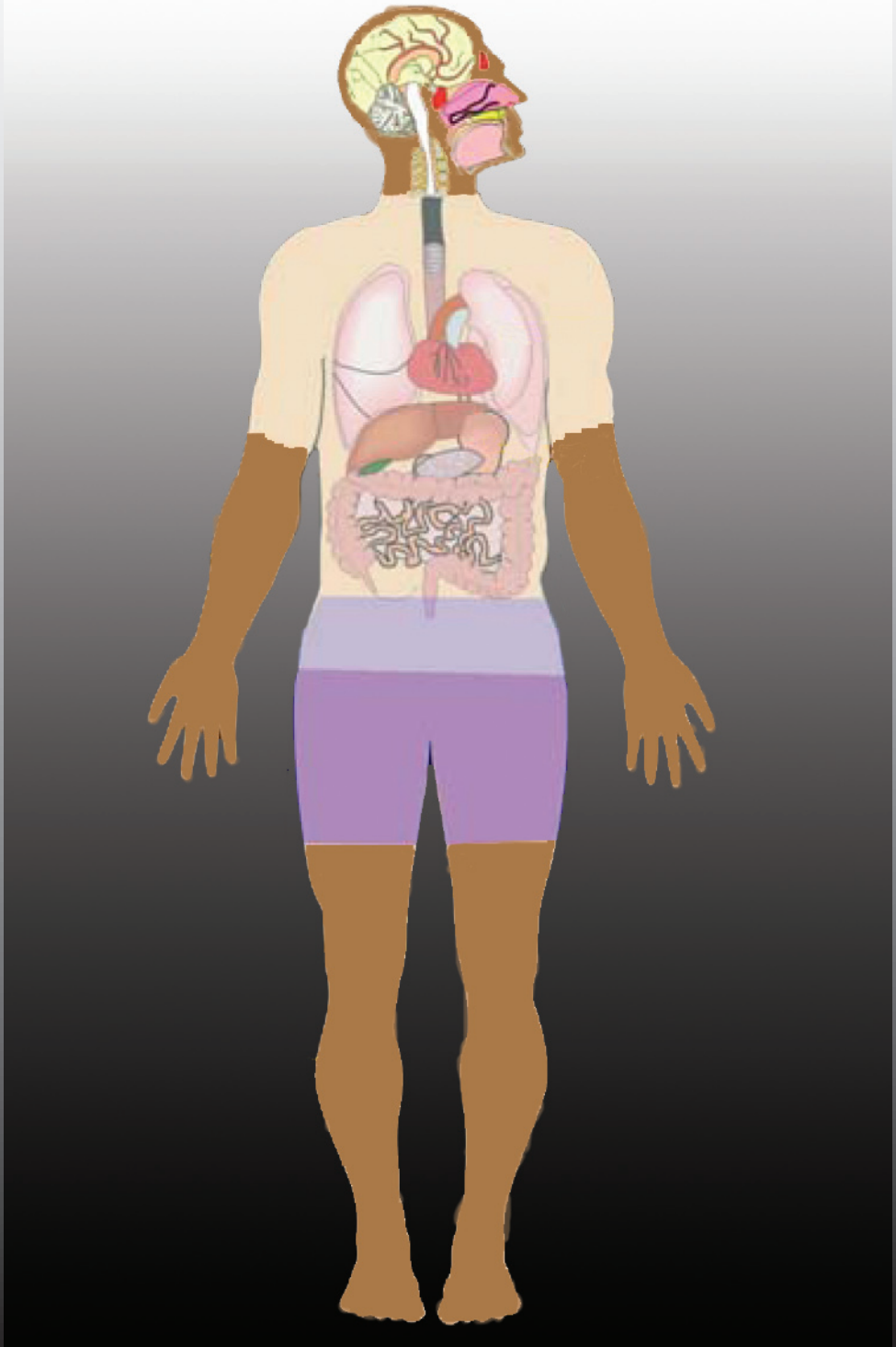
A Strategic Framework for Water-Related Human Health Research

Nozi Mjoli & Fanus Venter



TT 257/06

A STRATEGIC FRAMEWORK FOR WATER-RELATED HUMAN HEALTH RESEARCH

Report to the Water Research Commission

by

Nozi Mjoli
Hlathi Development Services
and
Fanus Venter
Department of Microbiology and Plant Pathology
University of Pretoria

WRC TT 257/06

FEBRUARY 2006

Obtainable from:

Water Research Commission
Private Bag X03
Gezina
0031

The publication of this report emanates from a project entitled: The compilation of a framework and strategic plan for future water-related health research (Consultancy K8/605)

ISBN 1-77005-404-9

Printed in the Republic of South Africa

FOREWORD

For more than three decades, the Water Research Commission has made large investments in supporting the building of an extensive knowledge base on water and human health research. The research funded by the WRC has kept pace with global trends and national priorities on water and human health. However, there has been little concerted effort to ensure that research undertaken on water and human health contributes to policy formulation and influence water sector practice. This is one of the aspects which will be addressed in the new strategic framework.

The recent incidence of typhoid outbreak that occurred in Mpumalanga highlights the importance of water quality management in the protection of public health. The current HIV/AIDS epidemic that is affecting millions of people in our country also makes it imperative to ensure that the population is not exposed to water of poor quality. These are the challenges we face and the research community should join forces with all the role-players in the water sector to ensure that we address this problem in an efficient manner applicable to the unique circumstances in South Africa.

The strategic framework provides guidance for future water research that will address national health priorities and also support the implementation of the Drinking Water Quality Management Framework for South Africa. The strategic framework will, *inter alia*, put emphasis on research needed to support the regulation of compliance to national water quality norms and standards and lack of models for a governance system for safeguarding human health and public health from water-related impacts. A new thrust has been proposed for research on governance systems for safeguarding human health. The strategic framework also addresses all water related impacts that can pose a threat to human health such as poor sanitation, polluted recreational water; quality of irrigation water, occupational water quality and risks associated with the use of waste as a resource. It is envisaged that this framework will assist in directing future research in water related human health to ensure a better level of health and an improved quality of life for all our people.

Dr Rivka Kfir
CHIEF EXECUTIVE OFFICER
WATER RESEARCH COMMISSION

EXECUTIVE SUMMARY

Introduction

The core business of the Water Research Commission is the funding of strategic water research of national importance and management of water-centred knowledge. Research is addressed under various key strategic areas (KSAs) and cross-cutting domains which form integrating frameworks across the KSAs. “Water and Health” was identified as an important cross-cutting domain within the research strategy. The purpose of this domain is to draw together programmes and projects which are being addressed within the research portfolios of the different KSAs. In addition, the cross-cutting domain needs to provide leadership and support for new KSA initiatives to further knowledge with regards to the impact of water on human health.

Valuable research in the field of water related health, funded by the WRC and other institutions, has been performed in the country. It has however, become necessary to review what has been done thus far and put it in context with national water related human health needs and priorities. In order to guide the investment strategy of the WRC in this domain over the following three to six years, a re-assess of the current situation is required to ensure optimal research investment in terms of the improvement of human health and general quality of life.

The overall aim of the project was to compile a strategic framework document that would provide guidance on future research required to protect human health from water-related impacts. Specific objectives were as follows:

- To compile a strategic plan to guide the future funding of priority research on the improvement of water related human health in Southern Africa. The plan should include health related aspects of all human-water interactions.
- To provide guidance on how the Thrusts and Programmes of the Water and Health Crosscutting Domain should be named and structured.
- To provide a prioritized investment framework for these thrusts, down to programme level, based on the above strategy plan.
- To review the state of current water related health research, both locally and (to a less exhaustive extent) internationally.
- To identify research gaps for future research on water related human health.
- To compile a list of institutions and researchers active in the water related human health.
- To provide a link between governance and water related health, in terms of Government institutions involved, relevant policies and acts, etc.

A review international and national literature on water and health was undertaken to assess the current state of water related human health research at national and international levels. The output of this process was a report entitled 'Status Review of Water and Human Health Research.' This status review report was used as a background document for stakeholder consultation. Workshops, focus groups and individual interviews were conducted to solicit inputs from the key sector institutions, namely, government departments, water boards, metro councils, science councils and universities.

The project deliverables include the following:

i) A report entitled '*Status Review of Water and Human Health Research'*, was prepared. This report presented an overview of water and health research that has been undertaken in South Africa. The report also summarized international trends in water and health research. Relevant national government policies have also been reviewed.

ii) A comprehensive strategic framework document identifying and prioritising the national research needs, categorised and prioritised down to programme level has been compiled. A summary of the key issues addressed by this document is provided below.

iii) A list of institutions, with contact details, active in water-related health research nationally and a further, similar, but less exhaustive, list for water-related health institutions internationally has also been prepared.

Strategic framework

The strategic framework is guided by the fundamental principle of an integrated preventative management approach applied from the catchment level to the water user. This approach is advocated by the WHO 3rd Edition of the Water Quality Guidelines (2004). The Department of Water Affairs & Forestry has also adopted a similar approach in the development of a Drinking Water Quality Management Framework for South Africa. The preventative management approach moved requires an understanding of the entire water supply system; this include factors that compromise the quality of water used for drinking, irrigation and recreation water as well as the water treatment technologies that are necessary to protect public health. It also deals with the prevention and control of point and diffuse pollution of water resources.

The strategic framework for water and human health research has identified a number of key elements that must be addressed by research to ensure protection of human health from negative water related impacts. In line with international trends, the strategy not only addresses research required for the management of drinking water quality but other aspects of the water uses with a potential health impact on humans such as the quality of recreational

waters, grey water management, use of wastewater for agricultural purposes, sludge disposal and prevention of pollution of surface and groundwater. Attention is also given to the impact of limited quantities of water on human health and hygiene practices. The following key elements formed the basis of the strategic framework:

- Protection of water resources

  Water resource management is an integral component of the preventive risk management approach used to protect human health. Protection of the resource from biological and chemical contaminants is the first barrier for protecting public health. . Interventions must be put in place to prevent contaminants from entering source waters and where the water quality has already been compromised, remedial measures must be implemented to improve the quality of source water.

- Ensuring safe drinking water for all

  The integrated preventive management approach proposed to ensure safe drinking water requires use of comprehensive risk assessment and risk management approaches that cover all steps in the water supply chain from catchment to consumer. These approaches are called Water Safety Plans (WSPs) and are powerful tools for managing and ensuring the safety of drinking water supply systems and they also assist water quality surveillance by public health officers. Implementation of this approach requires closer cooperation between Catchment Management Agencies, Water Services Authorities, Water Boards and Water User Associations; this is in line with the South African legislative context.

  Apart from measures to prevent the contamination of water sources and to control the transport of these contaminants through the water supply system, the use of water treatment technologies to reduce the levels of contamination is also crucial. These types of interventions will, however, not be successful without a clear public understanding of the risks associated with water use and how preventative measures can assist in reducing these risks.

- Protection of public health

  Water quality surveillance forms an integral part of public health protection; this is necessary in order to make sure that the water provided to users meets the public health quality norms and standards. Public Health protection should not only be limited to those who have access to piped water but the health needs of communities who lack access to piped water supply systems should also be addressed. Surveillance systems should, however, not only focus on quality issues but other aspects such as quantity, accessibility,

coverage, affordability and reliability of the water supply systems also need to be addressed in order to have a sustained impact on public health protection.

Public Health should also be protected from potential diseases that can be caused by the use of wastewater for irrigation through surveillance of the quality of wastewater being used and enforcement of compliance with the national water quality standards. The use of human waste from ecological sanitation as a resource for agricultural purpose should also be monitored on a regular basis in order to safeguard public health.

- Assessment of health impacts and risks

  The primary purpose of this strategic framework is to ensure that water does not have negative health impacts on the users. Research must therefore focus on the assessment of the various health impacts of biological and chemical contaminants. Risk assessment is an integral part of the preventive risk management approach that is advocated. Such an approach focuses on the identification of hazards and assessment and their contribution to water quality risks from the catchment to the consumer. This approach requires an increase in investment in risk prevention through identification and reduction of common major risks of contamination of source water. It also addresses health risks associated with collection, transportation and storage of water in households that collect water from communal standpipes. Once hazards and risks are identified, it is necessary to develop preventative strategies for eliminating or reducing the health impacts of hazards to acceptable levels.

- Creating an enabling governance framework

  The integrated preventive management approach requires a well coordinated governance system that supports the management of the entire water supply system from the catchment to the consumer and the discharge of effluents back into the water resources. In the South African legislative context, the Catchment Management Agencies (CMAs) are responsible for water resources management while Water Services Authorities (WSAs) which are responsible for providing safe drinking water to all the citizens have limited control over the management of land use activities that can impact negatively on the quality of source water. Effective governance for the protection of the quality of source water should be guided by the principles of stakeholder participation, transparency, equity, accountability, coherence, responsiveness, integration and ethical issues.

Investment framework

In order to facilitate implementation of the newly developed strategic framework for water-related human health research, research has been categorized into six research thrusts and programmes as outlined below:

Thrust 1: Resource protection

The focus of research under this thrust is on the safeguarding human health through the protection of both surface and ground water resources from impacts that compromise the quality of water and the health of users. Research under this thrust is addressed under the following programmes:

Programme 1: Detection, prevention and management of water related microbial agents

Programme 2: Detection, prevention and management of chemicals and radioactive contaminants in water resources.

Programme 3: Management of eutrophication and algal toxins.

Programme 4: Management of impacts of land use activities on surface and groundwater at a catchment level.

Thrust 2: Drinking water

This thrust focuses on all health impacts of drinking water quality, risk assessment and risk management approaches such as water safety plans and development of water quality monitoring systems. Research is addressed under the following programmes:

Programme 1: Drinking water quality management.

Programme 2: Water treatment technologies and reticulation systems

Thrust 3: Public health and hygiene issues

This thrust focuses on proximal factors such as water quantity, health and hygiene education that have a direct link to disease transmission. It also addresses the distal causal factors such as socio-economic factors that have an impact on both the health of a society and the individual through the linkages to the proximal factors. Research is addressed under the following programmes:

Programme 1: Public health and hygiene awareness and educational materials

Programme 2: Capacity building and training programmes for public health professionals and practitioners.

Programme 3: HIV/AIDS linkage with water quality and quantity and access to adequate sanitation services.

Programme 4: Impact of water quantity and service levels on human health

Thrust 4: Sanitation and waste management

This thrust focuses on health aspects of the different sanitation technologies and waste management practices, with special reference to health implications of using waste as a resource. Research is addressed under the following programmes:

Programme 1: On-site sanitation treatment technologies

Programme 2: Use of waste as a resource

Programme 3: Management of waterborne sewerage and storm water systems

Thrust 5: Health implications of water uses other than domestic use

Research under this thrust focuses on the health implications of other water uses such as health risks associated with the irrigation of crops with water of poor quality; polluted recreational waters and occupational exposure to water of poor quality. Research is addressed under the following programmes:

Programme 1: Impacts of quality of irrigation water on human health

Programme 2: Ensuring safe water for recreation

Programme 3: Management of health impacts associated with occupational exposure to water of poor quality

Thrust 6: Governance systems for safeguarding human health

This thrust focuses on research that supports the implementation of the basic principles of effective governance (stakeholder participation, transparency, equity, accountability, coherence, responsiveness and integration) within the context of water and human health. The research contributes to the development of a regulatory framework for the protection of public health from all water related health impacts. Research is undertaken under the following programmes:

Programme 1: Governance system for the protection of public health from water related impacts on human health.

Programme 2: Regulatory framework for an integrated water quality management approach

Research support infrastructure

The strategic framework also includes a section on the research support infrastructure showing important aspects that must be tackled to support research on water and human health. The major issues that are addressed are:

- Building and strengthening of the human capital
- Local and international research collaboration and partnerships
- Establishment of accredited laboratories
- Stakeholder awareness and training
- Dissemination channels for research outputs

An attempt has been made to develop a strategic framework for water related health research that encompasses all the aspects of human exposure to water related health hazards and interventions necessary to protect public health from water related diseases.

The strategic framework advocates for building strong international research partnerships so that South Africa can benefit from international expertise and financial resources. This approach will also ensure that while South Africa focuses on supporting research that is addressing problems of high priority to the people of South Africa, researchers also contribute and participate in addressing global water problems in collaboration with well resourced international research institutions.

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Acknowledgements

The authors of this document wish to acknowledge the contribution of representatives of the Water Research Commission, Government Departments, Water Boards, Science Councils, Water Services Authorities and Universities to the development of the strategic framework for research on water and human health.

LIST OF ACRONYMS

AWWA	American Water Works Association
DWAF	Department of Water Affairs & Forestry
EDC	Endocrine Disrupting Chemicals
GIS	Geographic Information System
HACCP	Hazard Analysis Critical Control Point
HIV/AIDS	Human Immuno Virus/ Acquired Immuno-Deficiency Syndrome
ICM	Integrated Catchment Management
KSA	Key Strategic Area
LGWSETA	Local Government Water Sector Education Training Authority
MRC	Medical Research Council
PCR	Polymerase Chain Reaction
POPs	Persistent Organic Pollutants
SA	South Africa
SANS	South African National Standard
UDS	Urine Diversion Sanitation System
UKZN	University of KwaZulu-Natal
UNDP	United Nations Development Programme
US-EPA	United States- Environment Protection Agency
UV	Ultra Violet
VIP	Ventilated Improved Pit toilet
WHO	World Health Organization
WIN	Water Information Network
WRC	Water Research Commission
WSA	Water Services Authority
WSPs	Water Safety Plans
WSSD	World Summit on Sustainable Development

1. INTRODUCTION

1.1 Background

The core business of the Water Research Commission is the funding of strategic water research of national importance and management of water-centred knowledge. Research is addressed under various key strategic areas (KSAs) and cross-cutting domains which form integrating frameworks across the KSAs. The cross-cutting domains draw together programmes and projects which are being addressed within the research portfolios of the different KSAs. In addition, the cross-cutting domains provide leadership and support for new KSA initiatives which can further knowledge with regards to domain related strategic research issues. The domains can also drive specific programmes and projects that are overarching and related to all KSAs in a general manner. The cross-cutting domains address the following:

- Water and Society
- Water and Economy
- Water and the Environment
- Water and Health

Valuable research in water related health has been supported by the WRC and other research institutions in South Africa. To guide the development of a new investment strategy for the Water and Health domain over the next three to six years, the WRC decided to review the research that has been conducted in recent years within the context of national needs and priorities. A report on the current status of water and health research entitled: "*Status Review of Water and Human Health Research"*, is provided in **Annexure 1**. This review provided guidance for the development of this strategic framework for ensuring optimal research investment in terms of the improvement of human health and general quality of life, in line with national health priorities.

National and global perspectives on water and health

The Department of Water Affairs & Forestry through the Strategic Framework for Water Services (2003) has set targets for access to safe drinking water for all South Africans by 2008 and access to adequate sanitation by 2010. This strategic framework also highlights the importance of health education in the delivery of water and sanitation infrastructure. At an international level, the Millennium Development Goal (2000) for water is to halve the proportion of people without sustainable access to safe drinking water by 2015. The 2002

World Summit for Sustainable Development (WSSD) called for the halving the proportion of people without access to basic sanitation by 2015.

A combination of access to safe drinking water, adequate sanitation and hygienic practices is recognized as fundamental to human well-being (UNDP, 2003). According to the World Health Report of 2002, unsafe water, poor sanitation and hygiene are in the top ten leading risks for disease in Africa and Asia. This report suggests that priority should be given to managing those risks that are well understood, substantial and widespread, and for which effective and acceptable risk reduction strategies are available.

1.2 Challenges facing the water sector in South Africa

Research within the Water and Health domain contributes to finding solutions to the following challenges facing the water sector:

- Lack of a governance framework for regulating water quality for the different user sectors;
- Lack of compliance with the required drinking water quality standards by non-metro Water Services Authorities (Manxodidi et.al., 2004);
- Lack of capacity to monitor water quality in most rural municipalities;
- Drinking water quality data not easily accessible to all stakeholders;
- Lack of an integrated approach to the management of microbial and chemical water quality in catchments;
- Poor coordination of water quality monitoring initiatives undertaken by the different sector players (DWAF, Environmental Health Practitioners, Water Boards and Water Service Authorities);
- Lack of reliable epidemiological data on water associated diseases to determine the health impacts and risk to water users;
- Poor access to safe water and adequate sanitation services places the health of vulnerable groups such as those affected with HIV/AIDS at a high risk;
- Implementation of latest treatment technologies to maintain and improve the water quality supplied to urban populations;
- Compliance with international conventions such as Stockholm Convention on Persistent Organic Pollutants (POPS) and toxicant monitoring programme.

1.3 The Context for the Water and Health Cross-cutting Domain

1.3.1 Water as a life sustaining medium

Access to safe drinking water is a basic requirement for human life, without water human life can only be sustained for a few days. Lack of access to adequate clean water and poor sanitation is responsible for the spread of water-borne diseases resulting in millions of children under five that die every year in developing countries. Health improvement is therefore one of the primary objectives of the national government's investment in the delivery of water and sanitation infrastructure and hygiene education.

1.3.2 Water-related human health impacts

The major impact of water on human health is through the ingestion of water contaminated with pathogenic microbes or harmful chemicals. This is, however, not the only route of exposure that needs to be addressed as part of the strategic framework. Inhalation of contaminated aerosols and skin contact with contaminated water can also result in infections or irritations. Water is also the habitat for a number of disease vectors (malaria and bilharzia) as well as algae that can produce toxins, or unacceptable tastes and odours (Figure 1).

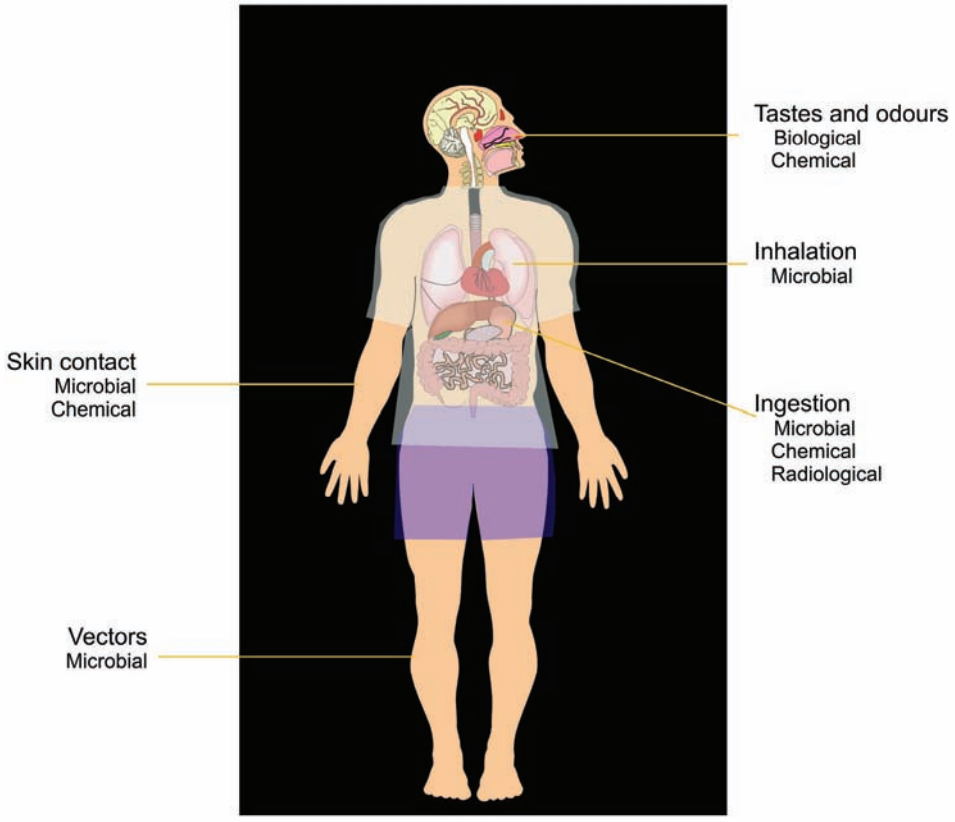

Figure 1: Exposure routes of humans to harmful compounds and microbes in water.

1.4 Scope and objective of the strategic framework for water and human health research

The primary objective of research within the Water and Health domain is to contribute to the protection of human health by investigating sources of chemical and biological agents that pollute the water resources and developing methods for prevention and control of the health impacts caused by these agents. The strategic framework addresses research needs associated with all human health exposure routes, namely, exposure to harmful chemicals and biological agents through ingestion, inhalation, skin contact and vector-borne diseases (malaria and bilharzia). The impact of access to limited quantities of water on human health and hygiene behavior also forms part of the scope of this strategic framework.

1.5 Purpose and structure of this document

The document presents a strategic framework for research on water and human health, it highlights the key elements of the strategy, proposes an investment framework for research pertaining to water associated human health impacts and highlights research gaps that must be addressed in order to contribute to the protection of people from negative health impacts that are caused by exposure to polluted water and to the overall safeguarding of public health. It also includes a section on the research support infrastructure showing important aspects that must be tackled to support research on water and human health and to facilitate knowledge sharing and information dissemination. The methodology followed in the development of this strategic framework is presented in **Annexure 2.**

2. STRATEGIC FRAMEWORK FOR RESEARCH ON WATER AND HUMAN HEALTH

The strategic objective of this framework is to support research that contributes to the improvement of human health and general quality of life, in line with national health priorities and global trends in water and health. The research within the domain of water and human health contributes to the protection of human health by providing technical solutions and health risk management guidance for reducing human exposure to biological and chemical contaminants in drinking water, on crops and in recreational waters.

The strategic framework is guided by the fundamental principle of an integrated preventative management approach applied from the catchment level to the water user. This approach is advocated by the WHO 3rd Edition of the Water Quality Guidelines (2004). The Department of Water Affairs & Forestry has adopted a similar approach in the development of a Drinking Water Quality Management Framework for South Africa (Draft, November 2004) and it has moved away from the focus on a compliance monitoring approach. A preventative management approach requires an understanding of the entire water supply system (Figure 2), including factors that compromise the quality of water used for drinking, irrigation and recreation water as well as the water treatment technologies that are necessary to protect public health. It also deals with the prevention and control of point and diffuse pollution of water resources.

The strategic framework for water and human health research identifies the key elements that must be addressed by research to ensure protection of human health from negative water related impacts. In line with international trends, the strategy not only addresses research required for the management of drinking water quality but other aspects of the water uses with a potential health impact on humans such as the quality of recreational waters, grey water management, use of wastewater for agricultural purposes, sludge disposal and prevention of pollution of surface and groundwater all form part of the strategy. Attention is also given to the impact of limited quantities of water on human health and hygiene practices.

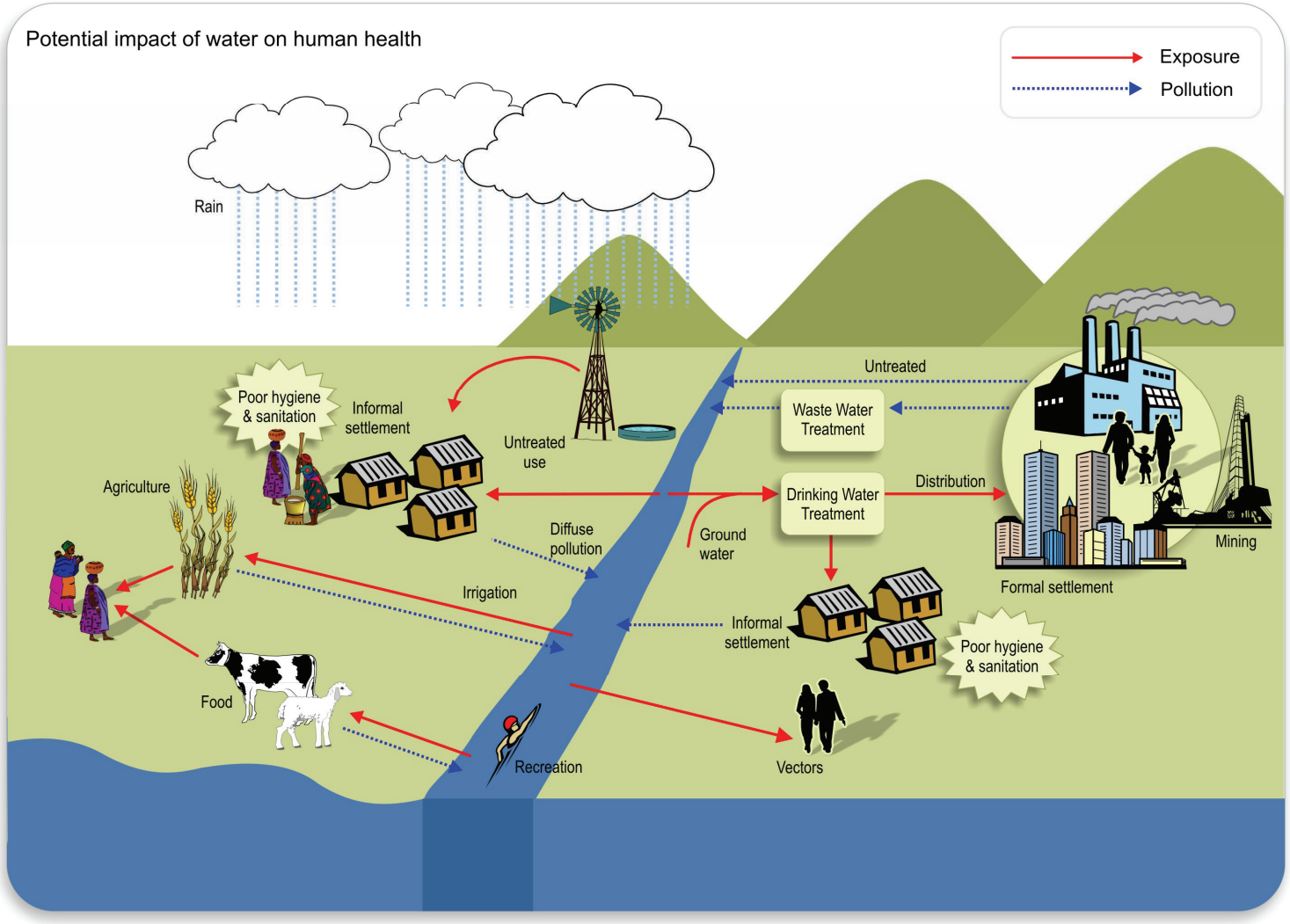

Figure 2. Diagrammatic representation of the potential impacts of water on human health.

2.1 Key elements of the strategic framework

2.1.1 Protection of water resources

Water resource management is an integral component of the preventive risk management approach used to protect human health. Protection of the resource from biological and chemical contaminants is the first barrier for protecting public health (WHO, 2004). The following threats to source water quality must be managed in order to protect human health (http://www.epa.gov/safewater):

Microbial contaminants – bacteria, parasites and viruses originating from poor sanitary practices, sewage effluents, surface runoff, livestock and intensive farming, municipal waste dumps etc.;

Inorganic contaminants – salts and metals from natural sources, urban storm water runoff, industrial or domestic waste discharge, mining and agriculture;

Organic chemical contaminants – synthetic organic chemicals from industry, urban storm water runoff, petrol stations etc.;

Pesticides and **herbicides** – agriculture, domestic uses (gardens) and storm water runoff;

Radioactive contaminants – naturally occurring or result from oil production and mining activities.

Globally, there is a growing global recognition of the importance of protecting the quality of surface and ground water sources of drinking water and its contribution to the reduction of the cost of treating drinking water to meet the drinking water quality norms and standards. Interventions must be put in place to prevent contaminants from entering source waters and where the water quality has already been compromised, remedial measures must be implemented to improve the quality of source water.

2.1.2 Ensuring safe drinking water for all

The integrated preventive management approach proposed to ensure safe drinking water requires use of comprehensive risk assessment and risk management approaches that cover all steps in the water supply chain from catchment to consumer. These approaches are called Water Safety Plans (WSPs) and are well documented in the WHO Guidelines (2004). The WSPs are based on similar principles and concepts used for other risk management approaches such as the multi-barrier approach and the Hazard Analysis Critical Control Point (HACCP), commonly used in the food industry. WSPs are powerful tools for managing and ensuring the safety of drinking water supply systems and they also assist water quality surveillance by public health officers. Key aspects of this approach are:

- *System assessment* - this assesses whether a water supply chain from catchment to consumer can deliver water of good quality that meets the health-based targets.
- *Effective operational monitoring* - is required for rapid detection of any deviations of water supply system from producing water of good quality.
- *Management* – spells out management actions for ensuring effective performance of the water supply chain, monitoring and communication plans and supporting programmes necessary to achieve the health based target.
- *Independent surveillance system* - this is required to verify that all water quality control points are operating effectively. (WHO, 2004)

The primary goal of the preventative management approach is to minimize contamination of water resources, the reduction or removal of contaminants through the treatment processes and prevention of contamination during storage, distribution and handling of drinking water. Implementation of this approach requires closer cooperation between Catchment Management Agencies, Water Services Authorities, Water Boards and Water User Associations, this is in line with the South African legislative context.

Effective drinking water quality management relies on the use of multiple barriers for human health protection. Apart from measures to prevent the contamination of water sources and to control the transport of these contaminants through the water supply system, the use of water treatment technologies to reduce the levels of contamination is also crucial. These types of interventions will, however, not be successful without a clear public understanding of the risks associated with water use and how preventative measures can assist in reducing these risks.

2.1.3 Protection of public health

The Constitution of the South Africa (1996) guarantees a right of access for South Africans to an environment that is not harmful to their health or well-being. The Environmental Health Practitioners (EHPs) have a responsibility for water quality surveillance in order to make sure that the water provided to water users meets the public health quality standards or norms. The surveillance of water required for various applications and uses deals with the improvement of water quality, quantity, accessibility, coverage, affordability and reliability of the water supply systems because all these factors have an impact on public health protection.

Box 1- Definition of Public Health

Public health *is defined as 'the science and art of preventing disease, prolonging life and promoting health through organized efforts of society'. The primary objective of public health is the protection and improvement of health. It focuses on monitoring the health of the population, identification of health needs, fostering of policies that promote health and evaluation of health services (Eisenberg et.al 2001)*

Public Health protection should not only be limited to those who have access to piped water but the health needs of communities who lack access to piped water supply systems should be addressed so that they can be protected from drinking water of poor quality. Periodic assessment of the quality of water used by these communities should be undertaken so that efforts can be made to minimize contamination of these sources and negative health impacts.

Public Health should also be protected from potential diseases that can be caused by the use of wastewater for irrigation through surveillance of the quality of wastewater being used and enforcement of compliance with the national water quality standards. The use of human waste from ecological sanitation as a resource for agricultural purpose should also be monitored on a regular basis in order to safeguard public health.

2.1.4 Assessment of health impacts and risks

The primary purpose of this strategic framework is to ensure that water does not have negative health impacts on the users. Research must therefore focus on the assessment of the various health impacts of biological and chemical contaminants. Risk assessment is an integral part of the preventive risk management approach that is advocated in the drinking water quality management framework for South Africa (DWAF, 2004). In terms of this DWAF framework, the most effective means of consistently ensuring the safety of a drinking water supply is through the adoption of a comprehensive risk-based approach. Such an approach focuses on the identification of hazards and assessment and their contribution to water quality risks from the catchment to the consumer. This approach requires an increase in investment in risk prevention through identification and reduction of common major risks of contamination of source water. It also addresses health risks associated with collection, transportation and storage of water in households that collect water from communal standpipes. Once hazards and risks are identified, it is necessary to develop preventative strategies for eliminating or reducing the health impacts of hazards to acceptable levels.

2.1.5 Creating an enabling governance framework

The integrated preventive management approach requires a well coordinated governance system that supports the management of the entire water supply system from the catchment to the consumer and the discharge of effluents back into the water resources. Integrated Catchment Management (ICM) approach provides an effective way of managing both water quantity and water quality at the different stages of the water supply system. In the South African legislative context, the Catchment Management Agencies (CMAs) are responsible for water resources management while Water Services Authorities (WSAs) which are responsible for providing safe drinking water to all the citizens have no control over the management of land use activities that may impact negatively on the quality of source water. Effective governance for the protection of the quality of source water should be guided by the principles of stakeholder participation, transparency, equity, accountability, coherence, responsiveness, integration and ethical issues (UN World Water Development Report, 2003).

Box 3: Definition of governance

For the purpose of this strategic framework, governance is defined as the framework of social and economic systems, legal and political structures through which water resources and water services are managed according to objectives that reflect the health goals and values of society (MacKay et.al. 2004 ; World Humanity Action Trust, 2000.)

2.2 Investment framework

In order to facilitate implementation of the strategic framework for water-related human health research, research has been categorized into six research thrusts, namely, Resource Protection, Drinking Water, Public Health and Hygiene Issues, Sanitation and Waste Management,Health Implications of water uses other than domestic uses and Governance systems for safeguarding human health . This division is based on the application of the principle of an integrated preventive management approach to the protection of human health from exposure to hazardous chemicals and biological agents found in water.

2.2.1 Thrust 1: Resource protection

Scope

The focus of research under this thrust is on the safeguarding human health through the protection of both surface and ground water resources from impacts that compromise the quality of water and add to the economic burden of treating water so that it meets the national water quality norms and standards for different water uses that may have a negative effect on human health. Point and diffuse sources of pollution are addressed through pollution

prevention interventions and remediation where water quality has already deteriorated. The focus is on the detection, prevention and management of all contaminants that pose a threat to human health. Development of health risk assessment and management tools for protecting human health from water-related health hazards is addressed under this thrust.

Research under this thrust is addressed under the following programmes:
Programme 1: Detection, prevention and management of water related microbial agents.
Programme 2: Detection, prevention and management of chemicals and radioactive contaminants in water resources.
Programme 3: Management of eutrophication and algal toxins.
Programme 4: Management of impacts of land use activities on surface and groundwater at a catchment level.

2.2.2 Thrust 2: Drinking water

Scope

This thrust focuses on research on all health impacts of drinking water quality, risk assessment and risk management approaches such as water safety plans and development of water quality monitoring systems. Research is contributing to ensuring that drinking water is safe, i.e. it does not cause any harm to human health, and it is free from pathogens and chemical contaminants that can potentially induce pathological and physiological damages to humans. This is achieved through the development of rapid and sensitive technologies for detecting contaminants in drinking water and innovative treatment technologies for removing contaminants from water. Research also contributes to the development of effective governance systems which are necessary to facilitate the regulation of drinking water quality.

Research is addressed under the following programmes:
Programme 1: Drinking water quality management.
Programme 2: Water treatment technologies and reticulation systems

2.2.3 Thrust 3: Public health and hygiene issues

Scope

This thrust focuses on proximal factors such as water quantity, health and hygiene education that have a direct link to disease transmission. It also addresses the distal causal factors such as socio-economic factors that have an impact on both the health of a society and the individual through the linkages to the proximal factors (Eisenberg et.al, 2001). Public health protection has the following components:

- Surveillance to measure risk associated with specific water uses;
- Comparisons of measured risk and predefined acceptable risk thus leading to the development of control strategies;
- Public awareness campaigns and promotion of sanitation, health and hygiene education;

The main focus of this research thrust is on the development of tools for the identification of conditions that are conducive to water-borne disease outbreaks and appropriate precautionary and preventive measures that can be taken to protect public health. Examples of tools include water quality monitoring systems, early warning systems, disease surveillance systems and health and hygiene awareness and education materials. The impact of sanitation, water quality and quantity on the health of HIV/AIDS patients is also addressed with a view to developing strategies for reducing their exposure to microbial agents associated with contaminated water. Capacity building and training of sector professionals is also addressed under this thrust because availability of skilled personnel is critical to public health protection.

Research is addressed under the following programmes:
Programme 1: Public health and hygiene awareness and educational materials
Programme 2: Capacity building and training programmes for public health professionals and practitioners.
Programme 3: HIV/AIDS linkage with water quality and quantity and access to adequate sanitation services.
Programme 4: Impact of water quantity and service levels on human health

2.2.4 Thrust 4: Sanitation and waste management

Scope

This thrust focuses on health aspects of the different sanitation technologies and waste management practices, with special reference to health implications of using waste as a resource. Promotion of ecological sanitation technology is leading to a growing interest in the use of human excrement and grey water in crop production. There is a need to find a balance between increasing food security for poor households and the protection of public and environmental health. Research provides scientific information and health risk management strategies for guiding decision-makers in setting minimum quality standards for use of wastewater in crop production in order to protect human health. Research addresses safe treatment and disposal of sludge from on-site sanitation systems, for example, pit latrines, septic tanks and urine diversion systems. Health implications of malfunctioning waterborne sewerage and poor storm drainage systems are addressed under this thrust.

Research is addressed under the following programmes:

Programme 1: On-site sanitation treatment technologies

Programme 2: Use of waste as a resource

Programme 3: Management of waterborne sewerage and storm water systems

2.2.5 Thrust 5: Health implications of water uses other than domestic use

Scope

Research under this thrust focuses on the health implications of other water uses such as health risks associated with the irrigation of crops with water of poor quality; polluted recreational waters and occupational exposure to water of poor quality. Irrigation of crops with water of poor quality can have both direct and indirect effects on human health. Health risk assessment studies for the different use categories should be undertaken and appropriate management strategies should be developed to mitigate negative health impacts of exposure to water of poor quality.

Research is addressed under the following programmes:

Programme 1: Impacts of quality of irrigation water on human health

Programme 2: Ensuring safe water for recreation

Programme 3: Management of health impacts associated with occupational exposure to water of poor quality

2.2.6 Thrust 6: Governance systems for safeguarding human health

Scope

This thrust focuses on research that supports the implementation of the basic principles of effective governance (stakeholder participation, transparency, equity, accountability, coherence, responsiveness and integration) within the context of water and human health. The research contributes to the development of a regulatory framework for the protection of public health from all water related health impacts. It also develops tools and guidelines for the implementation of comprehensive risk management strategies for managing drinking water quality from the catchment to the end-users. Research necessary to evaluate and guide policy formulation process is addressed under this thrust. Models for appropriate governance systems necessary to support effective regulation of water quality are addressed. These models should be flexible enough to accommodate the challenges faced by small water service authorities with regards to water quality aspects.

Research is undertaken under the following programmes:

Programme 1: Governance system for the protection of public health from water related impacts on human health.

This programme focuses on governance issues that must be addressed to safeguard public health from water related impacts on human health.

Programme 2: Regulatory framework for an integrated water quality management approach

This programme addresses governance issues pertaining to the protection of the resource focusing on the development of appropriate instruments and tools for regulating integrated water quality management and enforcing compliance.

2.3 Research needs

The research needs identified by stakeholders have been categorized according to the proposed investment framework and presented in the following tables:

Thrust 1: Resource Protection

Programme	***Research topic***
1. Detection, prevention and management of water related microbial agents	a) Improved methods for the detection of microbial pathogens in water b) Catchment management strategies for preventing microbial water pollution c) Improved methods for the detection of indicators of microbial pollution
2. Detection, prevention and management of chemicals and radioactive contaminants in water resources	a) Health implications of chemicals in groundwater b) Determination of health risks associated with exposure to EDCs c) Impacts of pesticides on human health d) The health consequence of chronic exposure to high levels of metals in water e) Improved methods for the detection of indicators of various chemical pollutants
3. Management of eutrophication and algal toxins.	a) Management of eutrophication and toxin pollution in water resources b) Improved methods for the detection of algal toxin indicators c) Development of methods for the detection of algal toxins
4. Management of impacts of land use activities on surface and ground water quality at a catchment level.	a) Impacts of food grade wastes on the pollution of surface and groundwater

Thrust 2: Drinking Water

Programme	***Research topic***
1. Drinking water quality management	a) Guidelines for the application of HACCP principles for improving the quality of drinking water supplied by small WSAs b) Strategies for the implementation of water safety plans by small water services authorities c) Survey of the quality of drinking water supplied to rural schools and health care facilities
2. Water treatment technologies and reticulation systems	a) Effect of aging distribution systems on the water quality and health. b) Evaluation of sustainability of in-house water treatment systems e.g. filtration systems c) The role of plumbing materials on water quality d) Disinfection guidelines for rural communities at household level

Thrust 3: Public health and hygiene issues

Programmes	***Research topics***
1. Public health and hygiene awareness and education materials	a) Assessment of the role played by social and cultural factors in shaping individual's perceptions of health risks. b) Assessment of the contribution of water quality and quantity on the effectiveness of hand-washing practice in breaking the cycle of disease transmission. c) Development of guideline documents for managing chemical pollutants d) Consolidation and evaluation of education and awareness material that will support sustainable behavioural changes (Water Information Network) e) Investigate the burden of disease associated with water determined at the provincial and local levels. f) Evaluation of the impact of education material.
2.Capacity building and training programmes for public health professionals and practitioners	a) Technical guidelines on water quality management for use by environmental health practitioners b) Development of a public health booklet for non-technical decision makers c) Support systems for the development of analytical infrastructure and human capacity. d) Technology transfer of new methods for water quality monitoring e) Development of technical manuals/guidelines e.g. algal toolbox
3. HIV/AIDS linkage with water quality and quantity and access to adequate sanitation services	a) Prediction of the effect of HIV/AIDS epidemic on water service demand patterns b) Impact of water quality on the health of HIV/AIDS patients c) Impact of different levels of water and sanitation on the health outcomes for HIV/AIDS patients
4. Impact of water quantity and service levels on human health	a) Contribution of the improved water and sanitation infrastructure to the reduction of waterborne diseases

Thrust 4: Sanitation and waste management

Programme	***Research topic***
1. On-site sanitation treatment technologies and waste management	a) Evaluation of dry sanitation options for informal settlements. b) Investigation of geotechnical factors that promote migration of bacteria from pit latrines to groundwater sources. c) Development of more effective and faster methods for destroying pathogens in pit sludge to facilitate safe disposal or re-use of pit sludge. d) Guidance on the selection of on-site treatment options/technologies
2. Use of waste as a resource	a) Evaluation of health impacts of using stabilized sludge and urine from on-site sanitation systems in crop production b) Development of guidelines for grey water management for dense settlements with dry on-site sanitation systems
3. Management of water-borne sewerage and storm water systems	a) Investigating the effects of malfunctioning sewerage systems on resource water quality and public health

Thrust 5: Health implications of water uses other than domestic use

Programme	***Research topic***
1. Impact of quality of irrigation water on human health	Management options to protect water sources used for crop irrigation
2. Ensuring safe water for recreation	a) Effect of increased urbanization on the quality of recreational water (fresh water and marine) b) Guidelines for the management of health impacts of school swimming pools.
3. Management of health impacts associated with occupational exposure to contaminated water	a) Risk assessment and management of occupational health hazards of exposure to water of poor quality b) Occupational exposure to contaminated water and effluents e.g. in mines, industry, sewage treatment works, etc.

Thrust 6: Governance systems for safeguarding human health

Programme	***Research topic***
1. Governance system for the protection of public health from water related impacts on human health	a) Development of policy framework on the re-use of treated sewage in agriculture b) Evaluation of the impacts of policy decisions and regulations on human health c) Development of a national disease surveillance system for water associated diseases.
2. Regulatory framework for an integrated water quality management approach	a) Integrated management of chemical and microbial water quality. b) Evaluation of national water quality monitoring programmes and their sustainability

3. RESEARCH SUPPORT INFRASTRUCTURE

3.1 Building and strengthening of the human capital

Successful execution of the research identified to protect human health and support for the implementation of a South African drinking water quality management framework depend on the availability of researchers with the necessary skills. Their main purpose will be to develop tools and provide information for use by government, WSAs and water boards so that these institutions can provide users with water of good quality that meets the national water quality norms and standards. There is also a need to build and strengthen the human capital within the water services institutions so that they are able to use the tools provided by researchers to improve the implementation of the integrated preventative management approach. The Water Research Commission should work closely with the Local Government SETA to find innovative solution to address the problem of skills shortage within the water quality management field especially with regards to conducting the national water quality monitoring programmes. There is also a need to build capacity to undertake surveillance of drinking water quality at a community level especially in those areas where households do not have access to piped water supply but still rely on water from untreated sources.

3.2 Research collaboration and partnerships

South Africa's approach to drinking water quality management is based on the WHO drinking water quality guidelines; this creates an opportunity for South Africa to draw from international best practice. The WRC has made significant progress in fostering partnerships among research groups active in the field of Water and Health. Research in new focus areas such as EDCs, emerging pathogens, algal toxins and risk assessment is already benefiting from partnerships with well established international research institutions and through the Global Water Research Coalition. South African researchers can also access international funding from organization that supports research, which is necessary to assist member countries to comply with international conventions. The WRC can play an important facilitating role in the establishment of partnerships and accessing of international research funds. A list of national and selected international institutions active in water and human health research is attached (**Annexure 3**).

3.3 Establishment of accredited laboratories

Monitoring of compliance to national drinking water quality standards must be based on a sound scientific basis, therefore, all laboratories responsible for testing compliance must be certified/accredited to ensure that they are analyzing drinking-water samples accurately using approved laboratory methods and procedures and also implementing quality assurance plans. South Africa is a signatory of international conventions for environmental quality, such as the Stockholm Convention on Persistent Organic Pollutants (POPs); tests for compliance can only be done by accredited laboratories. The WRC should support an audit of laboratories that are competent to be considered for accreditation and where there are short falls; strategies must be developed to facilitate accreditation of more laboratories.

3.4 Knowledge/Information management

3.4.1 Stakeholder awareness and training

The review of the status of research on water and health supported by the WRC shows that valuable research reports, guidelines and decision support tools have been produced, but use and awareness of these documents is not widespread, especially, among WSA's who are responsible for delivery of drinking water of good quality that meets the national water quality norms and standards. There is a need for effective methods of promoting stakeholder awareness of materials that are available from the WRC. Training in the use of some of the tools and manuals can be done in partnership with the relevant Local Government SETA.

3.4.2 Dissemination channels for research outputs

A review of research undertaken in the Water and Health domain showed that a lot of new knowledge has been generated on more sensitive methods for the detection of bacteria and viruses in water; however, there is no evidence that these sensitive molecular detection methods have been assimilated by water quality management laboratories into their routine water quality management procedures. Research must be undertaken to assess the contribution of these new sensitive detection methods to the improvement of water quality management in water service institutions. Procedures must be developed for validation and verification of new water quality analytical methods before these methods are added to a suite of standard water quality analytic methods. There is also a need to evaluate the contribution of water and health research to influencing national water and health policy development. The WRC should consider making its key publications on water and health available on its website so that information is easily accessible to the stakeholders

4. CONCLUSION

An attempt has been made to develop a strategic framework for water related health research that encompasses all the aspects of human exposure to water related health hazards and interventions necessary to protect public health from water related diseases. Most of the research needs identified by stakeholders can be funded within the key strategic areas. Certain research programmes that cut across the resource protection and public health protection may require funding under the Water and Health Cross-cutting domain. For example, research on governance framework required to support preventive management of water quality from the catchment to consumer would be difficult to support under one specific KSA.

The strategic framework advocates for building strong international research partnerships so that South Africa can benefit from international expertise and financial resources. This approach will also ensure that while South Africa focuses on supporting research that is addressing problems of high priority to the people of South Africa, researchers also contribute and participate in addressing global water problems in collaboration with well resourced international research institutions.

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ANNEXURE 1

STATUS REVIEW OF
WATER AND HUMAN HEALTH RESEARCH

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Background

The Water Research Commission has a responsibility of addressing key strategic water issues of national importance. These issues are addressed under various key strategic areas (KSAs) and through cross-cutting domains which form integrating frameworks across the KSAs. The cross-cutting domains draw together programmes and projects which are being addressed within the research portfolios of the different KSAs. In addition, the cross-cutting domains provide leadership and support for new KSA initiatives which can further knowledge with regards to domain related strategic research issues. The domains can also drive specific programmes and projects that are overarching and related to all KSAs in a general manner. The cross-cutting domains address the following issues:

Water and Society

Water and Economy

Water and the Environment

Water and Health

A brief overview of water and health research shows that very valuable research in the water related health domain has been supported by the WRC and other research institutions. The WRC has decided to take stock of the research that has been done and to put it within the context of national needs and priorities in the area of water related human health. In order to guide the investment strategy of the WRC in the Water and Health domain over the next three to six years, it is necessary to assess the current research programmes and provide strategic guidance for future research in order to ensure optimal investment in terms of the improvement of human health and quality of life.

1.2 Water and Health Cross-cutting domain in context

1.2.1 Water as a life-sustaining medium

Access to adequate safe drinking water is a basic requirement for human life, without water human life can only be sustained for a few days. Unsafe drinking water is often responsible for exposure to chemicals and the spread of water associated diseases, which may be aggravated by poor hygiene and sanitation practices due to limited supplies. Millions of children under five die every year because of poor access to adequate safe water and sanitation services. Health improvement is therefore the primary objective of the government's investment in the delivery of water and sanitation infrastructure.

1.2.2 Water-related human health impacts

The major impact of water on human health is through the ingestion of water contaminated with pathogenic microbes or harmful chemicals. This is, however, not the only route of exposure as can be seen in Figure 1. Inhalation of contaminated aerosols and skin contact with contaminated water can also result in infections or irritations. Water is also the habitat for a number of infectious disease vectors as well as algae that can produce toxins, or unacceptable tastes and odours. For the purpose of the research status review, which forms part of this document, water-related human health problems have been grouped under the following categories:

Water-borne diseases

These diseases are mainly caused by drinking faecally contaminated water that transmits pathogens to humans. Water-borne pathogens are often associated with diarrhoeal diseases such as cholera, gastro-enteritis, typhoid etc. People drinking untreated water of poor quality are at high risk of infection from these waterborne pathogens. Transmission of these pathogens can sometimes be indirectly linked to water, for example, through consumption of uncooked food that is contaminated during irrigation or that is produced in contaminated water is a well known vehicle for these pathogens. Certain water-borne pathogens are only transmitted by inhalation of contaminated aerosols or skin contact during recreational activities. Improvement in water quality management and treatment will reduce incidence of water-borne diseases.

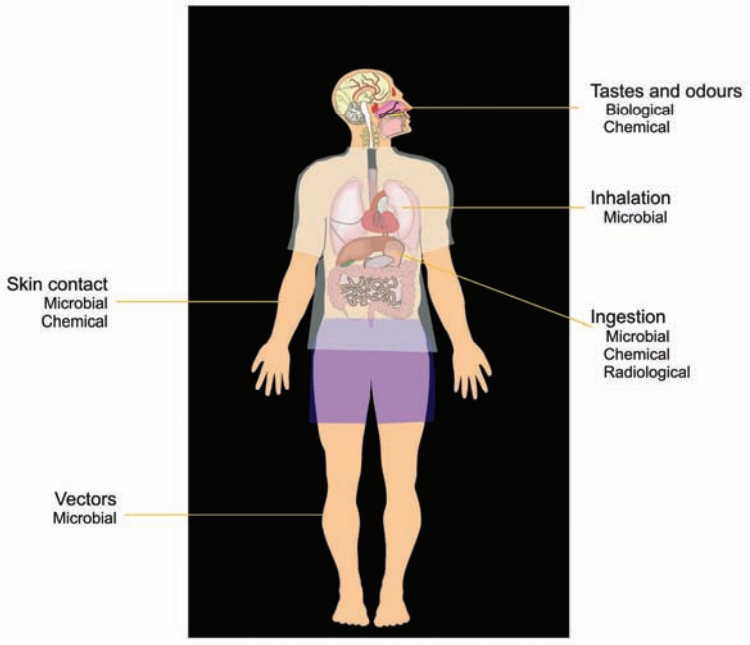

Figure 1. Exposure routes of humans to harmful compounds and microbes in water.

Water-washed diseases

These diseases are caused by lack of access to adequate water thus resulting in poor personal hygiene, for example, trachoma, scabies etc. These diseases can be prevented by providing adequate quantities of water so that individuals can improve their personal hygiene practices.

Water-related vector diseases

These diseases are caused by parasites that spend part of their life cycle in aquatic hosts, e.g. bilharzias (snails) and malaria (mosquitoes). Malaria can be controlled by providing good drainage which leads to the elimination of mosquitoes; and bilharzia can be controlled by providing access to adequate water at a household level so that children do not have to rely on river water for bathing and washing of clothes.

Chemicals in drinking water and exposure through skin contact

Adverse health effects of chemically contaminated drinking water are usually associated with long-term exposure. Naturally occurring chemicals in groundwater such as arsenate, fluoride and nitrates cause adverse health impacts in many countries. Other point and diffuse sources of chemical pollution include waste discharge effluents from industrial activities, agriculture, sewage treatment plants, on-site sanitation systems and other human activities that have a high content of chemicals. Nitrates, pesticides, endocrine disruptors and heavy metals are amongst these pollutants. The formation of harmful disinfection by-products and the release of cyanobacterial toxins during drinking water treatment have also raised some concern.

1.3 Scope of the Water and Health Domain

The primary objective of research within this domain is to contribute to the protection of human health. The research addresses a number of topics including the effect of land use activities on water resources and the development of methods for the detection and quantification of microbial and chemical pollutants. Attention is also given to the impact of these pollutants on the health of water users by means of risk assessments and epidemiological studies. The development of innovative technologies for the treatment of water and strategies for the prevention and management of human exposure are also supported. The emphasis is on pro-active approach to identify and address causes, rather than on a reactive response of treating symptoms.

Currently, research under this domain is undertaken under the following thrusts:

Thrust 1: Microbial Water Quality and Associated Health Impact

The focus of this thrust is on improving knowledge of biological agents responsible for water-borne diseases and epidemiology of such diseases; assessment of health risks especially in

high risk communities, HIV/AIDS infected people and immuno-compromised individuals; and the development of cost-effective management strategies for preventing contamination of water sources and spread of diseases.

Thrust 2: Chemical quality of water and associated impact on health

This thrust focuses on gathering data on chemicals present in water, both anthropogenic and naturally-occurring, which may have the potential to cause detrimental health effects in humans and animals. Special emphasis is currently on endocrine disrupting contaminants (EDCs) and algal toxins associated with eutrophication of water resources. The development of simple, rapid and cost-effective detection methods for these agents is being addressed.

Thrust 3: Safeguarding public health

This thrust focuses on investigating conditions that are conducive to the outbreak of water-linked diseases and development of appropriate and preventive measures which can be taken to mitigate the impact of the disease outbreak. The development and use of pollution monitoring systems, early warning systems and promotion of health and hygiene awareness are appropriate in this regard. The thrust supports the development of protocols, guidelines and manuals for microbial, toxicant and EDCs monitoring programmes, and the development of public awareness and educational materials.

1.4 Purpose of this document

This document starts with a review of the national policy, legislative and strategic context for water and health research in South Africa. This is followed by a summary of the current status of water and human health research, which mainly deals with the research undertaken in South Africa. International trends have, however, also been taken into consideration. In order to compile a strategic framework for water and human health research as part of the Water Health Cross-Cutting Domain strategic research needs and gaps had to be identified. For this purpose the abovementioned research status review was used as a discussion document to solicit stakeholder inputs into the process. A matrix that categorizes research in the field of water and health has been used to identify strategic health issues and research gaps that must be addressed to meet the national water and human health priorities. This information served as the basis for the development of the strategic framework for water related health research, which is discussed in an accompanying document.

2. POLICY, LEGISLATIVE AND STRATEGIC CONTEXT FOR WATER AND HUMAN HEALTH

The following national policies, strategies and pieces of legislation provide a governance framework for the national water and health research agenda:

The Water Services Act of 1997

This Act guarantees the right of access to basic water supply and basic sanitation necessary to secure sufficient water and an environment not harmful to human health or well-being.

The National Water Act of 1998

This Act recognizes that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interest of all water users.

National Water Resources Strategy (2004)

One of the objectives of the NWRS is to establish the national framework. Water quality management which is very important to human health falls under this objective. Three approaches are used to mange water quality, namely:

receiving water quality objectives approach for non-hazardous substances;

the pollution minimization and prevention approach for hazardous substances;

source directed controls for water quality such as the identification of emerging threats to the water resources and priorities for appropriate action.

The White Paper on the Transformation of the Health Systems in South Africa of 1997

This policy recognizes the importance of knowledge, information and evidence by stating that health research must be linked and integrated into planning, policies, programmes and implementation. The Department of Health has adopted the Essential National Health Research (ENHR) approach in order to promote the linkage between health research and health care. ENHR is an integrated strategy for organizing health-related research. It emphasizes an integrated, multidisciplinary approach in addressing health problems, and the essential requirement to link research with implementation. The ENHR approach advocates for research on national health problems and also global health research to solve health problems of global significance. This policy provides guidance on the setting of priorities, utilization of the full range of methodologies for tackling health problems, and harmony

between research and health needs, so as to inform planning, delivery, management and policy.

The National Health Act of 2003

The objective of this Act is to fulfill the right of the people of South Africa to an environment that is not harmful to their health or well-being.

The White Paper on Science and Technology (1996)

This White paper calls for the integration of the Science and Technology system into a larger system of innovation. The concept of a national innovation offers a means of identifying what needs to be done focusing on innovation, i.e. doing new things in new ways rather than simply focusing on the production of knowledge. The system of innovation poses a challenge of ensuring that research and development results are translated into new or improved products, processes and services.

The Health Research Policy in South Africa (2001)

This policy attempts to create a framework and environment for health research to contribute effectively to health development and is envisaged as an integral part of long-term health development aimed at improving the health and quality of life of all South Africans.

The following are some of the goals of this research policy:

- to develop a national health research system that contributes to equitable health development;
- to promote innovation in health and health related service delivery;
- to nurture talent and develop capacity to conduct and utilize research findings;
- to encourage uptake of research-based knowledge into the health care system.

The following objectives of the policy are relevant to the water and health research:

- to create a framework for a health research system that would improve the quality, impact, effectiveness and efficiency of the research;
- to utilize monitoring and evaluation as a strategy tool to improve the quality and impact of research;
- to build research capacity in all its facets within the community, health services, research institutions and decision-makers;
- to develop a communication strategy that establishes mechanisms for the dissemination of information and ensures that benefits of research are systematically and effectively translated into practice;

- to establish links and partnerships both locally and internationally between those involved in health, funders of research, researchers, research institutions and users of research outputs in public and private sectors.

The policy highlights the current problem of poor stakeholder involvement in the identification of health research priorities and a lack of communication and dissemination of the research results.

White Paper on Basic Household Sanitation of 2001

The primary goal of the national sanitation policy is to improve human health. The policy aims to highlight the impact of poor sanitation on health, living conditions and the environment.

Disaster Management Act of 2002

The Disaster Management Act provides an integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery. Natural disasters such as cholera outbreaks, floods and droughts have an impact on water and human health.

National Health and Hygiene Strategy of 2004

The vision of the national health and hygiene strategy is a clean and healthy South Africa that is free from the burden of diseases in relation to water and sanitation services. The strategy aims to provide minimum standards for health and hygiene education to ensure uniform and quality health and hygiene education delivery.

Strategic Framework for Water Services of 2003

The strategic framework highlights the importance of health education in the delivery of water and sanitation infrastructure. Health and hygiene education should be integrated into the infrastructure delivery in order to achieve a reduction in water-related diseases such as cholera and other diarrhoeal diseases.

Strategic Priorities for the National Health System 2004-2009

The following priorities are relevant to water and human health:

- to improve governance and management of the National Health System with reference to a strong regulatory framework for compliance to drinking water quality standards;

- to promote health lifestyle with special reference to public health awareness campaigns and health and hygiene education;
- to improve management of communicable and non-communicable diseases through scaling-up of epidemic preparedness and response (cholera) and risk assessment and prevention strategies;
- to strengthen support services through the establishment of integrated water-borne disease surveillance system;
- to strengthen human resource planning and management through strengthening the Community Health Workers (CHWs) programmes and their role in ongoing promotion of health and hygiene education at local community level, in addition, gender mainstreaming is required to improve the health of households.

A Drinking Water Quality Management Framework for South Africa, draft, November 2004

DWAF has initiated the preparation of the Drinking water quality management framework to ensure effective management of drinking water quality in South Africa to protect public health. The framework has adopted a preventive risk management approach that is comprehensive from catchment to consumer. It promotes an understanding of the entire water supply system, the events that can compromise drinking water quality and the operational control necessary for optimizing drinking water quality and protection of public health.

3. STATUS REVIEW OF WATER AND HUMAN HEALTH RESEARCH IN SOUTH AFRICA

3.1 Water-borne diseases

Since its establishment in 1971, the Water Research Commission has supported a lot of research aimed at the identification of sources and understanding the nature of bacteria and viruses that are responsible for causing water-borne diseases. Detection and treatment methods for these pathogens have been developed in line with international trends of finding most rapid and sensitive methods for detecting bacteria and viruses in water. Research in the last decade has focused on emerging pathogens and parasites such as *Giardia*, *Cryptosporidium* and pathogenic *Escherichia coli.* Guidelines have been developed to assist water quality managers in testing microbial quality of water provided to their consumers.

Research on detection methods has addressed a wide range of techniques from culture based methods, enzyme-linked immuno-assays (ELISA), tissue-culture and DNA based methods (PCR). However, the uptake of the more sensitive DNA based methods by water services institutions has been slow because of the high costs and technical expertise required. Most water laboratories still rely heavily on culture based methods although there is strong evidence that culture based methods are only able to detect less that 10% of bacteria present in water samples.

A simple hydrogen sulphide (H_2S) strip test for monitoring microbial water quality of small community water supply sources was developed by the CSIR. This method is suitable for small communities without access to laboratories because no special laboratory equipments are required to conduct the test. The correlation between the H_2S method and the standard test for indicator organisms was found to be statistically significant. The method can be conducted in the field because it does not require any incubation. The test causes the contaminated water to turn black while a negative sample remains colourless. Environmental health officers were trained to use the H_2S strip test in conducting the field tests in their provinces. They found the H_2S strip test to be very easy to use, however, they expressed concern that in some cases the results obtained from standard bacterial indicator test were negative for total and faecal coliforms whereas the H_2S test was positive. This might indicate that the H_2S test is more sensitive than the traditional culture methods.

The CSIR and University of Pretoria have registered the following patents from the research funded by the WRC:

- An oligonucleotide primer, a PCR based method for the amplification of virulent *Shigella* species and entero-invasive *E.coli* strain; (a diagnostic test kit for the two species was developed).
- A similar diagnostic test kit was developed for the detection of toxigenic *Vibrio cholerae.*

Emerging viral, bacterial and parasitic pathogens

In line with international research trends in water related diseases, the WRC has funded research on new emerging pathogens. The research consortium lead by the University of Pretoria focused on the optimization of detection methods for these pathogens and monitoring source and treated water for their presence. The research showed that emerging pathogens were absent from drinking water and groundwater, however, the pathogens were detected in some water sources and waste waters. It also showed a general correlation between the presence of the emerging pathogens and that of faecal coliforms. This indicates that current water quality guidelines and management procedures based on normal microbial water quality indicators provide some protection against these emerging pathogens.

New procedures and more sensitive detection methods have been developed for the isolation of *E.coli 0157*:*H7* from sewage and river water. This study confirmed for the first time the presence of *E.coli 0157*:*H7* and a variety of pathogenic *E.coli* strains in sewage and sewage–contaminated river water, respectively. However, the incidence of *E.coli 0157*:*H7* was very low; therefore, it does not pose any meaningful risk to the public who uses the water for recreational purposes.

The Medical Research Council is focusing its research on pathogens that cause diarrhoeal diseases. It is conducting rotavirus vaccine trials; this virus causes gastro-enteritis in children. Other viral agents associated with gastro-enteritis, namely, human astroviruses and enteric adenoviruses are also studied. MRC is studying entero-virulent *E.coli*, the research focuses on the molecular epidemiology of *E.coli* and development of commercial assays for the detection of enterotoxigenic *E.coli.* The MRC is also conducting research on the characterization and development of detection methods for *Cryptosporidium.*

Bacteriophages as indicators of water quality

The WRC has supported research to assess the feasibility of using certain groups of bacteriophages as indicators of water quality. The research findings showed that bacteriophages met the fundamental requirements of indicators of faecal pollution because

their behaviour resembles that of human enteric viruses. They are also detectable by simple and inexpensive methods within 8 hours, while human enteric viruses require complex tissue culture methods that may take more than a week to yield results. This research optimized practical techniques for the quantitative and qualitative detection of three groups of phages, namely, somatic phages, male-specific coliphages and *Bacteroides fragilis* HSP40 phages.

3.2 Water-washed diseases

There is no documented evidence that the WRC has supported any research on the detection and prevention of water-washed diseases. There are also no reported studies on the incidence of these diseases in South Africa.

3.3 Water-related vector diseases

In the past the WRC has not supported any research on the prevalence and control of malaria and bilharzias in South Africa. However, it has recently approved funding for a new project on the management of environmental flows to keep incidence of aquatic vector diseases to a minimum, this project will commence during 2005. The research will focus on bilharzia and malaria vectors (snails and mosquitoes respectively). The MRC is currently conducting research on the malaria transmission and control in African refugee camps. MRC in collaboration with the University of KwaZulu-Natal is conducting a South African country study on the potential impact of climate change on human health; the study is investigating a linkage between climate variables such as temperature and rainfall and the distribution of malaria and bilharzia infections.

3.4 Chemicals in water and their impact on human health

Research has focused on monitoring water pollution from nitrates, fluorides and pesticides. The WRC has supported a project on the removal of fluoride from drinking water using clay pellets; this study achieved seventy percent defluoridation efficiency at a laboratory scale. A current study is investigating the impact of fluoride on human health and low cost treatment options for removing fluoride from drinking water. Another study has assessed the extent and severity of nitrate pollution in groundwater and developed strategies for protecting rural water supplies from the negative impacts of nitrate pollution. Although there has been a lot of debate on the contribution of pit latrines to ground water pollution, no studies have been undertaken in South Africa to demonstrate unequivocally the linkage between nitrate pollution of groundwater and pit latrines. Research undertaken by the University of Fort Hare has revealed high levels of cadmium in Umtata River, health impact of this metal on rural

communities who rely on the river as source of drinking water is currently under investigation.

Endocrine disrupting chemicals

Endocrine disrupting chemicals (EDCs) are defined as chemicals that interfere with the structure or function of hormone receptor complexes. There is a growing interest in the research on endocrine disrupting chemicals and their impact on human health, with special reference on the impact of EDCs on male and female reproductive systems. EDCs have been associated with an increase in testicular and prostate cancer and certain female reproductive health and fertility problems such as endometriosis and adenomyosis of the breast and certain cancers of the female reproductive system. A literature survey on the presence of estrogen and estrogen mimicking substances in the South African water environment showed that these substances occur in our water environment. The sources of these chemicals were industrial and agricultural effluents. Organochlorine pesticides, for example, DDT, DDE and DDD have been detected in the rivers in the eastern parts of the country, the Western Cape and Free State. Current research is focusing on the detection, prevention and management of EDCs in water resources. There is a need for research on the potential health impacts of EDCs on the nervous system, immune system and thyroid function.

Pesticides in water

The WRC has supported research to assess the level of pesticides in rural water sources in the Western Cape. The study demonstrated the presence of chlorpyrifos and endosulfan in three regions. Modelling of possible health impact from consuming water with pesticides indicated that the low levels of contamination did not appear to represent an immediate threat to human health. However, the study cautioned that the endocrine disrupting factors associated with these pesticides, especially endosulfan, may warrant greater attention to the problem.

Algal toxins in water

Algal toxins in surface water lead to acute and chronic toxicity to humans. The problem of toxin blooms is being investigated under the Cyanobacteria programme. The expected outputs of this research include a model for the prediction of toxic bloom events based on the cellular mechanisms of modulation of toxin production by nutritional environmental parameters. Research has been done on toxins produced by cyanophytes in the freshwaters of South Africa and implications for human health.

Total Organic Halogens in drinking water

Trihalomethanes (THM) have been implicated as potential carcinogens. Studies have shown that THM production could be roughly proportional to the initial concentration of dissolved organic carbon concentration. Research has been conducted to determine the occurrence and concentration of THMs in South African drinking waters. The study showed that most sample sites had less than 100ug/l THM. A follow-up study was conducted by Rand Water to investigate total organic halogen formation after disinfection of drinking water by chlorine. The study found that the concentration of adsorbable organic halogens (AOX) was five times higher than the levels of purgeable organic halogens (POX) in chlorinated waters. More research is required to determine the nature of AOX and potential contribution to carcinogenesis.

3.5 Public Health Protection

3.5.1 Quality of domestic water supplies

The Water Research Commission in partnership with the departments of Water Affairs & Forestry and Health has supported the development of a series of user-friendly guidelines on the quality of domestic water supplies. These guidelines target different levels of role players involved in the use and management of domestic water supplies. The following documents form part of series:

Volume 1: Assessment Guide

The target users for this guide include Environmental Health Officers (EHOs), Water Service Providers, Water Resource Developers, educators and the general public. The guide allows the user to assess whether water is suitable for domestic use and provide guidance on measures to be taken to make the water suitable for domestic use. The guide uses a colour-coded classification system of water based on the suitability for domestic use. The information is presented in a simple format to enable a wide spectrum of users to understand the underlying principles of water quality assessment and the impacts on the domestic users.

Volume 2: Sampling Guide

This guide targets the same users listed for the assessment guide above. The guide provides information on the correct procedure to be followed to collect a representative water quality sample from a water supply intended for domestic use.

Volume 3: Analysis Guide

This guide targets those responsible for assessment and analysis of water samples.

Volume 4: Treatment Guide

This guide provides general information on the treatment of water for domestic use. It does not go into technical details but focuses on the suitability of treatment processes for different types of water and the limitations and relative costs of the different processes. The target users

include water treatment plant operators and managers, water committees and local authorities responsible for water supply, environmental health officers, water service provides and educators.

Volume 5: Management Guide

The guide provides guidance on domestic water quality with regard to planning of new domestic water supply schemes, operation and management of domestic water supply schemes and actions to be taken under emergency situations such as floods or droughts. The target users include water resource managers, water service authorities, environmental health officers, users of domestic water, water service providers and educators.

3.5.2 Drinking water treatment technologies

The WRC has supported research on the use of innovative membrane technologies to remove chemicals and biological agents from drinking water especially *Cryptosporidium* and *Giardia* which are difficult to treat with conventional treatment technologies. A special programme on water treatment for rural communities focuses on the development of low cost technologies that are more appropriate for rural water supply schemes. These treatment technologies include the treatment of brackish groundwater, which is readily available to rural communities with poor access to safe drinking water. A guidebook for alternative small-scale water treatment technologies for potable household water augmentation in South Africa has been developed for providing water service providers with information on a range of treatment technologies from desalination to simple household augmentation methods such as rain-water harvesting. Research has been conducted to evaluate different nanofiltration membranes in the removal of nitrates, fluorides, sulphates and chlorides from groundwater sources in the North West province. The study showed that the monovalent ions such as fluorides and nitrates could not be adequately removed. A literature review on the application of *in situ* groundwater treatment showed that this technology has a potential for application in the removal of high nitrates from aquifers before pumping water to the surface. Current research is focusing on the removal of algal toxins and endocrine disrupting chemicals in water treatment plants.

3.5.3 Development of public awareness and education materials

The WRC is currently funding the development of public health awareness and education materials. The outputs of this project will advocate and promote the safe use of water with aim of building public awareness of water related health risks. The following publications will emanate from this project:

Management of Legionella and health risk assessment guidelines

Guides on the management of water-related microbial diseases

Risk communication guidelines

Child-centred course for teachers to promote basic health in rural communities.

Research has also been undertaken to promote health and hygiene awareness with special reference to contamination of water storage within the household due to poor hygiene practices.

3.5.4 Use of treated sewage effluent in agriculture and aquaculture

A review of the applicability of the South African guide for the permissible utilization of treated sewage effluent in agriculture and aquaculture against international trends showed that the South African guide places too much emphasis on wastewater treatment options and it was found to be more restrictive in terms of its zero faecal coliforms per ml for irrigation of crops likely to be eaten uncooked when compared with the WHO Health Guidelines (1989) and US-EPA guide (1992). The SA guide does not provide criteria for recycled water quality for use in aquaculture.

The WRC is currently supporting the preparation of sewage disposal guidelines; they consist of following five series to be published towards the end of the year:

Overview guide;

Agricultural use;

Dedicated disposal (land and sea disposal);

Beneficiation – use of sludge to make bricks, fertilizers;

Incineration – consideration of air pollution and relevant policy and legislative framework.

Researchers from the University of KwaZulu-Natal (UKZN) in collaboration with Ethekwini Metro Council are conducting studies on the use of stabilized human excreta from Urine Diversion Sanitation Systems (UDS) for agricultural purpose.

The WRC has initiated a new project on health considerations for the use of grey water in agriculture. The use of grey water provides an alternative source of water for household and urban food gardens.

3.5.5 Linkage between HIV/AIDS and access to water services

HIV/AIDS transmission is not related to poor access to water and sanitation services, however, lack of access to these services has a negative impact on people infected and affected by the disease. Better hygiene, adequate sanitation service and safe drinking water can contribute to the improvement of the quality of life for the infected people and those who

care for them. Access to water services allows HIV infected people to stay healthy longer and can contribute to social and economic development in their communities.

There is growing evidence that links prevalence of cholera and other water-borne diseases with provinces with a high incidence of HIV/AIDS infected people; it is suspected that the infected people are more susceptible to cholera and other water-borne diseases due to their immuno-compromised status. So far no comprehensive research has been undertaken to confirm this linkage.

The WRC has recently initiated a research programme on HIV/AIDS water-related linkage and its impact on water use and waste. A new project under this programme will investigate the molecular relatedness of enteric pathogens isolated from water sources and HIV/AIDS patients diagnosed with diarrhoea in order to identify waterborne opportunistic bacteria that may pose a serious health threat to HIV/AIDS patients.

3.6 Water-related health risk management

The WRC has supported research on the assessment of health risk associated with emerging pathogens and the findings showed a very low incidence of these pathogens. It has also supported the development of a guide for risk assessment for water quality management with special reference to point sources of water pollution. No studies have been conducted locally to assess the health risks associated with EDCs.

4. REVIEW OF INTERNATIONAL TRENDS IN WATER AND HUMAN HEALTH RESEARCH

4.1 Water-borne diseases

Highly sensitive detection techniques for a number of bacteria, viruses and protozoan parasites are still required and various research groups are trying to improve on existing techniques. Methods for the rapid detection of microbial pathogens in water are also receiving a lot of attention. The main focus for the development of these new detection techniques has been on the use of molecular techniques, in particular, the Polymerase Chain Reaction (PCR). The use of real-time PCR has improved both the speed and the reliability of pathogen detection. Although numerous rapid detection techniques have been developed, they are still not widely used by water utilities and catchment agencies because of high costs and technical expertise required to undertake molecular detection techniques.

At present various researchers and research groups are developing microbial source tracking techniques that could improve efforts to manage and protect drinking water supplies. Various approaches are being followed with the main focus on tracking indicator organisms such as *E. coli*. Studies to understand the fate of water-borne pathogens under various climatic and environmental conditions in aquatic systems (surface, ground and marine) are still limited and the role of biofilms and sediments still needs to be fully understood.

There are ongoing efforts to study the origin, fate, survival and clinical relevance of emerging and re-emerging microbial pathogens. Concern about the spread of zoonotic diseases has increased and in a recent book on this topic by the World Health Organization (WHO) it is estimated that up to 75% of emerging water-borne pathogens are of zoonotic origin (Cotruvo *et al.*, 2004). Population growth, increases in the size of vulnerable sub-populations and an increase in urban agriculture will likely increase the incidence of water-borne zoonoses. An aging world population, increased use of immuno-suppressive treatment and the spread of HIV/AIDS has also resulted in a growing population with impaired immune systems. Emerging diseases caused by viruses and parasites e.g. *Cryptosporidium* and microsporidia, and the *Mycobacterium avium* complex (Pedley *et al.*, 2004) are of major concern for these vulnerable groups.

Many developed countries have public health surveillance networks (e.g. NNDSS and Pulsnet in the USA) and teams for the investigation of epidemics. These groups are very effective in detecting and dealing with water-borne outbreaks and are part of governmental organizations such as the Centers for Disease Control (USA), the National Institute of Public Health and the Environment (RIVM, Netherlands) and the Health Protection Agency (UK). The European Centre for Disease Prevention and Control (ECDC), a network for disease control agencies of EU member states, has newly been established and will be hosted in Sweden.

The deterioration of treated drinking water in water distribution systems due to the possible re-growth of pathogens in biofilms is one of the main concerns of water utilities (Ainsworth, 2004). The public health implications of heterotrophic bacteria present in drinking water have been investigated and under the guidance of the World Health Organization (WHO) a monograph dealing with this issue has been published (Bartram *et al.*, 2003). The influence of various factors on re-growth and survival such as the presence of biodegradable organic matter, disinfectant residuals and heterotrophic bacteria has been studied. Pathogenic microorganisms not related to faecal contamination but that are naturally present in the environment e.g. Mycobacteria species, *Pseudomonas* and Aeromonas, are receiving growing attention.

4.2 Water-washed diseases

Similarly to the case in South Africa water washed diseases have not featured high on the research agenda. In dealing with water-washed diseases the emphasis lies more with the supply of adequate quantities of water and health education to improve hygiene levels in communities.

4.3 Water-related vector diseases

The focus of the current malaria research is mainly on the development of vaccines and the spread of treatment resistance, areas that have fallen outside the scope of water based projects. Some researchers focus on the influence of environmental and climatic factors on the spread of this major killer in Africa and the potential health risks associated with new dams and irrigation schemes have also been studied. The use of irrigation management and changed practices to limit the disease is also under scrutiny.

4.4 Chemicals in water

In certain areas of the world natural occurring ground water constituents such as arsenic, fluoride, selenium or radon are of a major concern when the water is used as a source of drinking water. According to estimates high levels of arsenic and fluoride may put millions of people at risk. Although nitrogen species may occur naturally in ground water, nitrates due to agricultural activities and on-site sanitation systems are also of concern. The occurrence of these compounds is reasonably well described and the main focus has been on how to effectively manage these problems.

At present a major area of concern in the field of chemical water quality is the presence of endocrine disrupting compounds, pharmaceuticals and personal care products in water used as a source for drinking water. Analytical methods to detect these compounds, methods to quantify their effects and epidemiological data to determine the significance of their impacts are being developed.

There has been a worldwide movement from the highly toxic, persistent and bio-accumulating pesticides to less toxic and more degradable pesticides. Some of the older compounds such as DDT, and insecticides classified as persistent organic pollutants (POPS) are, however, still used in agriculture and for public health protection. These pesticides often end up in the water sources used by rural communities where they pose a health risk to water users. Under the Stockholm Convention on POPS these compounds are still monitored in some areas and their transport to water systems, especially ground water is being studied.

Although the Cyanobacteria only grow in aquatic environments their cyanotoxins may be released during drinking water treatment and could affect human health. The major concern would be during algal blooms when these bacteria reach levels of high cell density due to excessive growth. A number of groups are investigating this phenomenon to develop a better understanding of the factors that could lead to such events. Alternative techniques to detect the cyanotoxins in drinking water are under development but is still limited to a few of the better described toxins e.g. mycrocystins.

4.5 Public Health Protection

4.5.1 Management of source waters

Protecting drinking water sources against contamination is the first barrier in ensuring safe drinking and recreational water. The approaches in dealing with surface and ground water

sources differ noticeably and are usually investigated separately. The impact of land-use activities on water quality and how to manage these impacts has become an important aspect of catchment management strategies and water safety plans. In the USA, efforts are underway to develop ambient water quality criteria and management plans in order to protect water users.

4.5.2 Quality of domestic water supplies

The 3rd Edition of the Water Quality Guidelines recently published by the WHO (World Health Organization, 2004) is based on an integrated preventative management framework applied from catchment to consumer. The management of potential risks is addressed by using a risk management tool similar to the Hazard Analysis Critical Control (HACCP) approach commonly used in the food industry. The use of multiple barriers, which include catchment protection, selection of appropriate treatment steps and the management of the distribution and storage network, is of great importance in ensuring the microbial safety of the water. The development of water safety plans addressing issues such as quality assessment and monitoring, management and communication are also strongly advocated. This new direction has created a worldwide need amongst many of the water utilities for guidance on how to implement this approach.

4.5.3 Treatment technologies

The WHO has recently published a critical review of current treatment options for eliminating pathogens from drinking water (LeChevallier and Au, 2004). Alternative disinfection technologies to deal with issues such as resistant microbes and disinfection by-products are investigated on a continuous basis. The alternative use of technologies such as UV disinfection and ozone to deal with viruses and parasites such as *Cryptosporidium* has to be balanced with the risk of by-product formation and biofilms growth in distribution networks. The use of household treatment and safe storage devices for developing communities without safe water supply systems are currently being investigated and promoted.

With the scarcity of fresh water in many areas, reuse, recycling and reclamation have become viable approaches to alleviate this problem. In terms of human health the quality requirements and implications as well as the treatment technologies needed are being addressed.

4.5.4 Recreational water quality management

Guidelines for the safe use of water environments for recreational purposes have been proposed by the WHO (WHO, 2003). These guidelines were based on a number of epidemiology and case control studies performed in the USA and Europe. At present only the

enterococci are used as a quality indicator but the use of other indicators is still under considerations. Based on the Annapolis Protocol, the approach to ensure the safety of recreational water users has been to use both sanitary inspections and microbial quality monitoring. Apart from faecal pollution, free living microbes such as *Vibrio* spp, *Aeromonas* spp. and some of the unicellular protozoa are also of concern. The occurrence of such infections is, however, low and more epidemiological information is required before appropriate guideline values can be set.

4.5.5 Occupational water quality management

Legionella spp. is the most prominent water-borne pathogen associated with occupational settings. Improvement of control strategies for this pathogen in cooling, air-conditioning and hot water systems is being addressed by a number of research groups. Occupational exposure to contaminated aerosols in a variety of settings e.g. waste treatment plants, has only received limited attention.

4.5.6 Use of wastewater in agriculture

In many areas with limited water supplies or lack of treatment infrastructure, wastewater is considered to be a valuable resource. The use of wastewater for irrigation and aquaculture are strongly advocated and the health implications for this type of approach are being addressed. Organizations such as the International Water Management Institute are supportive of this type of approach in dealing with wastewater, especially in developing countries.

4.5.7 Development of public awareness and educational materials

A number of NGO's, Universities' Schools of Public Health and government departments have amongst others studied the issues of public health awareness and promotion. Various approaches to optimise community participation and ensure long term success have been evaluated. The United Nations Children's Fund (UNICEF) has also been very supportive of these actions (UNICEF and LSHTM, 1999).

4.6 Governance and policy frameworks

At present the major international driver for the improvement of water and sanitation coverage is the Millennium Development Goals. A number of the goals set by the United Nations specifically impact on the field of water and health and various international bodies and agencies work towards meeting these goals e.g. the WASH campaign of the Water Supply and Sanitation Collaborative Council (WSSCC). The International Water Association has also released the Bonn Charter in which it provides an internationally accepted framework

for the supply of safe drinking water. It is foreseen that studies will be conducted to evaluate the impact of these and other international initiatives.

5. ANALYSIS OF THE RESEARCH PORTFOLIO

5.1 Introduction

Over the years various approaches have been used for the protection of human health against water-related diseases and other hazards such as chemical components. Globally, there is a strong move away from only relying treatment processes and compliance monitoring to ensure safe water quality, to a more holistic approach that focuses on addressing the entire water supply system. This new approach is referred to as an integrated preventative management approach and covers water supplies from the catchment to the consumer. This approach is, for example, strongly advocated by the WHO 3rd Edition of the Water Quality Guidelines (2004). The integrated preventative management approach is, however, not only limited to drinking water supplies and can be used amongst others for agricultural and occupational water uses as well. For this approach to be successful an understanding of the entire water cycle (Figure 2) is required. It also implies a far better understanding and control of point and diffuse pollution of water resources.

Based on the information requirements of the integrated preventative management approach, a research matrix (Figure 3) has been developed. This matrix combines all the key areas that must be addressed by research to ensure adequate protection of human health from negative water related impacts. In line with international trends, the focus has not only been on research required for the management of drinking water quality but research required to dealt with other aspects such as recreational water quality, grey water management, wastewater re-use for agricultural, sludge disposal and pollution prevention of surface and groundwater sources are all addressed. Five key areas required for the protection of human health have been identified and will be discussed in Section 5.2. The first two areas deal with land and water use issues whereas the other three areas cover important aspects of management and prevention strategies. Together these key areas form the basis of the research matrix.

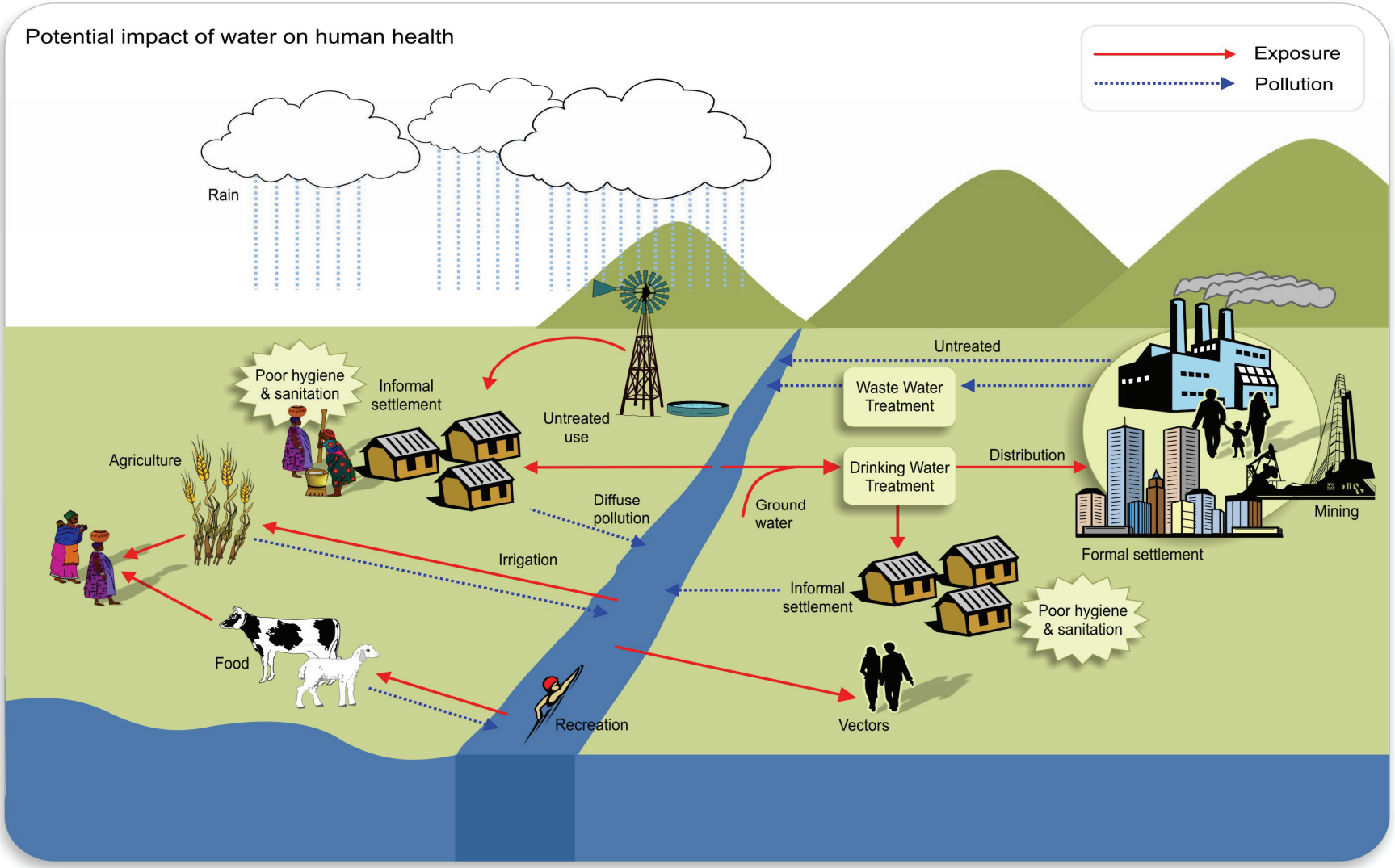

Figure 2. Diagrammatic representation of the possible sources of water contaminants that impact on human health.

		Resource protection		Public health protection			
		Ground	Surface	Drinking water	Agriculture and food	Recreation / Occupation	Basic human needs
Impacts / Risks	Techniques / Tools						
	Monitoring / Surveillance						
	Risk assessment						
Interventions	Prevention / Treatment						
	Management						
	Education and awareness						
Governance	Policies						
	Regulation / Compliance						

Figure 3: Research Matrix

5.2 Components of the research matrix

5.2.1 Resource protection

Resource protection addresses both surface and ground water; the focus is on the detection, prevention and management of biological and chemical contaminants that impact negatively on the quality of water sources. A regulatory framework is necessary to regulate compliance to national water quality norms and standards for the different water user groups at a catchment level.

5.2.2 Public health protection

Public health protection addressed all the interventions that undertaken to protect human and public health from all water-related hazards. These include ensuring access to safe drinking water and adequate sanitation for all sanitation provision, water for personal hygienic needs, wastewater management, public health awareness and protection of human exposure to contaminated water. A governance framework for regulating compliance to public health water quality standards for the different use categories is a very aspect of safeguarding public health.

5.3 Evaluation of the current research portfolio

Utilizing the above described research matrix the current and ongoing research projects have been grouped in order to get a better understanding of research gaps that must be addressed in order to support the implementation of integrated preventive management approach. The fact that certain areas have not received funding may be due to a number of reasons, for example, these areas may be of very low priority in terms of

national needs or the methodology for conducting such research may not be available. Figure 4 provides a summary of the completed research projects and it is based on the information provided in Section 3 of this report. The current projects are listed in Figure 5 and are based on the information extracted from the current WRC business plan (2005-2006).

		Resource protection and development		**Water use protection**			
		Ground	Surface	Drinking water	Agriculture and food	Recreation / Occupation	Basic human needs
Impacts / Risks	Techniques / Tools	1,3	1,3,4	1,2,3,4,8	1	1	
	Monitoring / Surveillance		4	4,6,7			
	Risk assessment		5,13,14	5,12,13	13	11,13	
Interventions	Prevention / Treatment			10			
	Management			9			
	Education and awareness			6,7,8			
Governance	Policies						
	Regulation / Compliance						

The numbers in the table refer to the following projects:

Number	**Name**	**Number**	**Name**
1	Viral and bacterial identification	8	Drinking water analysis guide
2	H_2S strip	9	Drinking water treatment guide
3	Emerging pathogens	10	Drinking water management guide
4	Indicators: Bacteriophages	11	Legionella assessment guide
5	Monitoring fluoride, pesticides	12	Risk communication guide
6	Drinking water assessment guide	13	Health risk assessment
7	Drinking water sampling guide	14	NMMP (surface)

Figure 4: Research matrix depicting WRC projects already completed.

		Resource protection and development		Water use protection			
		Ground	Surface	Drinking water	Agriculture and food	Recreation / Occupation	Basic human needs
Impacts / Risks	Techniques / Tools		9,11,12,14 15,24,25	5,11,12,28			
	Monitoring / Surveillance	29	2,9,10,17, 18,20,22	1,3,8,10, 17,20,28	20, 27		
	Risk assessment			1,3,8,21	7		
Interventions	Prevention / Treatment			6			
	Management	19	4,13,16,23 26				
	Education and awareness			30	30	30	
Governance	Policies						
	Regulation / Compliance						

The numbers in the table refer to the following projects:

Number	Name	Number	Name
1	HIV /Aids water source impact	16	Non-point source and agriculture
2	Origin and fate of pathogens	17	Toxicant monitoring programme
3	Diarrhoea in rural areas	18	Sampling freq for toxicants
4	Aquatic vectors	19	Trace compounds in ground water
5	Human health biomarkers	20	POPs
6	Disinfection programme	21	Effect of microcystin
7	Grey water and agriculture	22	Cyanobacterial programme
8	Cadmium and health impacts	23	Management of algal blooms
9	EDC sentinel species	24	Methods for cyano monitoring
10	EDC in raw and treated water	25	Cyanobacteria identification
11	EDC assays	26	Eutrophication management
12	WET testing	27	Aquaculture and irrigation
13	Toxicology in management	28	Detecting sewage in water
14	WET chronic test	29	National microbial groundwater P
15	Fish toxicity tests	30	Guideline: Waterborne diseases

Figure 5: Research matrix depicting projects currently supported by the WRC.

Based on the information depicted in Figures 4 and 5, areas within the research portfolio that have not received funding from the WRC during the last few years can easily be identified. This information is depicted in Figure 6. The analysis served as the basis for the identification of possible gaps in the research portfolio of the Water and health domain.

		Resource protection and development		Water use protection			
		Ground	Surface	Drinking water	Agriculture and food	Recreation / Occupation	Basic human needs
Impacts / Risks	Techniques / Tools						
	Monitoring / Surveillance						
	Risk assessment						
Interventions	Prevention / Treatment						
	Management						
	Education and awareness						
Governance	Policies						
	Regulation / Compliance						

The shaded areas depict research areas not previously or currently funded by the WRC.

Figure 6: Analysis of the Water and Health Domain's research portfolio.

From Figure 6 it is clear that until now governance issues have not received much attention in the field of water related health. The actions that have taken place have traditionally been conducted outside the research arena within the realm of the government departments and the SABS. Water resource management policies have also concentrated strongly on the protection of the natural eco-system and human health has not been one of the prime policy drivers. Another area that has not been addressed in the portfolio is the impact of water availability on the human health. Traditionally the focus has only been on water-washed diseases, and the risks and effect of limited water on overall human health have not been addressed in detail. Figure 6 also indicates that the management of water quality for recreational, occupational and agricultural water use to avoid unwanted impacts on human health is not one of the current priorities and that only limited information on the quality of the water is available for management purposes. The focus of health education and awareness campaigns have been the education of water users, especially hygiene practices associated with the protection of public health.

6. IDENTIFICATION OF RESEARCH NEEDS

Water and human health research needs

The following research gaps are based on the review of current research on water and human health, international research trends and stakeholder inputs:

6.1 Resource Protection

Improved methods for the detection of microbial pathogens in water and utilization of this data for risk assessment studies

New methods for the rapid and sensitive detection of microbial pathogens in water environments are still required. In order to support the performance of accurate quantitative risk assessments, the focus should be on the detection of clinical relevant strains. The only way to distinguish between harmless and pathogenic strains will be to understand the pathogenicity of the microbes and targeting appropriate virulence markers during detection.

Chemicals in groundwater

Studies should be conducted to verify the occurrence of trace constituents in areas identified as being at risk and to clarify policy issues for safeguarding people against harmful constituents found in drinking water. There is a need to monitor pesticides in groundwater and the development of modelling tools for the prediction of the fate and behaviour of pesticides in the environment.

National disease surveillance system for water associated diseases

At present the only data available on the prevalence of potential waterborne diseases are the reports generated by hospitals. A screening of representative stool samples may provide a better idea of the prevalence of potential waterborne diseases in the community. Such a study should, however, be well designed to ensure that it is cost effective and that the transmission link with contaminated water could be made with great certainty.

Impacts of food grade wastes on the pollution of surface and groundwater

Studies must be conducted to assess the impact of biological and chemical agents that leach from landfills where food grade wastes are dumped. There is a need to develop innovative methods for stabilizing food grade waste, for example, through recycling and re-use. Currently food grade wastes from the food industry, such as mango and avocado waste produce highly toxic leachates. Technology is required to stabilize the food grade wastes through processing to produce high value products and prevent pollution of groundwater. This approach can contribute to job creation and sustainable development.

Integrated management of chemical and microbial water quality

Efforts to manage the microbial and chemical quality of water are often fragmented and do not necessarily address the problem in a holistic manner. Projects to evaluate various management strategies in terms of their overall impact on water quality, human health and the environment should be initiated. To assist these evaluations, the development of models that will help to predict the water quality and potential health outcomes based on the interactions of various variables needs to be investigated. The compilation of water hazard maps will also be of benefit.

Catchment management strategies for preventing microbial water pollution

At present the main focus of catchment management strategies is on the protection of aquatic ecosystems and the reserve. In South Africa, the microbial quality of water resources is often poor and may impact on the health of communities through direct use or after only limited treatment; this aspect of water quality must be prioritized. Management strategies should be developed and tested that could assist in improving the microbial quality of both surface and groundwater at a catchment level. The setting and achievement of ambient microbial water quality criteria can even be used as part of a process to improve the microbial quality of water resources.

Sector collaboration

There is need for effective mechanisms of sector collaboration of all the role players involved in monitoring the quality of drinking water and the development of a national drinking water quality monitoring data management system should be prioritized in order to improve access to water quality data for all stakeholders.

Strategies for the implementation water safety plans by small local authorities

The 3rd edition of the drinking water quality guidelines published by the WHO (2004) and the Drinking Water Quality Management Framework for South Africa (2004 draft) place a great emphasis on the preventative management approach applied from catchment to consumer, this approach requires the implementation of water safety plans to protect water quality from the catchment to the tap. Guidelines to assist small local authorities with the implementation of water safety plans are urgently required. A project to provide a number of case studies will be of great benefit.

Grey water management

The provision of a basic level of water supply (communal stand-pipes) and on-site dry sanitation systems (VIP toilets or Urine Diversion Systems) in dense formal or informal settlements has created a problem of poor drainage and grey water disposal for households living in these areas. Poor drainage around the stand-pipes provides a breeding environment for disease vectors such as mosquitoes (malaria) and lack of grey

water disposal systems results in polluted water pools within the residential area. This polluted grey water poses an environmental health problem and also contributes to the pollution of rivers that flow near these areas. There is a need to develop innovative methods for safe disposal and management of grey water and improved drainage of stand pipes in these dense informal settlement areas. Research is needed to promote re-use of grey water for irrigation of crops which can contribute to poverty alleviation for local communities. Studies should be conducted to assess the health risks associated with re-use of grey water and strategies should be devised to manage health risks.

Basic sanitation service level

Research is needed to develop more effective and faster methods for destroying pathogens in pit sludge to facilitate safe pit emptying and disposal of pit sludge or re-use as soil conditioner or fertilizer.

Although there are lots of claims that bacteria can migrate from pit latrines and pollute groundwater, no research has been conducted in South Africa to demonstrate this phenomenon. Research must be conducted to demonstrate bacterial migration from pit latrines to groundwater and geotechnical factors that promote the rate of bacterial migration must also be assessed.

Double VIP toilets have a potential of increasing the lifespan of dry sanitation systems, however, research is needed to investigate the optimum time required to inactivate pathogens and parasites (*Ascaris*) in full pits in order to make the pit safe for emptying and re-use of sludge for compost or safe disposal to the environment.

Development of strategies for emptying and disposal of pit latrine sludge without any negative impacts on surface and groundwater must be prioritized in order to ensure sustainability of basic sanitation services.

6.2 Public health protection

Governance framework for regulating quality of drinking water

In South Africa the responsibility for water quality management falls under the Department of Water Affairs & Forestry in its capacity as the custodian of water resources while the responsibility for environmental health services such as water quality monitoring, waste management and control of environmental pollution falls under the Department of Health. Currently, there is no independent institution with an oversight responsibility for the protection of public health. The absence of an independent regulator of drinking water quality is believed to be responsible for the poor of enforcement of compliance with the national drinking water quality standards. Most rural municipalities that have inadequate capacity and resources and are not able to perform routine water quality monitoring of drinking water they supply to their rural communities. Consequently, the most vulnerable rural communities are forced to drink water of poor quality and this poses a serious health threat to these communities.

Research is required to develop governance models that can contribute to better regulation of the public safety of drinking water. These models should address the following issues:

- Formulation of a uniform protection plan for national water resources;
- Implementation of an integrated water quality monitoring programme which is separate from the water quality management programme;
- Identification of links between water quality and human health;
- Public awareness and public participation in the monitoring and reporting of water quality problems;
- Models for the establishment of a governance institution that will be empowered to take legal action against non-compliance with the national water quality standards and norms for the different human uses.

In addition, the following issues must be addressed in order to support effective governance of drinking water quality:

- Development of suitable governance and regulation models for monitoring compliance with the drinking water quality management framework standards;
- Assessment of WSA's compliance with SANS 241 and other national water quality norms and standards including recommendations for improving compliance.

Development of appropriate methods for assessing the overall impacts of water on community health

A need still exists to assess the total impact of water quantity and water quality on the health of communities with special reference to different service levels. The assessment methodology to be developed should be based on a holistic approach and should be able to take all water-associated impacts into account and link these with the collected clinical data. The combined effect of both the microbial and chemical quality of the water should be addressed.

Burden of disease associated with water determined at a provincial and local level

The MRC is currently undertaking a study to estimate the burden of disease associated with water and other environmental factors on a national level. This work should be expanded to a provincial and local level, as it would provide valuable information for both the national and provincial governments when allocating resources for the improvement of water supply and sanitation services.

Contribution of improved water and sanitation infrastructure to human health.

Children are especially vulnerable to common helminth infections in areas of the country where clean water and sanitation has been inadequate. Three species are soil-transmitted (*Ascaris lumbricoides, Trichuris trichiura and Necator americanus)* and one water-borne (*Schistosoma haematobium*). Because these infections are all transmitted via human excreta, their prevalence and intensity can serve as an indicator of the pollution of the environment which will persist for some time after water and sanitation programmes

have been introduced. Research is needed to map areas where human health is at risk from parasite infections and diarrhoeal disease. Research should also assess the impact of water and sanitation infrastructure to the reduction in the incidence of these water related diseases.

Impact of water quality on the health of HIV patients

AIDS patients suffer from a wide range of infectious diseases and may be adversely affected by chemical exposure. The disease burden associated with water needs to be established. This study should address all environmental routes of expose to be able to determine the relative contribution of water. It is very important to clear the ethical issues associated with such a study.

Impacts of level of water supply and sanitation services levels on the health outcomes of HIV positive individuals

An epidemiological study should be undertaken amongst households with HIV positive individuals to determine the effect of different water supply and sanitation service levels on the health status of these individuals. Such a study will help in the planning and selection of appropriate water supply and sanitation service levels for communities at risk.

The health consequences of chronic exposure to high levels of metals in water

GIS maps indicating areas where communities are possibly exposed to high levels of metals are available from the Council of Geosciences. Studies should be conducted to investigate the quality of water used by these communities and to determine the presence of any adverse health effects within these communities.

Risk assessment studies to determine the health risks associated with exposure to endocrine disrupting contaminants

Data on the presence of endocrine disruptors are being collected from various inland water sources. In order to determine the public health risk associated with these compounds present in the environment, the collected data should be used in risk assessment studies. The risk assessments should also be verified with epidemiological data.

Survey of the water quality available at rural schools and health care facilities

Poor water quality may have a major impact on health outcomes, especially for school children and patients visiting health care facilities. Little attention is paid to the water quality of health care facilities and no knowledge is available on the severity of the situation. A survey of a number of randomly selected rural facilities (schools, hospitals and clinics) should be conducted. The WHO has expressed an interest in such information as it would strengthen their efforts to convince governments to pay attention to this serious problem.

Impacts of pesticides on health

Epidemiological studies must be undertaken to assess the health impacts of drinking pesticide contaminated water on rural communities. This research should also assess the health risks associated with exposure to pesticides in drinking water.

Evaluation of dry sanitation options for informal settlements

Dry sanitation systems may be a viable alternative sanitation technology option to water-borne systems in informal settlements because of affordability problems. A thorough investigation into the efficiency as well as health and environmental impacts of such systems need to be undertaken.

Health impacts of pre-paid meter systems

Large cities such the Johannesburg Metropolitan areas are implementing a pre-paid meter system for water supply. Concern has been expressed that such systems may lead to deterioration in general household hygiene practices. A scientific study should be conducted to investigate whether such perceptions are true.

Effect of increased urbanization on recreational water quality (fresh water and marine)

South Africa is a major tourist destination and these tourists are often using beaches and rivers for recreational purposes. The possibility of new job opportunities in popular tourists' destinations has led to a rapid growth in the populations of these coastal towns and cities. The people are often accommodated in informal settlement without proper sanitation infrastructure. Run-off from these areas could have a major impact on the quality of water used for both fresh water and marine recreation. Studies should be conducted on the water quality and public health impacts reported at the recreational sites. The current data available for certain beaches dates back from the 1980's and urgently needs to be reassessed.

Prediction of the effect of HIV on water and sanitation demand patterns

HIV/AIDS epidemic is severely impacting the demographics in the country. This has serious implications for issues such as water demand and sanitation services planning. Current statistics on the epidemic can assist in adjusting current projections to more realistic figures for use in long term planning. This information would help government in prioritizing water and sanitation infrastructure to the worst affected areas.

Survey of opportunistic water-borne infections associated with HIV/AIDS

AIDS patients may suffer from a number of opportunistic infections, some of which may be transmitted by water. A survey of these pathogens and proof of the link with water transmission would form the basis of water quality management strategies aiming at the protection of vulnerable populations. Such a study should be well planned to also take other environmental exposures into account. The ethical issues surrounding such a project should also be cleared.

Assessment of the role played by social, cultural and economic factors in shaping individuals' perceptions of health risks

The perceptions of health risk by experts are often different from those of ordinary people. There is a need to assess the perception of health risks, and health & hygiene by the different socio-cultural groups so that health messages can be better targeted to address people's perceptions.

Effect of aging distribution systems on the water quality and health

The water distribution networks in a number of our urban areas are over 80 years old and the physical infrastructure and integrity of these may be compromised. The effect of an aging system on the quality of water within the distribution network and the associated public health risk has not been studied and require urgent attention.

Technical guides on the management of water quality issues to be used by environmental health officers

A need has been expressed for technical guides to compliment the already existing domestic water quality guidelines published by the Water Research Commission. The target audience will be environmental health officers involved in water quality monitoring.

Evaluation of sustainability of in-house water treatment systems

Due to the current backlog in the supply of treated water to communities, the use of in-house treatment systems has been encouraged as an interim measure. The sustainability of many of these interventions has not been evaluated and needs urgent attention.

The role of copper pipes in the inhibition of biofilm formation in drinking water distribution systems

Copper has been known to inhibit microbial growth. The effect of copper piping on the formation of biofilm in drinking water distribution systems needs to be investigated as a possible measure for inhibiting biofilms in certain areas within health and frail care facilities.

Evaluation of the impacts of water supply and sanitation interventions

During the last ten years the government has invested heavily in the provision of water supply and sanitation infrastructure. The sustainability and health benefits of these schemes need to be evaluated in order to assist with the planning of future schemes.

Management and health impacts of water quality of school swimming pools

Swimming pools at schools could be a source of infectious diseases if not properly managed. The extent of the problem and appropriate management approaches to deal with this problem should be addressed.

Education and awareness approaches that will support sustainable behavioural changes

Current approaches to health education and awareness programmes should be evaluated to determine the long-term success of these programmes and to establish the required changes that could lead to sustainable behavioural changes.

The effect of water quality on hand-washing practices

The benefits of washing hands as an effective basic hygiene measure in limiting the spread of diseases has been well documented. No information is, however, available on the impact of water quality on the effectiveness of this practice.

Improving quality of drinking water supplied by the small WSAs

There is a need for guidelines for the application of HACCP principles to water treatment works where there is limited capacity to undertake routine tests associated with the production of drinking water that meets national water quality standards

Use of treated sewage and sludge from on-site sanitation systems in agriculture and aquaculture

There is a growing interest in the implementation of ecological sanitation systems such as Urine Diversion System (UDS) as an alternative sanitation technology option for communities that cannot afford the costs of full waterborne sanitation technology. Ecological sanitation promotes the use of stabilized feacal matter and urine as crop fertilizers. The UKZN and Ethekwini Municipality (Water and Waste services) have initiated research to investigate the feasibility of re-using stabilized sludge from UDS systems as a fertilizer/soil conditioner for fruit trees. These studies also include investigation the die-off rate for pathogenic bacteria and *Ascaris*; this is necessary to ensure protection of public health. Grey water generated in these communities is being used to irrigate crops such as spinach, peppers and cabbage and the risk of bacterial contamination of these crops is also being investigated.

Research in the following areas is required to safeguard public health:

- *Water quality*- Focus should be on the health-related microbiological quality of stabilized faecal matter and urine effluents including criteria for nematodes, parasites such as *Giardia* and human enteric viruses should be addressed.
- A guide should be developed with emphasis on the protection of public health while supporting optimal re-use of human waste products.
- *Monitoring and compliance*- A monitoring strategy must be developed to address the frequency of monitoring and mechanisms for dealing with non-compliance.

- *Effluent classification*-The guide should include effluent classification because this forms the basis for decision making on water quality criteria, treatment criteria, and crop irrigation restriction as well as irrigation type requirements.
- *Irrigation technology options*- The guide should make provision for water quality criteria for different irrigation technologies such as hydroponics cultivation, sub-surface drip irrigation and protection of the users.

Public Health booklet

A booklet is required to guide non-technical decision–makers in understanding the water treatment technologies so that they can make informed decision with regards to budget allocation to this important component of public health protection.

Potential impacts of climate change on human health

Climate change and the predicted increase in the occurrence of extreme weather events such as floods and droughts present new stresses on water ecosystems. It is anticipated that diseases caused by water-borne pathogens (bacteria, viruses and parasites such as *Giardia* and *Cryptosporidium*) will occur more frequently. Heavy precipitation and flooding will flush micro-organisms, nutrients and chemical contaminants into waterways thus impacting negatively on the quality of water resources. Mosquito-borne diseases will increase because of floodplains that will provide more breeding ponds for mosquitoes. Research must be undertaken to assess the potential risks of climate change on human health and also development of risk management strategies for mitigating the negative impacts of climate change.

Evaluation of health impacts of policy decisions

National, provincial and local government often make policy decisions and start implementation of these decisions without first evaluating the possible health impacts or implications of such actions. Guidance on how these policy impact assessments should be undertaken are required in order to avoid implementation of policies that could have negative health implications and pose a threat to the sustainability of services.

Development of a policy framework for the re-use of treated sewage in agriculture and aquaculture

Currently, there is no policy framework that sets minimum quality standards for re-use of treated sewage in agriculture and aquaculture.

7. CONCLUSION

The status review report provides a basis for stakeholder consultation and the assisted in the development of a strategic framework for research on water and human health. The research needs identified have been taken into consideration in the development of an investment framework for research on water and human health. (Please refer to the main document entitled, “A Strategic Framework for Water Related Human Health research”).

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ANNEXURE 2

METHODOLOGICAL APPROACH TO THE COMPILATION OF A STRATEGIC FRAMEWORK FOR WATER RELATED HUMAN HEALTH RESEARCH

A review of the state of current water related human health research at national and international level was undertaken. This review was mainly based on research funded by the Water Research Commission and Medical Research Council. It was not possible to undertake a review of research funded by other institutions because most South African tertiary institutions do not post research reports on their websites. It was much easier to access international research as information is often readily available on websites. South Africa still lags behind in this regard; resources must be made available to ensure South Africa is in par with the international peers in terms of making information easily accessible electronically.

The review also drew from other strategic plans already prepared by the WRC in various aspects of water and human health research, namely:

- Strategy for Endocrine Disrupter Chemicals and Toxicant research (November 2004 draft);
- Microbiology related research in water and health in South Africa from 1993-2003 and identification of research needs with special reference to HIV/AIDS (November 2004, draft);
- Development of a research strategy for the detection and management of algal toxins in water sources (March 2005 draft).

The draft status review report was used as a background document for stakeholder consultation. Workshops, group and individual interviews were conducted to solicit inputs from the key sector institutions, namely, government departments, water boards, metro councils, science councils and universities. A list of stakeholders that were interviewed for this project is included, **Table 1**. Researchers were not interviewed because most of them already participated in the development of the above-mentioned strategic plans.

The draft strategic framework document was presented to a stakeholder workshop to solicit further inputs before preparing a final strategic framework document. The list of stakeholders is provided in **Table 2**.

Table 1: A list of stakeholders that were interviewed for this project

Name	Department	Tel	e-mail
Mr Leonardo Manus	DWAF	082 802 1005/ 012 336 6583	manuslev@dwaf.gov.za
Dr Philip Kempster	DWAF- RQS	012 808 9599	ebp@dwaf.gov.za
Dr Anneli Kuhn	DWAF - RQS	012 808 9506	kuhna@dwaf.gov.za
Ms Jabu Mhlophe	DOH- Environmental Health	012 312 3153	mhlopd@health.gov.za
Ms Qaphile Gcwensa	DOH- Environmental Health	012 312 3141	ntseleq@health.gov.za
Ms Thembisile Kumalo	DEAT	012 310 3567	tkumalo@deat.gov.za
Dr Kevin Petersen	WRC	012 3300340	kevinp@wrc.org.za
Mr Renais Dube	WRC	012 3300340	renaisd@wrc.org.za
Mr Greg Steenveld	WRC	012 3300340	gregs@wrc.org.za
Mr Meiring du Plessis	WRC	012 3300340	meiringd@wrc.org.za
Ms Annatjie Moolman	WRC	O12 3300340	annatjiem@wrc.org.za
Dr Sue Pinches	CSIR- Foodtek	012 841 2403	spinches@csir.co.za
Ms Martella du Preez	CSIR- Environmentek	012 841 3950	mdupreez@csir.co.za
Mr Aussie Austin – Boutek	CSIR- Boutek	012 841 2568	laustin@csir.co.za
Mr Bill Pfaff	Ethekwini Metro	031 302 4783	billpf@dmws.durban.gov.za
Mr Teddy Gounden	Ethekwini Metro	031 302 4667	Teddygo@dmws.durban.gov.za
Ms Renuka Lutchminarayan	Ethekwini Metro	031 502 3552	renuka@durban.gov.za
Mjikisile Vulindlu	Cape Town Metro	021 684 1000	Mjikisile.vulindlu@capetown.gov.za
Dr Nicola Rodda	UKZN – School of Biology and Conservation	031 260 3015	roddan@ukzn.ac.za
Dr Stephen Knight	UKZN – Medical School Community and Public Health	031 260 4226	knights@ukzn.ac.za
Dr Chrissie de Wet	Rand Water	011 682 0911/0447	cdewet@randwater.co.za
Ms Manu Pillay	Umgeni Water	033 341 1111	Manu.pillay@umgeni.co.za
Mr Pumezo Jonas	Umgeni Water	033 341 1111	Pumezo.jonas@umgeni.co.za
Mr Piet Grobler	Lepelle Water	015 295 4100	pietg@lepelle.co.za
Mr Max Sirenya	Amatola Water	043 721 0814	msirenya@amatolawater.co.za
Dr David Bourne	University of Cape Town- Infectious Diseases Epidemiology unit	0827819867	dbourne@mrc.ac.za
Ms B Genthe	CSIR- Stellenbosch	021 888 2498	bgenthe@csir.co.za
Prof P Jagals	University of Johannesburg – Water and Health Unit	082 469 7080	jagals@twr.ac.za
Dr K Keddy	Enteric Pathogens Unit, National Health Laboratories	011 4899151	karen.keddy@nhls.ac.za
Ms A Mathee	Health and Development Research Group, Medical Research Council, Johannesburg	021 938 0911	Angela.mathee@mrc.ac.za
Dr Ruth Stern	School of Public Health, University of the Western Cape	021 959 2809	rstern@uwc.ac.za

Table 2: Stakeholder workshop participants, 8 September 2005

Title	Initials and surname	Organization	E-mail address	Tel No.
Dr	AL Kühn	DWAF, RQS	kuhna@dwaf.gov.za	012-8089506
Mrs	A Moolman	WRC	annatjiem@wrc.org.za	012-3300340
Mr	K Lubout	Rand Water	klubout@randwater.co.za	011-6820352
Dr	D Bartie	NIOH	delene.bartie@nioh.nhls.ac.za	011-7126404
Mr	T Gounden	Ethekwini Water Services	teddygo@dmws.durban.gov.za	031-3024667
Dr	S Knight	Univ of KwaZulu-Natal	knights@ukzn.ac.za	031-2604226
Mr	A Sundram	Umgeni Water	ashogan.sundram@umgeni.co.za	033-3411342
Dr	R Kfir	WRC	rkfir@wrc.org.za	012-3300372
Dr	N Rodda	Univ of KwaZulu-Natal	roddan@ukzn.ac.za	031-2603192
Ms	B Genthe	CSIR	bgenthe@csir.co.za	021-8882498
Dr	P Kempster	DWAF, RQS	ebp@dwaf.gov.za	012-8089599
Dr	N Mjoli	Hlathi Development Services	nozimjoli@mweb.co.za	012-9916777
Dr	SN Venter	University of Pretoria	snventer@postino.up.ac.za	012-4204100
Mr	JF Taljaard	JTPScc	jtps@eject.co.za	012-3331260
Dr	G Offringa	WRC	gerhardo@wrc.org.za	012-3300340

ANNEXURE 3

INTERNATIONAL AND NATIONAL INSTITUTIONS ACTINVE IN WATER AND HUMAN HEALTH RESEARCH

A. A Selection of International Institutions Involved in Water and Health Research

American Water Works Service Company
Voorhees, New Jersey, USA
Contact: Mark leChevallier

AWWA Research Foundation
Denver Colorado, USA
Contact: Martin Allen

Center for Water and Waste Technology
University of New South Wales,
Sydney, Australia
Contact: Nicholas Ashbolt

Centers for Disease Control and Prevention
Atlanta, Georgia, USA
Contact: Deborah Levy

Colorado Water Resources Research Institute
Colorado State University
Fort Collins, Colorado, USA
Contact: Robert Ward

Department of Environmental Science and Engineering
University of North Carolina
Chapel Hill, North Carolina, USA
Contact: Mark Sobsey

Department of Microbiology
University of Barcelona
Barcelona, Spain
Contact: Juan Jofre

Drinking Water Inspectorate
London UK
Contact: Jenni Colbourne

Health Canada
Ottawa, Ontario, Canada
Contact: M Giddings

Health Policy and Practice
School of Medicine
University of East Anglia
Norwich, UK
Contact: Paul Hunter

Health Protection Agency
London, UK
Contact: Susanne Surman-Lee

INRS-Institut Armand-Frappier
Universite du Quebec
Laval, Canada
Contact: Pierre Payment

Institute of Hygiene and Public Health
University of Bonn
Bonn, Germany
Contact: Martin Exner

International Water Management Institute
Battaramula, Sri Lanka
Contact: Meredith Giordano

Kiwa NV Water Reseach,
Nieuwegein, The Netherlands
Contact: Dick van der Kooij

Melbourne Water
Melbourne, Australia
Contact: Melita Stevens

PHLS Communicable Disease Surveillance Centre
London, UK
Contact: Gordon Nichols

RIVM (National Institute of Public Health and the Environment)
Bulthoven, The Netherlands
Contact: Arrie Havelaar

Robens Centre for Public and Environmental Health
University of Surrey
Surrey, UK
Contact: Gareth Rees

Swedish Institute for Infectious Disease Control
Solna, Sweden
Contact: Yvonne Andersson

TWZ (Water Technology Centre)
DVGW
Karlsruhe, Germany
Contact: Wolfgang Kühn

United States Enviromental Protection Agency
Washington DC or
Cincinatti, Ohio, USA
Contact: Al Dufour

Water Environment Research Foundation
Alexandria, Virginia, USA
Contact: Daniel Woltering

Water, Sanitation and Health Programme
World Health Organization
Geneva, Switzerland
Contact: Jamie Bartram

B. LIST OF NATIONAL INSTITUTIONS IN ACTIVE IN WATER AND HUMAN HEALTH RESEARCH

Institutions	Focus areas
University of Venda	Pathogens in water
Rand Water	Pathogens in water, Environmental fate of organic chemicals Algal toxins, Cryptosporidium and Giardia in water Potable water treatment &supply
University of Pretoria	Application of chemical and sentinel species to measure EDC activity in source water Detection of toxic cyanobacteria Cryptosporidium and Giardia in water Origin and fate of pathogens
CSIR	Occurrence and fate of EDCs in raw and treated drinking water, Cryptosporidium and Giardia in water, National Microbial Monitoring Programme for surface and ground water National Toxicants Monitoring Programme
Univ of Stellenbosch	Development and implementation of assay for EDCs Aquaculture and water quality Effect of microcystins on the immune system
Rhodes Univ	Whole effluent testing Aquatic toxicology Diagnostic system for the detection of sewage levels in drinking water
	Development of chronic toxicity test methods
Ecosun cc	Development of protocols for acute fish toxicity bio-assays
	Trace constituents in groundwater and health impact
North West University	Persistent organic pollutants (POPs) in the water environment
PU for CHE,	Cyanobacterial Programme: toxin bloom formation, nutrient utilization and toxin production
UPE	Cyanobacteria Programme
Technikon Pretoria	Cyanobacteria Programme
Council for Geoscience	Calibrate and verify a predictive model for the occurrence of naturally occurring hazardous trace constituents in groundwater
Sigma Beta Consulting	Non-point source pollution in agriculture
Umgeni Water	Waterborne diseases Cryptosporidium and Giardia in water Health related guidelines
Technikon Witwatersrand	Waterborne disease
University of Fort Hare	Microbial water quality EDCs programme
Technikon Free State	Microbial water quality
Technikon Northern Gauteng	Microbial water quality
Durban Institute of Technology	Microbial water quality
MRC	Cryptosporidium and Giardia in water Diarrhoeal pathogens Malaria transmission and control Rotavirus and other viral agents associated with gastro-enteritis

UKZN	Pollution management, Sanitation Use of human waste for agriculture
DWAF -RQS	Cryptosporidium and Giardia
Pulles, Howard and de Lange	Link between ecosystem and human health
University of Western Cape	Growth of pathogens in biofilms
University of Zululand	Microbial water quality
Medunsa	EDCs Programme
SABS	EDCs Programme
ARC-PPRI	EDC s Programme
Highveld Biological Association	Management of toxin pollution
Lenehan Engineering and Environmental Consulting	Health and Hygiene Education
BKS	Public awareness and educational material
ARC	Public awareness and educational material
DWAF	Public awareness and educational material
Ethekwini Municipality	Health and hygiene and waste management
University of Cape Town	Pesticides in water
SA Institute for communicable diseases	Water related pathogens and disease vectors
The Mvula Trust	Health and hygiene education
University of Free State	Algal toxins
University of Johannesburg	Biomarkers for drinking water quality