact that the sewerage and cemeteries are among the chief anthropogenic sources of pollution and contamination of groundwater in urban areas and beyond, in the area of hydrogeology (Figure 1). In the case of cemeteries, 0.4–0.6 liters of leachate is produced per 1 kg of body weight, during the decomposition of a human corpse, which may contain pathogenic bacteria and viruses that may contaminate the groundwater.[5-7] Further, sewerage from hospitals or households or quarantine centers may discharge sewerage and wastewater with viruses (Figure 1). Burial in any means causes soil contamination and then leads to groundwater pollution via the discharge of inorganic nutrients, nitrate, phosphate, ammonia, chlorides etc. and various microorganisms. High biochemical and chemical oxygen demands, ammonia, and organic carbon have been reported as high as several hundreds of mg in L from cemeteries and mass burial sites. In the case of viruses, recent studies indicate that viral may transport in soil with rainfall infiltration and extends specifically to drinking water from an untreated groundwater source.[8] Several scientific publications report virus occurrence rates of about 30 percent of groundwater.[6,7]

In most cases, it is the general thinking that only the enteric viruses are found in groundwater; however, other types of pathogenic viruses have also been reported (Table 1). Severalstudies suggest that certain enveloped virusessuch as SARS, MERS, COVID-19, and avian influenza are capable of retaining infectivity fordays to months in aqueous environments, which implies the danger of untreated wastewater andgroundwater contamination.[9] Given the vulnerability of our groundwater aquifers, and lack of understanding about the behavior of COVID-19 virus, there can be a risk from corpses, septic waste or sanitary waste are having any contact with water sources. Hence, it is advisable to have careful measures in destroying the infected dead bodies, septic, and sanitary waste in proper conditions without provisioning chances in groundwater contamination for any future disease outbreak in any case of viral pandemicity.

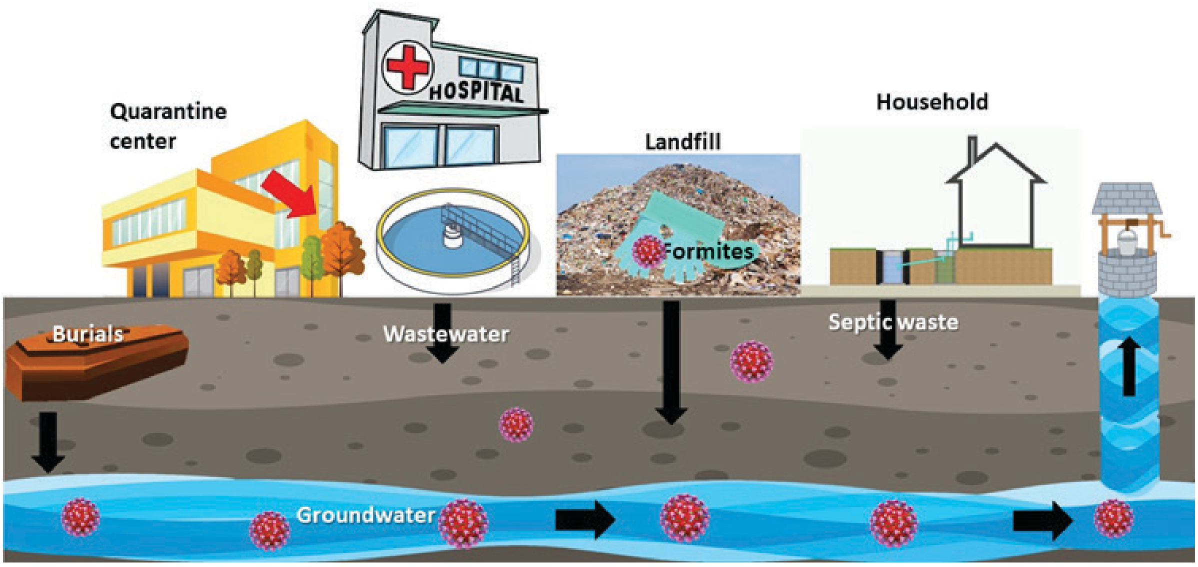

Figure 1: Possible sources of viruses in groundwater

Table 1: Detection of various viruses other than enteric in soil and groundwater environments

Virus common name	*Virus type*	*Associated illness*	*Country*	*Environmental condition*	*Reference*
Lassa virus	H40/1	Acute viral hemorrhagic illness	Germany	Gravel aquifer	[10]
Adenovirus	PRD1	Respiratory disease, pneumonia,gastroenteritis, keratoconjunctivitis	USA	Unconfined aquifer	[11]
	HAdV2		France	Unconfined and confined aquifer	[12]
Enterovirus	Poliovirus	Polio	USA	Unconfined aquifer	
Avian influenza virus	HPAI	Avian influenza	USA	Mississippian limestone	[13]
Hepatitis	HAV	Hepatitis	Korea	Unconfined aquifer	[14]

References

1. Anders, R. and C.V. Chrysikopoulos, Virus fate and transport during artificial recharge with recycled water. *Water Resources Research*, **2005**. *41*(10).
2. Berger, P. Viruses In Ground Water. in Dangerous Pollutants (Xenobiotics) in Urban Water Cycle. 2008. Dordrecht: Springer Netherlands.
3. Jansons, J., et al., Survival of viruses in groundwater. *Water Research*, **1989**. *23*(3): p. 301-306.
4. Powelson, D.K., J.R. Simpson, and C.P. Gerba, Effects of organic matter on virus transport in unsaturated flow. *Applied and environmental microbiology*, **1991**. *57*(8): p. 2192-2196.
5. Abia, A.L.K., et al., Microbial life beyond the grave: 16S rRNA gene-based metagenomic analysis of bacteria diversity and their functional profiles in cemetery environments. *Science of The Total Environment*, **2019**. **655**: p. 831-841.
6. Oliveira, B., et al., Burial grounds' impact on groundwater and public health: an overview. *Water and Environment Journal*, **2013**. *27*(1): p. 99-106.
7. Żychowski, J. and T. Bryndal, Impact of cemeteries on groundwater contamination by bacteria and viruses – a review. *Journal of Water and Health*, **2014**. *13*(2): p. 285-301.
8. Yates, M.V., C.P. Gerba, and L.M. Kelley, Virus persistence in groundwater. *Applied and Environmental Microbiology*, **1985**. *49*(4): p. 778.
9. Wigginton, K.R., Y. Ye, and R.M. Ellenberg, Emerging investigators series: the source and fate of pandemic viruses in the urban water cycle. Environmental Science: *Water Research & Technology*, **2015**. *1*(6): p. 735-746.
10. Blanford, W.J., et al., Influence of water chemistry and travel distance on bacteriophage PRD-1 transport in a sandy aquifer. *Water Research*, **2005**. *39*(11): p. 2345-2357.
11. Mallén, G., et al., Determination of bacterial and viral transport parameters in a gravel aquifer assuming linear kinetic sorption and desorption. *Journal of Hydrology*, **2005**. *306*(1): p. 21-36.
12. Ogorzaly, L., et al., Occurrence, Survival, and Persistence of Human Adenoviruses and F-Specific RNA Phages in Raw Groundwater. *Applied and Environmental Microbiology*, **2010**. *76*(24): p. 8019.
13. Borchardt, M.A., et al., Avian Influenza Virus RNA in Groundwater Wells Supplying Poultry Farms Affected by the 2015 Influenza Outbreak. *Environmental Science & Technology Letters*, **2017**. *4*(7): p. 268-272.
14. Ryu, S., et al., Hepatitis A Virus Infection from a Contaminated Tap of Ground Water Facility in a Neighborhood Park, Republic of Korea. *Infection & chemotherapy*, **2019**. *51*(1): p. 62-66.