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## Tanzania Ministry of Water and Irrigation

# National Water Quality Management and Pollution Control Strategy

**Author:** Peter Hawkins

**Approved:** Nasser Harrasy

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# EXECUTIVE SUMMARY

A ministry responsible for water has existed in Tanzania for many years and the first laws to manage water quality were enacted in 1973. Since then, plans to manage the country's water resources have been implemented and revised regularly since the donor sponsored regional 'Water Master Plans[1]'were developed in the early 1980s.

More recently, significant legal[2] and institutional changes[3] have been implemented based on the Integrated Water Resource Management (IWRM) model. Tanzania's current national policy for water resource management is enunciated in the National Water Sector Development Strategy, 2008, which outlines the broad strategic and political directions for the development of the sector. The NWSDS includes a simple action plan for water quality management. This strategy document complements and expands on those directives through the following plans and recommendations:

- recommendations for more focused and cost-effective water quality monitoring programmes with a phased development that initially emphasises the provision of water quality monitoring to determine the safety and cleanliness of water for human use;
- recommendations to extend provision of drinking water quality monitoring services more widely across the country;
- identified national priorities for operational water quality management;
- a model water quality management cycle for operational use at basin level, with advice to managers to consult with stakeholders to establish water quality objectives and also to focus more effort in reviewing their management actions.
- recommendations to improve financial sustainability, data quality and efficiency of operation in water quality monitoring, particularly through government laboratories developing more client focus;
- recommendations to improve data management including unified management and storage, improved accessibility and reporting tools so all users and stakeholders can access results;
- recommendations to improve institutional performance by funding human resource development through training and education programmes, plus emphasising the importance of identifying common goals and pooling resources to develop more collaborative projects at every institutional level (high level Ministerial council);
- a review of the legal regulatory framework which identified actions to improve the implementation of effluent controls;
- recommendations to develop national water quality standards;
- recommendations to improve national drinking water quality standards, with a focus on criteria relevant for protecting human health.

### Current situation and future challenges for water quality management in Tanzania

The legal and institutional frameworks for management of the water sector in Tanzania have been restructured by recent initiatives like the National Water Policy (2002), the National Water Sector Development Strategy (2008) and the Water Resources Management Act (2009). Now the agencies in the water sector are challenged by the new operational paradigm to improve water resource management that increasing demand for water to power economic growth can be satisfied, whilst maintaining and improving the quality of the resource.

There is demonstrable capacity to effectively manage water quality in Tanzania, evident from the response to the EU import ban on product from the Nile Perch fishery in Lake Victoria.

[1] The 'Temporary Water Quality Standards' which remained in force until 2007, were an outcome of this program.
[2] Environmental management Act, 2004 and Water Resources Management Act, 2009
[3] Basin Water Offices established in all major hydrological basins and stakeholders represented on Basin Boards

The threat of economic damage to this valuable export industry focussed political and institutional support in a co-ordinated 'whole of government' response,which quickly resolved the problem. Unfortunately, the responses to other pressing water quality problems in Tanzania have not been so well been co-ordinated or resourced.

The main hazards to drinking water quality and sustainability of fisheries and aquatic biodiversity in Tanzania are well known. Yet drinking water sources in rural and urban areas continue to be contaminated, licensed discharges to streams and rivers from commercial and government enterprises fail to comply with national effluent standards, and conditions on licences for mining, water abstraction and discharge are unenforced.

The challenge now is for the institutions responsible for managing the nation's water resources to co-ordinate their efforts, motivate their staff and focus on taking the actions necessary to maintain and improve the quality of the nation's water resources to the benefit of current and future generations.

## Abbreviations and Acronyms

| | |
|---|---|
| BWB | Basin Water Board |
| BWO | Basin Water Office |
| DANIDA | Danish International Development Agency |
| DFID | Department of International Development (U.K.) |
| DRC | Democratic Republic of Congo |
| EAC | East African Community |
| EIA | Environmental Impact Assessment |
| FAO | Food and Agriculture Organization |
| GEF | Global Environment Fund |
| GoT | Government of the United Republic of Tanzania |
| IUCN | International Union for Conservation of Nature and Natural Resources |
| IWRM | Integrated Water Resource Management |
| JICA | Japanese International Cooperation Agency |
| LKEMP | Lower Kihansi Environmental Management Project |
| LMBC | Lake Malawi Biodiversity Project |
| LTBCP | Lake Tanganyika Biodiversity Conservation Program |
| LVEMP | Lake Victoria Environmental Management Project |
| MKUKUTA | National Strategy for Growth and Reduction of Poverty |
| MoWI | Ministry of Water and Irrigation |
| NAWAPO | National Water Policy |
| NBI | Nile Basin Initiative |
| NELSAP | Nile Equatorial Lakes Investment Program |
| NEMC | National Environmental Management Council |
| NGO | Non-governmental Organization |
| NSGRP | National Strategy for Growth and Reduction of Poverty |
| PBWO | Pangani Basin Water Office |
| RBMSIIP | River Basin Management and Smallholder Irrigation Improvement Project |
| RIPWARIN | Raising Irrigation Productivity and Releasing Water for Intersectoral Needs Projects |
| RWRA | Rapid Water Resources Assessment |
| RWSSP | Rural Water Supply and Sanitation Project |
| SADC | Southern African Development Community |
| SIDA | Swedish International Development Cooperation Agency |
| SMUWC | Sustainable Management of the Usandu Wetland and its Catchment |
| TPRI | Tropical Pesticide Research Institute |
| UDSM | University of Dar es Salaam |
| UNEP | United Nations Environment Programme |

| | |
|---|---|
| UNIDO | United Nations Industrial Development Organization |
| WLS | Water Laboratory Services Division of MoWI |
| WQMPC | Water Quality Management and Pollution Control |
| WRD | Water Resources Division of MoWI |
| WSSA | Water Supply and Sanitation Authority |
| WUA | Water User Association |

# PART A - PRINCIPLES OF A WATER QUALITY MANAGEMENT STRATEGY

## 1 INTRODUCTION

Tanzania's water sector is a vital component of the national economy. The important uses of the nation's water resourcesare listed in Table 1 and the characteristics of the main hydrological basins and their uses described in Table 2. The sustainable development of these freshwater resources is essential for the continued social, economic and environmental well-being of the nation. Human activities are degrading the quality of these resources and threatening uses of water fordrinking, fisheries, biodiversity, recreation, irrigation and industry. Surface and groundwaters are being polluted by untreated or partially treated sewage, non-compliant discharges of effluents from point sources, leakage and spills of chemicals and petroleum, illegal dumping od solid and liquid waste, mining operations (large and artisanal), poor farming methods that release agricultural chemicals, and atmospheric deposition. Pollution undermines the use of an important, and in some cases, an increasingly, scarce resource. Pollution also transfers the consequences (or cost of treatment) to downstream users.

**Table 1. Examples of important beneficial uses**

| Use | Examples |
|---|---|
| Human Uses | Domestic (potable) water, Washing, Recreation |
| Maintain Ecosystems | Aquatic biodiversity, Fisheries, terrestrial wildlife |
| Agriculture | Irrigate crops, Water stock animals |
| Hydropower | Reservoir storage - Energy prodn |
| Industrial use | Food processing (fish) |

**Table 2. Characteristics and important water uses in Tanzania's hydrological basins**

| Basin | Human popn[A]. (M) | Basin area ($km^2$) | HEP installed (MW) | HEP potential (MW) | Irrigated Area (Ha) | Fishery (000s T/yr) | Mines | % Basin as Park | No. Wild [B]areas |
|---|---|---|---|---|---|---|---|---|---|
| Nyasa | 2.2 | 39,520 | | 222 | n/a | | | 1% | 1 |
| Ruvuma | 2.2 | 103,720 | | | 9,483 | | minor | 5% | 1 |
| Rufiji | 2.4 | 177,420 | 464 | 3,207 | 27,221 | | | 35% | 2 |
| Rukwa | 3.1 | 88,180 | | | 96,687 | | | 5% | 1 |
| Pangani | 3.4 | 56,300 | 97 | 21 | 137,680 | | | 8% | 4 |
| Victoria | 4.2 | 79,507[C] | | | 45,885 | 284 | 4major | 54% | 2 |
| Tanganyika | 4.5 | 151,900 | | | 16,543 | 180 | 1major | 1% | 3 |
| Wami/Ruvu | 5.4 | 72,930 | | | 46,993 | | | 7% | 3 |
| Internal Drain | 7.0 | 153,800 | | | n/a | | 3major | 2% | 3 |
| Totals | 34.5 | 923,277 | 561 | 3,450 | 380,492 | 464 | | | 20 |

A - Human population at 2002 Census (now estimated at ~40M in 2010)
B - Wild areas are major National Parks, Game reserves and Ramsar wetland sites
C - The estimate for Lake Victoria is the area within Tanzania and includes the area of the lake in the National Park area.

## 1.1 Specific hazards to water quality in Tanzania

The main hazards placing the beneficial uses of Tanzania's water resources at risk in all basins are:

- faecal contamination and water borne disease from poor domestic waste management in urban and peri-urban areas; that threatens water sources for human use
- contaminants in sewage and industrial waste water from point sources that threaten fisheries and other aquatic resources and the sustainability and biodiversity of aquatic ecosystems;
- sediment, nutrients and agrochemicals lost from the catchments, through poor landuse; that threaten aquatic resources and the sustainability and biodiversity of aquatic ecosystems; and
- hazards associated with uncontrolled discharge of mining wastes; that threaten human, stock and wildlife water drinking sources and aquatic ecosystems.

In additional to these ubiquitous dangers, there are some hazards which are basin specific, namely:

- eutrophication, which threatens both the human use of aquatic resources and the sustainability and biodiversity of aquatic ecosystems in large lakes;
- illegal use of biocides in fishing particularly in large lakes, which threaten both the aquatic resource and the sustainability and biodiversity of these important ecosystems;
- seasonal salinity increases in surface and groundwater sources due to over exploitation of these resources in in coastal areas, which threaten the availability of water for human, stock, wildlife and agricultural use; and
- naturally occurring levels of fluoride in basins across the fluoride belt, which threatens the health of people and livestock.

A list of the more common hazards to beneficial use of water in Tanzaniais presented in Table 3. The persistence of some of these hazards over many years indicates the need for new management approaches toresolve the problems.

**Table 3. Hazards to beneficial use of water in Tanzania**

| Hazard | Human Use | Aquatic life | Agriculture | Hydro power |
|---|---|---|---|---|
| Agrochemicals | ■ | ■ | | |
| Arsenic | ■ | | | |
| Biocides | ■ | ■ | | |
| Faecal contamination | ■ | | ■ | |
| Fluoride | ■ | | | |
| Heavy metals | ■ | ■ | | |
| Mercury | ■ | | | |
| Mining waste | ■ | ■ | ■ | |
| pH | ■ | ■ | ■ | |
| Salinity | ■ | ■ | ■ | |
| Toxic algae | ■ | ■ | | |
| De-oxygenation | | ■ | | |
| Eutrophication | | ■ | | |
| Nutrients | | ■ | | |
| Oil | | ■ | | |
| Sediment | | ■ | | ■ |

### 1.1.1 Hazards to potable water use and populations at risk

The most important water borne hazards to human health are ranked in order of the population at risk in Table 4. The single most important hazard is faecal contamination of potable water. Although this hazard has been identified by all previous major reviews of water quality in Tanzania, it still persists today as the biggest danger to human health in the country. Moreover, a recent United Nations report placed Tanzania amongst those nations with least improvement in access to safe water[4].

Contamination of water sources and spread of diarrhoea, cholera and typhoid are preventable using cheap and proven interventions, such as pit latrines and hand-washing with soap. Despite this, progress in control of water borne disease has been painfully slow in Tanzania. Only 31% of urbanites and 3% of rural populations have household piped-water connections supplying 'treated' water, and these supplies are often interrupted, requiring householders to store water in the home.  The rest of the population rely mainly on open wells, public taps, and surface sources (rivers or streams) that are frequently contaminated at the source and may also be degraded during collection, transport and use in the home.  Moreover more than 50% of the population have no access to improved sanitation (see BOX: Water Borne Disease).

Safe water and adequate sanitation are interlinked issues. Water quality monitoring data shows that the microbiological quality of potable water sources in Tanzania rarely meets the national standard for drinking water, especially in rural areas[5].At this level of contamination all Tanzanians are potentially at risk from contagious water borne diseases like diarrhoea, dysentery, cholera and typhoid.The combination of poor sanitation, poor personal hygiene, and unsafe drinking water results in an estimated 1.7 million cases of diarrhoeal disease annually andmakes diarrhoea the fourth ranked cause of death in children less than 5 years.

**Table 4. Human populations at risk from various hazards to water quality**

| Hazard | Population at risk (M) | Locations |
|---|---|---|
| Water borne disease | 35 [B] | All basins [A] |
| Fluoride | 10 | Pangani, IDB, Rukwa |
| Mercury | >2.0 | Artisanal gold mines (6 basins) |
| Arsenic | 1.7 [C] | Victoria Basin (gold mining) |
| Nitrate (babies only) [D] | ~0.6 | Semi-arid areas; Dodoma, Dar es Sal |
| Biocides | unknown | All (agriculture areas) |
| Heavy metals | unknown | All (industrial areas) |

A - The highest incidence is in high density urban areas
B - Water borne diseases account for more than half the incidence of disease in the population of Tanzania and more than 80 % of disease incidence in rural areas.
C – Regional population of 4.2million and 40% of water sources > WHO guideline.
D – High levels of nitrate reported in aquifers in Dodoma region

[4]UNICEF/WHO (2008).Progress on Drinking Water and Sanitation, Special Focus on Sanitation, UNICEF New York, and WHO Geneva.
[5]NIMR survey results, 2007. (in press)

**BOX: Water borne disease hazards in Tanzania**

Overall water borne diseases represent more than half of all disease incidences in Tanzania and more than 80 % of disease incidence in rural areas. Health studies have shown that 60 – 80% of hospital outpatient cases arise from consumption of unsafe water or poor sanitation. In part this is driven by population pressure – Tanzania is experiencing an increasing rate of population growth and increasing GDP. Both factors increase demand for the existing finite supply of water and potentially generate increasing pollutant loads which threaten sustainable water quality. Faecal contamination of potable water sources is most prevalent in the proximity of populated urban areas.

The occurrence of diarrhoea is directly related to water shortage and consumption of unsafe water. More than 1.7 million episodes of diarrhoea are reported annually in Tanzania and children are at greatest risk. Diarrhoeal diseasewas the 4$^{th}$ranked cause of child mortality in Tanzania in 2006.There are regular outbreaks of cholera and between 1998 and 2008 there were 71,895 cases and 2,118 deaths. The spread of cholera is facilitated by faecal contamination of surface and groundwater water sources.

The spread of diarrhoea, cholera and typhoid and the contamination of water sources can be easily prevented with cheap and proven interventions, such as pit latrines and hand-washing with soap. Despite this, progress in control of water borne disease has been painfully slow in Tanzania. Apart from poor sanitation infrastructure, surveillance monitoring of potable source waters is inadequate.

As an example, RWRA (1995) reported that the Kigoma area needed special attention, as more than a quarter of the population suffered more than one reportable episode of water borne disease in a year (incidence of diarrheal disease per year was 130:100 people) and the faecal coliform concentrations were amongst the highest in Tanzania. In 2010 the Kigoma Basin Water Office reported cholera was endemic in the area with regular outbreaks in recent years. Despite this, thereis no routine microbiological testing of potable water sources in the L Tanganyika Basin[6].

Where monitoring evidence is available,it shows that faecal contamination of source water supplies for human use is a continuing problem in all basins. Groundwater has traditionally been regarded as a safer source than surface water. However, these sources too are becoming increasingly polluted[7]. A high proportion of the groundwater bores that contribute to the domestic supply for Dar Es Salaam, have been reported to “not comply with the national drinking water standards for faecal coliforms.[8]

The sewage systems in most major urban centres have recently been transferred to WSSA. One survey of the performance of these plants reported that national standards for effluent prior to discharge were met in 88% of cases (n=250 samples). However, the Pangani Basin Water Office effluent monitoring program, which is the longest running and most comprehensively reported of all the basins, found the Local Government Sewage Treatment Plants serving the towns of Arusha and Moshi performed poorly in 2008-2009, and there were high levels of faecal contamination in the rivers downstream of the discharge points.

#### 1.1.1.1 Fluoride

There are areas in the Rift Valley regions of Tanzania which have naturally high fluoride concentrations including Arusha, Kilimanjaro, Singida, and Shinyanga. The fluoride level in water sources in this ‘fluoride belt’ often exceed the WHO guideline for prolonged exposure to

[6]Personal communication from the Laboratory manager, Kigoma Water Laboratory.

[7] Surveys of groundwater supplies in cholera epidemic areas found faecal coliforms in all springs and shallow wells and in 26% of deep wells

[8]Mato 2002

fluoride in drinking water of 1.5 mg/L, so human and animal populations are at risk from fluorosis[9], which weakens teeth and bones.

Based on the distribution of fluoride affected water sources in each basin, a total human population of around 10.5 million people are potentially exposed to potable water with fluoride levels above the WHO Guideline maximum level in drinking water (Table 5). The Tanzanian Drinking Water Standard for the maximum acceptable level of fluoride was recently revised down from 8mg/L to between 1.5 - 4 mg/l.

**Table 5. Human population potentially consuming water with unsafe fluoride levels**

| Location | Population (M) [A] | % at risk [B] | Population at risk (M) |
|---|---|---|---|
| IDB | 7.0 | 100 | 7.0 |
| Pangani Basin | 3.4 | 50 | 1.8 |
| Rukwa Basin | 3.1 | 50 | 1.7 |
| Tanzania | 35 | 27 | 10.5 |

A Population data from 2002 census

B Percentage of population exposed to water with fluoride >WHO guideline of 1.5mg/L

The estimate of the population affected by elevated levels of fluoride (10 million people) is based on the population living in areas where fluoride in the potable water sources exceeds 1.5mg/L. The analysis does not take account of some other known variables. Firstly, the risk of fluorosis is **reduced** for educated and higher income sections of exposed populations because:

- Educated or wealthier people in risk areas (are able to) avoid using water sources contaminated with high levels of fluoride;
- Dietary components like milk consumption raises the calcium intake and thus can reduce the likelihood of fluorosis

Secondly, the risk of fluorosis can be **increased** by applying an externally derived guideline to the Tanzanian population:

- Fluorosis can occur in people exposed to fluoride levels below the WHO guideline (genetic diversity).
- Consumption of fluoride rich foods like tea, fish, potatoes and food additive trona/magadi[10] add to the total fluoride load in the diet and increase the risk.
- WHO guideline based on water consumption in a temperate climate. This would underestimate the fluoride intake if the water consumption rate was higher (e.g. tropical weather).

### 1.1.1.2 Nitrate

Nitrate concentrations exceeding 50 mg/l may cause methaemoglobinaemia in bottle-fed infants in short-term exposure. Such high levels of nitrate are almost exclusively restricted to polluted groundwaters. In Tanzania, groundwater is a major supplement for surface water for many areas and in semi-arid areas such as Shinyanga, Coast, Mwanza, Arusha, Mara, Tabora, Dodoma,

[9] Dental fluorosis is a hypo mineralization of tooth enamel produced by chronic ingestion of excessive amounts of fluoride. The risk group is children at age from birth until about six years of age only. Skeletal fluorosis is from fluoride accumulation in bone and is progressive over many years. In severe cases the bone structure may change and ligaments may calcify, with resulting impairment of muscles and pain (WHO http://www.who.int/water_sanitation_health/diseases/fluorosis/en/.

[10] Magadi is a calcium salt precipitate from spring water that can contain high levels of fluoride. It is used as a food additive in Tanzania

Singida, Mtwara and Lindi it is often the primary source. The population of these regions [11]estimated at 12.5 millionpeople, are dependent on groundwater sources.

Contamination of aquifers by effluent from poorly built and operated sanitation facilities is common in Tanzania. For example, the mean nitrate level of water from deep level crystalline aquifers in the Dodoma region was 34 mg/l (Nkotagu 1996).

Methaemoglobinemia impairs the oxygen transfer capacity of the patient's blood. A study of children in Dar es Salaam found levels of 2% methaemoglobin in healthy children and significantly higher levels in patient with malaria (Table 6). The authors reported that even modest concentrations of methaemoglobin in blood were likely to exacerbate and complicate recovery from other diseases which affect the ability of the blood to carry oxygen (e.g. malaria - a very common childhood disease in Tanzania) (Anstey, Hassanali et al. 1995).

Assuming children <1 years represent 5% of the population potentially consuming nitrate contaminated water, then the health of 600,000 young children could potentially be affected by elevated nitrate and some lesser fraction of these would likely suffer from methaemoglobinaemia or its side effects.

Although medical records of the frequency of occurrence of this disease in Tanzania were unavailable, the high occurrence of malaria in children and the potential for a lethal synergy between methaemoglobinaemia and malaria must pose a significant risk for bottle-fed infants in Tanzania, in locations where nitrate levels in drinking water exceed 50mg/L.

**Table 6. Incidence of methaemoglobinaemia in children in Dar es Salaam**

| Type of Malaria in patient | Cases | meanMethaem. (as % haemoglobin) [A] | Methaem>10% [A] (% cases) |
|---|---|---|---|
| Cerebral malaria - unrousable coma but complete recovery | 32 | 4.7 | 12.5 |
| Cerebral malaria - unrousable coma and death or neurological sequelae | 18 | 5.8 | 22.2 |
| Malaria - severe anaemia - no severe respiratory distress | 6 | 4.7 | 16.7 |
| Malaria - uncomplicated | 37 | 4.1 | 5.4 |
| Asymptomatic parasitaemia | 5 | 3.3 | not found |
| Healthy controls | 34 | 2.0 | not found |

A - Level of methaemoglobinaemia (Methaem.) as percentage of haemoglobin in the blood

### 1.1.2 Pollution from mining activities

Mining activity has grown rapidly in Tanzania and the trend is expected to continue. In 2010 there were at least seven major gold mines operating in the country (Table 2) and around one million artisanal miners. The two forms of mining represent different potential and actual hazards to water quality.

#### 1.1.2.1 Pollution hazards from artisanal mining

The expansion of artisanal mining in Tanzaniais mainly due to the rising price of gold. These miners operate on a small scale. Their mining of alluvial deposits releases sediment into rivers and streams. But the greater hazard is from uncontrolled release of mercury used in the gold

[11]The population estimate based on regional population data from the Tanzanian Bureau of Statistics http://www.nbs.go.Tanzania/index.php?option=com_content&view=article&id=103&Itemid=114

extraction process. The important issues associated with mercury use by artisanal gold miners are:

- the hazard to human health from ingestion of mercury contaminated food or water (Minamata disease) and the potential for damage to valuable fisheries because of the environmental persistence of mercury;
- thelimited understanding of the extent of the threat from environmental mercury, because of diminished monitoring since 2004, despite increased numbers of miners.
- the ineffectiveness of the management actions[12]to modify the use of mercury by artisanal miners (summarised in APPENDIX 2 :APPENDIX 1 :) (see also BOX: **mercury use by artisanal miners)**.

**BOX: Human populations at risk from mercury use by artisanal miners**

Artisanal gold miners use mercury to extract gold from sediment. Up to 2kg of mercury can be released into the environment for each kilogram of gold won. During the gold extraction process a large proportion of the mercury is vaporised into the atmosphere and ultimately deposited over a wide area. A smaller fraction is retained in the mining waste and finds its way into local soils and waterways.

Elemental mercury is highly toxic to humans and even more so if transformed into methyl mercury. The main human exposure pathway is through ingestion so mercury contamination of water and soil poses a serious risk to human health. The risk is amplified by two other factors; mercury's persistence in the environment and its potential to concentrate (through bio magnification)in top level carnivores (e.g. Nile perch).

The monitoring of mercury in the environment around artisanal mining areas has been limited despite concerns over human exposure. Therefore the number of people at risk from mercury in water and food is difficult to estimate. A study around the Rwamagasa goldfields in 2003 showed that mercury concentrations in water, soil and biota were unsafe within the goldfields, but fell to safe levels within a short distance downstream[13]. However, since then the increased mining activity throughout Tanzania is expected to have added substantially to the environmental mercury load, despite various measures to minimise mercury release[14].

Artisanal miners directly contacting mercury in the gold extraction process are the highest risk group. The larger population living in and downstream of artisanal mining areas also risk exposure to mercury by ingestion of contaminated water or animals (e.g. fish and ducks) contaminated by mercury entering the aquatic food chain[15]. Based on estimates of one million active artisanal miners[16]; and assuming an equal number of co inhabitants in the mining settlements, the population at risk from exposure to water borne mercury is estimated in the order of two million people.

#### 1.1.2.2 Water pollution hazards of industrial scale mining

Modern industrial mining can extract metals such as gold from very low grade ore. The liquid and solid wastes produced in the extraction process are potentially hazardous because of the high concentrations of co-occurring elements (e.g. arsenic); the residual extraction chemicals like

[12] These include new mining regulations; raisingpublic awareness of the risks of mercury exposure; and technological developments to improve mercury retention in the gold extraction process.

[13]reportedin Appleton, J., H. Taylor, et al. (2004). Final Report for Assessment of Environment and Health in the Rwamagasa area, Tanzania. UNIDO Project EG/GLO/01/G34**:** 306, Taylor, H., J. Appleton, et al. (2005). "Environmental assessment of mercury contamination from the Rwamagasa artisanal gold mining centre, Geita District, Tanzania. ." Science of the Total Environment**343**: 111-133.

[14]H. Mmbando, Commissioner for Minerals, Mtwara Region, pers. comm. (2010).

[15] Other important exposure pathways are direct contact, inhalation of vapor and contaminated dust, ingestion of contaminated soil or vegetables grown on same and the use of skin bleaching creams are described in Unknown (2010). A clinical perspective of geomedical hazards caused by toxic contaminants in mining areas Mwanza Mining and Environment Conference (Draft only), Mwanza, Tanzania, NEMC.. Whilst these routes and pathways are relevant to estimating the potential health risks to select groups like artisanal miners, they are not directly relevant to strategies for managing water quality.

[16]MrRAfikHirji, World Bank, pers. comm.. 2010

cyanide and the large quantities of powdered rock. Therefore mine wastes must be contained for the life of the mine and beyond.

All developing and operating mines are subject to Tanzania's environmental laws and regulations (e.g. EIA, EMA and Water Quality standards), to protect the environment and water resources. As with all development projects, mines are expected to institute a variety of measures to mitigate or avoid environmental impacts should development proceed. Large mining companies usually intend to operate in an environmentally responsible manner and in accordance with relevant laws and industry standards. To avoid environmental harm and degradation of water resources from activities of companies operating or establishing mines in Tanzania, the state agencies and particularly the Basin Water Offices need to ensure that the existing laws and regulations are fully enforced;that operators comply with the water quality regulations during operations; and that if a pollution event occurs there is adequate payment for rehabilitation and compensation.

#### 1.1.2.3 Arsenic associated with mining

Mining activities can release arsenic to surface or groundwaters when the element co-occurs in mined ore and is then released by oxidation from waste dumps. A recent survey of arsenic levels in drinking water sources in mining areas in the Lake Victoria basin found that 41% of samples tested exceeded the WHO guideline of 0.01mg/L (Kassenga and Mato 2008). These authors warn that if mining operation expand and are not managed correctly, arsenic contamination of more water sources could potentially affect 1.7 million people in the basin (Table 4).

**BOX: North Mara Gold Mine Incident**

A recent example of environmental damage from large scale mining in TZ occurred at the North Mara Goldmine site in 2007, when tailings water leaked into the Tigithe River. The result was damage to the ecology of the river system downstream, stock losses and complaints of human illness from people living nearby. The leak was caused by the theft of the plastic liner which had sealed the tailings dam[17]. Subsequent management actions included replacement of the liner and ongoing monitoring of downstream water quality.

The North Mara example emphasises the potential for hazards created by mining to degrade water quality even when companies adopt appropriate care. The impending development of a uranium mine in Tanzania will demand even more care and attention. Asan event similar to the North Mara incident involving leakage of radioactive tailings will have much more serious consequences, due to the greater hazard of radionuclides to human and environmental health.

### 1.1.3 Pollution from agricultural activities

Poor agricultural land use practices like over-grazing (Tanzania has very extensive herds of grazing animals)and deforestation (wood is a favoured fuel in rural areas) are causing serious soil erosion in many of Tanzania's hydrological basins. Inappropriate landuse is aggravated by the increasing population pressure on agricultural land. For example, destruction of riparian vegetation and use of the exposed river banks for cropping is a common yet particularly damaging practice. Riparian corridors of stream bank vegetation are very effective barriers to soil export from fields to streams, when disturbed or removed they lose this function and moreover, stream banksthen become very sensitive to erosion.

Excessive loads of fine sediment transported in river systems can become a hazard to the sustainability of aquatic ecosystems because the sediment and associated nutrients contribute to eutrophication of lakes and rivers. Furthermore, the deposition of this sediment in man-made storage lakes shortens the effective operating life of dams built for irrigation supply and hydro-power generation (Tanzania's main source of electric power).

[17](LVBWO Interviews 2010; Dixon RutagemwaMoWI, pers. comm. 2010).

Agro-chemicals like nutrients and biocidesalso pollute water bodies where farming practices are inappropriate. A special hazard in Tanzania is the use of agricultural chemicals to catch fish in lakes and rivers. There are laws and regulations intended to modify all these behaviours, but at the operational level more attractive incentives seem to be necessary to address these problems of pollution form diffuse sources in rural areas.

#### 1.1.3.1 Eutrophication affecting the sustainability of aquatic ecosystems

Eutrophication[18] is an emerging issue in all the major Tanzania lakes, but it has most serious in Lake Victoria, which is already suffering from excessive plant and algal growth, oxygen depletion in deep waters and subtle changes in the ecosystem affecting biodiversity and fishery productivity[19]. The Lake Victoria fishery was valued at 300-400 M USD in 2007, so threat from eutrophication needs a serious co-ordinated management response.

### 1.1.4 Industrial effluent and other point source pollution

Pollution by effluentsfrom point sources is an issue in most river basins. Although water quality monitoring of point sources is not systematic in Tanzania, surveillance monitoring in the Pangani Basin is a good example of chronic non-compliance with the national effluent quality standards, by large companies, over many years (see Box: **Point source pollution in the Pangani Basin**).

**BOX: Point source pollution in the Pangani Basin**

The Pangani Basin Water Office (PBWO) is the longest established BWO in Tanzania. It has been monitoring river water and point source effluent quality since 1993. A Tanzania government sponsored survey of the basin in 1995 [20] identified point source discharges operated by industry and local government as major pollution problems.

More recent surveys by the PBWO report that the same industries continue to pollute the Pangani River ((Pangani BWO 2009)(Pangani BWO 2009)(Pangani BWO 2009)(Pangani BWO 2009)Pangani BWO 2009). Of nineteen industrial sites tested, only two complied with the national effluent standards. The BOD of effluent from both thecompanies with the worst compliance performance (Fibre Board (2000) and Tanzania Breweries) was more than thirty times the maximum acceptable to comply with the national standard. Theextent of non-compliance revealed by these surveys is a clear sign that point source pollution of rivers in Tanzania is uncontrolled and anti-pollution regulations are not being enforced.

### 1.1.5 Management efforts

A ministry responsible for water has existed in Tanzania for many years and the first laws to manage water quality were enacted in 1973. International interest in Tanzania water resources and support for development of water quality management has been significant (Figure 1).

The first systematic plans to manage the country's water resources were regional 'Water Master Plans[21]'that were implemented in the early 1980s. Since then there have been several major

[18]Eutrophication: Is the progressive enrichment of waters with nutrients, primarily phosphorus, causing abundant aquatic plant growth and often leading to seasonal deficiencies in dissolved oxygen.

[19]Kaufmann, L. (1992). "Catastrophic change in species-rich freshwater ecosystems: the lessons of Lake Victoria." Bio Science**42**: 846-858.; Hecky, R. E. (1993). "The eutrophication of Lake Victoria." Verhandlungen Internationale Vereinigung Limnologie**25**: 39-48.; Mugidde, R. (2001). Changes in phytoplankton primary productivity and biomass in Lake Victoria (Uganda), University of Waterloo, Canada. **PhD Thesis:** 196.; Verschuren, D., T. C. Johnson, et al. (2002). "The chronology of human impact on Lake Victoria, East Africa." Proceedings of the Royal Society. Series B. Biological Sciences**269**: 289-294. and Kolding, J., P. Zwieten Van, et al. (2008). Are the Lake Victoria fisheries threatened by exploitation or eutrophication? The Ecosystem Approach to Fisheries. G. Bianchi and H. R. Skjoldal, CAB International, London: 309-354.

[20]Rapid Water Resource Assessment (RWRA, 1995)

[21] The 'Temporary Water Quality Standards' which remained in force until 2007, were an outcome of this program.

water resource investigations in Tanzania's hydrological basins, and data produced by those programmes provide anongoing basis for water quality assessments[22].

However, in general the GoT has not given less a lower priority to monitoring water quality as compared to water quantity, despite the importance of quality for the overall management of water resources. Where water quality data have been collected, the data management has been poor, so it is usually inaccessible to stakeholders. Moreover the data are usually inadequate to characterize total contaminant loads accuratelyor to identify the contaminant contributions from sub-basins or point sources.

The pollution control framework and infrastructure are rudimentary. The existing pollution control capacity is still weak as the institutions responsible for this function lack experience and need an 'all of government' approach to support the development of their roles.

This strategy provides a guide to the sustainable development of Tanzania's water resources and identifies key requirements to improve the management of water quality.

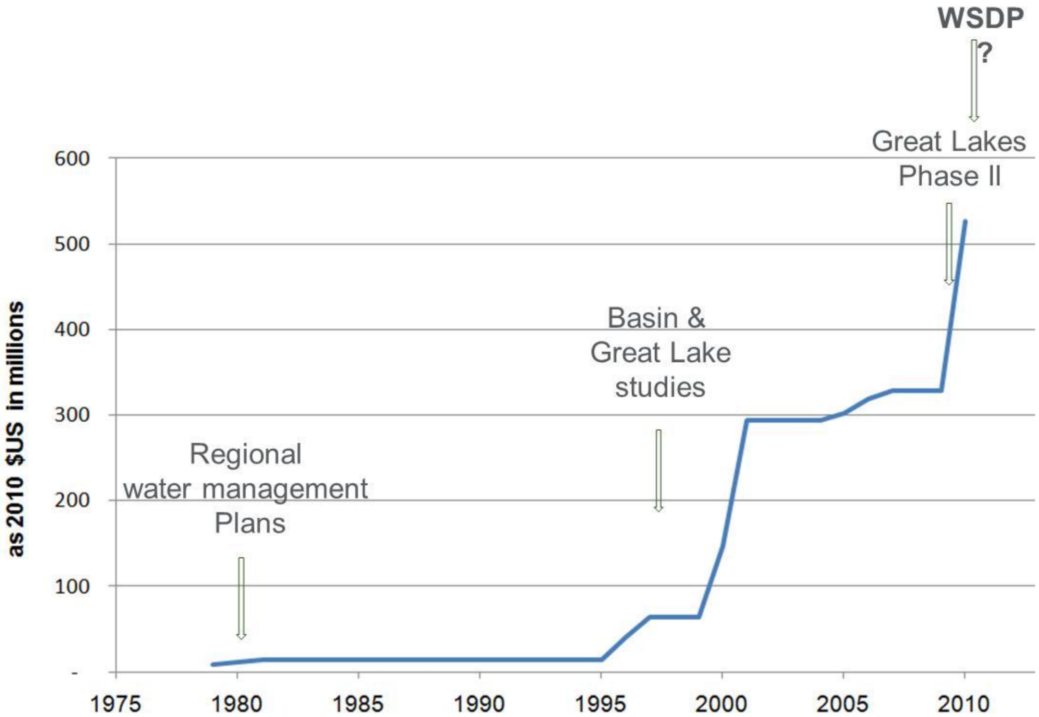



**Figure 1.Water resource management project funding from funding International sources**

Spending in Tanzania since 1970 adjusted to 2010 $US(in millions)

[22]Rapid Water Resources Assessment (RWRA), River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP), Lake Victoria Environment Management Project - Phase I (LVEMP1), Lake Tanganyika Biodiversity Project (LTBP) Phase I, and Lake Nyasa Biodiversity Conservation Project.

# 2 WATER QUALITY AND THE ENVIRONMENT

The relative presence or absence of water and its quality substantially determines the richness and diversity of terrestrial and aquatic ecosystems. Diverse ecosystems are more stable, provide more resource use opportunities and offer alternate pathways for production and nutrient cycling when ecosystems are stressed.   Any marked change in the quality or quantity of water will result in an immediate change in the range and structure of ecosystems including the numbers and types of organism that can survive in the altered environment.

Healthy ecosystems are not only intrinsically important, but also provide direct and indirect benefits to human society, because water is a basic economic input that determines regional productivity and development of society.

An adequate supply of clean water for domestic and economic use determines the distribution of human and animal populations, the quality of life and culture.   The scope and complexity of water resource management issues together with the economic requirements to maintain and improve the functions of water sector to better meet Tanzania's needs, makes this an essential national strategic endeavour.

However, it must be recognised that water resourcesare always part of the broader environment and sometimes solutions to a water resource problem could have an adverse impact on other parts of the environment.

The movement and storage of water in the environment is regulated by a complex set of physical processes, which are influenced by climate, regional topography and the local environment, and are highly variable in time and space.Change in any of these factors affects the outcome from the hydrological chain and human activity can disturb almost every stage of the cycle with the potential for significant, if not irreversible, impacts on water quality and aquatic habitat.

Except in its vapour form, water in nature is never pure. Water quality is defined by the physical,chemical, biological and sensory characteristics that affect its suitability for community uses.These characteristics can vary widely and are different for different uses.The chemical characteristics of water are particularly important for human use, agricultural and industrial purposes and its suitability for aquatic organisms.

Growing urbanisation, changing agricultural practices and industrialisation have increased both the demand for clean fresh water and the load of pollutants entering the waterways.In Tanzania, water pollution is directlylimiting economic development, through human disease caused by poor drinking water quality;diminished or excessive productivity of aquatic ecosystems;and diminished biodiversity. Slowing and reversing the degradation of Tanzania's water resources will requirechanges in behaviour by government agencies responsible for management; by water users and industries in every basin; and by individual farmers and households.

The relationship between water quality and environmental management leads to three conclusions.

1) One, water quantity and quality both vary in time and space.
2) Two, availability of adequate water of suitable quality is essential for the sustainability of natural ecosystems and the nation's social and economic development.
3) Three, the continued availability of water for all beneficial uses is vulnerable to impact not only from natural events, but also from human activities.

# 3 POLICY FRAMEWORK AND OBJECTIVES

## 3.1 Management philosophy

There is worldwide recognition that ecologically sustainable development is not only desirable, but an essential strategy to ensure that economic and social gains that benefit the current generation are not at the expense of future generations.The concept of ecologically sustainable development recognises that the natural, economic and social spheres interact within a closed system and disturbance in one sphere will impact the others. This does not imply the elements of the system or their interactions are static. Instead, it accepts that natural and human environments are not only interdependent; but that society has options in choosing the character of each element.

However, as there will always be some uncertainty in defining truly sustainable development, the general preference of the community is to conserve the natural environment whilst maintaining economic and social development. Therefore, the costs and benefits of any potential trade-off in resource development should always to be made clear and understandable to society.

Tanzania's national strategy for Growth and Reduction of Poverty (MKUKUTA) is based on three clusters:

1) Economic development and reduction of poverty;
2) Improved quality of life and social wellbeing; and
3) Governance and accountability

MKUKUTA is a very important driver for improving water quality management, as reduction of poverty and improved quality of life are directly linked to the beneficial uses of water.Poor people are highly dependent on natural ecosystem services. Livelihoods like subsistence farming and animal raising, fishing and informal forestry are precisely the activities most affected by degradation of aquatic ecosystems and loss of biodiversity(Sukhdev 2010)(Sukhdev 2010)(Sukhdev 2010)(Sukhdev 2010)(Sukhdev 2010). Secondly, contaminated water is a significant cause of disease which impact on the quality of life and the social wellbeing of all Tanzanians. Most especially the young and the least advantaged members of society.

The government of Tanzania has recognised the centrality of these issues for national development and have set a goal to provide "safe clean water for all people". The policy and national strategy for developing the water sector to achieve this goal are described in the National Water Policy (2002) and the National Water Sector Development Strategy (2008).

## 3.2 Policy

Thewater quality management strategy described here uses a policy framework based on integrated catchment management. Every resource use, improvement or conservation has a cost. Governmentultimately decides whether the cost is acceptable. But the decision should not be made without careful consideration of community views and wider community interests. It should combine economic considerations and value judgements. The community must determine the trade-offs made to acceptably balance aspirations, economic realities and cultural values. Of particular relevance is the principle of maintaining inter-generational equity, and allowing future generations the same opportunities for using these natural resources. International experience is that development that maintains or enhances water resources will yield greater social and economic benefit over the long term than developments that result in degradation of either the quantity or quality of water resources.

The GoT has clearly signalled its ambition is for sustainable development that maintains the quality of the nation's water resources. This policy principle provides the fundamental strategic direction for water quality management.

### 3.2.1 Core objectives and guiding principles for water quality management

The aim of this water quality management and pollution control strategy is to:

- improve quality of life and social wellbeing by promoting development that safeguards the welfare of current and future generations; and
- to protect biological diversity and maintain essential ecological processes, as these benefit all but especially the poorest members of society.

The guiding principles of the strategy are that:

- resource management decisions should integrate considerations of short and long term economic, environmental, social and equity consequences;
- where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used to justify delaying measures to prevent environmental degradation;
- actions and policies should consider any transboundary economic, social and environmental impacts;
- a strong, growing and diversified economy will be needed to enhance the capacity for environmental protection;
- environmentally sound methods must be used to maintain and develop internationally competitive industries;
- cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive measures; and
- Management decisions and actions should allow for broad community involvement on issues which affect them.

The challenge is

***to develop and manage water resources, so that economic, social and community needs are satisfied and aquatic ecosystems are sustained.***

This requires a balanced approach that applies all the foregoing principles and objectives equally, allowing no single one to predominate.

Tanzania's water policies stipulate that a water quality management and pollution control strategy is needed to protect the beneficial uses of the nation's surface and groundwaters from pollution and degradation. The policy identifies the following requirements for successful implementation:

- systematic water quality monitoring and assessment procedures to establish the status of water resource quality; to detect problems at an early stage and to permit their timely management and remediation;
- conjunctive and comprehensive management of quality and quantity of water resources;
- application of the "polluter pays" principle along with other legal and administrative tools;
- development and enforcement of standards for in-stream flows, industrial effluents and other waste discharges to meet environmental objectives;
- practical and cost effective water quality and pollution control monitoring programs (including networks); and
- raisingpublic awareness of the importance of protecting water resources from pollution and degradation.

# 4 FRAMEWORKS FOR WATER QUALITY MANAGEMENT

## 4.1 Legal Frameworks

Water quality management and pollution control in Tanzaniaare governed by a number of national, regional and international legal instruments. At the national level, the Environmental Management Act, (EMA – 2004), and the Water Resources Management Act (WRMA – 2009) are the key legal initiatives for improving the management of water resources.

### 4.1.1 The Environmental Management Act (EMA)

The EMA is a framework, cross-cutting piece of legislation for the promotion, protection and sustainable management of all aspects of the environment regardless of the fact that specific aspects may be assigned to other ministries. The principles of environmental management are set out in Section 7 of the Act. The Minister has a mandate to make regulations where necessary to manage any aspect of the environment if the relevant sector ministry has not taken the necessary environmental protectionmeasures.

The National Environmental Standards Committee of the Tanzania Bureau of Standards is required to develop environmental quality standards for different uses of water,establish standards for the treatment and discharge of effluent, for approval by the Minister responsible for the environment.

The Environmental Management (Water Quality Standards) Regulations, 2007, were enacted as part of this process. Although the title suggests that the regulations are for all uses of water they only provide minimum quality standards for drinking water and permissible quality of effluent discharges into water.

Other provisions of the EMA which address or have an impact on water quality issues are as follows:

**Section 60:** which requires an applicant for a water use permit to indicate the likely impact of the proposed use on the environment to enable the Basin Water Boards to monitor compliance with conditions with respect to:

- the return of the water after use to the water body, unpolluted;
- taking precautions to the satisfaction of the Basin Water Board to prevent silt, sand, gravel, stones, sewage, etc., accumulations likely to harm humans and the environment.

**Section 61:** which empowers the Minister to advise or issue directions to local government authorities on matters relating to the discharge of sewage.

**Section 62:** which empowers the Minister to consult and advise the Minister responsible for water on the making of rules governing the issue of permits for effluent discharge.

**Section 77:** which requires sector ministries to take legal and administrative measures to reduce or eliminate releases of intentionally produced persistent organic pollutants in accordance with the Stockholm Convention.

**Part VIII:** which requires measures for the prevention of pollution and prohibits the violation of any standards prescribed under the EMA or any other law regulating any segment of the environment. The NEMC, or any other authority under any other law, is required, in determining the issue of discharge permits, to ensure that the prescribed best practicable option (which is the best method for preventing or minimizing adverse effects on human health, life and the environment) is adopted. The Minister has wide-ranging powers to make regulations establishing requirements, standards and guidelines for the prevention and control of pollution.

**Sections 109 and 110** specifically prohibit the pollution of any stream including the discharge of any hazardous substances into any waters in the process of producing, transporting, trading, using, storing or disposing of chemicals, oil, toxic substances, etc. and require compliance with any regulations in place on safety.

**Part IX:** which deals with waste management. Section 125 requires local government authorities to ensure appropriate treatment of sewage to prescribed standards before disposal into water bodies.

**Part XI:** which provides for the issue by the NEMC of restoration, compensation and penalty orders against any person who has caused harm to the environment.

### 4.1.2 The Water Resources Management Act, 2009

The Water Resources Management Act (WRMA) provides the legal framework for the management of Tanzania's water resources. The WRMA is based on the internationally recognised and promoted philosophy of Integrated Water Resource Management (IWRM) which advocates the principle of subsidiarity and decentralisation of water resources management to the basic hydrological unit, the water basin. The WRMA also provides for the sustainable use of water resources for human and environmental needs. Specific provisions of the Act for water quality management and pollution control are as follows:

**Section 32:** requires the Minister responsible for water resources to prescribe a system of classifying water for purposes of determining water quality objectives for each class of water resource. Further, the Minister is required to:

- establish procedures designed to satisfy the quality requirements of water users with respect to each class of water resources as far as is reasonably possible without a significant alteration in the natural water quality characteristics of the water resource;
- set out water uses for in-stream or land-based activities regulated to protect the water resource.

**Section 34:** gives the Minister power to prohibit human activities within 60 metres of a water source.

**Section 37**: gives the Minister power, after consulting with the institutions responsible for land management, to establish Protected Zones on land draining to or above:

- any water source, borehole, treatment or other water works; or
- any sewer, sewage works or outfall; or
- any catchment, swamp, reservoir, aquifer, wetland spring;

for protection from pollution, erosion or other adverse effects. Basin Water Boards have power to construct and maintain any works or take any measures they consider necessary in a Protected Zone for the protection of any water resources.

**Sections 39-42:** provide for measures for the prevention of pollution, enforceable by Basin Water Boards.

**Section 48:** provides that avoidance of water pollution is an implied condition of every water use permit.

**Section 49:** requires Basin Water Boards to take quality into account for the sustenance of ecosystems when allocating water when there is insufficient water to satisfy all permits.

**Section 64:** penalises pollution involving effluents.

**Section 65:** provides for the designation by the Minister of water quality laboratories for analytical references for purposes of the WRMA in accordance with water quality and effluent standards set in terms of the EMA. In addition, discharge permit holders are required to comply with these effluent standards.

**Section 66:** provides for conditions to be attached by Basin Water Boards to discharge permits.

**Part XII:** provides for the enforcement of the obligation to honour international and regional treaty obligations undertaken by Tanzania in respect of the sustainable use and management of trans-boundary waters.

### 4.1.3 Water Supply and Sanitation Act

The legislative framework for water supply and sanitation is based on the *Water Supply and Sanitation Act No. 12* (May 2009). The Act outlines the responsibilities of government authorities involved in the water sector and establishes Water Supply and Sanitation Authorities (WSSA) as commercial entities. It also provides for the registration and operation of Community Owned Water Supply Organisations.

### 4.1.4 Transboundary responsibilities and treaty obligations

Tanzania shares seven of its nine water basins with neighbouring states. These transboundary waters are potential sources of both co-operation and dispute and Tanzania is party to several important regional arrangements, which govern their management and use[23].

Existing domestic legislation (EMA and WRMA) is in harmony with the principles and objectives of these treaties and provides a sound basis for Tanzania's participation in the management of its transboundary waterways[24].

## 4.2 Institutional Frameworks

The institutional arrangements for the management of water resources in Tanzania are framed by the laws described above and by the National Water Policy (NAWAPO) of 2002. The policy aims are for sustainable development and management of Tanzania's water resources for economy-wide benefits and an increase in the availability of water supply and sanitation services. Most importantly for water quality management, NAWAPO introduced the principle of Integrated Water Resource Management (IWRM)with the hydrological basin as the planning and management unit, and ushered in significant change to the institutional framework by decentralising water supply management to the basin level.

In 2008, the Ministry of Water and Irrigation (MOWI) issued "The National Water Sector Development Strategy", which is its blueprint for implementing NAWAPO. The strategy is designed to support re-alignment of policies in the key water dependent sectors of energy, irrigation, industry, mining, and environment. It defines the roles and responsibilities of various actors, including the separation of delivery of water supply and sanitation services and regulation.

[23] Important regional arrangements to which Tanzania is a party are: (1) the East African Community (EAC) Treaty; (2) the Lake Victoria Basin Commission's Protocol for the Sustainable Development of the Lake Victoria Basin; (3) the Revised SADC Protocol on Shared Watercourse Systems; and (4) a number of bilateral and multilateral arrangements, some concluded and others in the process of being negotiated, between Tanzania and neighbouring states.

[24] The EMA (in Part XV), provides that where Tanzania is a party to an international or regional agreement concerning the management of the environment, the relevant sector ministry should initiate appropriate legislation to enable implementation of the agreement. It should also initiate discussions with the relevant authorities of neighbouring countries on programmes and measures to minimise negative trans-boundary environmental impacts. The WRMA (in Part XII), imposes similar obligations specifically for water resources management. It requires the development of policies and strategies which ensure the sustainable, equitable utilisation and management of trans-boundary waters.

The Strategy notes that MOWI “has started to restructure its institutions to be compatible with the requirements of the country’s decentralisation and reform policies”, but also recognised that “we need to improve co-ordination and full participation internally between the Nation’s cross-sectoral interests in the Water Sector”.

## 4.3 Frameworks supporting non-governmental stakeholders

The ultimate objective of natural resource management is to improve community welfare through sustainable development of natural resources. Therefore the general community has a vital interest in the objectives of water quality management. However, community behaviouris a largedeterminant in many impacts on water quality. In Tanzania it will be very important to educate the community about the consequences of poor landuse and waste disposal activities for water quality. All government agencies should committo awareness raising efforts and provide communities with relevant information on their responsibilities and opportunities in water management. Government must then build on-going community involvement in improved water quality management by developing and applying appropriate policy and regulation.

Industry has a dual interest and involvement in water quality management. It is a resource water user requiring water quality suitable for a range of purposes.But industrial waste can also degrade water quality. Although exploitation of water resources can provide short-term benefits, industry should be made to realise that the long term economic benefits for industry are greater when it aligns its interests with those of the general community.

# 5 ACHIEVING THE NATIONAL POLICY OBJECTIVES

## 5.1 Policy Objectives

The national water quality policy objectivesused in this document are derived from the Vision 2025 targets for the Water Sector and from the National Water Sector Development Strategy.
The general objective is

| |
|---|
| ***to maintain (or improve) the quality of Tanzania's water resources***[25] |

and the specific objective is

| |
|---|
| ***toincrease community access to clean, safe water***[26] |

The strategies proposed to achieve these objectives recognise that point and diffuse sources of pollution, modifications to river flows and land use changes all affect water quality and the management of pollutants at source is equally important as management of water bodies. Cleaner production methods and waste minimisationwill both be necessary to reduce pollution loads. Theweak enforcement of regulations in Tanzania suggests that other incentives to reduce pollution need to be considered.

## 5.2 Developing Water Quality Objectives[27]

### 5.2.1 Beneficial Uses

Beneficial uses are those uses of a water body that contribute to public or private benefit, welfare, safety or health. If the community wants to preserve some or all of these uses, the water resource will require protection from pollution and management to avoid over exploitation.

### 5.2.2 Water Quality Objectives and criteria

The suitability of a waterbody for a particular beneficial use is determined by its physical, chemical and biological attributes.The water quality criteria used to establish national standards and set water quality objectives are based on the ranges or maximum level of the attributes including contaminants, which can limit each beneficial use.

Once the beneficial uses to be protected have been agreed, water quality objectives need to be developed based on water quality criteria drawn from the appropriate National Standard or international guideline. The scientific knowledge to accurately define critical threshold levels for some contaminants affecting human use is still evolving and the requirements to sustain environmental values are even less well defined. Therefore, water quality objectives should be conservatively based on the best available scientific criteria, to give an additional safety factor and the precautionary principle should be invoked where necessary in resource development decisions.

[25] From NWSDS p 37 - Goals for water quality and pollution control.

[26] This is based on the National Development Vision 2025 target for the Water and Sanitation Sector of universal access to safe water by 2025.

[27] Water Quality Objectives: are agreed and accepted community values and uses for rivers, creeks, estuaries and lakes. An example would be'water suitable for fishing, swimming, and drinking'. The water quality objective may specify values of particular water quality indicators to help assess the condition of the waterway for sustaining those values and uses.

## 5.3 Water resources are community assets

Tanzania's water resources belong to the people. Accordingly, the wider community can expect their asset to be protected. Water uses which do not cause deterioration in water qualityshould attract a fee-for-use linked to the cost of providing and maintaining access to the resource. This is done through the abstraction permit system managed by the BWB. However, if agreed uses are likely to degradewater quality, then the loss of value and the cost of replacement should be acknowledged and accountedin either the EIA process or in an effluent discharge permit.

As it is very difficult to accurately estimate coststhat adequately account for future value, the precautionary principle[28] must be considered in these decisions. A conservative approach to assessing return on the asset is necessary to maintain the quality of water resources to agreed objectives.

[28]Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

# 6 A SYSTEMS APPROACH TO WATER QUALITY MANAGEMENT

## 6.1 Incentives to control pollution

Incentives to deter pollution can be classified by intent to influence behaviour as follows:

- regulation - intended to **compel** change;
- marketbased incentives - intended to **induce** change; and
- community engagement and education - intended to **facilitate** change.

Observations on how incentives are perceived and applied by communities elsewhere in the world are summarised below:[29]

- successfully changing farmer behaviour to adopt better land management practices dependson cultural and economic factors; plus location, soils and the degree of institutional support;
- economic motivations appear to be a dominant factor; and
- regulation is usually the community's least preferred incentive option.

### 6.1.1 Regulation

Regulatory controls work by setting limits on water quality (e.g. the levels of hazardous chemicals in industrial effluent). The strength of regulatory control is the expectation that harm will not occur, if levels of a hazardous chemical are kept below a legally defined limit.

Regulations are most effective in protecting high value environments where risk should be avoided; and for managing point source effluent discharges, where quality cannot otherwise be guaranteed.

The EMA, 2004 and the Water Quality Standard Regulations, 2007, both provide water quality management regulations supported by financial and custodial penalties for pollution offences. The maximum fines of 10 million TSH (Water Quality Regulations) or50 million Tsh (EMA) are unlikely to be adequate deterrent or compensation for major pollution events like oil spills or mining accidents.

However, the law allows that these fines can be combined with custodial penalties and other economic sanctions like revocation of Permits, issuance of Stop Orders and payment for restoration and compensation.If these penalties are applied flexibly and together, they should be adequate to maximize the deterrent and fully implement the 'polluter pays' principle to recover the cost of premeditated or poorly planned activities that cause pollution.

Most importantly, successful regulation depends on establishing water quality standards for effluent and ambient receiving waters, having adequate monitoring to detect non-compliance; and being willing to prosecute offenders. These essential elements for an effective regulation regime are weak or missing in Tanzania (See BOX:Point source pollution in the Pangani Basin); rendering the regulatory regime 'toothless' and largely ineffectual in maintaining water quality in receiving waters at acceptable levels.

The disadvantages and limitations of the regulatory approaches used in Tanzania are:

- no incentives to reduce effluent concentration below prescribed standards;
- regulationsare not load based (there is no limit on the volume of the discharge).

[29] This evaluation of incentives was drawn from experiences in the Burdekin River catchment in Queensland, Australia, with reviews of experiences from other countries (Lankester and Greiner, 2007).

- noaction can be taken to reduce water quality impacts and environmental damage caused by compliant discharges, because there are no receiving water quality standards.

### 6.1.2 Economic instruments

Economic instruments include tax benefits, subsidies, grants, competitive tender mechanisms, cap and trade mechanisms, offset mechanisms, transferable development rights, etc. Unlike regulation, economic incentives can be tailored to specific situations taking into account cultural conditions, lifestyles and any other factors pertinent to target groups. So these market–based incentives are useful when people cannot otherwise see a private benefit.

Market-based instruments, attempt to ensure that resource-use decisions take into account all the social costs and benefits of those decisions. Market-based measures may be used to influence decisions about the use of clean water and about the management of wastes. By bringing costs of these impacts to account, waste management becomes an integral part of decision making with respect to optimising production choices and profit opportunities.

This perspective requires *inter alia* a shift in focus from end-of-pipe control of waste to one encompassing the full range of potential options to solve waste problems. A cradle-to-grave approach means that economic optimisation can be applied across the full length of the production chain and can also involve minimising costs of waste management. Many resources are under priced in terms of the opportunity cost of their use. There is also a downward bias in estimating the cost of supply of particular resources to the extent that external impacts such as environmental costs are not included. Economic instruments can be authorised under Section 80 of the EMA, 2004. As yet these have not been developed in Tanzania.

Application of the 'user' and 'polluter pays' principlesare necessary to ensure that resource users pay the full cost for their activities. In particular, the real costs of pollution are generally not accounted for in pricing and investment decisions. This means that the costs of pollution are borne by the community at large, rather than by those who benefit from the production process that generates the waste and pollution problem.

The primary difficulty in implementing a market-based approach to waste management lies in costing the environmental damage caused by pollution. In relation to water quality management, this focuses on the social and environmental costs associated with the degradation of a particular water body by the addition of wastewater. If the receiving water is thought of as a capital asset, the use of a water body for wastewater disposal results in the depreciation of that asset through a reduction in water quality. The extent of degradation can be measured scientifically and the cost estimated from the treatment costs to restore the receiving water to its original state.

A charge or levy on pollution equivalent to cost to restore the water to its original state would transfer the costs currently borne by societyto the polluter. The implementation of these charges could induce waste producers to re-evaluate their production system and change the economic profitability of various disposal waste recycling or options.

This approach promotes water resource management by strengthening cost pressures for efficiency in resource use, by including them in the overall production cycle. Efficiency of resource use is the beginning of sustainable use of the nation's water resources, the central element of the policy objective. Moreover, explicit costing for water asset depreciation would give effect to the policy to protect and enhance water quality, while maintaining economic and social development. Increasing the private cost of water resource degradation will inhibit this as a waste disposal choice and force more consideration of other disposal options, or even more fundamental responses such as waste minimisation.

### 6.1.3 Public education

Public education is an essential element of water quality management in Tanzaniaas the community have a critical role in addressing all the major water quality hazards. Public education of the hazard of faecal contamination of water sources and the health benefits of improved personal hygiene is a simple and effective approach which has markedly reduced the incidence of diarrhoeal disease in trials in Tanzania. Public education about these hazards complements capital investment in water supply and sanitation infrastructure, and can deliver significant health outcomes at a fraction of the cost. Public awareness and education campaigns to explain the dangers of pollution of water sources by hazards like domestic waste; mercury; and agrochemicals is an integral part of the national water quality management strategy.

### 6.1.4 Cleaner production technologies

Efficient production is a goal of all industrial process management. 'Cleaner Production' focuses on reducing waste production by adopting more efficient processes. If waste generation is unavoidable, recovery, recycling and reuse of waste are the next preference, with disposal as a 'last resort', to be considered when all other opportunities for minimisation have been fully explored. Better approaches to waste management are needed in Tanzania and the hierarchy of methods listed in Table 7that minimise the environment impact need to be encouraged.

**Table 7.Hierarchy of approaches waste management to minimize the environmental impact**

| Waste management approach | Impact on environment |
|---|---|
| waste avoidance | Least impact (most desirable) |
| recycling or reclamation | ⇩ |
| re-use | |
| treatment to reduce impact | |
| Disposal | Most impact (least desirable |

A focus on waste can provide opportunities for business to improve productivity and efficiency and the application of the 'polluter-pays principle' should also encourage these approaches.There are 'win-win' examples in Tanzania, where cleaner production and waste minimisation are reducing manufacturing costs and benefitingriver water quality (see BOX: Mtibwa Sugar Mill waste stream processing).

**BOX: Mtibwa Sugar use mill waste as cattle feed**

The Mtibwa Sugar Estate (MSE) in the Wami-Ruvu Basin used to discharge sugar mill waste including molasses to a tributary of the Wami River. The high BOD of this effluent degraded the river water quality affecting the suitability of the water for human use and the sustainability of the aquatic ecosystem. When MSE considered re-use of the mill waste,they found that it could be used as a feed additivefor cattle, and so developed a cattle-fattening business. This has reduced the impact on the environment and been economically beneficial to the company as the cattle salesprovide a new income stream.

MSE plans further waste reuse initiatives like using the cattle manure as fertilizer replacement in their cane fields and in the longer term, to convert molasses into ethanol for sale to local distilleries and to recycle bagasse, a by-product of sugar production, by using it to manufacture fibreboard.

### 6.1.5 A mix of approaches for managing wastewater disposal

An effective regulatory regime is a necessary basis for building more flexible economic and social management approaches. Effluent quality standards provide a form of 'insurance' against failures in market-based measures. But a mix of regulatory and market based measures have delivered improved water quality outcomes elsewhere. Clean production processes provide the technological limits for industrial effluent standards. But other technologies can be applied to optimise waste management. A mixof regulatory and market-based measures needs to be investigated further in Tanzania.

# PART B -A PROCESS for WATER QUALITY MANAGEMENT

## 7 CONTEXT FOR DEVELOPMENT OF A MANAGEMENT PROCESS

The GoT has recognised the importance of the water sector to the economic and social development of Tanzania and introduced policy (NAWAPO, 2002) and legislation (WRMA, 2009) to reform and improve water resource management in Tanzania. The institutional structures for water resource management are based on the IWRM philosophy which uses the hydrological basin as the lowest management unit.

The government agencieswith key responsibilities in the water sector (i.e. water, health, environment, mining, fisheries, forestry, and agriculture) broadly acceptthat effective management of water sector issues requiresa multi-sectoral perspective. This National Water Quality Management Strategy provides a framework within which all stakeholders can contribute to improve water quality. However, more formal mechanisms may be required to convert recognition of the need for better collaboration between government agencies into actions to achieve common goals and objectives.

This document sets out the policies and provides a model water quality management process, which can be adapted to meet particular basin or sub-basin conditions and needs. Another discussion paper(SMEC 2010) addressesthe management process and capabilities for water quality monitoring and assessment in more detail.

# 8 A PROCESS FOR WATER QUALITY MANAGEMENT

## 8.1 Generalprinciples

Despite recent advances the water quality management processesto implement the principles and policies established in Tanzaniastill require the following attributes and supports:

- a consistent process for setting water quality objectives;
- relevant and up-to-date National water quality Standards to protect beneficial uses;
- involvement of all stakeholders in defining water quality objectives, developing management plans and implementing strategies;
- clearly defined responsibilities for administration of water resources;
- provision of a mix of for incentives to change stakeholder behaviour, based on enforceable regulations, market forces and community education and awareness of the issues
- water quality monitoring that is well designed, cost effective and quality assured
- ready access for stakeholders to water quality data and information;
- financial support from government to ensure the interests of the wider community are protected;
- transparent administrative processes;
- accountable reporting

## 8.2 Integration of basin, national andtransboundary planning

The national vision of provision of safe clean water and sustainable use of water resources for economic and social development will be implemented at the basin level by the Basin Water Boards.The planning and operational processesof each Board will depend on a national framework of water quality standards and enforceable laws and regulations.The BWB operations will require technical support from central agencies to ensure monitoring reporting and storage of water quality data is standardised.

The management process will involve:

- Basin Water Boards usingtheir own water quality planning tools to set water quality objectives that are consistent with national guidelines and standards
- Communities participating in the process to identify the local beneficial uses to be protected
- Local management strategies developed and implemented by relevant stakeholders.
- Technical and material support to the BWBs from central government agencies

The water quality management process is illustrated in a flow chart (Figure 2). The establishment of appropriate planning mechanisms and processes which span multiple sectors is a necessary first step to achieving sustainable water quality management. Such processes should aim to:

- integrate land and water planning
- assess the economic, social and environmental trade-offs involved in different water resource development options and environmental allocations
- demonstrate all costs associated with each option
- establish efficient and effective management strategies
- maximise stakeholder involvement in both the planning and management phases.

## 8.3 Water quality objectives

The mechanism for establishing the water quality objectives to sustain water resource usage is a two-step process which involves:

- establishing the beneficial uses to be protected; and
- establishing scientifically based water quality criteria corresponding to each environmental value.

The process of setting regional water quality objectives through consultation with communities will require education and awareness raising in communities and strengthening of structures to ensure communities are adequately represented. Local Government and Water User Associations are obvious participants, but BWB need to be inclusive and encourage participation by all groups in these consultations.

Community groups need education in the significance of water quality and the long term implications of poor management to allow them to make informed recommendations on regional water quality objectives and resource management issues.

### 8.3.1 Beneficial uses

Beneficial uses are public or private uses of water resources that support the welfare, safety, health and economic wellbeing of individuals or communities, and therefore require protection from pollution and over exploitation. They include:

- drinking water
- agricultural water
- maintenance of biodiversity
- fisheries
- industrial water
- recreation and aesthetics

Determining the beneficial use(s) and locations to be protectedis the first step in developing a water quality management program. In Tanzania's water basins it will be necessary for the BWB to categorise rivers, lakes and aquifers (or segments thereof) according to community preferences for particular use or uses, and to establish water quality objectives to maintain and protect those uses. The BWB will also need to recognise and consider the potential for population growth and urbanisation to impact on water quality and to take account of the interests of downstream and transboundary users of water bodies in setting water quality objectives.

### 8.3.2 Water quality objectivesand water quality criteria

The term 'Water Quality Objective' (WQO) is widely recognised in the IWRM literature and defined in many national laws. However, most MOWI staff are unfamiliar with the term. Nevertheless, they do recognise the "provision of safe clean drinking water for public use" as a primary Water Quality Objective for the country. Furthermore, Tanzania's National Drinking Water Standards provide ready-made WQO for assessing the safety of drinking water sources.

The only basin where WQO have been formally established is the Pangani Basin [30]. These WQO aim to maintain receiving water quality suitable for human aquatic ecosystem and industrial uses, by implementing waste load allocations, effluent standards and other pollution control measures. A major deficiency of these regional WQO is the lack of numerical water quality criteria or other quantitative measures for determining if ambient water quality is suitable for maintaining aquatic life.

[30]These WQO were derived from the now defunct Water Utilization and Control Act, 1974' and are the only WQO for protection of aquatic life being applied in any basin.

### 8.3.3 National water quality Standards

The EMA, 2004 directed the National Environmental Standards Committee (NESC) of the Tanzania Bureau of Standards to establish the criteria and draft national water quality standards[31] for sustaining and protection the important beneficial uses listed in Table 8.

Receiving water standards define the maximum pollutant concentration permitted in the environment at any place and often form the basis for setting WQO to protect aquatic ecosystems. Therefore, the lack of national standardsfor most uses is an impediment to effective water quality management in Tanzania. As an interim measure, some internationalguidelines for important uses are provided in Table 8.

**Table 8. Status of water quality standards for beneficial uses in Tanzania**

| Use | Tanzania Standard | International Guideline | Reference |
|---|---|---|---|
| Drinking water | (URT 2007) | WHO Drinking Water Guidelines | (WHO 2004) |
| Agriculture | No standards | FAO Guidelines: water quality for crops | (Ayers and Westcot 1994) |
| Recreational use | No standards | WHO Guidelines for safe recreational water environments | (WHO 2003) |
| Wildlife and stock | No standards | Stock water tolerances | Annex in (SMEC 2010). |
| Fishery and Environment | No standards [A] | n/a [A] | (MRC 2008)[A] |

A – Some ambient Water Quality Objectives for receiving waters are more appropriately derived from measurements of the normal or desirable (unpolluted) condition in a lake or river than from a National Standard for receiving water quality.

### 8.3.4 National water quality Tanzania's Drinking Water Standard

The Tanzania Drinking Water Standards (TDWS)[32] established in 2007 are based on the first edition 1984 version of the WHO Drinking Water Guidelines (DWG). However, the current WHO DWG[33] are more relevant for water quality management in Tanzania than the TDWS, as they are simpler; focus on criteria for protecting human health; and recommend different maximum levels for some important criteria (see Table 9).

#### 8.3.4.1 Two tiers of maximum acceptable level

The TDWS (2007) set 'upper' and 'lower' maximum levels for some criteria. Whilst the concept of a maximum acceptable level is well understood for potentially toxic elements and compounds, setting two different (safe) upper limits is counter-intuitive[34]. National drinking water Standards should clearly define the maximum safe level for a hazardous element or compound so that users can easily understand the risk. National Standards should not be set above accepted 'safe' levels to accommodate natural contamination (e.g. fluoride) or manmade pollution (e.g. nitrate).

[31] Part X of the EMA deals with Environmental Standards and Clause 143 (Water) states that the National Environmental Standards Committee shall: a) prescribe Criteria And Procedures For Measurement of Water Quality; b) establish minimum quality standards for all waters in Tanzania; and c) establish minimum quality standards for the major beneficial uses.

[32] TBS (2007).National Environmental Standards Compendium.

[33] WHO (2004).Guidelines for Drinking Water Quality. 3rd Edition, World Health Organization.

[34] How can there be two different maximum safe upper limits for a contaminant of drinking water?

#### 8.3.4.2 Elements and compounds not hazardous to human health

The TDWS sets criteria for many compounds (e.g. organoleptics) and elements (e.g. iron and major ions), which are not hazards to human health. As an example, dissolved iron and manganese sometimes occur at high levels in ground waters in Tanzania, but the levels of these elements which occur in potable water with simple treatment[35] are aesthetic concerns, not human health hazards. The schedule in Table 9 lists the elements/compounds that the World Health Organisation recommends for assessing suitability of water for human potable use.

**Table 9. Water quality criteria recommended for assessing suitability of drinking water**

| Parameter | Unit | WHO 2004 | Tanzania 2007 (low limit) | Tanzania 2007 (high limit) |
|---|---|---|---|---|
| *E. coli* or Faecal coliform [A] | cfu/100 ml at 44 C | <1 | <1 | |
| Arsenic* | mg/l | 0.01 | 0.05 | |
| Barium* | mg/l | 0.7 | 1.00 | |
| Cadmium* | mg/l | 0.003 | 0.05 | |
| Cyanide* | mg/l | 0.07 | 0.2 | |
| Selenium* | mg/l | 0.01 | 0.05 | |
| Fluoride | mg/l | 1.5 (F) | 1.5 | 4 |
| Nitrate** | mg/l | 50 [C] | 10 | 75 |
| Manganese** | mg/l | 0.4 | 0.1 | 0.5 |
| Copper** | mg/l | 2.0 | 1.0 | 3.0 |
| Mercury** | mg/l | 0.006 | 0.001 | |
| Chromium (VI) | mg/l | 0.05 | 0.05 | |

* Tanzania lower limit is >(WHO 2004) (Harmonisation required)
** Tanzania lower limit is < WHO (2004) (Harmonisation required)
(F) The daily consumption of water and other dietary sources of fluoride should be considered in setting national standards. Based on these risk factors, a maximum level of Fluoride in Tanzania may be less than the WHO maximum.

## 8.4 Recommendation for water quality standards

**Drinking water standards**

1. Although recently drafted, the Tanzania DWS are based on out-of-date sources. They should be revised to harmonise with the current WHO Drinking Water Guidelines and to focus on hazards to human health that are relevant in Tanzania, like indicators of faecal contamination; fluoride; and mining waste contaminants (mercury (Hg), cyanide (CN) and arsenic (As)).
2. All criteria in the TDWS which set two maximum levels should be revised to clearly define the single acceptable maximum safe for human consumption.
3. Redundant water quality criteria in the TDWS (i.e. those which are not hazards to human health and not listed in Table 9), are not essential for monitoring of water sources for human use and should be considered for omission in future revision of the TDWS.

[35] Both elements are only soluble in water as reduced or complexed forms. The reduced forms can be treated very simply by aeration and standing to oxidise, precipitate and sediment out.

**Other water quality standards**

4. Minimum quality standards for different uses need to be established to provide managers with a framework for setting water quality objectives; to assist Tanzania to meet its transboundary obligations for water quality management; and to fulfil Section 143 of the EMA.
5. Water quality objectives need to be established for various classes of water resources to sustain the respective beneficial uses and to fulfil Section 32 of the WRMA.

## 8.5 The management cycle

Achieving and sustaining water quality objectives requires an administrative process involving a management loop which continues to operate until the objective is satisfied. The process is illustrated diagrammatically in Figure 2 and its elements are described below in relation to the situation in Tanzania.

**Collection of background water quality information**: Despite the relatively undeveloped status of the Tanzanian economy and water sector, a very substantial amount of high quality scientific research and investigation has been undertaken into the nation's water resources over the past forty years. The high level of interest and investment from international agencies[36](see Figure 1) reflects the economic, social and ecological value that regional and international communitiesplace on Tanzania's water resources.

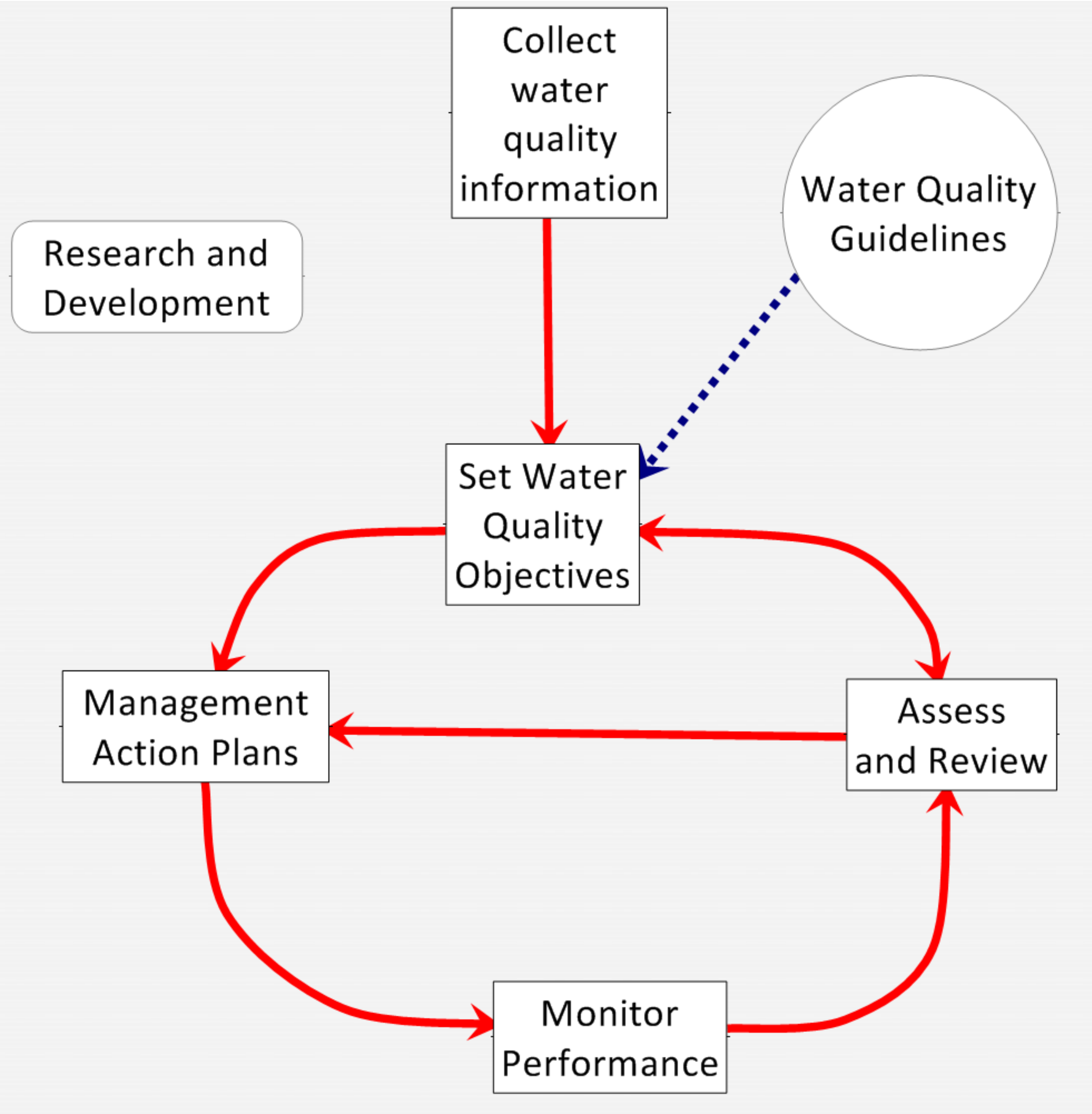
**Setting Water Quality Objectives (WQO)**: Water Quality Objectives are essential toolsforwater resource managers.They are applied at the local level to address specific concerns and to prioritise beneficial uses. Firstly, they identify the uses which the community values most highly. Secondly, the WQO provides the target values, which the manager can use to assess performance. Although the WQO terminology is unfamiliar to most Basin Water Officers, all grasp the necessity for management targets, expressed either as a statement: 'safe, clean water for all people' or as numerical water quality criteria which can be used to assess whether water is 'safe and clean'.

Ultimately the responsibility for setting WQO rests with the Basin Water Boards (BWB), which should lead the process of stakeholder consultation to identify the locations and uses to be protected. WQO to sustain ecological functions may require the BWB to seek technical advice for each situation as these can vary between water bodies. In contrast, WQO for human use can be derived from National Drinking Water Standards or WHO Drinking water guidelines as these should apply uniformly, irrespective of water body type or locality.

**Management Actions**: are activities designed to help maintain or improve water quality, usually after degradation has been identified (often from community concern), and confirmed by scientific investigation. These activities should be initiated by the BWB but should usually also involve stakeholders, particularly those whose actions may be responsible for the non-compliance/pollution.

In Tanzania there are many examples of identified water quality issues, where management actions have been identified and recommended but not implemented. Often this may be due to cost (e.g. urban sanitation improvements); lack of technical capacity; weak enforcement (e.g. control of point source pollution); or lack of implementation resources (e.g. extension of Fluoride management technologies to affected communities).

[36] SMEC (2010) valued past investigative programmes at more than 500 millionin current USD terms




Boxed items are essential elements of the strategy under direct control of water quality managers
Rounded box (R&D) contributes to many elements and should be influenced/directed by managers
Circled items are determined by the regulator (Government) and are inputs to the management process

**Figure 2. Proposed operational strategy for water quality management in Tanzania**

Alternatively, there have been some notable management successes (e.g. biological control of Water Hyacinth (*E. crassipes*) in Lake Victoria) or the control of biocides used to illegally harvest fish in Lake Victoria, which threatened the export market for Nile Perch to the EU.

**Monitor Condition:** is a measurementprogramme designed to determine the effectiveness of a management action. The resource manager (e.g. BWB) is also usually responsible for commissioning the monitoring and assessment steps, but these roles should be assigned to agents with the technical capacity to design, conduct and evaluate studies which are scientifically valid.

**Assess and Review Performance**: Critical analysis of the results of the monitoring program and feedback in an administrative loop to inform future water quality management activities. This is the weakest link in the management cycle in Tanzania because:

1) WQO are lacking or poorly defined, so there are no targets to review performance against;
2) Institutions are not enforcing anti-pollution regulations so there is little incentive for polluters to change behaviour; and
3) Absence or inaccessible water quality records prevents adequate review

**National Water Quality Standards**: National standards are an essential part of the regulatory framework for water quality management. The responsibility for establishing these National Standards lies with the NESC. The standards relevant to water quality management in Tanzania are deficient in their scope and their relevance. This document does suggest some alternative international guidelines which can be used as interim measures.

**Research and Development (R&D)**: are exploratory or inventive activities that require high level technical skill and understanding, because of the exploratory nature of the tasks. There is capacity in Tanzania to undertake R&D to assist water quality management and there are success stories. However, it is essential that R&D is targeted to deliver outcomes that are useful for water quality management. Therefore resource managers must become more involved in funding and directing R&D in partnership with service providers (especially tertiary institutions) with the technical capacity to deliver appropriate outcomes.

The management cycle illustrated in Figure 2 applies at basin or sub basin level, for any water quality issue (See BOX : Erosion control in the Simiyu River Basin).

**BOX: Trialling erosion control measures in the Simiyu River Basin**
R&D to support better management of diffuse sources

The Simiyu Basin was identified as an erosion hotspot by **baseline research** in the LVEMP. Soil erosion in the basin is detrimental to agricultural productivity because of the loss of soil and nutrients and it is also detrimental to the receiving waterbody (ultimately Lake Victoria) because the nutrients and soil transported into the lake are causing eutrophication. The causes of soil erosion are overgrazing, poor farming practices and excessive timber harvesting (for fuel). All problems common elsewhere in Tanzania.

The **research and development** project will also test the effectiveness of a range of **management actions** in providing incentives for better land management in the Barrigadi District. These include

- transfer land ownership to individuals (collaboration with Land Care Commission mapping project)
- consensus agreement on the landuse for each piece of land (within the village)
- mapping and maintenance of riparian vegetation strips (collaboration with National Land Care Commission mapping project in the Barrigadi District)
- subsidised re-forestation of land and riparian vegetation
- raise awareness of the impacts of over-grazing and over-harvesting of timber

There are no **water quality objectives** for the amount of sediment naturally exportedfrom the Simiyu catchment, so an aim of the study will be to establish what are 'normal' levels of sediment export and the extent of the seasonal variation. This will be done by detailed **monitoring** of sediment exports from both control and trial sub basins, to test the effectiveness of the activities.

The stakeholder engagement is extensive. Representatives from Local Government, Community based organisations, Schools, Faith based institutions and Government Agencies (Ministry of Agriculture and Prisons Department) will all be involved in the catchment restoration activities.

The **assessment and review** component will be undertaken by scientists working with the LVEMP II programme (Simon Msemwa pers. comm. 2010). Outcomes from this project may well provide the basis for managing erosion in other affected basins elsewhere in the country.

# 9 BASIN MANAGEMENT

## 9.1 Significance of the basin unit for water quality management and pollution control

Point sources of pollution can be managed by 'end-of-pipe' controls, but pollution from diffuse sources needs more diverse management measures. These sources need to be addressed at the river basin or sub basin level and the responsibility for implementation becomes multi sectoral. Effective catchment management requires an integrated approach that considers: water quality in relation to the use of land and other natural resources; co-ordination of all the agencies, levels of government and interest groups within the basin; and extensive community consultation and participation.

An inclusive approach that involves all stakeholders in the process, usually works better than the imposition of an external solution. Typically, local interests have a good understanding of the local issues and community involvement builds ownership of the water quality objectives chosen. Furthermore, community involvement in the decision process encourages greater commitment to the management action, which is essential for controlling diffuse pollution at the local level.

## 9.2 Management frameworks

The policy principles for water quality management encompass the entire water cycle, with administration devolved to each of Tanzania nine major hydrological basins. For this to be effective, all individuals, groups and organisations whose activities can potentially impact water quality at any point in the hydrological cycle, must be brought within the scope of the management process. Therefore the process must be sufficiently credible and robust to engage all stakeholders. The policy recognises that all stakeholders have key roles in implementing the strategy; sharing information; raising community awareness, setting water quality objectives and building strong networks and processes.

The role of the GoT is to balance individual stakeholder needs with the interests of the general community. Thus the BWB must set water quality objectives that are based on consultation to identify community preferences, but also ensure that these management decisions complement the national vision.

## 9.3 Institutional framework for basin management

The current institutional frameworks for water quality management in Tanzania demonstrate a desire to improve the linkages between all authorities involved in the management of water resources, commencing from institutions at the community level, in order to avoid fragmentation of operations and to create a systematic approach to water quality management.

This should facilitate harmonisation and synchronisation of operations within and across institutions to reduce contradictory operations and unnecessary duplications. The support of institutional structures at the community level is essential as this is where anti-pollution efforts and diffuse source control measures must be implemented. The institutional framework is therefore intended to ensure intra-sector and across sector linkages as well as linkages with the Ministry responsible for the environment, for the effective promotion of IWRM.

### 9.3.1 Ministry of Water and Irrigation

The Ministry of Water and Irrigation (MoWI)is the peak government institution responsible for management of water resources in Tanzania. The Ministry is undergoing significant structural changes as required by the Water Resources Management Act (2009). These changes will take time to penetrate the organisational structure and a good example of the institutional inertia that besets the MoWI is the organisational chart published on the MoWI website. This chart fails to illustrate the institutional realignments that are being undertaken. Most importantly,the Basin Water Boardsand the community stakeholders do not appear on the chart. These omissions are not trivial and but do perhaps illustrate the level of uncertainty within the MoWI about how its role in managing water resources in the IWRM context.

**Water Resources Division**

The Water Resources Division is the administrative unit within the MoWI that is most responsible for water quality management. The division collects hydrologic and water use data; collects and manages all water well log data; develops hydro-geologic maps; issues water use permits; inspects existing water abstractions systems. It is also responsible for water resources planning and research, regulation, enforcement and environmental issues associated with water resources. The Division offers a variety of educational programs to promote wise use of the national water resources. However, water quality is not mentioned explicitly in Divisional description of its roles and responsibilities. The roles of different Sections of WRD for managing water quality data or for providing advice to BWO on water quality data collection and management, were determined as follows:

**Water Resources Monitoring and Assessment Section**

This section seems to be misnamed as it monitors water resource quantity only, not quality. The section maintains a national water resources data base (but it is unclear whether this includes water quality data)

**Water Resources Planning, Research and Development Section**

- Maintains a water resources information system and disseminates information on water resources (but unclear whether this includes water quality data).

**Water Resources Protection Section**

- Provides guidance and support to the Basin Water Offices in their water allocation and water legislation enforcement functions (including legislation pertaining to groundwater drilling and groundwater exploitation).
- Manages the national register of water rights, water user associations and other user groups.
- Coordinates and support activities relating to the protection and conservation of water resources[37].

Overall the institutional responsibilities for water quality monitoring and data management within the Division of Water Resources are vague and ill defined.

### 9.3.2 Basin Water Boards and their Offices

IWRM is a concept which has increasingly dominated natural resources management approaches internationally. Its objective is to manage water resources in an integrated and comprehensive manner, to achieve equitable, efficient and sustainable development of the resources. The optimal management unit is the hydrological basin and this management model has been progressively introduced in Tanzania over the past fifteen years.

In conjunction with the legal changes described above, Tanzania has established nine administrative units corresponding to the nine major river or lake basins. The Basin Water Boards (BWB) are executive bodies with mandates to execute and promote integrated water resources planning and use. Water quality management is an essential component of IWRM. Thus, in order to protect water resources, Basin Water Boards have to regulate the way human systems operate in generating, abating and disposing of waste products through pollution control,

[37] This role is very vague and should be defined more precisely

prevention of sediment build-up and the degradation of wetlands and the imposition and collection of fees and charges. In this connection, under the WRMA, the specific functions and powers of Basin Water Boards are as follows:

- approve, issue and revoke water use and discharge permits (s23 (f));
- monitor and enforce water use and discharge permits and pollution prevention measures (s 23 (i));
- advise the Director (MoWI) on technical aspects of trans-boundary water issues (s.23 (m));
- classify water resources (s.31 (2)(c);
- identify areas which are to be made Protected Zones (s. 32 (2)(e).

Over the past two decades, Basin Water Offices (BWO) have been established as the operational centres for water resource management in each hydrological basin [38].

### 9.3.3 Functions of Basin Water Offices

BWO need realistic and achievable water quality objectives to properly engage in the water quality management process. National water quality Standards and the management process presented in this strategy provide a framework within which BWO can participate in selecting and pursuing beneficial uses for their basins. They are supported by the National Water Policy and regulations in the EMA and WRMA.In most cases the final responsibility for prescribing beneficial uses and the water quality objectives which derive from them will rest with the BWO. Thus, the BWO should exercise the following functions:

- participate in water quality objective setting, by seeking community, government and industry input on specific beneficial uses to be adopted,
- resolve competing interests for adoption of beneficial uses having varying cost consequences for the community and different environmental impacts, and then
- establish the beneficial uses to be designated for specific waters.
- develop strategic plans for water quality management within specific sub basins, based on the water quality objectives adopted;
- promote control of diffuse sources and encourage sound land use practices which minimise diffuse pollution;
- ensure that the management of discharges is consistent with the WQO adopted;
- participate in water quality monitoring and reporting;
- coordinate the activities of governmental authorities and private interests within the basin for resource management purposes.

## 9.4 Strengths in water quality management

**Tanzania's legal framework is adequate**: the legal framework provides a sound basis for the management of water quality in both national and international (transboundary) waters

**Institutional frameworks** are being established with a Basin Water Office now established and operational in every basin as the centrepiece for operational water quality management.

**Stakeholder Engagement**: is improving with the imminent inclusion of community representatives on Basin Water Boards.

**Increased technical and administrative capacity**: there has been an influx of graduate trained staff in recent years and there has also been a significant investment in the infrastructure and equipment needed for water quality management.

[38] Pangani River Basin (1991), Rufiji River Basin (1993), Lake Victoria (2000), Wami-Ruvu (2001), Lake Nyasa (2001), Lake Rukwa (2001), Internal Drainage Basin to Lake Eyasi, Manyara and Bubu depression (2004), Lake Tanganyika (2004), and Ruvuma and Southern Coast (2004).

However, the water sector is still in danger of losing its core experienced operational staff *en masse* to retirement or more enticing alternative employment unless mechanisms can be developed to retain their services.

**The information base is adequate**: Basic knowledge and understanding of the processes affecting the water quality of tropical rivers and lakes does exist and some of it has been developed by studies in Tanzania. Now people with appropriate skills are needed to use this information effectively.

### 9.4.1 Management successes

The legal framework is now established; the administrative structurehas been defined and is being implemented. Monitoring capabilities to support water quality management exist in Tanzania and are being reinforced by recent capital fundingof new material and equipment. These can deliver management successes, and the restoration of the Lake Victoria Nile Perch fishery after the EUimport ban shows what can be achieved if the political will and financial and human resources are aligned (See Box: ─ EU import ban on Lake Victoria Nile Perch).

**BOX ─ EU import ban on Lake Victoria Nile Perch**

– How regulations and incentives stopped polluting activities in the Nile Perch Fishery

An EU import ban on fish export of from Lake Victoria in 1997 was a serious economic blow to all the riparian states as the Nile perch fishery was valued at 100M USD/year. The ban was caused by bacteriological contamination of fish, which occurred during processing and rumoured biocide contamination of fish due to illegal fishing methods.

The response by the Tanzania government was rapid and direct, involving many different agencies in a co-ordinated and well-resourced response to improve the industry and remove the ban. Capital was invested in improving fish landing and processing facilities and building a testing laboratory to guarantee fish product was free of biocide residues. Education campaigns raised public awareness of the health risk from eating biocide contaminated fish; and local fishermen were trained as “Beach Management Units” to enforce fishing and health regulations and prevent the landing of contaminated fish in Tanzania.

The outcome was removal of the EU ban on Tanzania fish product within 12 months, whereas the ban on fish from Kenya and Uganda continued for more than 2 years.

The lessons from this action is that the government of Tanzania can successfully manage the nation’s water resources, when sufficient political will and human and financial resources are applied.

**BOX: Fluoride in drinking water: a hazard to human health in Tanzania’s fluoride belt**

The MoWI (Ngurudoto Research Centre) has worked for many years to research and develop methods to reduce the level of fluoride in water, which is a naturally occurring contaminant across a wide area of Tanzania (the fluoride belt) that potentially affects the water supplies for more than 10 million people. Unfortunately, despite considerable success (e.g. development of the bone char method for fluoride removal) outcomes from this R&D effort have not been widely implemented, and many people still consume water containing fluoride levels above the WHO maximum guideline level of 1.5mg/L.

A significant reason for the lack of implementation is that the Tanzanian drinking water quality standard accepts fluoride in potable water up to 4mg/L, a level that is reported elsewhere to be a risk to human health[39].

This example shows that although technologies may be available to improve water quality, strong political (e.g. community) support is essential to create a supportive legal and regulatory framework. Moreover, environmental health professionals must be involved in establishing water quality standards that can protect the community from natural or man-made hazards.

A downward revision of Tanzania's maximum acceptable fluoride level to harmonise with the WHO drinking water guideline would provide strong incentives to expand the application of fluoride removal technology and reduce the health risks to people living in the fluoride belt.

## 9.5 Weaknesses and limitations in water quality management

### 9.5.1 Limited technical and administrative capacity

Technical and administrative capacity limitations are the major challenge for effective water quality management in Tanzania. The availability of operational and management skills in the sector has been stretched by the expansion of the BWOs. In basin offices with trans boundary responsibility, inexperienced staff are confronted by the additional complexities of managing water resources across borders, including major lakes. The human resources with the skill sets required for these tasks are limited in Tanzania, and the situation is complicated by competition for these skilled staff from outside government (e.g. consultant firms) and by retirement.

#### 9.5.1.1 Inadequate response to water quality management challenges

There are two important examples of management system failure in Tanzania; (i) point source pollution in the Pangani Basin; and (ii) mercury contamination in the Malagarasi River basin Lake Tanganyika.

In both cases, the elements of the management cycle were applied but when the management actions did not change the behaviour of polluters, the administrative feedback loop failed to trigger any further management response.This is a sign of a lack of capacity at the BWO level to either, escalate the response and prosecute the point source polluters (Pangani Basin); or to develop alternative responses though better understanding of the artisanal miners issues for not adopting alternative technologies for removing mercury.The evidence of systemic failure in controlling point source pollution in the Pangani Basin is even more disturbing as the Pangani Basin Water Office is regarded as a model of the implementation of IWRM in Tanzania.

### 9.5.2 Pollution of water resources

There are still no permanent receiving water quality standards. Regular water quality monitoring is occurring in some basins, but even when data are available, there is not always the will to enforce regulations. Consequently, there is little effective regulation and control of water pollution.

**Regulatory Enforcement Gaps:** Adequate regulations exist for managing both water quality and for pollution control. What is lacking is enforcement of these regulations. Enforcement of compliance by point source polluters is almost completely absent.

[39] Bailey, K., J. Chilton, et al., Eds. (2006). Fluoride in Drinking-water.) for WHO

**Inability to change stakeholder/user behaviours**: This is the management deficiency which has hindered progress in managing significant human health issues like faecal[40] and mercury contamination of water sources (see BOX: Pangani Basin point source pollution; BOX: Mercury risk from artisanal mining).

### 9.5.3 Weak institutional frameworks:

**Lack of trust in the institutions**: The BWO need to build trust with the water users by operating in a transparent and fair manner and by becoming accountable for their actions.

**Co-operation between GoT agencies is poor:** Communication and co-operation between government institutions which have a stake in water quality management is recognised by all parties as poor and needs to be improved.

**No Framework for Establishing Environmental Flow Requirements:** There are no guidelines to assist irrigators and hydropower generators to determine the seasonal river flow requirement needed to sustain aquatic ecosystems (this deficiency is linked to lack of water quality objectives and lack of National Standards for receiving water quality).

### 9.5.4 Financialuncertainties

In the past, allocation of GoT funds for water quality management has been inconsistent and there has been a heavy dependence on donors to finance monitoring programs. The short term future seems brighter because of funding from an international loan package. However, the longer term financing of BWO operations will be challenging, as the GOT expects the BWO to ultimately be self-sustaining. Despite low income levels in rural areas and inexperience of BWO in operating successfully as commercial entities..

### 9.5.5 Weaknesses in monitoring capability

Limitations in the services provided to the BWO will affect the capacity to make appropriate management decisions. Inadequacies in water quality monitoring are described elsewhere. Here it is sufficient to say that improvement in the quality assurance and management of water quality data is urgently needed.

## 9.6 Recommendations to address weakness in basin management

There are some improvements to the institutional framework, which will assist Tanzania to meet its international treaty obligations for the management of water quality in transboundary waterways:

6. National water quality guidelines and water quality objectives for receiving waters will be needed for future negotiations over the quality of transboundary waters. As Tanzania has more trans-boundary basins than any other state in the region, it should position itself to participate effectively in trans-boundary water quality management and take a leading role, where necessary, in actively promoting the setting of uniform receiving water quality guidelines.

[40] A recent survey of household water treatment practice in Tanzania (Malebo 2005) reported that the most common practices were: boiling, chlorination, filtration using cloth, and no treatment at all. Surprisingly, given the high risk of water borne diarrhoea and other diseases in Tanzania, about 60% of all households interviewed did not treat their drinking water at all. Urban households were twice as likely to treat their household water as rural households, perhaps reflecting the higher risks of contaminated water in the urban environment. This evidence from a limited survey at four locations does suggest that programmes to raise public awareness and educate householders in the benefits of water treatment and safe storage at home should be a high priority, especially in rural areas.

7. Consultative processes using institutional frameworks set up under international treaties need to start before some other treaty objectives can be realised. For instance the SADC Protocol requires the setting of joint water quality objectives and listing of substances which should be: prohibited, limited, investigated or monitored in shared watercourses.
8. The Basin Water Boards provide the institutional capacity for water quality management and this role is especially important as the mechanism for meeting Tanzania treaty obligations to manage its transboundary and international water resources. BWB in basins with transboundary responsibility will need additional support and training to fulfil their transboundary roles.
9. All monitoring networks operating under GOT sponsored programs (but especially in transboundary basins) need better quality assurance to give credibility to the results and need improved data management processes to ensure information exchange is timely and efficient.

**Institutional reforms**

The legal and policy framework for water quality management in Tanzania is very new; institutions are still struggling to adapt to the recent changes and to implement new water resource management processes. A regional rather than a basin operating model still persists in some places and the legal and operational pre-eminence of the Basin Water Boards in water resources management, is not yet fully recognised or accepted by all institutional actors.

10. The MOWI needs to continue institutional restructuring to meet the requirements of the WRMA 2009. Part of that process should be to train all MoWI staff (starting with those in the Basin Water Offices) in the goals and objectives of IWRM.
11. The Office of the Director of Water Resources must ensure functional collaboration within the office and with the Basin Water Boards. Moreover, the BWBs must establish effective operational links with other government agencies, WSSA, and local authorities, to co-ordinate water quality management.
12. The MoWI should consider taking charge of all aspects of water resources management, through delegation from the NEMC[41] to give BWB personnel enforcement powers and the ability to obtain information necessary for water quality management and to influence management actions.
13. The polluter pays principle must be fully implemented by setting fees, charges, penalties and remedial orders that match the real cost of management or restoration of water resources and water quality. This requires regular review of the penalties under the EMA and the WRMA Acts and regulations.

**Minister responsible for water**

Coordinating divisional operations within MoWI to adopt the IWRM model[42] and helping the BWO as front line managers of water resources by providing suitable technical, administrative and legal support.The Minister for Water and Irrigation recognised in 2008 that "we need to improve co-ordination and full participation internally between the Nation's cross-sectoral interests in the Water Sector"[43].

[41] Section 26 of the EMA allows for delegation of the exercise of any of the powers or performance of any of the duties or functions of the NEMC. This would enable Basin Water Boards to exercise powerslike the issue of restoration orders (Section 151 of the EMA). The designation of Basin Water Board personnel as inspectors under section 182 (2) of the EMA.

[42] The Irrigation Division of the MoWI is using a regional operational framework rather than the basin model which is fundamental to the IWRM philosophy and in use everywhere else in the Ministry.

[43] Minister Mwandosya as quoted in the preface to the National Water Sector Development Strategy in September 2008

This quote identifies an ongoing problem of government agencies to identify mutual interests in water resource management and develop inter-sectoral collaborations to effectively address water quality issues like contamination of potable water sources.

Recommended activities to support the MoWI would be:

14. A formal institutional structure at the ministerial level (Ministerial Council) with responsibilities to: improve co-ordination and co-operation amongst cross-sectoral interests in the Water Sector; to provide a peak forum for consultation on items like development of water industry policy at international, national and basin levels; to drive the development of national standards; and to implement approaches to wastewater and effluent disposal.

**Recommendations on the MoWI Institutional structure**

15. A clearly defined and well distributed organisational chart is essential tool for explaining these changes and should be prepared and distributed widely both within and outside the institution as a matter of urgency.
16. MoWI needs to clearly define a mechanism for all Divisions to collaborate in supporting the BWO in collecting, managing, interpreting and reporting water resource data, which is an important input to resource management decisions.
17. develop water quality data management system for use at the basin level which could be used to integrate data at the national level
18. encourage BWO and to develop service agreements with the WLS
19. support the human resource needs at the operational level of water quality management by directing educational institutions to provide training in the fields of natural resource management specifically for improved water quality monitoring/ management.

**Community**

20. The formal involvement of communities in the water quality management of each Basin is still being implemented in Tanzania. It will be being facilitated by adding community representatives to each Basin Water Board. The MoWI needs to ensure that the community representation is participatory and adequately representative.

# 10 WATER QUALITY MONITORING

Monitoring is the systematic collection of physical, chemical and biological data. It is another key component of a water quality management program.Basin managers monitor to find out whether water quality is suitable for beneficial uses, to identify problems, determine the effectiveness of regulatory programs, evaluate long-term trends in environmental quality, and direct their management decisions.

Water quality data can be collected as a continuous time series at key sites within the basin, or as periodic surveys of river system profiles. Both methods have advantages and disadvantages and tend to be complementary. Neither has been adequately used in Tanzania.

The primary data on water quality in Tanzania is from detailed periodic surveys of particular water bodies conducted by specialist scientific programmes or donor sponsored projects (e.g. Pangani Basin or Great Lakes projects like LVEMP). Some of these have been sustained to produce time series at key sites within the basin (e.g. Pangani Basin). However, in most other cases, monitoring has been sporadic. Moreover, whilst reports of the larger studies can be found in the public domain, the actual water quality data is usually difficult to access (like the MoWI own data).

Wastewater management in particular, depends on strong monitoring and reporting arrangements. Stakeholders should share these responsibilities with the BWB which will coordinate at the basin level. Liaison with other government agencies will of course be critical in facilitating an effective national approach.

## 10.1 Historical overview

In the past, the Water Laboratory Services Division (WLS) of MoWI conducted a national water quality monitoring program. That programme became dysfunctional for the following reasons:

**Lack of clear objectives and defined users for the data**–Although WLS monitored for water pollution, the Division had no responsibility for water quality management and no enforcement powers. Therefore there were no legal or management drivers to utilise these data. The lack of real users for the data also produced other limitations like: failure to accommodate new pollution hazards in the network (e.g. sediment, mercury and other mine waste); no regular technical reviews; and no pressures to improve efficiency and cost-effectiveness.

**Poor data management:** The national water quality data program also suffered from poor data management.There was noaggregation of water quality data in a single location. A major component of the WLS workload is the analysis of water quality from new boreholes and potential irrigation schemes. Although this information does have defined users, the absence of an effective data management system has made these useful data inaccessible to all other stakeholders[44].

**Inconsistent financial support:**The WLS Laboratories capital equipment for water quality analysis were usually bought and maintained by donor support. This system is unsustainable as analyses can no longer be done when projects are completed and donors withdraw.As no budget was specifically assigned to water quality monitoring, shortfalls in the Divisional operating budgets were usually met by reducing the scope of monitoring programmes.

## 10.2 Capacity to undertake water quality monitoring

Tanzania's capacity for water quality monitoring has been long established through the public sector MoWI/WSL network. Although that capacity has been weakened by funding neglect and lack of focus it is being rebuilt by a major upgrade of infrastructure and equipment. At this stage:

[44] Mato (2002) describes the difficulties in accessing these data for arguably the most strategically valuable bore field in Tanzania that supplying the Dar es Salaam.

- the analytical capacity to measure the important water quality hazards in Tanzania exists in the main analytical service provider WLS, which is being strengthened by acquisition of new instruments in 2010.
- the WLS network is supplemented by other niche suppliers (e.g. Tropical Pesticide Research Institute, Government Chemist, and commercial laboratories like SEAMIC),which can provide most specialised chemical analyses that are needed (e.g. biocides, mercury);
- the capacity for integrative monitoring methods like bio-assessment in Tanzaniais weak and should be developed through support to national institutions to train the staff and develop the technical base;
- the quality assurance processes in the WLS laboratory network needs to be improved.
- the operational efficiency of the WLS network is poor and the laboratories are understaffed.

The WLS can improve these deficiencies, but the challenge will be whether the public sector service delivery model can improve sufficiently in the quality and efficiency of its service,to compete with private sector service providers entering the Tanzania market as the opportunities expand.

## 10.3 Current situation

The legal and institutional changes that have occurred in Tanzania have created new and well defined users for water quality information (BWO, potable water providers like WSSA, and private industry). These institutions are designing and implementing their own water quality monitoring networks to gather information that is relevant to their needs.

The BWOs are reviving the national water quality monitoring programme at the basin level by establishing or expanding existing effluent and receiving water quality monitoring networks. This has happened both with and without the advice of the MoWI monitoring division, the WLS. The status of basin water quality monitoring extends from long term, well established programmes (e.g. Lake Victoria and Pangani Basins), through newand developing programmes (e.g. Rovuma Basin), to basins where routine water quality monitoring is not yet occurring (e.g. L Tanganyika Basin). The level of water quality monitoring currently occurring in each basin is summarised in Table 10. The commitment and level of detail is quite variable between basins, and the challenge is to consolidate and standardise these efforts throughout the country so that all water resources are adequately monitored.

**Table 10. Current monitoring (2010) by BWO and others in each basin**

| Basin | Effl. Disch. | DW | Aq. Ecol. | Trans-B | Site (/y) | Start | comment |
|---|---|---|---|---|---|---|---|
| **Wami Ruvu** | Y | N | Y | N | 29 | 2006 | Freq = x4/y. Provider procured by open tender in 2010. Data storage in spread sheet |
| **IDB** | Y | Y | Y | N | 13 | 2010 | Monitoring for all uses, incl. mining waste. Aquatic ecosystem e.g. Lesser Flamingo in L Manyara. Monitoring network freq. = x4/ year. |
| **Tanga-nyika** | Y | Y | Y | Y | 14 (P) | 2010(P) | network **proposed** by BWO;<br>A trans boundary network proposed |
| **Victoria** | Y | Y | Y | Y | 1200 | 1990s | Aquatic ecosystem >10 yrs.<br>Other commercial = Fish processors |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Rufiji** | Y | Y | Y* | N | 130 | 1993 | 28 stations, 10 effl. disch. 18 receiving water, *ad hoc from 1993 |
| **Pangani** | Y | Y | Y | Y | 52 | 1990's | Well established |
| **Nyasa** | N | N | N | N | | nil | No network |
| **Rukwa** | N | N | N | N | | 2010(P) | BWO network is in plan stage |
| **Ruvuma** | N | Y | Y | N | 360 | 2009 | BWO = 20 sites x4/y; MTWASA 30 site monthly |

(P)- proposed and not yet activated

### 10.3.1 Deficiencies in the MoWI/WLS monitoring network

Apart from variations in the scope and the duration of water quality monitoring between basins, there are some limitations which are common to all the current BWO/WSAA monitoring designs, for example:
Frequency of monitoring of the microbiological quality of drinking water sources do not comply with national standards in many areas;

Timing of monitoring to assess the impacts of urban and agricultural waste is often appropriately to match production and hydrological cycles;

Scope of monitoring is limited to well known human health issues (e.g. faecal contamination and fluoride). Contaminants from emerging industries like artisanal and large scale mining have only received limited attention (e.g. mercury and arsenic contamination now being included in BWO monitoring programmes (e.g. Lake Victoria, Rovuma to establish existing levels).

## 10.4 Challenges to water qualitymonitoring services

The challenges to improve the standard of water quality monitoring in Tanzaniaare of two types. Firstly the BWO need to clarify the operational framework for their monitoring service providers by:

- establishing water quality objectives which define the scope of water quality monitoring programs;
- committing financial resources to multi-year monitoring programs, to give the service providers incentive to develop and improve services;
- collaborating with other stakeholders to focus develop programmes to monitor issues of mutual concern (this will make monitoring more efficient, prevent duplication, and consolidate the users of the data).

Secondly, water quality monitoring agencies/providers are challenged to:

- improve the scientific rigour of the monitoring network designs;
- provide information that is relevant for specific water quality objectives (e.g. remove irrelevant tests like total coliforms, major ions, etc.)
- improve the validation of results and develop better quality assurance systems
- givestakeholders more confidence in the reliability of monitoring results[45].
- develop more reliable and accessible data management systems
- make services more cost effective

[45] Comment from Health Department officials on why they would hesitate to use MoWI laboratory to measure microbiological water quality in supplies which MoWI manages

### 10.4.1 Sources of funds

There are two key issuesat the heart of sustaining and developing the capacity for water quality monitoring in Tanzania. Firstly, the commitment and financial capacity of the BWO (and other semi government authorities like WSAA) to invest in adequate levels of water quality monitoring; and secondly, the policy decision over whether the work is undertaken by the private or public sector laboratories.

The cost of some components of water resource monitoring programs can and should be passed directly on to users (e.g. WSAA should contribute to the cost of monitoring potable water sources and point source dischargers should pay for the cost of monitoring both the effluent and the receiving waters upstream and downstream of discharge points).

However, ambient water quality monitoring is in the national interest and funding will be dependent on the GoT rather than stakeholders. Therefore the GoT should provide guaranteed funding for some level of long term ambient water quality monitoring.

In delivering aGoT sponsored monitoring programme, the BWO must demonstrate that the water quality information is useful (i.e. for national planning, policy development, investment targeting, or regulatory purposes), or they will be unlikely to receive the political and institutional support needed when national budgets are stressed. Therefore managers of water quality monitoring programmes in the BWO need to be educated about the types of information they shouldobtain from water quality monitoring programmes. They also need to learn how to challenge service providers to design monitoring programmes that are more timely, relevant and effective. One way to start this process is to ask questions like:

Why monitor at that location using those parameters?

How can I use that data for management?

Can this monitoring be done more cheaply or more effectively in a different way?

### 10.4.2 Private versus public sector service providers

The policy issue, whether the BWO can select any laboratory to do the work, or whether the GoT will direct the funding of monitoring to the Public sector laboratories is still being resolved. The GoT may retain its commitment to the public sector as the principal provider of monitoring services or it may allow the BWO to outsource these services to private laboratories. There are advantages and disadvantages in both service models.  At present the WLS is being reinvigorated by a significant capital injection. However there will be significant challenges for the WLS in future, namely:

- staffing levels especially in the smaller laboratories are inadequate;
- the timing and the adequacy of GoT funding has been unreliable in the past and there are not guarantees this will change (of course this would also affect the capacity for developing private sector water quality monitoring capability too);
- retention of income from sales is weak;
- clients will requireimproved standards of efficiency and quality of performance;
- private sector competition;

Traditionally the private sector is more adaptable to client needs and quicker to respond to market challenges. The public sector monitoring network managed by WLS has a competitive advantage in its established human and material infrastructure.

## 10.5 A phased approach to improved water resource monitoring

The existing limitations to effective water quality monitoring in Tanzania, require a phased approach with an initial focus on monitoring to protect the beneficial uses at greatest risk. Thehuman use of water is a priority in Tanzania and the greatest hazard, in terms of the size of the population at risk, is faecal contamination of potable water sources (Table 4). Therefore monitoring for this hazard in potable sources as the highest priority is recommended as the first step in a phased approach to monitoring the quality of water resources in Tanzania.

### 10.5.1 Principles for improved bacteriological monitoring of potable sources

The MoWI and BWO should initiate a national plan to improve the safety of the potable water sourcesin collaboration with other key stakeholders like the WSSA and the Ministry of Health.The routine water quality monitoring of potable sources should be implemented in every basin, with delivery via the MoWI laboratory network[46]. Much of the analytical capacity is already in place, although upgrading of skills equipment and quality assurance is necessary.

The GoT (through the Ministries of Water and Health) should subsidise the routine monitoring of community water points to afford every consumer the security of an ongoing supply of 'safe' water. At the level of the urban water authorities, the MoWI should adopt a commercial approach and negotiate long term service contracts for water quality monitoring, based on sampling frequencies mandated by the Tanzania DWS. This has already occurred in many basins but needs to be extended into a full national coverage.

The costs to the BWO should be minimised by training the community water point managers in correct sampling procedures and by optimising the sample transport and delivery network for speedy return to the laboratory.

Sampling and analysis should be coupled to a web based data management package to support rapid data entry and compliance reporting and to provide graphic display of results. Ideally the human health related water quality characteristics of each water source should be matched and co-ordinated with other water resource information managed by MoWI like licensing and discharge quantity.

Thesewater quality monitoring results are a performance measure and all data from this subsidised service should be accessible to consumers through a periodic review. The opportunity for public scrutiny also pressures administrators, resource managers and service providers to maintain and improve their standards.

### 10.5.2 Water quality monitoring designsfor potable sources

#### 10.5.2.1 Monitoring frequency to detect faecal contamination

The frequency of monitoring of raw water sources for potable supply is spelled out very clearly in the Tanzania standards and is reproduced in Table 11 below:

[46] Monitoring of other human health related parameters (e.g. fluoride and arsenic) is recommended in geographic areas where risk is highest. However, the monitoring frequency should be much lower than for bacteriology as it is not mandated in law and the human health risks from these elements are much lower.

**Table 11. Monitoring regulations for bacteriological testing in potable water sources**

| Type of Source/Population served | Up to 1,000 | Up to 2,000 | Up to 5,000 |
|---|---|---|---|
| **Borehole deeper than 8m** | **6 months** | **4 months** | **3 months** |
| **Well less than 8m.** | **2 months** | **1 month** | **1 month** |
| **Surface water, lakes, rivers, springs, dams** | **1 month** | **2 weeks** | **2 weeks** |

Source: Table 4 in TanzaniaS 789:2003 - Drinking (potable) water -Specification (TBS 2007)

#### 10.5.2.2 Selecting appropriate indicators

**Total coliform test is a poor indicator of health risk**

The Tanzania DWS uses both total coliforms and thermotolerant (or faecal) coliforms/ *E. coli* to estimate the risk to the public health in non-chlorinated piped potable waters (Table 12). However, this use of total coliforms is inappropriate as the total coliform group have clearly described failings as indicators of health risk from bacterial pathogens (Ashbolt, Grabow et al. 2001); WHO (2004).

The water industry uses total coliform concentration measurements to assess efficiency of removal and disinfection processes in treatment and distribution systems, not as an indicator of the chance of faecal contamination. The Tanzania DWS misrepresent the usefulness of the total coliform test as an indicator of the safety of water for public health by assigning values from 'excellent to unsatisfactory' to total coliform concentrations in non-chlorinated piped water supplies (Table 12). This misrepresentation leads to error in assignment of risk and the standards need to be reviewed Meanwhile the WLS should avoid using this test except where it is appropriate for assessing the disinfection process efficiency.

**Table 12. Classes of potable water based on microbial contamination in Tanzania**

| Class of piped Water/Type of test count | Coliform count per 100 ml at 37°C | E. Coli (faecal coliform) count per 100 ml at 44°C |
|---|---|---|
| Excellent | 0 | 0 |
| Satisfactory | 1 - 3 | 0 |
| Suspicious | 4 -10 | 0 |
| Unsatisfactory | More than 1 0 | 1 or more |

From Tanzania DWS p25.Section 5.4.2.Microbiological classification of non-chlorinated piped water supplies.

***E. coli* and thermotolerant (or faecal) coliforms**

There is no single microbiological test that is 100% definitive for faecal contamination. The faecal coliform test is a 'misnomer' as it also detects bacteria of 'non faecal' origin (Ashbolt, Grabow et al. 2001) and physicians and public health officials have repeatedly misinterpreted results of the faecal coliform assay when applied to food, beverage, or water samples (Doyle and Erickson 2006). The Australian Drinking Water Guidelines (NHMRC 2002) and the WHO Drinking Water Quality Guidelines (WHO, 2004) have both replaced the term 'faecal' coliform with 'thermotolerant' coliform to indicate the non faecal specificity of the test.

The *E. coli* test is recommended as a superior (although not absolute), indicator of faecal contamination by WHO (2004)[47]. An *E. coli* test is likely to give around 5% fewer false positives than a thermotolerant coliform test because it excludes *Klebsiella,* which is the most common microbe of non-faecal origin detected by the thermotolerant coliform test.

#### 10.5.2.3 Analytical methods to determine the risk of faecal contamination

Methods in common use elsewhere for determining thermotolerant and *E. coli* coliforms in natural waters are two step membrane filtration or proprietary tests (Colilert) with colour labelled reagents to simplify identification.

Membrane filtration - thermotolerant coliforms with a second incubation step for *E. coli* by growth in a confirmation broth that incorporates a chromogenic molecule;

Colilert™ a test kit for total coliform and *E. coli* which gives a Most Probable Number (MPN) result. The kit contains growth media and chromogenic molecules, which are added to the sample and incubated in a 48 or 96 well plastic trays. The colour of the test identifies presence of both total coliform (yellow) and *E. coli* (blue under UV) and the MPN value is estimated from the number of wells that react. This test is simple and easy, uses relatively basic equipment but the cost of the reagentsmay be a limiting factor in Tanzania.

## 10.6 Recommendations to improve the BWO monitoring networks

21. Licensed dischargers should be required to monitor their own effluents and contribute financially to the cost of ambient monitoring of receiving waters up and downstream of their discharges.
22. Monitoring should focus on the indicators of hazards to beneficial use. The WHO 2004 Drinking Water Guidelines are recommended as a model for assessing safety of potable water sources (not the TanzaniaNational Drinking Water Standard).
23. All WLS laboratories should be equipped to monitor for the important water quality hazards identified in this strategy, either in house (locally) or by transferring samples through the WLS network (e.g. all labs should be equipped to monitor in house or in the field for indicators of catchment land degradation like suspended sediment concentration and transparency).
24. The existing BWO monitoring program designs should be reviewed by an ‘expert panel’with focus on improving the scientific rigor and the cost effectiveness. Some elements for review are listed below:

**Site selection:** Locations of monitoring sites should be based on risk to the designated beneficial use. The site selection will require the following information:

1) the type of hazard and the location where the concentrations are likely to be highest

2) the designated beneficial uses that would be affected

3) the location of some unimpacted sites to represent the baseline condition.

A final consideration in locating any water quality monitoring station is the availability of hydrological data of river flow or lake level, as the value of water quality data will usually be enhanced if it can be related to reliable stream flow records.

[47]Even environmental strains of *E. coli*can occur in high numbers in natural waters, with reports from public water supply reservoirs in Sydney and Canberra, Australia (Dr Peter Cox, Sydney Water Corp. pers. comm. 2010). Environmental strains of E. coli may be distinguished from other thermotolerant forms grown on agar plates, by presence of a mucoid capsule which makes the colonies appear watery, slimy, shiny with less well defined edges.

**Sampling time**

The periods of greatest risk must be established beforehand by researching the process producing the water quality hazards. Sampling should then be planned to coincide with these high risk periods. These may be seasonal (e.g. wet season overflows of tailing dams), or associated with industrial production cycles.

**Selection of more relevant indicators**

The choice of indicator to be monitored is very important in maximising the reliability and accuracy of the information, whilst minimising the cost. In cases like monitoring the distribution of mercury from artisanal gold mining or contamination of fish flesh by biocides, the toxicant itself must be measured. In other cases, a surrogate indicator which is easier and cheaper to measure can be used. In these situations the surrogate must be:

- an innate characteristic of the contaminant;
- conservative (does not change or changes slowly in the environment);
- easy to distinguish against the baseline water quality; and
- easy and cheap to measure.

Examples of surrogate indicators are electrical conductivity or characteristic ions for detecting ground or surface water contamination from mining tailings or *E. coli* or thermotolerant coliforms for detecting faecal contamination of water sources.

**Improved Quality Assurance and Quality Control (**QAQC)

**QAQC** is an essential element of any water quality monitoring program. The essential QAQC elements are:

- Reporting of the precision of the analytical method (by analysing replicate samples);
- Reporting of contamination in sampling preparation (by analysing blank samples prepared under field sampling conditions);
- Reporting of accuracy of the analysis (by addition of standard spikes and by regular inter lab calibration exercises); and
- Determination of baseline levels (by including control sites in the monitoring design).

**To improve cost effectiveness of monitoring**

The GoT or donors should apply the following investment criteria before funding any public sector laboratories in Tanzania. The laboratory should demonstrate that:

- the operational cost of the new/increased service can be recovered (e.g. by direct charge or by subsidy);
- the investment will not duplicate analytical services that are already available in Tanzania from other public sector labs at commercially acceptable terms of cost and quality.
- the return on the investment in cash or in strategic advantage to Tanzania will be sustainable.

**Better monitoring for risk of faecal contamination**

25. As a minimum, each lab in the WLS network should be equipped with the infrastructure (e.g. sterile isolation area) and equipment (incubator and autoclave) to measure microbiological indicators of faecal contamination in waterOR have the capacity to send samples to a lab with that capability, within sufficient time that sample integrity is not compromised.

26. Testing for faecal contamination of drinking water sources should continue to use the well-established thermotolerant coliform test. However, all labs should also develop the capability to conduct a confirmative test for *E. coli* (e.g. sub-culturing into lauryl sulphate broth tubes or performing the indole and oxidase tests).

27. The priority for monitoring to protect public health should be based on risk, not ability to pay. Therefore the highest priority will be to monitor water sources that supply the largest human populations AND sources in areas with a prior history of water borne disease outbreaks (e.g. cholera).
28. The WSSA managing potable supplies in urban areas are also responsible for monitoring water quality. The BWO and the MoHSW should collaborate with the WSSA to ensure that monitoring is compliant with best practice standards.

## 10.7 Water quality data management

Scientific data is the basis for understanding and knowledge. Water quality data provides a basis for informed and scientifically based management decisions. In the 21st century, powerful systems for collecting organising and displaying data are available, to help convert it into understanding and knowledge.

In the past the agencies undertaking water quality monitoring in Tanzania have neglected their role as ultimate custodians of water resource data. Numerous reviewers ((URT 1995); (Mato 2002); (Sugden 2003) have noted that water quality data records are stored (as flat files) by individuals or sections within the bureaucracy, rendering these data almost useless. These actions make assessment and review, the last and most important component of the water quality management cycle almost impossible.

A recent survey by the WaterAid NGO (Sugden 2003) identified eight different water sector data bases[48], NOT including those managed by the MoWI. The proliferation of databases is a signal that there is a real need for this facility in Tanzania. In future the MoWI through the WRD and WLS should take a lead in initiating development of a data base that can store, manage and report water quality data.

Water quality data must also be transformed into information that is accessible and suited to the needs of water resource managers, stakeholders at the basin level, and other actors at the national and international level, or the entire water quality monitoring process becomes awaste of time, money and valuable human resources.

### 10.7.1 Data management operations within the MoWI

Historically, data management was fragmented and records were inaccessible. Now the BWO are more active in water resource data collection, but where will the data go? Tanzania urgently needs to develop a modernunified data management system to use across the country. The MoWI (Information Communications and Technology Unit) should coordinate these activities. The aim should be to integrate water quality data from a number of sources including the BWO and make the government sponsored data collections accessible to all stakeholders. The data management systems should also include information tools to simplify data analysis interpretation and reporting. The monitoring laboratories will have an important role in preparing data in standardised electronic reporting format for efficient and accurate uploading to data management systems.

[48] Local Government Monitoring and Evaluation System; The Tanzania Socio-Economic Database (TSED), District Water and Sanitation Database (DWSDB), National water supply and sanitation database (WSSD), Rural Water Supply Database (RWSDB), Urban Water and Sewerage Database (UWSSD), Central Water Board Database (CWBDB) and River Basin Management Project Database (RBMDB).

## 10.8 Recommendations for improved data management

29. The MoWI Information Communications and Technology Unit have mandate for establishing and maintaining database hardware and software in the MoWI. Other Divisions should respect this mandate and actively collaborate with the ICT Unit to develop mechanisms to consolidate water quality data in a central system but also make it accessible to users across the BWO network.

30. The proposal for a web based data collection and display project led by the ICT Unit (Water Point Mapping Project) should be developed as a model project to demonstrate capability and encourage intersectional collaboration in data collection, storage and display.

## 11 ENFORCEMENT

Whether regulatory, economic, or public education instruments are used to control pollution, an enforcement program is vital for maintaining compliance. The Minister responsible for the environment has power to appoint employees of the NEMC as "environmental inspectors" and can also designate employees of other agencies as environmental inspectors, for purposes of compliance and enforcement[49]. The powers of environmental inspectors enable themto:

- stop any vehicle or vessel believed to be discharging or has discharged a contaminant in contravention of the EMA;
- seize any such vehicle or vessel;
- take samples;
- order removal of any waste deposited in contravention of the EMA.

More importantly the NEMC can delegate the exercise of any of the powers or performance of the duties or functions of the NEMC to any sector Ministry[50]. This provides opportunities for fulfilment of institutional mandates within collaborative frameworks and solves problems of jurisdictional overlaps and competition between institutions, in addition to lessening fragmentation of power for the execution of some functions.

### 11.1 Empowering Basin Water Boards to enforce water quality standards

Although the EMA provides an institutional framework for enforcement of its provisions, in general, enforcement of any requirement for environmental management of water resources lies in the first instance with the MoWI (with the support of the EMA as required). The WRMA is the legislation supporting the MoWI and the BWB as water resource managers.

The responsibilities of BWB for enforcing Water Quality Standards are not explicit in the Water Quality Standards, Regulations (WQSR, 2007)[51].Part V of the WQSR, which deals with compliance and enforcement, authorises the NEMC[52] or environmental management officers from local authorities to issue compliance orders to any persons in breach of any conditions of a permit or of the WQSR. The NEMC is also authorised to take and analyse samples.

Neither the EMA, 2004nor the WQSR, 2007mention Basin Water Boards in connection with collection of samples or issuance of compliance orders. However, WRMA, 2009does confer these powers on Basin Water Boards[53] and also requires them to monitor for compliance with the conditions of discharge permits.

Under section 151 of the EMA, the NEMC has power to issue environmental restoration orders which are an important tool in water resources management especially in instances of water pollution. Basin Water Boards do not have this power under the WRMA and have to approach the NEMC to issue a restoration order where needed. It would be a natural devolution of this responsibility to Basin Water Boards, even by delegation in terms of section 26, which would improve their capacity for water quality management without relying on the NEMC.

### 11.2 Incentives and penalties for pollution control

The maximum fines chargeable for polluting activities provided for in the EMA and WRMA are likely inadequate in themselves, and must be combined with other existing penalties like custodial

[49]under section 182 (1) of the EMA
[50]Section 26 of the EMA
[51]WQSR see Environmental Management (Water Quality Standards) Regulations, 2007
[52]Under section 198 of the EMA, 2004 or and Part V of the WQSR, 2007
[53] Section 76 of the WRMA, 2009

sentences; Permit revocation; Stop Orders; payments for restoration and compensation to third parties; to maximize the deterrent to pollute and to fully implement the 'polluter pays' principle. Used flexibly and together ,these instruments should be adequate to recover the cost of polluting activities and deter this behaviour.

Analyses elsewhere have ranked Government regulation as the community's least preferred option for pollution control. Better management practices are more likely to be adopted if the public interest can be closely aligned with private benefit.Therefore pollution control options that offer incentives including economic motivations are usually more effective than regulation.

The EMA allows for regulations that introduce economic instruments as incentives. However, none have yet been developed. Before this is done, Tanzania should take advantage of lessons learnt elsewhere and commission a socio-economic study to determine the mix of incentives for managing water quality that is most likely to be effective in the different basins and different social and geographic situations in the country. The blind provision of incentives across the board, without proper consideration of local situations is highly unlikely to produce the desired results.

Education of communities is a powerful tool in Tanzania for changing polluting behaviours because of the lack of awareness and understanding about these issues. For example, public education programs to explain the risks to human health from faecal contamination of water sources and the benefit of better personal hygiene have resulted in marked reductionsin incidence of diarrhoea disease in those areas where they have been trialled[54].

## 11.3 Recommendations for better enforcement

31. Remedies to improve the water quality regulations include, establishing ambient water quality standards and water quality objectives; improving surveillance monitoring; and prosecuting serial non-compliance with effluent water quality standards.

**Address unresolved issues in the EMA legislation by:**

32. Resolving inconsistencies in penalty for the same offence between different legislations (e.g. EMA and Water Quality Regulations) to avoid complainants "shopping[55]" for the least severe penalty[56].
33. Some penalties are stated as either a fine or imprisonment. Others are stated as either a fine or imprisonment or both. The 'or both' is recommended as imperative in all instances.
34. Because custodial sentences are normally stated as "not exceeding…", the sentencing practices of courts are crucial if sentences are to provide a deterrent. The seriousness with which courts will regard the offences will depend on how frequently prosecutions are brought to court and how well the authorities make their cases. The NEMC, MoWI and BWO need to collaborate in careful preparation of test cases.

**Empower Basin Water Boards**

In practice, it is likely that Basin Water Boards and local authority officers will have primary responsibility for enforcement of compliance with water quality standards. Therefore:

35. the WQS Regulations should be amended to clearly specify the responsibility of the BWB for collection of samples and issuance of compliance orders in their basins;

[54] Malebo, H. (2005). Evaluation of Performance of Participatory Hygiene and Sanitation Transformation Strategy (PHAST) in Tanzania. NIMR Report..

[55] 'shopping' is a practice where defendants challenge the prosecution brought down under one piece of legislation on the basis that the penalty is more severe than for the same offence under a different piece of legislation. This unwanted nuisance should be remedied by making penalties for the same offence consistent across all legislation.

[56] The penalty depends on which Agency brings the action. If it is the BWB, the penalty will be from the WRMA or the Water Quality Regulations. Alternatively, if an action is brought by the NEMC, penalties under the EMA will apply.

36. the NEMC should delegate Inspection and Restoration powers to the BWOs.

**Address unresolved issues in the institutional structure by:**

37. creating awareness among the implementing and enforcement agents, up and down the institutional structure, of their roles and functions in the new water resources management legal framework, to achieve integration in water resources and environmental management as a whole, and water quality management in particular;

38. creating awareness of the centrality of the Basin Water Boards in water resources management and develop standard operating practices for Basin Water Boards to integrate functions and processes, eliminate fragmented operations and territorial practices, and standardise procedures across all basins.

**Reduce public tolerance for point source pollution by:**

39. raising public awareness of the environmental, social and economic costs of pollution and explaining the "polluter pays principle";

40. identifying and prosecuting significant polluters and mobilising public opinion against pollution (and polluters) by publicity in the popular media of the environmental damage (graphic images of degraded water resources in print and television media can heighten public awareness in the same way as campaigns to raise awareness of the health risk from cigarette smoking).

# 12 KEY ELEMENTS OF A MANAGEMENT APPROACH

## 12.1 Point-Source Effluents

Tanzania uses a permit system to control effluent discharges. The Basin Water Offices issue effluent discharge permits and are responsible for monitoring and enforcing permitswithin each basin[57]. The Director, Water Resources (MoWI), is ultimately responsible for enforcement of permits throughoutTanzania[58].

The Effluent Quality Standards for major industries in Tanzaniaare technology-based[59]. These standards should be the minimum conditions for permitted discharges.The BWO must also consider the water quality objectives for a water body in setting discharge permit conditions. Non discharge options should always be considered in preference to discharge to receiving waters. The use of market-based instruments may also be used to encourage waste minimisation.

The BWO should require dischargers to use technology that is consistent with on-going economic viability of the industry (i.e. technology-based guidelines) even where the discharge will not compromise the water quality objectives for the water body. This approach prevents a waterbody becoming rapidly polluted up to the limit, reserves the maximum opportunity for other uses, and is precautionary when the environmental outcomes of development are uncertain.

Where feasible, the BWO should establish the relationship between effluent and ambient water quality by monitoring and/or modelling. However this is not essential for pollution control programswhich are directionally correct. If water quality objectives cannot be met using the effluent standards then stricter source controls (i.e. water-quality-based effluent limits) may be necessary for some point source discharges.

## 12.2 Recommendations for discharge permits

41. The permits should incorporate economic instruments to encourage permit holders to consider more positive pollution control responses;
42. Prosecution of persistent, long term offenders is urgently required to test the new legislation and to raise the awareness of new laws with offenders and the general public.
43. Discharge permits should ideally use load based rather than concentration based criteria (permits can start to impose load conditions on applicants for discharge permits by requiring them to give an estimate of the average volume of effluent discharged (on a daily or monthly basis), then converting this to an annual load limit using the maximum acceptable concentration from the effluent standard, multiplied by the average effluent volume.
44. The discharge permits regulations should require applicants to limit the average volume of effluent discharged (on a daily or monthly basis) to an acceptable fraction (e.g. 5%) of the volume of the natural flow in the receiving water. Note that this will require an estimate if the natural flow rates in the receiving waters.
45. The power to issue restoration orders [60] is held by the NEMC. These should be delegated to the BWB to supplement their enforcement capability.

[57] Section 76 of the WRMA
[58] The Discharge Permit regulations must be formulated by the Minister in terms of section 75 of the WRMA, and the water quality standards prescribed under the EMA
[59] Technology based effluent standards are achievable by accepted, economically viable technologies. They do not specify the technology to be used to achieve them.
[60] (ss. 151-155, EMA, s. 105, WRMA).

46. BWO issued discharge permits and NEMC issued conditions for EIA approval can designate laboratories to be used for water quality monitoring. This power should be used to force laboratories to improve their levels of quality accreditation.

## 12.3 Control of Diffuse Source Pollution

A comprehensive water quality management strategy must also consider the diffuse sources of pollution that can affect beneficial uses. Diffuse sources are more difficult to manage than point sources because they are widely dispersed. The absence of measurable cause-effect relationships between diffuse sources and degraded water qualitymakes it difficult to design incentives to deliver better choices. A systems approach to water quality management in the rural sector and the use of 'Best Management Practice' criteria can help to fully expose the costs of diffuse pollution.

The implementation of 'best practice' uses similar education, regulation, and market-based policies that apply to management of point source pollution. However, changes in land management practice have slower and less predictable effects on receiving water quality than changes in point sources.

Targeted research and development can provide better understanding of the scientific and economic relationships between landuse and water quality, allowing policies and procedures to be refined (See BOX: Trialling erosion control measures in the Simiyu R Basin).

### 12.3.1 Runoff from agricultural lands

Sediment and nutrients are the water quality hazards associated with diffuse pollution from agriculture. These hazards can cause eutrophication (an issue in the lake basins), algal blooms and loss of storage capacity in reservoirs.

The destruction of stream bank vegetation and use of the river banks for growing small crops is a particularly damaging practice, as these riparian corridors are very sensitive to erosion, as well as being effective vegetative barriers against soil transport from fields into streams.Poor farming practices also result in agro-chemical pollution from nutrient and biocide wash off and accumulation in water bodies. Another risk in Tanzania is the ongoing use of biocides for illegal fishing.

All these hazards are by products of human misbehaviours. Although there are regulations against destroying vegetated riparian corridors, more attractive incentives are needed to persuade farmers and herders to change their behaviours.People are more likely to adopt landuse practices to improve water quality when a 'mix' of different types of incentives are offered, which are tailored to meet the local economic, social and environmental conditions.

The main constraints to effective adoption of improved land management practices are:

- lack of labour, time and money to implement the practice;
- lack of conviction about the supposed benefits of the practice ; and
- incompatibility of the practice with people's beliefs, values or lifestyle.

As direct regulatory controls are often impractical or ineffective for controlling pollution from diffuse sources, community education becomes more important and awareness raising activities that involve farmers in catchment management can be more successful in changing behaviour than regulation. Market-based solutions should also have a role in encouraging waste minimisation and pollution control in rural areas.

Some useful measures are:

- limitations on vegetation clearance and encouragement of tree planting;
- soil erosion measures generally;
- use of slow release fertilisers and avoidance of excessive fertilisation;

- more careful use of biocides;
- maintenance of natural stream-bank vegetation;
- control of pollution from intensive agricultural industries.

## 12.4 Groundwater

Groundwater is more important than surface water supply in many areas in Tanzania, where because it safer and cleaner and the supply is more reliable.Groundwater can be contaminated from surface sources but seepage from waste disposal sites and leaking storage vesselsis more difficulttocontrol. Moreover, the clean-up of contaminated groundwater is difficult and costly because of the potentially wide range of toxic substances. Therefore groundwater resources deservespecial attention. The important factors to consider in managing groundwaters include:

- recognition that groundwater quality is only observed at a few locations, so contamination may not be recognized until it is too late to fix.
- the assimilation or breakdown of contaminants may be slower than for surface water.
- groundwater storage may cross surface water catchment boundaries.
- clean up of contamination is more difficult.
- groundwaterrecharge is slower than for surface waters, so the time from contamination to impact could take years, as could clean-up.

# 13 ECONOMIC INCENTIVES FOR ENVIRONMENTAL MANAGEMENT

Until the regulatory framework in Tanzaniais implemented effectively, the use of economic instruments to manage water quality must remain a supplementary tool. Nevertheless,Tanzania should consider experiences elsewhere in the design and implementation of market based instruments and trial these approaches. A few potential methods are:

- pricing of the water resource to reflect the environmental impact of the use and the loss in asset value due to degradation;
- imposing licence fees that recover the full cost of regulation and monitoring;
- applying load related pollution charges;
- trading in effluent permits;
- non-compliance fees, where the charges for exceeding effluent limits reflect the profitobtained by non-compliance;
- performance bonds, where money is held in trust, to be repaid once compliance with the standard is achieved;
- levies and higher rates on users of water and sewerage services;
- subsidies or soft loans and tax allowances to encourage the adoption or development of waste minimisation technology.

Criteria for assessing the suitability of these measures are:environmental effectiveness, economic efficiency, equity, administrative feasibility and cost, and community acceptability. The objective - to provide a dis-incentiveto pollute - should not be not confusedwith revenue-raising

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# 14 SUMMARY AND CONCLUSIONS

## 14.1 Pollution control challenges

- The legal framework for water quality management seems robust, but needs to be tested
- The monitoring capacity is available, but service needs improvement
- Management capacity is developing in the basins, but financial and technical support is needed during this phase, especially through collaboration with other agencies
- The evaluation and review record is poor and this should become a performance measure for BWOs
- Water quality standards are out of date and not relevant –need review
- R&D capacity exists but needs to be focussed on specific problems, under the direction of the BWO.

## 14.2 Improving Institutional relationships

Integrated water resource management is an inclusive approach, first requiring the engagement of all stakeholders and then their cooperation and collaboration to optimise the resource use. The MoWI needs to communicate and collaborate better with other institutional stakeholders who can influence water quality management. This would be facilitated by the establishment of a ministerial level council for agencies operating in the water sector.

At the operational level, there is extensive representation of government agencies on the Basin Water Boards,but little evidence of inter-agency collaboration or joint projects. As stakeholder collaboration is fundamental to successful IWRM and also given that many agencies report their human and financial resources are inadequate, joint projects to share and optimise these scarce resources should be beneficial to all and must be encouraged. The Minister should require the MoWI to make collaboration with other stakeholders a key performance indicator (KPI) for its operations.

The MoWI needs to communicate better with its service providers to clearly identify the services it needs and give them the opportunity to supply those requirements. At the same time, service providers must continually strive to raise their standards and better understand their client's needs.Another important challenge is to improve compliance with the effluent discharge standards by better enforcement of the laws and regulations.

## 14.3 Research and Development needs

Research and Development (R&D) is another fundamental component of operational water quality management. R&D activities can be applied at all stages in the management cycle. However, it must be targeted and directed. There is ample evidence in the literature of missed opportunities for better application of R&D in Tanzania. One example is the large investment over the years in studies of the African great lakes. Despite considerable international research, there is little evidence that well defined and accessible water quality objectives have been produced that catchment managers can use to managethese resources. In part, this is a fault of management in not directing researchers to deliver useful management outcomes.

Another example where more research and development is urgently needed is to develop techniques to either replace the use of mercury by artisanal miners for extracting gold, or to reduce the loss of mercury to the environment (and the human exposure to this toxic metal).

There is a requirement for R&D in monitoring methods to develop the scientific basis for conducting bioassessment in Tanzania waterways.

## 14.4 Technical challenges

The technical challenges are to improve the reliability and effectiveness of the water quality monitoring services by matching the service to client needs; improving monitoring designs; choosing more relevant tests; and improving quality assurance and quality control.

## 14.5 Recommendations to support water quality management in the basins

47. BWO need to ensure that water quality objectives are set;
48. The regulator (TBS/NESC) needs to support water quality management by establishing appropriate national water quality standards;
49. Water quality monitoring service providers need to provide a better standard of service;
50. BWO need to conduct annual or bi-annual reviews of their monitoring programs;
51. MoWI must establish an accessible water quality data base with reporting tools as a necessary support for the review process;
52. MoWI/GoT should require program/project assessment and evaluation as a Key Performance Indicator (KPI) for continued support/funding;
53. BWO need to give stakeholders better incentives to change behaviour and not just rely on regulations, which are difficult to enforce;
54. Other government agencies need to support BWO in water resource management by being involved in management actions and coordinating their responses with the BWO.
55. BWO should direct R&D service providers to develop better methods of diffuse source pollution control

# 15 References


Anstey, N. M., M. Y. Hassanali, et al. (1995). "Elevated levels of methaemoglobin in Tanzanian children with severe and uncomplicated malaria." The Royal Society of Tropical Medicine and Hygiene.

Appleton, J., H. Taylor, et al. (2004). Final Report for Assessment of Environment and Health in the Rwamagasa area, Tanzania. UNIDO Project EG/GLO/01/G34**:** 306.

Ashbolt, N. J., W. O. K. Grabow, et al. (2001). Indicators of microbial water quality. Water Quality: Guidelines, Standards and Health. L. Fewtrell and J. Bartram. London, UK, IWA Publishing**:** 289-316.

Ayers, R. and D. Westcot (1994). "Water quality for agriculture." FAO Irrigation And Drainage Paper**29 Rev. 1**.

Bailey, K., J. Chilton, et al., Eds. (2006). Fluoride in Drinking-water.

Doyle, M. P. and M. C. Erickson (2006). "Closing the Door on the Fecal Coliform Assay." Microbe**1**(4): 162-163.

Hecky, R. E. (1993). "The eutrophication of Lake Victoria." Verhandlungen Internationale Vereinigung Limnologie**25**: 39-48.

Kassenga, G. and R. Mato (2008). "Arsenic contamination levels in drinking water sources in mining areas in Lake Victoria Basin, Tanzania, and its removal using stabilized ferralsols." International Journal of Biological and Chemical Sciences **2**: 389-400.

Kaufmann, L. (1992). "Catastrophic change in species-rich freshwater ecosystems: the lessons of Lake Victoria." Bio Science**42**: 846-858.

Kolding, J., P. Zwieten Van, et al. (2008). Are the Lake Victoria fisheries threatened by exploitation or eutrophication? The Ecosystem Approach to Fisheries. G. Bianchi and H. R. Skjoldal, CAB International, London**:** 309-354.

Malebo, H. (2005). Evaluation of Performance of Participatory Hygiene and Sanitation Transformation Strategy (PHAST) in Tanzania. NIMR Report.

Mato, R. R. (2002). Groundwater Pollution in Urban Dar es Salaam, Tanzania: assessing Vulnerability and Protection Priorities Eindhoven, Technische Universiteit Eindhoven.

MRC (2008). An assessment of water quality in the Lower Mekong Basin, Mekong River Commission.

Mugidde, R. (2001). Changes in phytoplankton primary productivity and biomass in Lake Victoria (Uganda), University of Waterloo, Canada. **PhD Thesis:** 196.

NHMRC (2002). Australian Drinking Water Guidelines, National Health and Medical Research Council.

Nkotagu, H. (1996). "Origin of High Nitrate in Groundwater in Tanzania. ." J. Afri. Earth. Sci. **21**(4): 471-478.

Pangani BWO (2009). Water Quality And Pollution Control Summary, Pangani Basin Water Office**:** 35.

SMEC (2010). Final Report. Consultancy Services For Preparing The Water Quality Management And Pollution Control Strategy In Tanzania Dar es Salaam, The United Republic of Tanzania, Ministry of Water and Irrigation, Water Sector Development Programme.

Sugden, S. (2003). Databases for the water sector: research from Nepal and Tanzania Water and Poverty Dialogue Initiative at the 3rd World Water Forum, Japan, Water Aid.

Sukhdev, P. (2010). The economics of ecosystems and bio diversity, Interim Report.

Taylor, H., J. Appleton, et al. (2005). "Environmental assessment of mercury contamination from the Rwamagasa artisanal gold mining centre, Geita District, Tanzania. ." Science of the Total Environment **343**: 111-133.

TBS (2007). National Environmental Standards Compendium. T. B. O. Standards.

Unknown (2010). A clinical perspective of geomedical hazards caused by toxic contaminants in mining areas Mwanza Mining and Environment Conference (Draft only), Mwanza, Tanzania, NEMC.

URT (1995). Rapid Water Resources Assessment for Tanzania, United Republic Of Tanzania, World Bank & Danida. **Part I**.

URT (2007). The Environmental Management (Water Quality Standards) Regulations 2007, Government Notice 239, Supplement No 42, 7th December 2007, Government of Tanzania Printer. **88:** 74-105.

Verschuren, D., T. C. Johnson, et al. (2002). "The chronology of human impact on Lake Victoria, East Africa." Proceedings of the Royal Society. Series B. Biological Sciences **269**: 289-294.

WHO (2003). Guidelines for safe recreational water environments. Volume 1: coastal and fresh waters, World Health Organization.

WHO (2004). Guidelines for Drinking-water Quality. 3rd Edition, World Health Organization.

## APPENDIX 1 : Tasks and responsibilities for implementing the national water quality management strategy

| Task | Definition | Responsible Agency | Capability to Deliver |
|---|---|---|---|
| Collect water quality information | Background or baseline water quality measurements and/or surveillance monitoring to acquire and develop understanding of the aquatic system | BWB; MoWI (Transboundary Div.) | WLS; Universities |
| Set Water Quality Objectives | a narrative statement or a numerical concentration limit, designed to support and protect beneficial use(s) of a waterbody or aquifer at a specified location | Basin Water Board (BWB) | WRD; WLS; Universities |
| Develop Management Action Plans | Activities to support the achievement or maintenance of water quality objectives | Basin Water Board (BWB) | BWO plus Stakeholders |
| Monitor Condition | Measurements to determine the effectiveness of the management actions | UWRA; MoWI (Community); LGA; BWO; other stake-holders | MoWI (WLS) |
| Assess and Review Performance | Critical analysis of the results of the monitoring program to inform future water quality management activities | BWO | Consultants; MoWI (WRD; WLS) |
| Develop National Standards | Water quality indicators with scientifically determined target values that indicate the potential for a harmful effect on a beneficial use, which are recognised in regulations enforceable by government agencies. | TBS/NESC | NEMC; Consultants; MoWI (WRD; WLS) |
| R&D to improve water quality management | Exploratory or inventive activities requiring high level of technical skill and understanding, where there is a reasonable chance that all outcomes may not be achieved, because of the exploratory nature of the tasks | MoWI (R&D), BWB, Stakeholders | Universities; Consultants; MoWI (WRD; WLS) |

## APPENDIX 2 : Measures to control and manage the use of mercury by artisanal miners

A number of different methods have been implemented in Tanzania, in attempts to control and manage the use of mercury in mining and limit its impact on the aquatic environment. The effectiveness of each of these measures and the limitations are listed below.

| Control measures | Effectiveness | Limitations | Recommendations for improvement |
|---|---|---|---|
| Artisanal miners licensed under Mining Act | Artisanal mining no longer illegal; to regulate activity and promote compliance | Policing is difficult in remote areas, miners not interested in complying with all conditions | Moderate some requirements - e.g. abandon royalty levy as Au production will be understated |
| Prohibition on clearing of riparian vegetation from stream bank | Effective to limit overland flow but not if mine waste is routed into streams | Policing is difficult in remote areas | Raise awareness of risk to water supply<br>Better enforcement. |
| Mining Reg. requires a buffer zone around amalgamation sites near river or wetland areas | Effective for promoting natural filtration | Enforcement difficult, miners will not voluntarily incur extra labour cost | Raise awareness of risk to water supply<br>Better enforcement. |
| Mining Reg. requires cement lined pond or plastic/metal amalgamation barrels to mix mercury with alluvial concentrate | Limits mercury losses to groundwater and benefits miner by retaining product | Ineffective if not well made or cracked in use; policing is difficult in remote areas | Raise awareness of financial benefits and risk to water supply<br>Better enforcement. |
| Educate miners of dangers and pathways of mercury exposure | Should be persuasive to people concerned to maintain their health | Behavioural change is difficult | Target women and youth for awareness raising as more risk aware and endangered groups |
| UNIDO pilot scheme promoted use of glass retorts to recapture mercury | mercury recovery should reduce production costs and limit impact of mercury on human and environmental health | Transparent “Thermex” (glass) retorts expensive (USD 300) and fragile. No obligation to use | Implement by M&E - redesign with better advice of local needs from miners |
| UDSM developed metal retorts as alternative to glass | Cheaper and less fragile than glass | Miners cannot see the product | Redesign retorts with advice from miners to meet their needs |
| **Recommendations (not yet implemented in Tanzania)** | | | |
| Require potable water wells be located at least 50 m up gradient | Limits physical pollution by process water and mine wastes during rainy | More cost involved in construction of up gradient well | Raise awareness of potential risk to water supply |

| Control measures | Effectiveness | Limitations | Recommendations for improvement |
|---|---|---|---|
| from amalgamation sites | season | | |
| Disseminate artisanal mining code of conduct (to explain health, safety and environmental concerns) | Limits public health and environmental impacts | Extension services to small scale miners are inadequate | Improve extension services to small scale miners from Ministry of Energy and Minerals (MEM) |
| Promote small group rather than individual miners to organise and modernise the artisanal mining sector | Cost effective, environment friendly approaches used, easy to own mining equipment like millers, amalgamation barrels, retorts etc. | Small scale miners come from different parts of the country, not easy to trust each other | Improve extension services to small scale miners from MEM – provide micro bank incentives to collectives |
| Establishment of Environmental committee at mining site | Promotes self-policing | Difficult to facilitate environmental groups | Provide incentives like make it a requirement for a micro loan... |
| Make mining safety gear (including retorts) obligatory | Reduces public health and environmental impacts | Enforcement difficult, most small scale miners are poor/not interested/unwilling to pay | Provide incentives like make it a requirement for a micro loan... |
| Restrict mining in sensitive habitats (e.g. wetlands, natural water sources and natural forest areas) to industrial or middle scale miners | Limits mercury usage and damage to sensitive habitats and protects fragile water sources | Lack of political will/co-operation at local level. Needs cooperation between Ministries responsible for minerals, water, land, fisheries and natural resources | Improve inter-agency collaboration |
| Provide micro finance facility to artisanal miners to fund capital improvements | Capital to improve mining efficiency and safety (if linked to loans) | Funds, micro-banking experience | |

A- this management action can be described as implementing one or more of the Appleton Report (AR) recommendations (1-6)

### Capability and methods for monitoring mercury in Tanzania

There is capability in Tanzania to analyse for mercury[61] in water and soil samples to 0.01 mg/L (the Tanzania DWS is 0.001mg/L, but WHO 2004 is 0.006mg/L). Water samples from the WLS network are sent to ARDHI University (on commission).

Baseline studies in the Lake Victoria goldfields have detected high levels of mercury in people, animals, soils and water in mining areas.

The Appleton Report (Appleton, Taylor et al. 2004) recommended the identification and understanding of the pathways for mercury dispersion and bioaccumulation in the Tanzania goldfields followed by assessment of the relative risk for human exposure before designing mercury monitoring programmes as a way to maximise the relevance and minimise the cost of these expensive analyses.

Integrative monitoring approaches could reduce the cost of the surveillance and increase the value of the data. For example ducks have been identified as bioaccumulators and may be useful as comparative indicators of the levels of contamination across and within basins. Programmes targeting bioaccumulators in the human food chain provide useful information on potential human health risk but the limitations of seasonality, gender, maturity etc. inherent in animal bioaccumualtion studies must be well understood.

### Recommended procedures for monitoring mercury contamination

The hazard of mercury contamination associated with artisanal gold mining is well known in the water quality management community in Tanzania. The BWOs reported at interview that artisanal gold mining activity was occurring in six basins (Table 13), but only three basin water offices (Lake Victoria, IDB and Rovuma) have current routine water quality monitoring targeting mercury (Rovuma only since Dec 2009). The IDBWO is conducting monitoring to establish baseline levels of heavy metals including mercury in groundwater around Williamson, El Hilal, Resolute and Shanta Mines.

**Table 13. Locations of artisanal gold mines**

| Basin | Location | Background Information |
|---|---|---|
| Internal | Shinyanga Nzega, Manyoni | No monitoring - artisanal miners active |
| L Rukwa | Songwe River basin | No monitoring |
| L Rukwa | Chunya | No data on mercury pollution – BWO recommend monitor for mercury |
| L Tanganyika | Rwamagasa | mercury in fish in L Tanganyika and Malagarasi R delta acceptable. Rwamagasa artisanal mining area mercury unacceptable |
| L Victoria | Tigithe R d/s North Mara gold mine | Surface water polluted by tailings leakage from mine dam (vandalism) |
| L Victoria | open pits in gold mining areas in L Victoria basin | mercury in pond water significantly higher than DW standard (1µg/L) |
| L Victoria | Mwanza Gulf, L. Victoria | sediment from near beaches within Mwanza City generally had higher concentrations of lead and zinc than stations near rural beaches and river mouths |
| L Victoria | L Victoria | mercury in Nile perch flesh were < level of concern for human |

[61] The consultant identified two analytical labs providing mercury analysis in Tanzania (ARDHI Uni and SEAMIC) and noted that the WLS did have an analytical capability for Hg but could not maintain it (probably through lack of demand for the service from agencies with funds to pay).

| Basin | Location | Background Information |
|---|---|---|
| | | health risk |
| Pangani | Zigi R near Muheza | No data - artisanal gold miners active on Zigi R (Amani area of Eastern Arc Mts) |
| Ruvuma/Sth | Mtwara Region (Lukwika; Msasi; Nanganga; Bachoto; Mchawuru; Liwhale districts) Lindi Region (Raungwa; Beckinyere; Namblage; Nachingwere Dist); | BWO monitoring since Dec 2009 (trace mercury). Artisanal gold miners active |