CHAPTER TWO
REVIEW OF LITERATURE

This chapter reviews the literature in four main areas along with a summary: (1) water microbiology, (2) drinking water for school students, (3) sanitary conditions of water supply in schools, (4) relevant research and (5) Summary

2.1 WATER MICROBIOLOGY

Contamination of microorganisms is a parameter of drinking water quality. The presence of particular bacteria indicates sanitary conditions of water supply for distributing water to consumers. Knowledge of water microbiology focuses on microbial indicators of drinking water quality and safety and microbial awareness of health hazards and risks from consumption of drinking water (WHO, 2001).

2.1.1 Drinking Water Quality and Safety

The world Health Organization [WHO] (2006) noted that drinking water is very essential to maintain life, and an adequate, safe and accessible supply must be available to all people. Improving approaches to safe drinking-water can result in high benefits to health. Every effort should be made to achieve drinking-water quality that is as safe as is practicable. Those facing the greatest risk of waterborne disease are infants and young children, the elderly and people who live under poor sanitary conditions. Microbial contaminants, such as bacteria and viruses are of special concern because they may cause immediate or acute reactions such as vomiting or diarrhea. Long term exposure to some contaminants at levels above standard limits may cause gastrointestinal problems. If a water supply system is contaminated with hazardous microbes, it may be difficult in treating the water to meet current safety standards.

WHO (2006) recommended that the development and implementation of risk management strategies that will ensure the safety of drinking-water supplies through the control of hazardous constituents of water are reasonable requirements of safe practice to protect the health of consumers. The basic and important requirements

to ensure the safety of drinking-water provide a framework for the management of safe drinking-water, comprising health-based targets established by a competent health authority; adequate and properly managed systems (adequate infrastructure, proper monitoring and effective planning and management); and a system of independent monitoring. An effective access to water supply risk assessment and risk management increases the assurances of the safety of drinking-water. This approach involves the systematic assessment of risks throughout a drinking-water supply, from its source on through to the consumer, and identification of the ways in which these risks can be managed, including methods to ensure that the measures are working effectively.

2.1.2 Microbial Awareness Associated with Drinking Water

2.1.2.1 Indicators of microbial water quality

According to the publication of WHO (2006), the greatest risk from microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta, although other sources and routes of exposure may also be significant. To recognize the risk, indicator organisms are used to assess the microbiological quality of water. The use of indicator bacteria as a means of assessing the potential presence of water-borne pathogens has been crucial for protecting public health. The examination of fecal indicator bacteria can be very useful in assessing water treatment efficiency at various points in the treatment process. Many pathogens are present only under specific conditions and, when present, occur in low numbers compared with other micro-organisms. Hence, the presence of indicator microbes may imply the presence of the pathogens. However, there is controversy about using the indicator microbes to indicate the existence of pathogens. Grabow (1996) maintains that there is no direct correlation between numbers of any indicator and enteric pathogens.

To eliminate the ambiguity in the term ‘microbial indicator,’ the following three groups are now recognized as defined in Table 1 (WHO, 2001).

Group 1. General or process microbial indicators

Group 2. Fecal indicators

Group 3. Index organisms and model organisms.

Table 1. Definitions for Indicator and Index Micro-Organisms of Public Health Concern

Group	Definition
1. Process indicator	A group of organisms that demonstrates the efficacy of a process, such as total heterotrophic bacteria or total Coliforms for chlorine disinfection.
2. Fecal indicator	A group of organisms that indicates the presence of fecal contamination, such as the bacterial groups thermotolerant Coliforms or *E. coli*. Hence, they only imply that pathogens may be present.
3. Index and model organism	A group/or species indicative of pathogen presence and behavior respectively, such as *E. coli,* as an index for *Salmonella* and F-RNA coliphages as models of human enteric viruses

Group 1. General (Process) indicator: Total Coliforms

Total Coliforms are a group of closely related, mostly harmless bacteria that live in soil and water as well as the gut of animals (WHO, 2001). The extent to which total Coliforms are present in the water source can indicate the general quality of that water and the possibility that the water is fecally contaminated. Total Coliforms are currently restricted by drinking water regulations or standards because their presence above the limit indicates problems in treatment or in the distribution system. If total Coliforms are found, then the public water system must further investigate the total Coliform-positive sample to determine whether specific types of Coliforms, i.e., fecal Coliforms or *E. coli* are present. The total coliform group of bacteria includes species such as *Enterobacter, Klebsiella, Citrobacter* and *Escherichia*. Fecal Coliforms are a sub-group of the total coliform group of bacteria, differentiated by their

thermotolerance, i.e., their ability to grow at 44.5 ^{o}C. Monitoring for bacterial indicators show a closeness in the incidence of bacterial disease caused by organisms such as *Vibrio cholerae* (cholera), *Yersinia entero-colitica* (gastroenteritis), *Shigella* (gastroenteritis), and *Salmonella* (gastroenteritis, typhoid). Although total Coliforms include species that often inhabit intestines of warm-blooded animals, they can also occur naturally in the environment and even multiply in certain environments. They are usually not pathogenic themselves, although their presence in drinking water often indicates a treatment failure or contamination event: thus, they are often associated with outbreak (WHO, 2001).

Group 2. Fecal indicator: ***Escherichia coli (E. coli*)**

As stated by Reynolds (2003) in 1948, methods were developed to distinguish thermotolerant (fecal) Coliforms from total Coliforms as it was discovered that *E. coli* represents the majority (more than 90 percent) of the population of total coliform bacteria in human and animal feces. *E. coli* is recognized as the most appropriate group of Coliforms to indicate fecal contamination from warm-blooded animals into water. In highly purified water, the presence of fecal indicator bacteria can result from a serious failure in the system. This may not mean, however, there is a human health risk. Epidemiological studies suggest a positive relationship between high concentrations of *E. coli* in ambient waters and incidents of gastrointestinal illnesses associated with recreational activities. *E. coli* is a member of the total Coliform group and is always found in feces, providing a more direct indicator of fecal contamination and possible presence of enteric pathogens (i.e., viral, protozoan and bacterial pathogens of the gastrointestinal route). Certain strains of *E. coli* are directly pathogenic themselves.

Reynolds (2003) added that pathogens enter water through fecal contamination that can lead to severe and widespread human illness from drinking, swimming and bathing. Sources of fecal contamination in surface waters include wastewater treatment plants, septic systems, domestic and wild animal manure, and storm runoff. Because direct testing of individual pathogens is cost-effective or practical, scientists have identified indicator organisms to indicate the presence of harmful pathogens.

Group 3. Index organisms and model organisms

This group includes waterborne pathogens that will be mentioned in item 2.1.2.2 below.

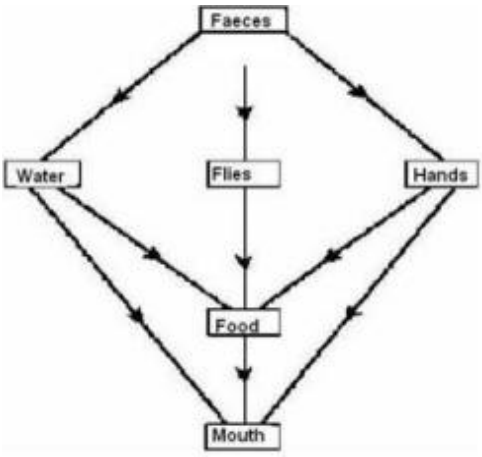
2.1.2.2 Waterborne pathogens

Waterborne pathogens are microbes that cause diarrheal diseases (WHO, 2006). They include a few types of bacteria, viruses, protozoa, and other organisms. Some pathogens are often found in water, frequently as a result of fecal matter from sewage discharge, leaking septic tanks, and runoff from animal feedlots into bodies of water. World Health Organization (2004) has stated that infectious diseases are the world's single largest source of human mortality. Poor water quality acts as a major threat to human health. Diarrheal disease alone amounts to an estimated 4.1 % of the total daily global incidence of disease and is responsible for the deaths of 1.8 million people every year. It was estimated that 88% of these are attributable to unsafe water supply, sanitation and hygiene, mostly concentrated in children in developing countries (WHO, 2004). Transmission, infection and prevention of waterborne illness are described next.

Transmission and infection of waterborne illness

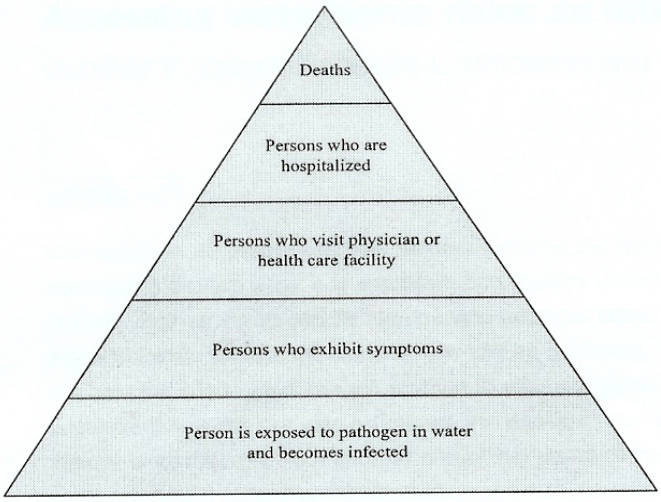
The United Nations World Water Development Report in "Waterborne Diseases", n.d., says that waterborne diseases are spread by contamination of drinking water systems with the urine and faeces of infected animals or people. However, there are many other ways in which faecal material can reach the mouth; for instance from hands or on contaminated food. Figure 1 shows the faecal-oral routes of disease transmission in which water is one possible route.

Figure 1. The faecal-oral routes of diseases transmission



Craun, Calderon, and Wade (2006) point out that if exposed to a waterborne pathogen, a human or animal host may become infected. The pathogen can multiply or pass through its life cycle within the host, and the host may excrete pathogens into the environment which become infectious to others. Illness refers to the symptomatic indication of an infection. The severity of illness can range from self-diagnosed, mild gastrointestinal illness and death as presented by a figure of the burden of illness pyramid in Figure 2. Symptoms may begin from two to ten days after drinking the contaminated water, and may include diarrhea, stomach cramps, nausea, vomiting, and fever.

Figure 2. The burden of illness pyramid



Craun, Calderon, and Wade (2006) added that infection without illness is also important. Although not displaying illness symptoms, asymptomatic persons may be sources of continuing infection and illnesses in the community. Frequent low-level exposures to some pathogens may generate protective immunity from illness in a person; however, not all pathogens can create protective immunity, and for some pathogens, the immunity may be temporary. This means that the immunity of individuals also varies considerably, whether infected by contact with a pathogen or influenced by such
factors as age, sex, state of health and living conditions.

Prevention of waterborne illness

The only way to break the continued transmission shown in Figure 1 is to improve people's hygienic behavior and to provide them with knowledge about facilities and sanitation of water used for drinking, washing and bathing (Craun, Calderon, and Wade, 2006). It is well recognized that the prevalence of water-borne diseases can be greatly reduced by the provision of clean drinking water and safe disposal of feces. Water is disinfected to kill any pathogens that may be present in the water supply and to prevent them from growing again in the distribution systems. Disinfection is then used to prevent the growth of pathogenic organisms and to protect public health and the choice of the disinfection depends upon the individual water quality and water supply system.

To demonstrate the incidence of diarrheal diseases occurring in children caused by poor sanitation in the water supply system and the significance of improving sanitation and hygiene education to people in reducing such diseases, WHO (2004) presented these facts in "Water, sanitation and hygiene links to health" as shown below:

- 1.8 million people die every year from diarrheal diseases; 90% are children under 5, mostly in developing countries.
- 88% of diarrheal disease is attributed to unsafe water supply, inadequate sanitation and hygiene.

- Improved water supply reduces diarrhea morbidity by between 6% to 25%, if severe outcomes are included.
- Improved sanitation reduces diarrhea morbidity by 32%.
- Hygiene interventions including hygiene education and promotion of hand washing can lead to a reduction of diarrheal cases by up to 45%.
- Improvements in drinking-water quality through household water treatment, such as chlorination at point of use, can lead to a reduction of diarrhea episodes by between 35% and 39%.

The above statistics reveal that providing safe drinking water and improving improving sanitary conditions in schools can definitely reduce the incidence of diarrhea waterborne illness in children.

2.2 DRINKING WATER FOR SCHOOL STUDENTS

Lack of sufficient clean and safe drinking water causes a reduction in both mental and physical performance in school children. Providing hygienic drinking water to students is a duty of school authorities (United Nations Educational, Scientific and Cultural Organization [UNESCO], n.d.)

2.2.1 School Students Need Safe Drinking Water

According to UNESCO (n.d.),

> Students spend long hours in schools, therefore; the school environment has a significant impact on their health and well being. An essential thing that affects students' health is the quality of drinking water which they consume in schools. Access to clean water and adequate sanitation of water supply facilities is a necessity that safeguards the health of students. (¶ 5)

UNESCO also states that diseases related to poor sanitation and water availability cause many people to become ill or even to die. Children are the most vulnerable to health hazards and, thus, are the most affected. In 1998, there were 2.2 million deaths due to diarrheal diseases, of which the vast majority were children. In addition, poor sanitation has led to the infection of nearly one billion people, mostly

children, with a variety of infectious waterborne diseases. Continued exposure to such illnesses prevents children from normal growth development and impairs the physical and mental abilities necessary for learning.

Department of Disease Control (2005) reported that Thai children between 5-9 and 10-14 were ill from diarrhea at the rate of 308 and 220 per 100,000 people in each group, respectively. Most of these children were students who consumed unhygienic food and drinking water in their schools. .

WHO (2006) suggests that a long-term approach to improving hygiene in the community includes working with children in schools. This promotes the concept of good hygiene, of which drinking-water safety is a part, to become part of a general understanding of health and the influence of the environment.

2.2.2 Providing Safe Drinking Water to Students

The United States Environmental Protection Agency (US EPA) (2003) introduces prevention of microbial contaminants in drinking water for school students by pointing out that schools officials have to be responsible for providing safe drinking water to students and staff. This includes protecting the source from contamination, regularly testing and reporting monitoring results, and maintaining the distribution system. The US EPA recommends that schools protect against the cross contamination that can occur. Because a contaminant may not have a strong taste, odor or color, cross contamination may not be immediately apparent. Cross connections can happen at schools when a water pipe is connected from a drinking water source to a storage tank or cafeteria equipment.

2.3 SANITARY CONDITIONS OF WATER SUPPLY IN SCHOOLS

According to WHO's Guidelines for Drinking Water Quality (2006), sanitary condition is defined as being clean and safe from disease-causing microbes. In most developing countries, sanitary and hygienic conditions at schools are often unpleasnnt, characterized by the absence of proper monitoring of the water supply for drinking and washing facilities. Schools that lack access to basic water supply and sanitation services will have an increased incidence of major childhood illnesses among their

students. The combination of safe drinking water and hygienic sanitation facilities is a tool against illness in school children. Water supplies use a variety of treatment process to remove bacterial contaminants from drinking water. The most reliable way to kill microbial pathogenic agents is boiling water for a proper period of time. Other techniques, such as varying forms of filtration, chemical disinfection, and exposure to ultraviolet (UV) radiation (including solar UV) have been noted to substantially reduce levels of waterborne disease. The United Nation Children's Fund (UNICEF) (2006) promotes strategies to improve drinking water quality in schools through fundamental education programs of health and hygiene which are an integral part of major sanitation programs. Providing knowledge of sanitary conditions to school administrators or headmasters will enable them to properly manage the water supply and sanitation in their schools.

After an investigation of lead, a toxic metal, in drinking water for school students all over Thailand in 2007, it was found that, in most schools in the country, water cooler tanks were used as water storage containers for distributing drinking water. Electric water cooler tanks are usually used to provide cold water for thirsty students. In some cases, water (cooler) tanks dispense drinking water through a number of valves or faucets for greater availability of water drinking or through multiple–faucet basins. In most circumstances, the water supply providing drinking water for school students initially flows through the water source (tap or ground water pipes and is stored in the water cooler tanks before dispensing to the consumers. A water filter is a device that is usually utilized to remove impurities or contaminants in water prior to flowing to the water tank or multiple–faucet basin. Water supply systems get water from a variety of sources, including municipal tap water, underground water, surface water (lakes and rivers) and rainwater. Apparently, the cleanliness of the water dispenser and the maintenance of water filters effect on drinking water quality.

2.4 RELEVANT RESEARCH

Each year, many outbreaks of illness among children due to waterborne disease bacteria are reported. The following two cases of food poisoning occurred in

two weeks (Ministry of Public Health Operation Center, 2005). On August 25, 2005, students aged 8-12 years in a school in Bangkok were ill from highly bacterial contaminated drinking water. One week later, on September 3, 2005, in a school in Burirum province, primary school students who had drunk unclean water were taken to the hospital because of waterborne disease. Moreover, Urapin Chukohtuad (2003) found the existence of sanitation indicator microbes (total Coliforms, *E. coli*) and waterborne pathogens (Salmonella, *Clostridium perfringens* and *Yersinia enterocolitica*) in tap water but not in bottled drinking water in primary schools in Bangkok. Also in other countries, the outbreaks among children due to waterborne disease bacteria have been reported (Baine et. al., 1975, Jiang, Kao, Lai, & Yu, 1995; Lim, Min, & Lee, 2005).

Because school students are exposed to the risk of diarrhea by drinking unclean water in schools, there are numerous studies on the determination of sanitary indicator microbes and waterborne pathogens. The results of those studies have been used for protecting students' health and raising the awareness of responsible persons to supply clean and safe water to students. In an investigation, samples of drinking water were collected directly from the personnel drinking water bottles of students at an elementary school in Alberta, Canada. The results show that over 10 % of samples failed to meet Canadian Drinking Water Quality Standards. Subsequently, the use of water bottles for students in elementary classrooms was not recommended (Oliphant, Ryan, & Chu, 2002).

S. Durmisević, Imamović, and J. Durmisević (1998) examined the quality of drinking water in schools by microbiological and physico-chemical analyses of water samples from 140 schools in the region of ten municipalities of Zenica-Doboj Canton (Bosnia and Herzegovina). It was found that 18.57% of samples in the microbiological analysis, and 80.26% of samples in the physico-chemical analysis, did not meet the standards prescribed for drinking water. The results were reported to schools and to the public for further improving the water quality. In the USA, the United States Environmental Protection Agency (US EPA) is very concerned about drinking water for children as it realizes that children are very sensitive to contaminants, including harmful microbes. Standard levels and recommendations for water sanitation management have been established to protect children (US EPA, 1999).

In Thailand, a study of the microbial quality of drinking water in schools in Bangkok revealed that there was bacterial contamination in some schools in Bangkok Metropolis and the Private Education Committee Bureau at the percentage of 19.1% and 18.8%, respectively (กรมอนามัย, กองสุขาภิบาลอาหารและน้ำ, 2547). Afterwards, these results were used to safeguard students' health from waterborne diseases. Another study was done in Pitsanulok province in 2005 (กรมอนามัย, กองสุขาภิบาลอาหารและน้ำ, 2548). It aimed to explore and set up guidelines of the most appropriate monitoring system of drinking-water getting quality in children day care centers and schools in order to prevent children from getting waterborne diseases. The results indicated that the score of the satisfaction level of drinking-water service was medium to good. Regarding water quality before the launch of monitoring program, only 29% of total water samples met to DOH guidelines for drinking water quality. However, after raising awareness about the importance of clean and safe water, drinking water quality became 25.0 % better than before setting up the monitoring system.

2.5 SUMMARY

Water microbiology is concerned with the microorganisms that live in water, or that can be transported from one habitat to another via water. Water can support the growth of many types of microorganisms, some of which are used as sanitary indicators of water for consumption, while others are pathogens causing diarrheal diseases, called "waterborne illness". Infants, children, and the elderly are among the groups at the greatest risk from waterborne diseases. To assess the risk, indicator organisms are used to test the microbiological quality of water. The use of indicator bacteria as a means of assessing the potential presence of water-borne pathogens has been used for protecting public health. A lack of good sanitation in the water supply in a public health environment, including schools, can cause waterborne illness in students. In schools, students drink a lot of water each day; therefore the quality and safety of drinking water needs special attention proper through a monitoring of the water supply. The administrators or the headmasters of schools should be responsible for providing clean and safe water for their students. Providing knowledge of good

sanitation practices to them will lead to proper management of the water supply and sanitation in their schools. Consequently, waterborne illness in school students can be prevented or reduced.

As the sanitary conditions of the water supply in schools can affect the cleanliness of drinking water for students, this study was planned to evaluate the quality of drinking water in schools after school administrators or headmasters obtained knowledge of good sanitation practices for maintaining clean and safe drinking water.