EXECUTIVE SUMMARY

Motivation

Previous water quality guideline research conducted since 1990 for the Water Research Commission (WRC) and Department of Water Affairs and Forestry (DWAF) had focused on establishing scientifically based guidelines for livestock watering relevant in South Africa, predominantly for the commercial sector (WRC Final Reports 301/01/1; 644/1/98; 644/2/98; 857/1/01 and 857/2/01). The emphasis during this process was to progress from static concentration-based guidelines to a flexible ingestion-based risk assessment modelling software program, named CIRRA (constituent ingestion rate risk assessment), and led later to the inclusion of different user categories, including wildlife and rural communal production systems.

The research conducted into water resource management in rural communal livestock production systems observed the occurrence of geochemical anomalies, assessed as potentially hazardous chemical constituents (PHCC), in predominantly groundwater used for agricultural and domestic uses. Associated hazard and risk assessments indicated that communities were exposed to hazardous concentrations of elements, such as bromide, selenium, lead, cadmium, strontium, fluoride, nitrate and iodine, with an environmental component of causation through multiple routes of ingestion, including agricultural products. Shared utilization of water sources and common exposure to geochemical anomalies with documented adverse health impacts between domestic and agricultural users, coupled to the inherent difficulties in applying primary prevention to community health, formed the motivation to develop and propose a mechanism to implement a process that utilizes water quality as a departure point, with geochemistry and biological monitoring as indicators for human health hazards, within a cost-effective multidisciplinary approach, to identify and propose management options for key water quality hazards in rural communities.

Problem identification

Problems regarding safe use of available water sources within rural communities are complex and multi-faceted, however, three broad areas may be identified. The first area concerns the presence of PHCC and constituents of concern (COC) that are present in water sources and the second area deals with the context of use within rural communal systems. The first area introduces the complexities of environmental toxicology and the impact of water quality constituents (WQC) on multiple norms for each water user. The second area incorporates the dynamics of site-specific factors that significantly alter the outcome of exposure through numerous components of hazard and risk equations. These two areas significantly influence the third broad area that is centered within difficulties in diagnosing disorders and diseases. These difficulties are largely due to direct factors affecting the developmental, chronic, subclinical route and latent presentation followed of adverse effects attributed to the constituents, and indirect environmental factors primarily responsible for observational challenges.

Accordingly, the problem may be stated as a need for measures that not only assess country-specific health problems correlated primarily to naturally occurring water quality

hazards within rural communities, but also for measures that acquire sufficient site-specific information to formulate viable actions to reduce risk and cope with the challenges in integrating varied specializations within environmental health assessments.

Within these broad problem statements, specific problem statements relate to constituent dependant toxicodynamic and toxicokinetic features where risk factors are associated with rural communal agricultural production systems. These problems all relate to critical knowledge gaps with reference to low-level, long-term, concurrent multiple hazard exposures in different sensitive user groups and may be addressed by identifying geochemical anomalies affecting community health using water quality and rural agricultural risk factors to enable differentiation between necessary and sufficient causation. The specific areas targeted are environmental controls and protection from natural hazards, with the preclinical phase assisted by the quantification of baseline conditions and developmental toxicity.

Study objectives

The initial objective of the study was to utilize the platform presented in CIRRA Version 2.03 to develop formal procedures for addressing water quality related hazards and risks for humans and livestock in rural communities within rural communal production systems. Following the severity of the PHCCs observed in selected rural communities, an additional investigation into the fitness for use of groundwater for domestic uses and animal uses in groundwater in rural communities throughout South Africa was also conducted. This was made possible by a collaborative investigation between the Agricultural Risk Assessment Division at Business Enterprises at the University of Pretoria, the Institute for Soil, Climate and Water at the Agricultural Research Council, and the Directorate for Land Use and Irrigation Development at the National Department of Agriculture.

The development of the formal procedures required sought not only to investigate the benefits of using biological monitoring as an integral aid for assessing related hazards and risks for humans in these communities, but also to assess which biological and environmental sampling was most appropriate. Although the main focus was intended to be on subterranean water this was expanded to include other water used as different water sources are at times mixed and groundwater often not utilized by a community in an attempt to maintain an adequate supply during dry conditions.

The methodology sequence was to conduct sampling, to perform biological experiments, investigate the extent of the hazards in groundwater in other communities in South Africa, and to develop and propose a system for managing naturally occurring water related hazards in rural communities. Where feasible capacity building initiatives were addressed in all aspects, as was international collaboration and consultation with different specialists in relevant fields.

As a final objective this project not only developed and proposed mechanisms for implementation of a tool that addresses aspects of water resource management, as it pertains to public health issues for rural communities within the context of water quality

related health hazards, but to acknowledges the increasing recognition of geochemistry and water quality as a valuable component in the rapidly growing field of environmental epidemiology.

The model proposed in this report is seen as a fundamental requirement that ensures that efforts by Water Service Authorities, Water Service Providers and Village Water Committees do not result in preventable direct and/or indirect adverse effects on human and animal users.

Further evidence supporting the concerns raised in the selected communities was obtained from a survey of the fitness for domestic and agricultural use of groundwater throughout South Africa conducted during 2005 for the National Department of Agriculture, Directorate of Water Use and Irrigation Development. Additional concerns regarding inorganic endocrine disrupting contaminants (EDCs) have also been subsequently raised. Discussions were held with relevant departments in the Limpopo and North-West Provinces during which these results and other aspects regarding water quality in rural communities were presented. Apart from the primary concerns regarding direct and indirect adverse effects to human health in the communities, the successful implementation of various agricultural initiatives and sustainable production at household and village level were also stated as having a high research priority.

Results and conclusions

The most significant conclusion is that the observations of PHCCs in point of use samples in rural communities at concentrations that exceed the local and international guideline limits by several order of magnitude pose significant hazards to the recognized norms for water use for both domestic and animal uses. This extends to multiple user categories within user types, for example, drinking, food preparation and bathing for domestic use, and use for household layers, broilers and crops.

The vast majority of household and village drinking water was classified as completely unfit for domestic purposes. The potentially fatal consequences of the excessive nitrate values warrant intervention, and a report detailing the hazards was submitted to the Limpopo Provincial authorities at Polokwane. The contribution of fertilizer applications and housing small stock on the household premises where hand pumps were located, in addition to natural occurrence in the aquatic environment, is well documented in the scientific literature, and management strategies concerning water sources and commuity agricultural practices need to be implemented. This extends to the village poultry and vegetable projects as they may serve as a significant source of potentially hazardous element intake in community members

Significant differences between villages were noted for elements reflected in different tissue types that accorded with the water chemistry observed. Differences in the presence of sensitive user groups (pregnant women, breastfeeding mothers, infants) and varying routes of exposure and dosages necessitate that the detection of PHCCs be used as an action level on which site-specific investigations commence.

It was found that liver samples predicted the variability between elements the best. Environmental samples did not describe element variance significantly and the collection of poultry specimens, either household or project sourced, appears to be the most reliable biological indicator.

The formulation of risk management strategies requires appropriate management that can reduce the risk to allow production and safe groundwater use to continue. However, failure to measure and monitor water quality prevents any successful management programme from being implemented. Failure to adequately describe water chemistry consequently reflects in uncertainty regarding adequate description of baseline conditions, a necessary step in fundamental epidemiological studies.

A generic level water quality risk assessment is recommended as the first step in determining baseline exposures required for the identification of constituents in the geochemical environment that may contribute to adverse effects on health, productivity, and product quality in animal users, and for health-related norms for domestic users.

Any potential hazards identified then require further investigation regarding the water, user, environment and nutrition in order to ascertain the hazard posed by the presence of toxic constituents at concentrations that exceed the various forms of recommended guidelines, and in so-doing acquire relevant site-specific risk factor information required for risk management strategies to be formulated.

This approach is addressed in detail by a proposed model that is a tool for Hazard Management for Rural Water Sources, referred to as HMRWS, and functions as a multidisciplinary effort between groups with specializations and commonalities, within a discreet functioning units that may be linked for various reasons (geographical and technical) referred to as a HUB.

The main components of the HMRWS are:

- A series of parent-child software programs
- A Central Administrator that receives, processes and directs information between five Specialist Groups:
    - Analytical Group
    - Animal Health Group
    - Geochemistry Group
    - Community Health Group
    - Rural Groundwater Implementation and Monitoring Group

The main processes within the HMRWS occur as four phases:

- Hazard Identification Phase (HIP)
- Exposure Assessment Phase (EAP)
- Toxicity and Risk Assessment Phase (TA & RA)
- Risk Management Strategy Phase (RMSP)

The HMRWS objectives are:

- Generic Objectives: For sustained water resource management issues in rural communal agricultural systems.
- Specific Objectives: For community-dependent risk factors that may range from agricultural productivity to safe household food preparation of high-risk agricultural products.

The benefits of biological and environmental sampling in acquiring site-specific data are further illustrated in the results presented later from the NDA Groundwater Project where the majority of the PHCCs reported were within 50% of the guideline thresholds. Risk for incurring both false negatives and false positives may be reduced by the acquisition of site-specific data.

The planning and implementation of community agricultural projects, typically poultry and food gardens, must take into account the role these projects may play in contributing to ingestion routes and total exposure of communities to PHCC in order to prevent a positive intention from having a potentially irreversible negative health impact.

It is suggested that the HMRWS should be implemented on a national scale, but initially commence as a single unit (HUB) that could serve to assess the most appropriate means for future expansion, and may consist of various stakeholders identified on a regional or provincial level. Primary stakeholders are specialist groups, whilst recipients of group outputs vary according to need, and level of application (local or provincial). The stakeholders presented in this chapter should not be seen as prescriptive, but rather as an example of viable working groups. The allocation of various stakeholders to groups is based on the facilitation of processes in the different phases, with flexible involvement in multiple phases suggested. Several protocol specific Research Partnerships may be incorporated where appropriate.

The current reality for the communities investigated for this report is that groundwater classified as potentially hazardous and/or completely unfit for use by animal and domestic users is still being used for these purposes, and continues to be a significant and at time critical water source. The effect of groundwater quality on the relationship between the fitness for use of animal products, various additional affected exposure routes and community health is of serious concern for both household consumption and community agricultural projects. These concerns are promoted by the irreversible developmental insults characterised for many of the constituents involved and firmly place responsibility on the various specialist fields to proactively seek to reduce the risk as much as possible, as opposed to simply complying with upper threshold limits. In contrast to endocrine disrupting effects that currently receive much attention, the physiological significance and well established cause and effect relationships following exposure to the majority of potentially hazardous chemical constituents presented in this report are known and accordingly warrants research attention and priority.

Following a collaborative and participatory approach, a model was developed and is presented in this report. Major stakeholders and individual participants indicated a strong interest to participate in the implementation thereof.

This approach is seen as integral to fundamental epidemiological principles applicable to human and animal studies. The role of groundwater in assisting the diagnostic and clinical interpretations for diseases and disorders should be seen as an opportunity.

The presence of the specific PHCCs and COCs in rural groundwater supplies presented in this report should be seen as worthy of receiving urgent attention on a National scale. The potential for *in utero* and neonatal insults suggest that a conservative approach be adopted.

Achievements

The 9th World Conference on Animal Production (WCAP) was held in 2003 in Porto Alegre, Rio Grande do Sul State, Brazil, from October 26 – 31. Professor NH Casey, Dr JA Meyer and Mr K Holele, were invited by the World Association for Animal Production (WAAP) to organise and chair a conference entitled "Water Use, Availability and Quality". Each member of the research team presented papers during the plenary session on the first morning of the conference. Additional papers were presented at other local and international conferences during the period of 2000 to 2005 by the researchers. Several popular articles were also produced and over 50 technical water quality assessment reports were produced for the commercial sector. A tender to assess the fitness for use of groundwater for domestic and animal use throughout South Africa was granted to the project team in 2004 from the National Department of Agriculture with a consultancy to monitor new groundwater points subsequently also awarded.

Academic achievements were:

Mr D Vilakazi:	MSc (AnimSci) UP – Awarded 2003
Mr K Holele:	MInstAgrar UP (submitted February 2006)
Mr C Mamabolo:	MSc (AnimSci) UP – (submission due June 2006)

The following students were involved in capacity building initiatives for the project:

Ms M Reuver:	MSc (Landou Universitiet Wageningen)
Mrs A Bichard:	PhD (Dept of Consumer Science – Developing viable production and marketing channels for cultural food products in rural communities)
Mr M Ramushu	Head of the Outreach Programmes – MSc (University of the North – community participation and safe agricultural programmes).

Numerous students and community members engaged in the Outreach Programmes for Poultry Production at Tompi Seleka Agricultural College were involved in the research process, as were extension officers in the Limpopo and North West Provinces. .

During the 9th WCAP conference closing ceremony it was announced that the 10th WCAP, to be held in 2008, was awarded to South Africa, with Professor NH Casey elected at the President of the Conference. This affords African scientists an excellent opportunity to showcase research achievements and to expand on water related research, with the HMRWS an appropriate vehicle for presenting research outputs for the 2008 conference.