14. SAFE DRINKING WATER

- Lessons to be Learned from Recent Large-scale Waterborne Outbreaks of *Cryptosporidium* -

Presenter

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INTRODUCTION

The greatest impact of water pollution on human health comes through drinking water acting as an important vehicle for the transmission of a large variety of infectious diseases. The sanitary engineering for safe drinking water has long relied on the application of the multi-barrier concept. These barriers, at the present time, are basically designed to have multiple removal capabilities through the treatment chains to give backup system to support continuous operation. While water treatment technology can successfully process poor quality source waters to produce potable water that meet accepted drinking water standards, there is still serious concern that the barrier to microbial breakthrough in the treated water may fail to measure up to our expectations. Conventional water treatment processes applied worldwide were not designed specifically to remove protozoan cysts or enteric viruses, and an approximately 3-log removal for *Cryptosporidium* oocysts can be expected for the entire treatment train, if it is operated properly (10). Any momentary or intermittent breaks in the treatment chain could allow substantial levels of pathogenic microbes to enter potable water. Unusual resistance of oocysts to conventional disinfectants (5) allows for penetration of viable oocysts into the treated water supply. Recent large-scale outbreaks of *Cryptosporidium* in many industrialized countries have shown that conventional drinking water treatment may not always be adequate to prevent waterborne disease transmission (12). In addition, the maintenance of water quality during distribution to the end user may not always be given careful attention. Thus, post-treatment contamination may occur in the distribution system due to microbial regrowth, infiltration, cross connection, back siphonage, line construction and repairs, and others (1,2,13).

The increasing world population leads to an increase in the requirement of fresh water for drinking, hygiene and household purposes, as well as for agricultural irrigation. Population growth also brings in its train a high load of municipal sewage, livestock excreta and industrial wastewater on the source of drinking water, both the surface and ground water. Most fecal-oral pathogens are identified to cause gastrointestinal illnesses with a few exceptions such as hepatitis and other viruses. There may also be myriads of emerging pathogens which are excreted by humans or animals. In many industrialized countries, the widespread occurrence of the protozoan parasites in surface waters demonstrates that any drinking water treatment plant which draws its water from a surface source is at risk (12). At the same time, water utilities which draw their source from ground water under the direct influence of surface water is not necessarily free from this threat (9).

SHARING HEALTH RISK

The survival of pathogenic organisms in drinking water is the result of multiple problems within the water source, the collection system, the treatment chains, and /or the distribution and storage facilities. It is thus necessary in principle to implement a multi-barrier approach based on a total system concept. Considering the enormous variety of possible contaminants both at source and within the distribution system itself, developing a real-time monitoring system for each pathogen will be impractical. One interesting approach would be to adapt the use of Hazard Analysis Critical Control Point (HACCP) principles for drinking water risk management (14). It is designed primarily for food industries as preventive system of control to assure product safety where effort is applied to reduce or remove risks as close to their source as possible. Key features of HACCP are the identification of hazards and the specific measures to control hazards emphasizing elements that can be monitored, and verified, in real time. Water treatment processes that reduce the level of contamination in the source to produce safe drinking water require reliable information about the microbial quality of the source water. Fluctuation due to peak events (heavy rainfall, dredging a riverbed, etc) and the level and source of variation, should be taken into consideration. It also requires knowledge about the effectiveness of different treatment processes in inactivating or removing pathogens. These, together with knowledge about the sources and risk of post-treatment contamination, make it possible to determine the most relevant risk management options in the water distribution system.

As risk management is a total system approach, involvement of a multiple-disciplinary team is essential. Catchment control, for example, may involve events with transboundary hygienic and environmental impacts, and thus requires an interregional or in some cases international approach. This means that effective risk management requires acknowledgement and co-operation of various agencies. For risk management, linkage of disease-based and of environmental surveillance networks needs to be strengthened to integrate data on waterborne diseases on condition that the public health benefits of surveillance are balanced with the individual human rights to privacy.

WATERSHEDS AS NATURE's BOUNDARIES FOR SURFACE WATER SUPPLIES

Although HACCP concept has been widely discussed for the production of safe drinking water at the present time, we should recognize one thing very basic that this management system can scarcely be applicable to the water treatment system if load of municipal sewage, livestock excreta and industrial wastewater are minimized on the source of drinking water. Measures should, then, be designed to reduce the microbial concentrations as far as possible in the source water by which we are able to reduce reliance on treatment for the protection of water quality in the conventional treatment chains.

Categorization of waterborne pathogens can be made by the combination of concepts such as the probability of an event and the severity of that event for the prioritization of the risk in the process of risk analysis. Recent concerns with *Cryptosporidium* and *Giardia* have centered on the method for water treatment, due to their unusual resistance to conventional disinfectants used worldwide. Many human activities have potential to disseminate *Cryptosporidium* and *Giardia* (oo)cysts into watersheds. These include livestock grazing, manure handling, human settlement, outdoor recreation and others. *Cryptosporidium* is known to be zoonotic, and infected calves deliver approximately 10^{10} oocysts daily for up to 2 weeks (4). It is likely that human patients also excrete a similar number. Fresh feces from grazing animals, yard and dairy washings and bedding leachates seem the most likely agricultural source of pathogenic agents including oocysts. It is not realistic, however, to ban all the economic and social activities in the catchment area. There are several key controls to keep pathogens from entering source waters: an appropriate level of grazing and the length of time without incurring damage to natural values, prevention and control of zoonotic diseases (animal health), correct handling and disposal of farm wastes (composting of manures)(11), and human settlement. Cattle kept in uplands might have little effect on water quality, as long as the range of the river is kept in good condition with riparian pastures (the ground cover provided by vegetation on land). Fencing around reservoirs and streams should be provided to restrict access by both farm animals and wildlife, though little is known about the prevalence of shedding among wildlife species. Improvement of off-stream animal water, at the same time, can disperse wildlife effectively from major watersheds and riparian pastures. In addition, as it is demonstrated that young animals, such as suckling and weaned animals (Table 1) are more likely to shed *C. parvum* oocysts (7,8), keeping young livestock away from the stream for a certain distance will also be an effective measure to mitigate impact of animal grazing on drinking water sources. It is clear that control of water contamination from agricultural wastes depends mostly on compliance with regulatory codes of agricultural practices for waste management. People have to be made aware that their voluntary compliance with these regulations is essential, for them and their descendants to enjoy the benefit of safe drinking water.

HUMAN SETTLEMENTS, OUTDOOR RECREATION AND OTHERS

There is always a low level of cryptosporidiosis in the community among humans and animals (Table 2). While it is unlikely that drinking water is a major cause of this background level, it is also true that most fecal-oral microbial agents have the potential to be transmitted through contaminated water. Human settlements in watersheds shall be properly planned and controlled to prevent adverse effect on water sources. It is crucial to have appropriate sewage treatment plants or on-site sewage disposal systems that are able to deal with the risk arising from the release of infectious microbes into nearby waters.

As watersheds contain streams, lakes and forests, they are potential sites for various recreational activities like off-road and on-road motorizing, backpacking, swimming, boat sailing, windsurfing, rafting and others. Little is known on the effects of recreation on source water quality. It is, thus, recommended that researches should be conducted on the impacts of different types of outdoor activities on drinking water sources. Knowledge obtained from results of such studies should be promptly incorporated into the watershed management strategies. In reality, the level of protection provided to drinking water sources from human-related activities should appropriately balance the cost and benefits of having safe drinking water.

RISK COMMUNICATION

Those at greatest risk of waterborne diseases are infants and young children, people who are debilitated or living under unsanitary conditions, the sick, the immunocompromised and the elderly. Additional protective measures, including risk communication, to these risk groups should also be involved in the total risk management. In particular, it is important to note that immunocompromised individuals such as AIDS patients and those administering immunosuppressive medications are unable to clear cryptosporidial infection and severe diarrhea, while immunologically healthy individuals experience a transient diarrhea. In addition, cryptosporidial infection occurs readily among those with impaired immunity (3) resulting in a life-threatening gastroenteritis with high mortality (6). Together with development of safe drinking water resources, the crux of mitigation of risks associated with microbial infections is managing how such information is communicated, since this will play an important role in public perception and in the exchange of sound scientific information. Rapid local liaison with water companies and local public health authorities should be developed to assess the impact of cryptosporidial contamination on water supplies. The prevalence of cryptosporidiosis among livestock in water sources as well as among the local population, sales of antidiarrheal medications, frequency of hospital emergency room visits for gastroenteritis, school absenteeism related to gastroenteritis in sentinel schools, and incidences affecting dissemination of *Cryptosporidium* oocysts through agricultural activities (manure storage, handling, disposal practices, etc.) are crucial for the detection of a current outbreak. Data sharing between authorities and the public (including the healthy population as well as those who have impaired immunity) should also be encouraged. Those who wish to take independent action to prevent/reduce the risk for waterborne cryptosporidiosis may choose to take precautions similar to those recommended during outbreaks, though the magnitude of the risk for ingesting *Cryptosporidium* oocysts from drinking water in a non-outbreak situation is uncertain. Education and counseling by the local health authorities at the local community basis, on one hand, is essential for the people's better understanding about the ways of transmission of cryptosporidiosis.

CONCLUSIONS

Almost two decades has passed since the first waterborne outbreak cryptosporidiosis due to *Cryptosporidium parvum* infection occurred. Since then, this obligate parasitic protozoan pathogen has become a significant public health concern that has potential to be readily transmitted through contaminated drinking water. Traditionally, the barriers for safe drinking water have included source water protection, physicochemical treatment, disinfection and protection of the distribution system. The treatment is not effective 100 % of the time in removing *Cryptosporidium* oocysts from the drinking waters, and unusual resistance of the oocysts to conventional disinfectants allows for penetration of viable oocysts into the treated water supply. It is, however, unwise to increase the capital outlays on the installation of additional treatment plants that would be needed to rescue poor sanitary source waters without giving much attention to the good source protection. Before it is too late, we should go back to the very basic concept that source water protection is crux to both the sanitary engineering and the cost-effective provision of safe drinking water. This, I believe, is the first alternative of the realistic ways of developing water resources to ensure adequate and safe drinking water for the next generation.

Strengthening alliances between local authorities and public health authorities as well as with water utilities for immediate appraisal of the potential health risk is conceptually another way to develop water resources for safe drinking water especially under conditions where there is less choice of source. At the same time, sharing health risks, monitoring efforts, treatment processes, and all other related information available with the public as well as with the media is also crucial to protect consumers from waterborne diseases, where the performance of conventional systems becomes questioned.

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Table 1. Prevalence and crude odds ratio for excretion of Cryptosporidium parvum oocyst in pokers

Factor		Prevalence of C. parvum oocysts (%)		Crude odds ratio (95%CI)		P value
Weaned piglets	Farm A	52/148	(35.1%)	2.7	(0.6-12.8)	ns**
	B	10/24	(41.7%)	3.6	(0.6-20.0)	ns
	C	13/48	(27.1%)	1.9	(0.4-9.6)	ns
	D	2/12	(16.7%)	1.0*		
	Age (month)					
Weaned piglets	1	69/213	(32.3%)	89.6	(12.3-652.9)	<0.001
	3	8/19	(42.1%)	136	(15.6-186.4)	<0.001
Fatting porkers	6 (Farm A)	1/187	(0.5%)	1.0*		
Weaned piglets	1-3	77/232	(33.2%)	125.2	(17.2-909.2)	<0.001
Fatting porkers	6	1/252	(0.4%)	1.0*		

(after Jpn. J. Infect. Dis 54:23-26, 2001.)

Table2. Detection of *Cryptosporidium* oocysts from fecal specimens of Diarrheal patients presented at Tokyo Metropolitan Komagome Hospital

Sources \ Years		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Imported		0/29	0/37	0/29	1/11	0/21	1/29	0/43	4/65	3/67	5/89	4/88	18/508
Domestic	Outpatients	0/23	0/29	0/7	0/4	0/8	0/1	0/17	0/37	0/51	0/32	0/49	0/258
	Inpatients	0/31	0/40	0/30	0/13	0/7	0/5	0/17	0/36	0/30	0/38	0/100	0/347
HIV/AIDS		0/3	0/7	1/3	0/1	0/1	0/5	1/9	0/17	1/17	0/27	1/50	4/140
Unknown			0/1	0/3									0/4
Total		0/86	0/114	1/72	1/29	0/37	1/40	1/86	4/155	4/165	5/186	5/287	22/1257

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