Chapter 1

INTRODUCTION

Waterborne diseases due to faecal pollution of human and animal origin, are responsible for approximately 2.2 million deaths annually in children under the age of five years in developing countries (WHO, 2002a; WHO, 2002b). Most of these deaths are due to inadequate potable water supplies, poor hygiene practices and insufficient sanitation infrastructures (Sobsey, 2002; WHO, 2002a; WHO 2002b). The World Health Organization (WHO) estimated that 1.2 billion of the world's population lack access to safe drinking water and these people use any source of water, usually the most convenient source, regardless of its quality (WHO, 2002a).

In many developing communities it is impossible to supply every household with an in-house tap due to economical reasons. A standpipe on the dwelling or a tap inside the house will reduce the need for storing water supplies and therefore decrease the risk of infections associated with stored water supplies (Jagals *et al.*, 1999). However, the provision of treated drinking water from standpipes is not sufficient to ensure safe drinking water, since water storage containers are often not cleaned properly or protected from contamination such as dirty hands, improper handling practices, dirty utensils, dust, animals, birds or insects (Esrey and Habicht, 1986; Daniels *et al.*, 1990; Mintz *et al.*, 1995; Reiff *et al.*, 1996; Genthe *et al.*, 1997; CDC, 2001; White *et al.*, 2002; WHO, 2002a; WHO, 2002b).

In order to improve the microbiological quality of water consumed by members of rural households, it is essential to address the quality of stored drinking water and the conditions under which the water supplies are stored. Several technologies for the treatment of household water in developing countries have been developed to improve the microbiological quality of the water and to reduce waterborne diseases (Mintz *et al.*, 1995; CDC, 2001; Sobsey, 2002). These technologies include physical methods such as boiling, heating, sedimentation, filtration, exposure to ultraviolet radiation from sunlight and chemical disinfection with agents such as sodium hypochlorite (Gilman and Skillicorn, 1985; Mintz *et al.*, 1995; Conroy *et al.*, 1996; CDC, 2001; Sobsey, 2002).

The Centers for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO), have designed a 20 litre storage container to decrease the risk of contamination during storage (Mintz *et al*., 1995; Reiff *et al*., 1996; CDC, 2001; Sobsey, 2002). This container has been evaluated and implemented in various parts of the world including South America (Bolivia, Ecuador, Nicaragua, Guatamala and Peru), Eastern Europe (Uzbekistan), the Indian subcontinent (Pakistan and Bangladesh), and Africa (Kenya, Uganda, Madagascar, Malawi, Guinea-Bisseau and Zambia) (Quick *et al*., 1996; Luby *et al*., 1998; Macy and Quick, 1998; Semenza *et al*., 1998; Sobel *et al*., 1998; Daniels *et al*., 1999; Quick *et al*., 1999; Sobsey, 2002; Sobsey *et al*., 2003). In all of these studies it was found that the container together with a sodium hypochlorite solution improved the microbiological quality of the water (Quick *et al*., 1996; Luby *et al*., 1998; Macy and Quick, 1998; Semenza *et al*., 1998; Quick *et al*., 1999; Sobsey *et al*., 2003).

Previous studies to determine the microbiological quality of household stored water have mostly focused on the detection of indicator organisms such as heterotrophic plate counts, total coliforms, faecal/thermotolerant coliforms, *Escherichia coli* (*E. coli*) and faecal enterococci which indicated the presence of faecal pollution of water samples (Quick *et al*. 1996; Luby *et al*., 1998; Macy and Quick, 1998; Semenza *et al*., 1998; Quick *et al*., 1999; Momba and Mnqumevu, 2000; Momba and Kaleni, 2002; Sobsey, 2002; Momba and Notshe, 2003). However, these indicator organisms have shortcomings in assessing the microbiological safety of water, since some of the indicators concerned can multiply in stored water supplies while waterborne pathogens cannot (Goyal *et al.*, 1979; Echeverria *et al.*, 1987; Fujioka *et al.*, 1988; Pinfold, 1990; Grabow, 1996; Handzel, 1998). Furthermore, these indicators are not specific and sensitive enough to indicate the presence of certain pathogenic microorganisms such as viruses and protozoan parasites (Goyal *et al.*, 1979; Echeverria *et al.*, 1987; Fujioka *et al.*, 1988; Pinfold, 1990; Grabow, 1996; Handzel, 1998).

In addition, people in rural communities live in close contact with domestic animals and pets, which drink from and defecate in the same primary water sources used by these communities for drinking water. This increases the risk of faecal contamination of the water (Theron and Cloete, 2002; Hackett and Lappin, 2003). Although most microbial pathogens are species specific, a few animal pathogens have been associated with

zoonotic infections (Meslin, 1997; Sinton *et al*., 1998; Franzen and Muller, 1999; Slifko *et al*., 2000; Enriquez *et al*., 2001; Hoar *et al*., 2001; Leclerc *et al*., 2002; Theron and Cloete, 2002; Hackett and Lappin, 2003). However, faecal pollution from human origin constitutes a greater health threat to consumers compared to animal faecal pollution, due to the possible presence of pathogenic microorganisms (Sinton *et al*., 1998).

The most commonly used faecal indicator microorganisms namely total coliform bacteria, thermotolerant coliform bacteria, *E. coli* and faecal enterococci, are found in both human and animal faeces, but do not allow to differentiate between human and animal faecal pollution (Sinton *et al*., 1998). However, studies have indicated that specific genotypes of male specific F-RNA bacteriophages are excreted by either humans or animals, and may be used to distinguish between faecal pollution of human and animal origin (Uys, 1999; Schaper *et al*., 2002a). Since male specific F-RNA genotyping may provide an indication of the origin of pathogens present, it could be used to determine the infection risk to the communities. This can assist in the implementation of preventative measures to control the transmission of waterborne diseases (Uys, 1999; Schaper *et al*., 2002b).

Currently, no meaningful information is available concerning the survival of waterborne pathogens such as bacterial pathogens, viruses and protozoan parasites during water storage practices in both traditional water storage containers and the CDC safe storage container in areas where communities have to use polluted water as their water source (Sobsey, 2002). A laboratory study by Momba and Kaleni (2002) have investigated the regrowth and survival of *Salmonella* spp, *Clostridium perfringens* (*C. perfringens*) bacteria, as well as somatic and male specific F-RNA bacteriophages on the surfaces of polyethylene and galvanized steel household storage containers used by rural communities in the Eastern Cape Province of South Africa. The results from this study have showed that both types of storage containers supported the growth and survival of these microorganisms for 48 h (Momba and Kaleni, 2002).

The present study focused on rural communities in the Vhembe region of the Limpopo Province, South Africa and investigated the microbiological quality of drinking water in rural households, evaluated the implementation, compliance and sustainability of intervention strategies such as the CDC safe storage container and chlorine practices,

assessed the survival of selected pathogens and investigated sources of faecal contamination in household stored water.

The objectives of this study were:

1. To assess an intervention strategy to improve the drinking water quality in rural households by:
   - Determining whether the household drinking water could be safely stored in the CDC safe storage container;
   - Determining the improvement of the microbiological quality of stored drinking water with the addition of a sodium hypochlorite solution;
   - Determining compliance of rural house households with the intervention strategy (improved storage container with addition of sodium hypochlorite solution);
   - Determining the sustainability of the intervention protocol.
2. To distinguish between faecal pollution of animal or human origin using molecular typing of male specific F-RNA bacteriophage subgroups isolated from water stored in the traditional household containers and the CDC safe storage container.
3. To determine the survival of selected indicator organisms (heterotrophic bacteria, total coliforms, faecal coliforms, faecal enterococci, *E. coli*, *C. perfringens*, somatic and male specific F-RNA bacteriophages) and selected waterborne pathogens (*Salmonella typhimurium*, vaccine strain of Poliovirus type 1 and Coxsackie B1 virus) in the CDC safe storage container using laboratory based seeding experiments. (Although a vaccine strain of Poliovirus was included in the original protocol, studies were excluded due to the global Poliovirus-containment).