Editor's Message

Outbreak of enteroviruses and groundwater contamination in Taiwan: Concept of biomedical hydrogeology

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The outbreak of enteroviruses (including 67 subtypes) in Taiwan that began in 1998 and continues today has been very serious and unprecedented. Prior to this outbreak, very few deaths had occurred in Taiwan from enteroviruses; at most, 1000 cases per year had been reported, principally in 1982 and 1986 (Chou and Malison 1988). Shen (1998) reports that the enterovirus outbreak in Taiwan has become the world's worst ever; about 300,000 people have been infected, and 85 children have died. This outbreak greatly exceeds the ones in Hungary in 1978 (45 deaths), in Bulgaria in 1975 (44 deaths), and in Malaysia in 1997 (31 deaths). More information is available at www.geocities.com/HotSprings/2188/outbreak.html.

Little is understood about the relationship between the Taiwan outbreak and hydrogeological conditions. The seriousness of the outbreak might be in part due to contamination of soil and groundwater in the wake of land burial of pigs that were infected with aphthoviruses (i.e., foot-mouth disease viruses). Enteroviruses and aphthoviruses are related and belong to the genera in the family of Picornaviridae; details are available at www.iah.bbsrc.ac.uk/virus/Picornaviridae. Since March 1997, more than five million pigs infected with aphthoviruses have been buried throughout Taiwan in the mainly coarse-grained fluvial deposits of the coastal plain. The increase in temperature and the production of nitrite due to the decomposition of the bodies possibly stimulated *E. coli* (or other bacteria) and enteroviruses. The enteroviruses and/or aphthoviruses could have used *E. coli* or other bacteria as new hosts and could have developed new variants (due to the temperature- or nitrite-sensitive effect) or recombinants. The new variants could have also developed due

to selenium-deficiency in the enteroviruses and/or aphthoviruses (Beck et al. 1994; Tu et al. 1995).

The leakage from the disposal sites of the buried pigs was probably absorbed in the unsaturated zone and subsequently percolated to the water table after heavy rainfalls of the monsoon and typhoon seasons. This groundwater is widely extracted for drinking, washing, and irrigation. In addition, waters of lakes, rivers, oceans, and estuaries might have been contaminated as well. Initial possible transporters of enterovirus in the environment are (1) leakage from solid-waste landfills, (2) sewage, and (3) surface runoff (Melnick et al. 1978). Land burial pits of pigs infected with aphthoviruses can be considered to be in the category of solid-waste landfills. Once in the environment, the enteroviruses might have been transported by various hydrologic media, such as groundwater, rivers, lakes, oceans, and estuaries. Before March 1997, no pigs infected with aphthoviruses were buried in Taiwan. At that stage, most of the enteroviruses were not apt to be mutated, and thus they were still benign; as a result, few infections and deaths occurred at that time.

The source of the enteroviruses has not been physically identified yet, due to the difficulties in isolating them from the subsurface material. Research in locating the source of the pathogens and measures to prevent and control the epidemic diseases involve biology, medicine, and hydrogeology. Thus, I have coined the term "biomedical hydrogeology." Knowledge of biology may help us understand the nature of viruses (e.g., enteroviruses, adenoviruses, aphthoviruses, etc.), bacteria, and other living organisms; medicine can help us understand the different types of waterborne and other diseases that can result from different types of viruses, bacteria, and other living organisms. For example, enteroviruses can cause hand-foot-mouth disease and herpangina, adenoviruses can cause pharyngoconjunctival fever, aphthoviruses can cause foot-mouth disease, and bacteria can cause typhoid fever, cholera, and so on. Finally, knowledge of hydrogeology may account for the source and nature of groundwater contamination and changes in geochem-

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ical factors (e.g., temperature, nitrite, selenium, other trace elements, etc.).

The value of this approach is illustrated by understanding the relation between the hydrogeological environment and the Blackfoot disease, which was endemic in southern Taiwan before the 1990s, when arsenic-containing groundwater from artesian wells was extracted for drinking water. Results of research made it evident that the disease is basically caused by arsenic-containing groundwater, but that the specific health effects depend on the availability of other substances and on the hydrogeological conditions (Jacobson 1998; Lu 1975, 1989; Chen et al. 1988; Chen and Wu 1962; Chen et al. 1962; Blackwell 1961; and Yang and Tsai 1961). The effects were serious with water from artesian wells that tapped groundwater under reducing conditions, and they were absent with water from shallow wells that tapped groundwater under phreatic conditions.

I urge interested readers to come to Taiwan for research during the wet period, usually from April to October, when the viruses are readily flushed from the unsaturated zone to the water table after heavy monsoon and typhoon rainfalls. This is an appropriate time to obtain water samples and to isolate and sample the viruses. Please contact me for further information on how to participate in these important studies of biomedical hydrogeology.

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