Nile Basin Initiative
Nile Trans boundary Environmental
Action Project

REPORT ON

TRAINING MODULES AND MATERIALS AND QUALITY ASSURANCE FOR TANZANIA

Date: September, 2006

NILE BASIN INITIATIVE

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EXECUTIVE SUMMARY

Impaired quality of water resources due to increased pollution has increased water unavailability for community and ecological uses. Substantial impacts prevail in lowlands and are therefore of cross-border importance for transboundary water resources where upper catchments contribute to water pollution which affects receiving water bodies located in the lowlands.

The study indicated that the main sources of water pollution in Tanzania are agricultural and mining activities in rural areas and solid, liquid and hazardous wastes disposal from domestic, industrial, commercial and agricultural activities in urban areas. The types, nature, quantities and spatial spread of the pollutants varied significantly depending on the use and waste residues of the pollutant.

In order to reduce pollution of country's water resources, several measures have been proposed and some implemented including the establishment of National Environment Management Council (NEMC) to oversee environmental monitoring activities in the country. However, effective monitoring of environmental conditions and in particular water quality (WQ) situation is hindered by country's low water quality analysis and human resources capacities. There are few laboratories which analyses water quality parameters whose spatial distribution is poor, with most laboratories located in Dar es Salaam, that many parts of the country are left unattended. The lack of highly qualified (with at least Bachelor's degree) and experienced personnel is worsening further the situation to the extent that results of WQ analyses from many laboratories supervised by technicians are in many cases doubtful. The situation for the small number of highly qualified personnel could be contributed by the nature of WQ training in the country in which specialed training is offered at the technician level while WQ training at graduate level is not specific and forms a small part of broad graduate degree programmes.

Although communities are the major polluters of water resources in Tanzania as elsewhere within the Nile basin, there is little effort devoted to involving them in the general management of water pollution. Currently, there is no any water quality monitoring programme that is essential for proper WQ monitoring. Owing to its absence, WQ assurance programme, which is among essential components of any practical WQM programme, is lacking in the country. This lack of WQ assurance programme is among the major factors contributing to doubtful results of WQ analyses from various laboratories. WQ assurance and WQ monitoring programmes were therefore proposed for Tanzania as part of the broad environmental monitoring programme and details of their implementation including coordination units, their compositions and interactions with main actors were detailed.

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ACRONYMS AND ABBREVIATIONS

AWWA	American Water Works Association
BOD	Biochemical Oxygen Demand
BSc	Bachelor of Science
CBO	Community Based Organisation
COD	Chemical Oxygen Demand
CoET	College of Engineering and Technology
CPE	Chemical and Process Engineering
EPA (USA)	Environmental Protection Agency of the United States of America
EU	European Union
FTC	Full Technician Certificate
GCLA	Government Chemist Laboratory Agency
GEMS	Global Environmental Monitoring System
GoT	Government of Tanzania
IMTU	International Medical and Technological University
ISO	International Standards Organisation
KCMC	Kilimanjaro Christian Medical Center
LKEMP	Lower Kihansi Environmental Management Project
LVEMP	Lake Victoria Environmental Management Project
MAFS	Ministry of Agriculture and Food Security
MoE	Ministry of Environment
MoW	Ministry of Water
MSc	Master of Science
MUCHS	Muhimbili University College of Health Sciences
MUTEX	Musoma Textile
NBI	Nile Basin Initiative
NEMC	National Environment Management Council
NGO	Non-Governmental Organisation
NTEAP	Nile Transboundary Environmental Action Project
NTU	Nephelometric Turbidity Unit
PhD	Doctor of Philosophy

QA	Quality Assurance
RWRI	Rwegarulira Water Resources Institute
SEAMIC	Southern and Eastern Africa Mineral Centre
SUA	Sokoine University of Agriculture
TBS	Tanzania Bureau of Standards
TFDA	Tanzania Food and Drug Authority
UCLAS	University College of Lands and Architectural Studies
UDSM	University of Dar es Salaam
WHO	World Health Organisation
WQ	Water Quality
WQM	Water Quality Management
WRE	Water Resources Engineering
WRED	Water Resources Engineering Department

SECTION 1
INTRODUCTION

1.1 INTRODUCTION

From its sources in Ethipian Mountains and Lake Victoria basin, River Nile traverses several riparian countries to discharge its water in the Meditterrenean Sea (Fig 1.1). Despite the source of Blue nile being almost in Ethipia, the Lake Victoria source of the White Nile is shared by many countries which form headwaters of several inflowing rivers. The River Kagera flows from Burundi across Rwanda and Kagera Region in Tanzania where it discharges its water into the lake. Several rivers in Tanzania and Kenya, including Mara, Simiyu, Grumeti, Mori, etc, drain various parts of the Lake Victoria basin to discharge their water into the lake.

Owing to this fact that the Nile is shared by many countries, it is important that any development in these countries that is related to the use of water from the Nile itself or and rivers and lakes that contribute in any way to the existence of the Nile shall not have to significantly affect other countries. This suggest the need for common use of the Nile resources and consequently calls for joint agreement on the use of water resources in the countries sharing the Nile.

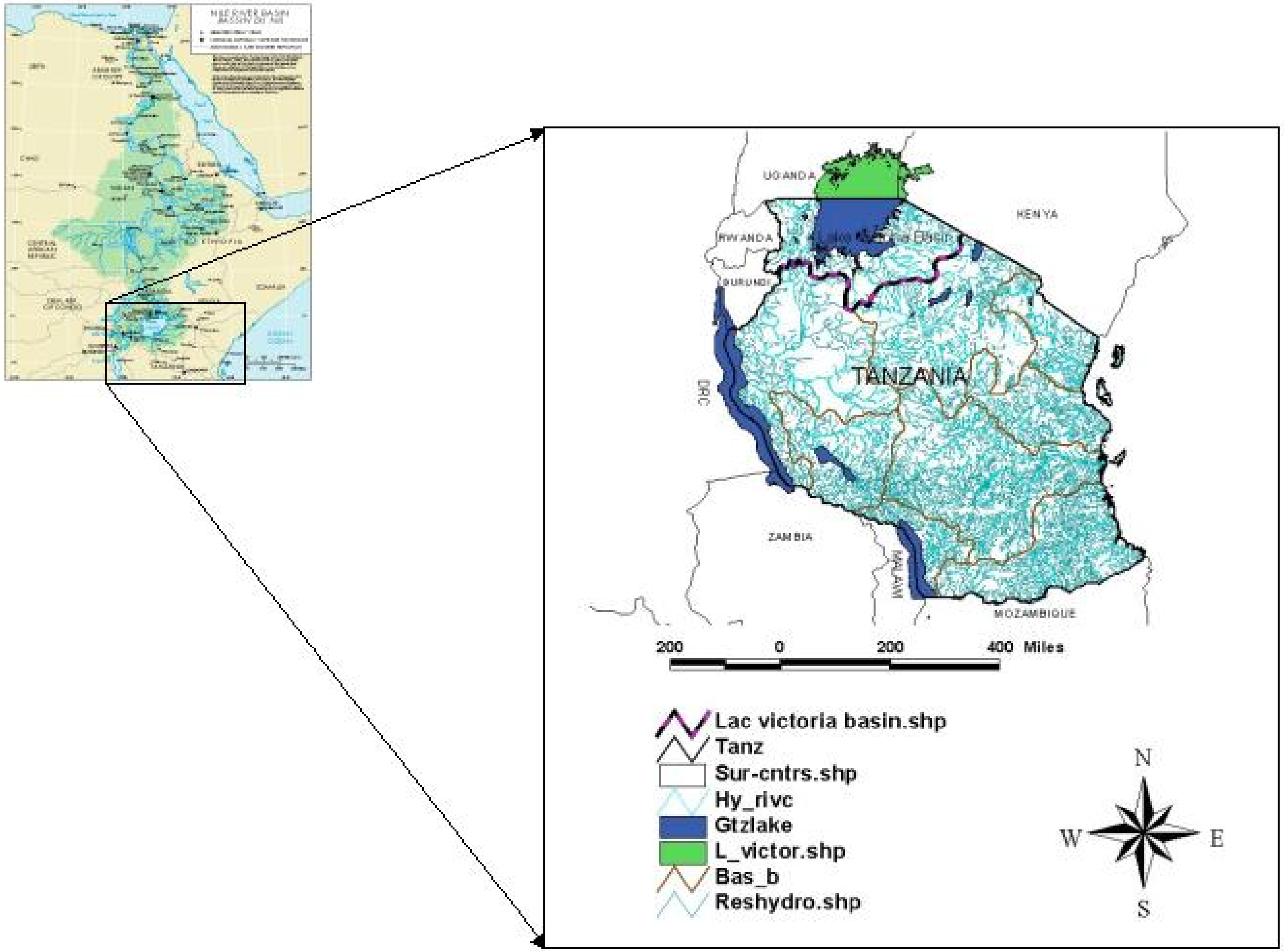

Fig 1.1: The location of Nile basin in Tanzania. Surface water resources in Tanzania are also shown.

Recognizing that cooperative development holds the greatest prospects for bringing benefits to the entire region, and aware of the challenges, the Nile riparian's took a historic step in establishing the ***Nile Basin Initiative*** (NBI). The NBI represents a transitional institutional mechanism, an agreed vision and a basin framework, and a process to facilitate substantial investment in the Nile basin to realize regional socio-economic development. Its establishment marks the beginning of the process of confidence building and realizing mutual benefits through shared projects.

To translate the shared vision into action, the NBI has launched a strategic Action Program, which includes two complimentary components:

- A basin wide Shared Vision Program (SVP) creating a basin wide enabling environment for sustainable development.
- Subsidiary Action Programs (SAPs).

The SVP is comprised of grant based activities to foster trust and cooperation and build an enabling environment for investment. The SVPs includes 8 projects:

i) Applied Training Project (ATP)
ii) Confidence Building and Stakeholder Involvement Project (CBSIP)
iii) Regional Power Trade Project (RPTP)
iv) Shared Vision Coordination Project (SVP)
v) Socio-economic and Benefit Sharing Project (SBSP)
vi) Transboundary Environmental Action Project (TEAP)
vii) Efficient Water Use for Agriculture Project (EWUAP)
viii) Water Resources Management Project (WRMP)

1.2 NILE TRANSBOUNDARY ENVIRONMENTAL ACTION PROJECT

The NBI provides an institutional mechanism, a shared vision, and a set of agreed policy guidelines to provide a basin wide framework for cooperative action. The long-term goal of the *Shared Vision Program* is to create the enabling environment for the Nile riparian's to realize their vision to achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources. ***Nile Transboundary Environmental Action Project*** is the largest project in the Shared Vision Program. It provides a strategic framework for environmentally sustainable development of the Nile River Basin and support basin wide environmental action linked to transboundary issues in the context of the NBI Strategic Action Program. The NTEAP consists of the following five main components

i) Institutional strength (IS)
ii) Micro grants (MG)
iii) Environmental education (EE)
iv) Wetlands and biodiversity (WB)
v) Water quality monitoring (WQM)

The WQM component stems out from the fact that the Nile basin countries differ in their consideration of water quality management as an immediate priority for sustainable water availability for various community and ecological uses. This necessitates a basin-wide dialogue on water quality and its management. It therefore calls for an improvement of our understanding of water quality issues within individual countries and between countries sharing the same water resources. Therefore, the WQM components of NTEAP is expected to initiate the in-country and cross border dialogues to improve capacities for monitoring and management of water quality and initiate exchange and dissemination of information on key-parameters.

The WQM component has the basic key elements as enhancement of national capacities and awareness raising and information sharing on water quality. Since the coordination of WQM issues within the Nile basin lies with NTEAP unit and there is a need for exchange and dissemination of information on key water quality (WQ) parameters, it was considered important to assessing existing water quality information on a national and regional scale and identifying major information gaps and needs. This will facilitate in the compilation of the Nile WQ report for further progress.

The success of this WQM component will depend on the how well are these two key elements implemented. To effectively improve national capacities on water quality issues, for example, it will be necessary to raise awareness of varoius stakeholders (communities, government, regulatory authorities, NGOs, CBOs, etc) on the importance of preservation of the quality of water resources. Among several techniques of awareness raising techniques, the knowledge creation on water quality pollution and its prevention is usually considered as among the first steps towards water quality management. It is therefore Therefore, before water quality (WQ) testing and training facilities in Tanzania are discussed, an overview of sources of water pollution in the country is presented.

1.3 WATER POLLUTION IN TANZANIA

Owing to country's large area, non-uniformity of natural resources and its consequential uneven distribution of population and socio-economic activities, water resources in Tanzania experience different levels of pollution from different sources within and outside the country. The sources of pollutants, which eventually end in water resources, are dependent on the location which is related to different types of socio-economic activities. The quantity and type of pollutants is affected by the location, whether rural, peri-urban or urban. Most pollutants from rural areas are related to agricultural or mining activities while pollutants from urban areas correspond to solid, liquid or hazardous wastes disposal from residential, commercial and industrial areas. Owing to the large number of individual sources of water pollution in Tanzania, it is useful to provide general georeferencing with regard to i) basin boundaries (Fig 1.2) and ii) major economic activities.

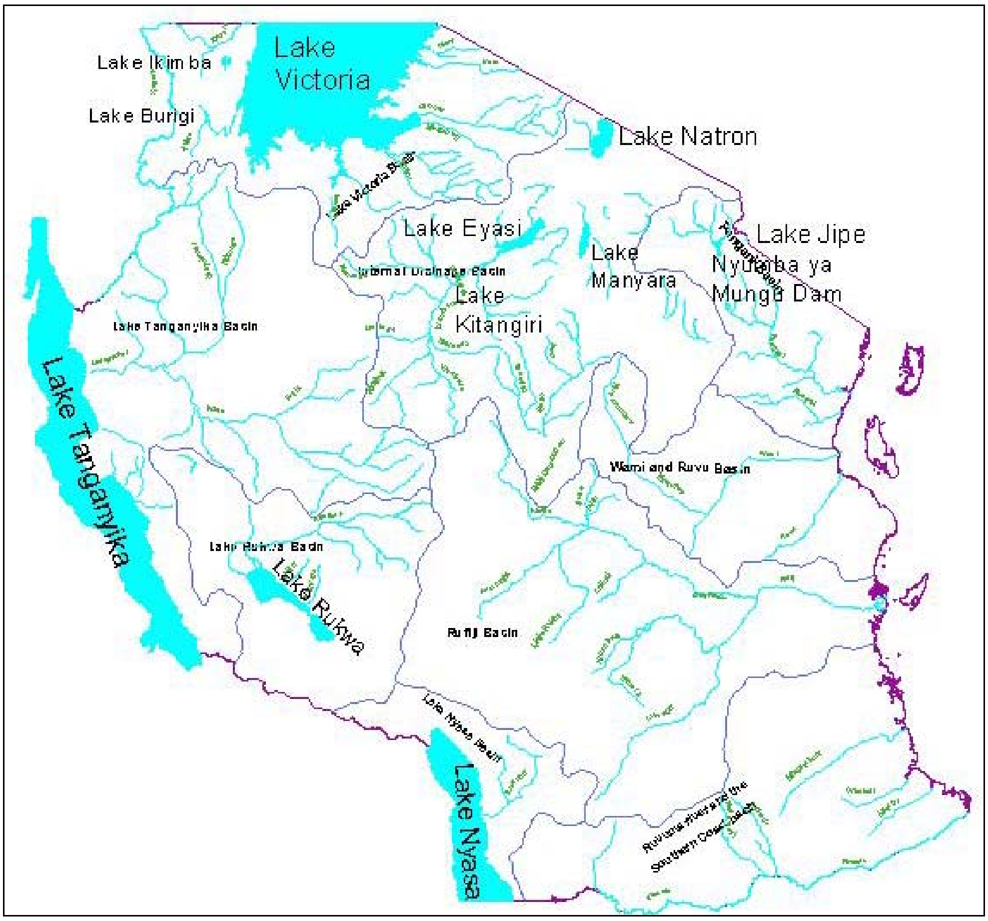

Fig 1.2: Major river basins of Tanzania.

The summary of water pollution from various major economic activities within individual drainage basins in Tanzania is given in Table 1.1. It indicates that the main sources of surface and ground water pollutions in Tanzania are agricultural activities and disposals of solid, liquid and hazardous wastes from urban centres.

Table 1.1: Water pollution in Tanzanian water resources.

Basin	Pollution Sources	Pollutants (Tables 1.1, 1.2 and 1.3)	Affected water bodies
Internal I (Lake Eyasi, M Natron) (Trans-boundar Tanzania, Keny	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Exploitation of Soda Ash from L Natron	• From agriculture (nutrients, herbicide and pesticide chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Eyasi, L Manyara, L Natron, L Babati, L Kitangiri, L Basuto, R Ndurumo, R Manonga, R Bubu, R Makuyuni
Lake Nyasa (Trans-boundary: Tanzania, Malawi, Mozambique)	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Mining of gold, coal and iron ore in Ludewa • Coal exploitation in Kiwila, Mbeya • Gold mining in Ruvuma	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Nyasa, R Kiwila, R Songwe, R Lufirio, R Mbaka, R Lupali, R Ketewaka, R Ruhuhu
Lake Rukwa	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres	• From agriculture (nutrients, herbicide and pesticide chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Rukwa, R Lupa, R Songwe, R Mtembwa, R Katuma, R Luiche
Lake Tanganyika (Trans-boundary: Tanzania, Burundi, DRC, Zambia)	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Mining of Tin, Tungsten, Gold, Colombium-tantalum ore in Burundi	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Tanganyika, Malagarasi-Moyovisi river system, R Ugalla, R Lugufu, R Luegere
Lake Victoria (Trans-boundary: All 9 Nile Basin countries)	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Mining of gold in Mara, Mwanza and Shinyanga • Mining of Tin, Tungsten, Gold, Colombium-tantalum in	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Victoria, L Ikimba, Mara Wetlands, R Mara, R Kagera, R Simiyu, R Grumeti, R Mbalangeti, R Duma, R Mori

Basin	Pollution Sources	Pollutants (Tables 1.1, 1.2 and 1.3)	Affected water bodies
	Rwanda and Burundi		
Pangani (Trans-boundary: Tanzania, Kenya)	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Gold and Tanzanite mining in Arusha • Small scale gold mining in the Usambaras	• From agriculture (nutrients, herbicide and pesticide chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	L Jipe, Nyumba ya Mungu Reservoir, L Ambuseli, R Ruvu, R Kikuletwa, R Pangani, Indian Ocean
Rufiji	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	Usangu and Kilombero Wetlands, R Rufiji, R Great Ruaha, R Little Ruaha, R Kilombero, R Ruhudji, Indian Ocean
Ruvuma and Southern Coast (Trans-boundary: Tanzania, Mozambique)	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	R Ruvuma, R Matandu, R Mavuji, R Lukuledi, R Lumesule, Indian Ocean
Wami-Ruvu	• Agriculture • Disposal of solid, liquid and hazardous wastes from urban centres • Small scale gold mining	• From agriculture (nutrients, herbicide and pesticide chemicals) • From mining and related activities (heavy metals, oils and grease, other chemicals) • From urban centres (industrial, domestic and commercial facilities discharges and emissions)	R Wami, R Ruvu, R Ngerengere, Indian Ocean

Small-scale rainfed agriculture is predominant in Tanzania. Its productivity is, however, low and fertilizers includig chemical fertilizers are extensively applied to enhance agricultural productivity. Unfortunately, there is poor management of fertilizers resulting sometimes into excessive nutrient loading into surface water bodies. Such nutrient loading has consequently led to eutrophication and waterweeds problems notably in Lakes Victoria and Jipe (Fig 1.3) in northern Tanzania.

Fig 1.3: Waterweeds problem in Lake Jipe.

Crude disposal of solid, liquid and hazardous wastes in urban centres is increasingly becoming among the major causes of surface and ground water pollution in the country. Inefficient collection, storage, transport and treatment facilities have contributed to this problem. Consequently, most industries discharge their untreated effluents directly into receiving water bodies while household (solid, liquid and hazardous) wastes are being deliberately thrown into the streets, stormwater channels and streams (Fig 1.4) Although small amounts are usually thrown into water bodies at a place at a particular time, the total amounts of wastes from the very many like sources in the towns are usually high depending on the size of the town and level of socio-economic development.

(a)

(b)

(c)

Fig 1.4: Crude disposal of wastes from urban areas of Tanzania: a) MUTEX effluent into Lake Victoria, b) household sewage into stormwater drainage channel, and c) household solid wastes on receiving stream.

Mining activities contribute to water pollution in few basins like Lake Victoria basin, Pangani River basin, Wami-Ruvu River basin and Lake Nyasa basin where intensive mining of gold, diamonds, tanzanite, etc is taking place. Water pollution from mining activities is concentrated in mineral-rich regions of the country. Gold mining is predominant in the basins and both small-scale gold diggers and large-scale multi-national companies operate. Water pollution occurs in any one or all of the following phases:

i) mining phase,
ii) processing phase,
iii) storage phase and
iv) transportation phase

The nature and amounts of pollutants as well as the spatial extent of polluted area vary between the phases. Actual mining operations can contribute to pollution within the "core" mining sites and surrounding water bodies. However, off-site processing, storage and transportation can cause water pollution of distant water bodies and consequently widespread pollution depending on the location of processing plants, markets and disposal sites. Among major contaminants during the actual mining phase and transportation of raw materials to processing plants is the dust which may end up in surface water bodies and leads to increasing water turbidity. However; it is the processing phase that contributes to high level of water pollution due to i) amounts and ii) types of chemical used in the separation processes. Mercury and cyanide, for example, are the major chemicals used in gold separation process in the country. They have been more often released into rivers due to poor handling particularly from small-scale mining activities. As a result, mercury contamination is among the main water pollution problems around gold mines and has led, for example, to the abondment of the use of water from the Nyamalembo Water Supply reservoir in Geita, Mwanza.

1.4 ACTORS IN WATER POLLUTION PREVENTION AND CONTROL

Owing to everincreasing levels of water and environmental pollution in Tanzania and their consequences on increasing water unavailability and impaired socio-economic development caused by water shortages, there is considerable efforts to reduce and reverse such pollution trend. This has seen an introduction of several measures against water and other sorts of environmental pollution. The measures include

i) Establishment of Water Utlisation Act No. 42 of 1974, as amended in 1981 Act No. 10
ii) Establishment of National Environment Management Act of 1983
iii) Establishment of National Environment Management Council (NEMC) in 1983
iv) Establishment of National Environmental Action Plan in 1994
v) Establishment of National Environmental Policy (NEP) of 1997
vi) Establishment of National Water Policy in 2002
vii) Establishment of environmental standards
viii) Establishment of comprehensive environmental laws
ix) Establishment of WQ testing facilities (laboratories)
x) Establishment of in-country WQ training

These efforts aim at providing legal basis for preventing and controlling environmental (including water) pollution. The environmental regulation in Tanzania is vested in two main agencies: the National Environment Management Council (NEMC) and the Ministry of Environment (MoE) under the office of the Vice President. NEMC is an agency responsible for environmental development in the country while MoE is responsible for providing policy and technical back-up.

Despite the overall environmental management of country's water resources being vested in NEMC and MoE, several different actors play important roles in WQ and environmental management. They include WQ analysis facilities such as laboratories, monitoring groups, evironmental management projects like Lake Victoria Environmental Management Programme (LVEMP), Lower Kihansi Environmental Management Programme (LKEMP) and research and academic institutions. In a combination, they generally provide useful information on the WQ situation in various parts of the country through results of analysis of numerous water samples.

SECTION 2
WATER QUALITY TESTING

2.1 INTRODUCTION

Among the major causes of water unavailability to societies are related to water hydrology and water quality. Whilst the hydrology is rather related to the quantity of water, the water quality is related to water safety for sustaining human life and ecological functions. The water quality aspects are mainly in terms of

i) physical characteristics,
ii) chemical characteristics and
iii) bacteriological characteristics.

These water quality aspects are briefly described with respect to the quality of natural water, drinking water and receiving water.

In order to ensure that the quality of water from any sources for various uses remains sustainably good, it is important to carry out frequent water quality (WQ) analyses for quality assessment (QA) and monitoring purposes. The analyses require competent WQ human resources and examination facilities including laboratories and field insitu testing equipment. Therefore, this section presents a brief overview of sources of water pollution in Tanzania, describes available human resources and quality assessment tools (WQ laboratories) and proposes WQ parameters that are of importance at the basin, national and trans-boundary scales.

2.2 ASPECTS OF WATER QUALITY

2.2.1 Physical aspects

The physical quality of water may affect its acceptability to users. The perception of water users and behaviour to use particular type of water for specific or general requirements are significantly affected by the water turbidity, colour, taste and odour. This may lead, for example, to the rejection of water as it is aesthetically unacceptable, for drinking purposes. In order to provide water of good aesthetic level, some guidelines have been prepared. However, despite such guidelines (e.g. for drinking water, Table 2.1) being based on the best available public health advice, there is no guarantee that users will be satisfied with water that meet meets those guidelines. It is therefore wise to be aware of consumer perceptions and to take into account both health-related guidelines and aesthetic criteria when assessing suitability of water for use. For example, turbidity exceeding 5 NTU may be noticeable; coloured water may indicate the presence of organic matter, metals or industrial wastes while odour may reflect the presence of organic substances. As a consequence, users may turn to other alternative sources which they perceive to be much safer aesthetically.

Table 2.1: Guideline for physical water quality of drinking water.

Physical parameter	Cause	Torelable level
Colour	Organic matter, metals or industrial wastes	< 15 mg/l Pt-Co
Odour	Organic substances	
Taste		
Turbidity	Particulate matter in water	< 5 NTU

2.2.2 Chemical aspects

Most chemicals arising in drinking water can affects human health, the environment and ecology. Their presence in water is either from natural occurrence or human-related activities such as treatment processes, agriculture, construction, mining, transportation, etc (Table 2.2). Whilst most nutrients found in surface water bodies come from agricultural activities, hazardous waste chemicals in Tanzania come from various sources including domestic areas where products containing hazardous chemicals like insect killers are being used. The level of concentration of these chemicals varies from one water source to another mainly depending on

i) the chemical properties of the parent rock beneath the water source
ii) the proximity of the water source to sources of chemical pollutants
iii) the quantity of chemical pollutants

The toxicity effects of the chemicals differs between chemicals depending on the toxic strength of the chemical, concentration of the chemical in water and accumulation nature of the effect. The most toxic chemicals show immediate harmful effects while others like heavy metals accumulate for years before the effects are observed.

2.2.3 Microbiological aspects

Micro-organisms including some pathogenic bacteria are among the naturally existing aquatic creatures in water. However, human and other animals related contamination can play a major role in their distribution between various water bodies resulting in widespread of these micro-organisms to areas where they were originally absent. The pathogenic micro-organisms are infectious to both human beings and animals and are therefore unwanted in water intended for human and animal consumption. Some of the infectious micro-organisms often found in water are given in Table 2.3 and their transmission pathways in Fig 2.1.

Table 2.2: Chemicals which are often present in natural and contaminated water.

Other chemicals	Inorganic chemicals	Organic chemicals
From water treatment	Naturally occurring	From industries, households
Disinfectants	Arsenic	Benzene
Monochloramine	Barium	Carbon tetrachloride
Chlorine	Boron	Di(2-ethylhexyl)phthalate
	Chromium	1,2-Dichlorobenzene
Disinfection by-products	Fluoride	1,4-Dichlorobenzene
Bromate	Manganese	1,2-Dichloroethane
Bromodichloromethane	Molybdenium	1,1-Dichloroethene
Bromoform	Selenium	1,2-Dichloroethene
Chloral hydrate	Uranium	Dichloromethane
(trichloroacetaldehyde)		Edetic acid (EDTA)
Chlorate	From industries, households, mining	Ethylbenzene
Chlorite	Aluminium	Hexachlorobutadiene
Chloroform	Cadmium	Nitrilotriacetic acid (NTA)
Cyanogen chloride	Calcium	Pentachlorophenol
Dibromoacetonitrile	Cyanide	Styrene
Dibromochloromethane	Iron	Tetrachloroethene
Dichloroacetate	Magnesium	Toluene
Dichloroacetonitrile	Mercury	Trichloroethene
Formaldehyde	Phenolphthalein	Xylenes
Monochloroacetate	Potassium	
Trichloroacetate	Sodium	From agriculture
2,4,6-Trichlorophenol	Phosphorus	Alachlor
Trihalomethanesb	Zink	Aldicarb
		Aldrin and dieldrin
Organic contaminants from	From agriculture	Atrazine
treatment chemicals	Nitrate	Carbofuran
Acrylamide	Nitrite	Chlordane
Epichlorohydrin	Phosphate	Chlorotoluron
	Carbonate	Cyanazine
Organic contaminants from		2,4-D
pipes and fittings	From water treatment	2,4-DB
Benzo[*a*]pyrene	Antimony	1,2-Dibromo-3-chloropropane
Vinyl chloride	Copper	1,2-Dibromoethane
	Lead	1,2-Dichloropropane
	Nickel	1,3-Dichloropropene
		Dichlorprop (2,4-DP)
		Dimethoate
		Endrin
		Fenoprop
		Isoproturon
		Lindane
		MCPA
		Mecoprop
		Methoxychlor
		Metolachlor
		Molinate
		Pendimethalin
		Simazine
		2,4,5-T
		Terbuthylazine (TBA)
		Trifluralin

The microbiological aspects of drinking water, for example, requires that none of pathogenic micro-organisms be present in drinking water. However, bacteria present in water vary from one source to another depending on the suitability of the water environment for their growth and reproduction. Therefore, those which in any way are related to human and animal faeces can be indirectly identified through identification of faecal contamination. The latter identification process usually uses faecal pollution indicator bacteria, the thermotorelant bacteria and faecal streptococci (Table 2.3).

Table 2.3: Pathogenic micro-organisms and indicator bacteria often present in natural and contaminated water.

Pathogenic bacteria	Protozoa and viruses	Indicator bacteria
Burkholderia pseudomallei Campylobacter jejuni, C. Coli Dracunculus medinensis (guinea worm) Legionella spp Non-tuburculous mycobacter Pseudomonus aeruginosa Salmonella typhi Shigella spp Vibrio cholerae Yersinia enterocolitica	Protozoa Acanthamoeba spp Cryptosporidium parvum Cyclospora cayetanensis Entamoeba histolytica Giardia intenstinalis Naegleria fowleri Toxoplasma gondii Viruses Adenoviruses Enteroviruses Hepatitis A virus Hepatitis E virus Norovirus and sapovirus Rotavirus	Thermotolerant bacteria Escherichia Coli Klebsiella Enterobacter Citrobacter Non-faecal coliform organisms Enterobacter cloacae Citrobacter freundii Serratia fonticola Rabnella aquatilis Buttiauxella agrestis Faecal Streptococci Enterococcus Streptococcus (S. bovis, S. equinus)

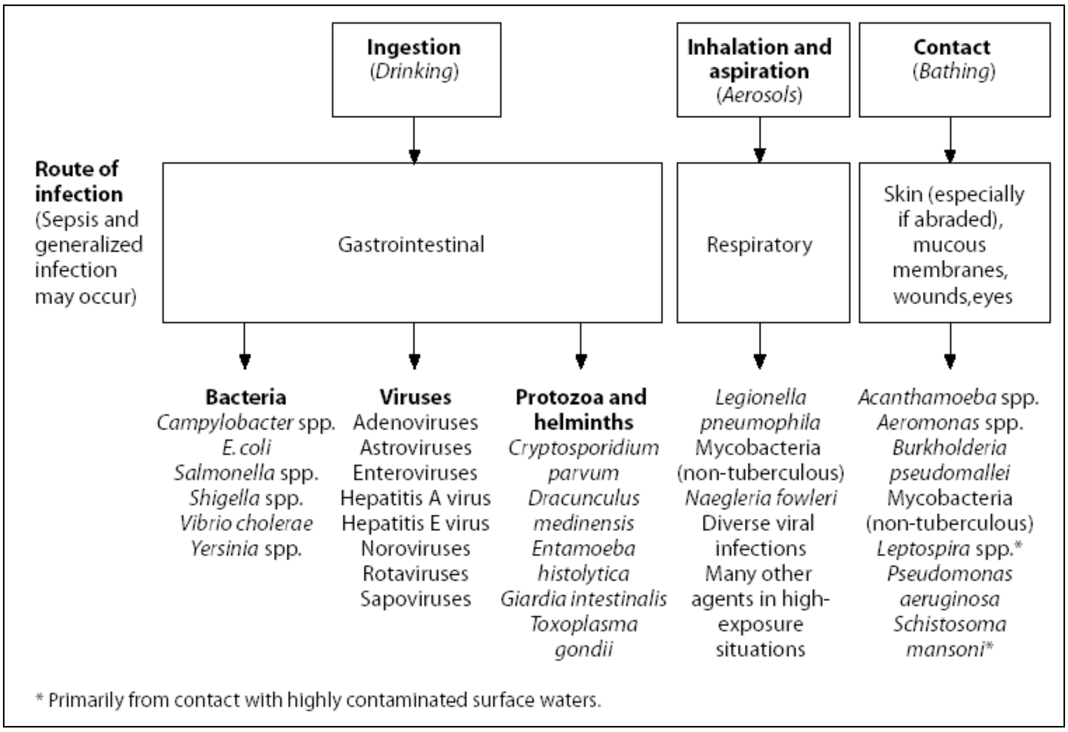

Fig 2.1: Transmission pathways for and examples of water-related pathogens (WHO, 2006).

2.3 WATER QUALITY STANDARDS

In order to maintain the ecology and quality of water sources (lakes, rivers, vegetated wetlands, ponds, etc) at its functional state, some 'allowable' levels of chemical and microbiological contamination have been recommended by various institutions. Beyond such limiting levels, the micro-organism or chemical concentration is considered potentially harmful to human, ecosystem and the environment. Some of the guidelines provided by several institutions include

i) WHO guidelines for drinking water quality
ii) ISO standards for water quality
iii) TBS Finalized Tanzania Standards: Specification for Drinking Water-Part-1
iv) EU water quality standards

Most of these standards were for reducing or eliminating microbial and chemical effects on human beings through provision of standard guidelines. However, the accumulative effects of some chemicals, particularly the heavy metals, on aquatic organisms (such as fish) and eventually on human beings have contributed to the establishment of guidelines for the quality of receiving water. The guidelines aim at protecting human beings, the environment and aquatic lives from the effects of excessive micro-organism and chemical concentrations in water.

2.4 WATER QUALITY TESTING

2.4.1 WQ testing facilities and human resources

The majority of testing to assess the quality of water from various sources is done in existing laboratories across the country (Table 2.4). The Ministry of Water (MoW) operates most of these laboratories and include regional laboratories in 11 regions, 4 zonal laboratories (Mwanza, Tanga, Mbeya and Kigoma) and 1 central laboratory in Dar es Salaam. The largest part of the remaining laboratories belong to various high education and research institutions.

The distribution of these laboratories, which can perform WQ analyses in the country, is spatially non-uniform with the majority being concentrated in Dar es Salaam (Fig 2.2). Moreover, almost all of these laboratories are found within the regional centres far away from most remote areas with exception of Dar es Salaam. Owing to predominantly poor transportation infrastructure between many areas within the regions and regional centres, it is difficult to ensure good WQ monitoring, through water quality sampling and testing, from regional centres. This situation indicates the need for an improvement of the network of WQ analysing facilities closest to remote areas, particularly in those regions like Tabora and Lindi which currently have none (Fig 2.2). This calls for centrally located WQ laboratory facilities between few districts with a reasonably good accessibility between district centres. Some criteria for locating new WQ analysis facility should be established and may include

Table 2.4: Water testing laboratories in Tanzania.

Institution	Department/Faculty	Number	Laboratory name
UDSM	Water Resources Engineering	1	Environmental engineering laboratory
	Chemical and Process Engineering	1	Chemical engineering laboratory
	Chemistry	1	Inorganic laboratory
	Chemistry	1	Organic laboratory
	Chemistry	1	Physical laboratory
	Chemistry	1	Electrochemistry laboratory
	Zoology	1	Physiology laboratory
MoW	Water Laboratories Unit	1	Central laboratory (Dar es Salaam)
		4	Zonal laboratory (Mwanza, Mbeya, Tanga, Kigoma)
		11	Regional laboratory (Arusha, Bukoba, Dodoma, Iringa, Morogoro, Mtwara, Musoma, Shinyanga, Singida, Songea, Sumbawanga)
UCLAS	Environmental Engineering	1	Environmental engineering laboratory
RWRI		1	Water quality laboratory
TBS		1	Food microbiology laboratory
		1	Chemistry laboratory
GCLA		1	Food and drugs division laboratory
		1	Chemical management division laboratory
		1	Forensic ce division laboratory
SUA	Faculty of Science	1	Water quality control laboratory
SEAMIC	Laboratory Services	1	Chemical and environmental section laboratory
Total		32	

i) the facility to be located in a district that is equal distant from the need districts in surrounding regions

ii) the facility to be located away from existing WQ analysing facilities

iii) the facility to be located in a district where it is easy for displacement of human resources and manpower

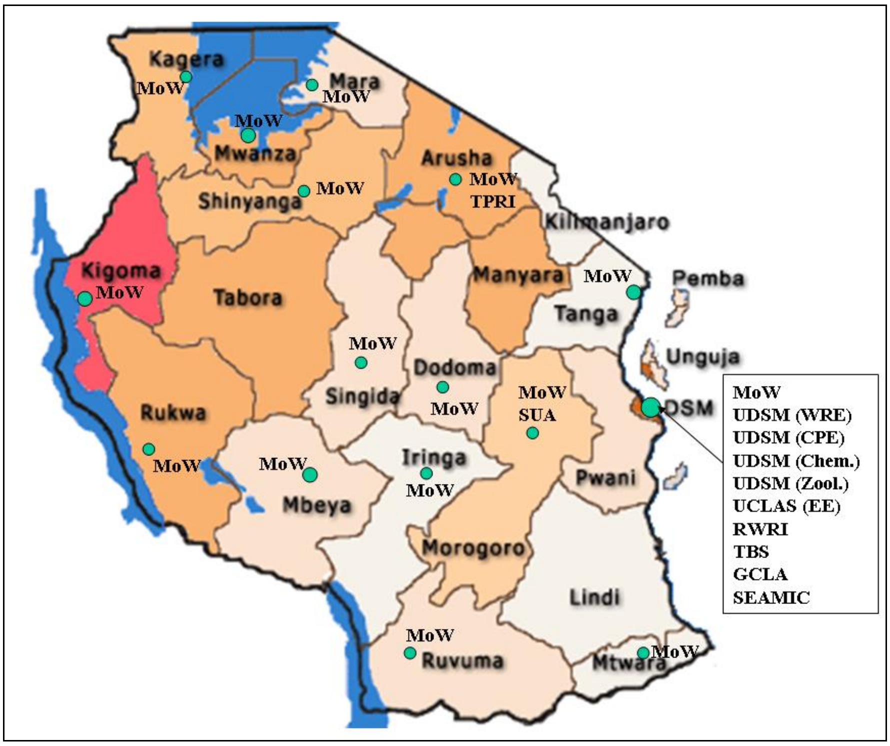

Fig 2.2: Distribution of WQ analysing laboratories in Tanzania.

The analysis capability differ from one laboratory to another depending on i) expertise and number of available staff and ii) the range and number of equipment available. Most of these laboratories have limited number of both equipment and highly trained (graduate) staff capable of performing WQ analysis. It was observed that there are quite few staff in operational and regulatory institutions with doctorate qualification while the number of those with postgraduate qualification is still small (Table 2.5). There is, for example, no PhD holder and only 6 Master's and 6 Bachelor's degree holders at Tanzania Bureau of Standards (TBS). On the other hand, there is only one (1) PhD holder and 5 Master's degree holder at the Ministry of Water (MoW) in its 16 laboratories across the country. Moreover, the majority of the 88 WQ staff in MoW are technicians with either a Diploma or a Full Technician Certificate (FTC) qualification.

Table 2.5: Available WQ human resources in some operational institutions in Tanzania.

	Academic qualification							
Institution	PhD	Masters	Bachelors	Advance Diploma	Diploma	FTC	Grade Tests	**Total**
MoW	1	5	8		9	62	3	**88**
TBS		6	6		2	1	2	**17**
SEAMIC			2		2	1		**5**
Total	**1**	**11**	**16**	**0**	**13**	**64**	**5**	**110**

The distribution of available WQ expertise is not uniform across the country and follows the distribution of WQ analysis facilities and reflects mainly the distribution of MoW staff in the country. Consequently, the largest number of WQ personnel is found in Dar es Salaam (Fig 2.3). It is therefore evident, from its role as the MoW central laboratory, that the majority (28) of WQ personnel in the MoW works in Dar es Salaam (Table 2.6). It was further observed that 12 of 14 graduate WQ staff in MoW work in the central and regional laboratories except for one (1) Master's degree holder in Musoma and one Bachelor's degree holder in Songea.

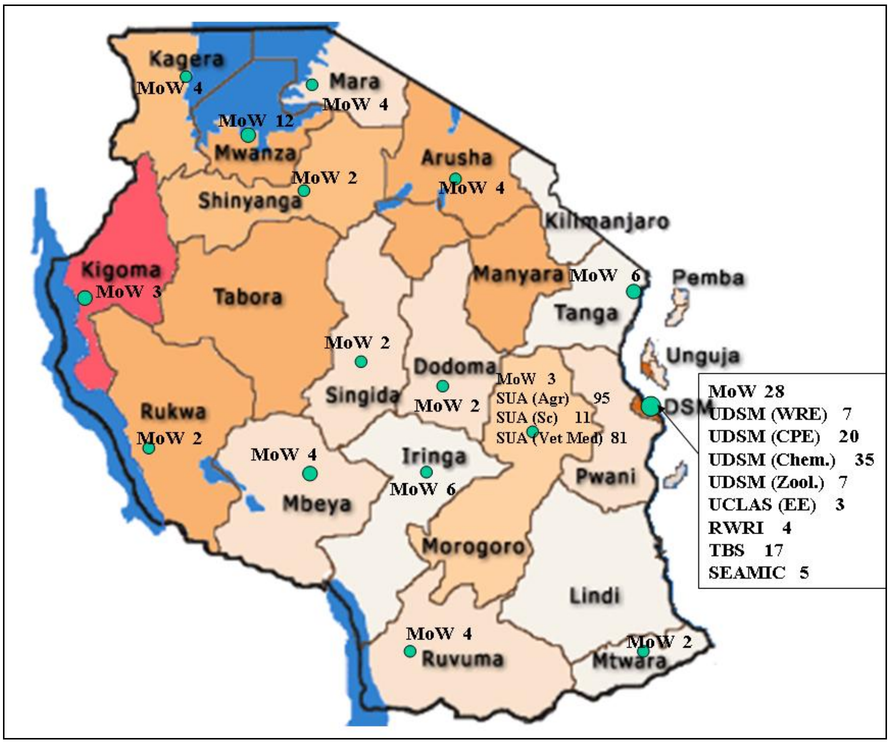

Fig 2.3: Regional distribution of WQ analysing staff in Tanzania.

Table 2.6: Available WQ human resources in MoW laboratories.

Laboratory	Academic qualification							
	PhD	Masters	Bachelors	Advance Diploma	Diploma	FTC	Grade Tests	**Total**
Dar es Salaam	1	2	2		1	22		**28**
Mwanza		1	3		1	5	2	**12**
Tanga			1		1	4		**6**
Mbeya		1			1	2		**4**
Kigoma			1			2		**3**
Morogoro						3		**3**
Musoma		1			3			**4**
Iringa					1	5		**6**
Arusha						4		**4**
Dodoma						2		**2**
Bukoba					1	3		**4**
Songea			1			3		**4**
Sumbawanga						2		**2**
Shinyanga						1	1	**2**
Mtwara						2		**2**
Singida						2		**2**
Total	**1**	**5**	**8**	**0**	**9**	**62**	**3**	**88**

2.4.2 Analysed WQ parameters and analysis equipment

The differences in staff number and qualification compostion are among major factors contributing to the variable capability of analysing WQ parameters between the laboratories. Despite such differences, the client demands have led to selective equipment of these laboratories to testing commonly and routinely analysed parameters recommended for drinking water quality. The parameters are generally divided into three major categories

i) physical parameters,

ii) chemical parameters and

iii) bacteriological parameters

The description of these parameters was given in section one. However, due to inadequate equipment in the laboratories, only some of these WQ parameters are analysed in the existing laboratories (Table 2.4) and insitu.

The majority of laboratories analyses almost all physical parameters. However, microbiological and chemical analyses depend, among other factors, on the purpose of laboratory. Laboratory in the Faculty of Science at the University of Dar es Salaam, for example, are not performing any kind of bacteriological analyses for WQ assessment purposes (Table 2.7). Moreover, the Physiology laboratory at the Department of Zoology of the University of Dar es Salaam does not carry any chemical analyses for metals apart from salts. Whenever the need arises, it sends water samples to SEAMIC laboratories for analysis. Similarly, almost all regional and some zonal laboratories of the MoW do not perform any chemical analyses for metals and they depend on the central laboratory in Dar es Salaam for such analyses.

Table 2.7: Frequently analysed water quality parameters in Tanzania.

SNo.	Parameter	MoW	UDSM (WRE)	UDSM (CPE)	UDSM (Chem)	UDSM (Zoo)	UCLAS (EE)	RWRI	TBS	GCLA	SUA
	Physical										
1	Colour	X	X		X	X	X	X	X	X	
2	Electrical Conductivity	X	X	X	X	X	X	X	X	X	X
3	Odour	X	X		X	X	X	X	X	X	
4	pH	X	X	X	X	X	X	X	X	X	X
5	Settleble matter	X	X	X	X	X		X		X	
6	Suspended solids		X	X	X	X		X	X	X	X
7	Taste	X	X		X	X	X	X		X	
8	Temperature	X	X	X	X	X	X	X		X	X
9	Total alkalinity	X	X	X	X	X		X	X	X	
10	Total Dissolved Solids	X	X	X	X	X	X	X	X	X	X
11	Total filtrable residue	X	X	X	X	X		X		X	
12	Total Hardness		X	X	X		X	X	X	X	
13	Total nonfiltrable	X	X		X			X		X	
14	Total suspended solids		X	X	X	X		X	X	X	
15	Total volatile fixed residue	X	X		X			X		X	
16	Turbidity	X	X	X	X	X	X	X		X	X
	Chemical										
1	Alkalinity	X	X	X	X	X		X	X	X	
2	Ammonical Nitrogen	X	X	X	X	X	X	X		X	X
3	Antimony				X		X			X	
4	Bicarbonate		X	X	X		X	X	X	X	
5	BOD	X	X	X	X	X		X	X	X	X
6	Boron				X		X			X	
7	Cadmium	X		X	X		X		X	X	X
8	Calcium	X	X	X	X		X	X	X	X	
9	Carbonate	X	X	X	X			X	X	X	
10	Chloride	X	X	X	X		X	X	X	X	
11	Chromium	X		X	X				X	X	
12	COD	X	X	X	X			X	X	X	X
13	Copper	X		X	X		X		X	X	X
14	Cyanide									X	
15	DO									X	
16	Fluoride	X	X	X	X		X		X	X	
17	Hardness	X	X	X	X			X	X	X	
18	Iron	X	X	X	X		X	X	X	X	
19	Lead	x		X	X		X		X	X	X
20	Magnesium	X	X	X	X		X	X	X	X	
21	Manganese	X	X	X	X		X	X	X	X	
22	Mecury	X			X		X		X	X	X
23	Molybdenium	X					X			X	
24	Nickel	X		X	X		X		X	X	
25	Nitrate Nitrogen	X	X	X	X	X	X	X	X	X	X
26	Nitrite Nitrogen	X	X	X	X	X		X		X	X
27	Non carbonate	X	X	X	X			X		X	
28	Organic Nitrogen	X	X	X	X					X	
29	Orthophosphate	X	X	X	X	X		X		X	
30	Permanganate	X		X	X			X		X	
31	Phenophthalein	X	X		X			X		X	
32	Phosphate		X	X	X	X		X		X	X
33	Potassium	X		X	X		X		X	X	
34	Silicate									X	X
35	Sodium	X		X	X		X		X	X	
36	Sulphate	X	X	X	X			X	X	X	
37	Sulphide									X	
38	Total Nitrogen	X	X	X	X				X	X	
39	Total phosphorus	X	X	X	X	X		X		X	
40	Zink	X		X	X		X		X	X	X
	Bacteriological										
1	Escherichia Coli	X	X	X			X	X	X	X	X
2	Total Coliform	X	X	X			X	X	X	X	X
3	Faecal streptococci							X		X	

Table 2.8: WQ equipment in use in various laboratories in Tanzania.

SNo.	Equipment	MoW (Dar)	UDSM (WRE)	UDSM (CPE)	UDSM (Chem)	UDSM (Zoo)	UCLAS (EE)	RWRI	TBS
1	Atomic absorption spectrometer	1		1	1				1
2	Autoclave	1	2	2	1			1	2
3	BOD apparatus and accessories		2	1	1	1	1	1	
4	BOD TRACK apparatus HACH Model				1		2		
5	Centrifuge		1	2		2	1	1	1
6	COD digester reactor	1		1	4		2		
7	Colorimeter	1		3	3	1		1	
8	Conductivity/TDS meter	2	1	2	4	1		1	
9	Cooled incubator	3	1	2		1			1
10	Denaturning gradient gel electrophoresis (DGGE) unit						**1**		
11	Desiccator vaccum	5	5	6	5	1	?		3
12	Digital Titrator			1			5		
13	Dissolved oxygen meter		1	1	1	1	2		
14	Electrolysis cooler	1							
15	Electronic balance	6	3	4	9	1	2	1	6
16	Flocculator	2							
17	Gas chromatograph mass spectrometer system			1	1		1	1	
18	High pressure liquid chromatography			2	1		**1**		
19	Hot air oven	3		4	5	2	2	1	
20	Hot plate	1	1	4	10	1		1	2
21	Hot plate magnetic stirrers	1	4	2	9	2	4	1	2
22	Incubator	2	3	1	1			1	4
23	Liquid scintillation analyzer	1						1	
24	Membrane filtration unit		2	1			2	3	1
25	Microscope with accessories			2	1	10	5	1	1
26	Muffle furnace	2	3	1	2				1
27	Organic carbon analyzer						**1**	1	
28	pH meter	2	2	2	7	1	2		2
29	Polymerase chain reaction						**1**		
30	Portable autoclave		2				1		
31	Portable incubator	3	4					1	
32	Refrigerator	2	1	6	4	1	1		6
33	Spectrophotometer	4		3	2	2	2		
34	SWI Soil and Irrigation kit						1	1	
35	Turbidimeter	1		1	2		1	1	
36	UV - Visible spectrophotomer	1			1	2			2
37	Vaccum pressure pumps	2	2		4		2	1	1
38	Water bath boiler with thermostat	2	2	1	5	2	1	2	3
39	Water distiller machine	2	1	2	3	1		1	3

On the other hand, being the country's backbone laboratory for analysis of all parameters including for water quality, the Government Chemist Laboratory Agency (GCLA) is the only laboratory in the country which possess necessary equipment and manpower to carry out almost all tests for WQ. It therefore analyses the whole range of WQ physical, chemical and microbiological parameters.

The situation leading to lack of equipment in many laboratories is partly contributed by the high costs of analysis equipment and limited financial capability of the institutions to acquire all required WQ analysing equipment. It was observed that MoW Dar es Salaam central laboratory, RWRI and TBS have most of required equipment for physical and bacteriological analyses as well as for analyses of metals (Table 2.8). However, CPE and Chemistry laboratories have most of equipment for analysing metals and salts.

2.4.3 Recommended additional WQ parameters for analysis

Despite the available capacities to analyse most of physical, chemical and bacteriological parameters, only GCLA is actually analysing hazardous waste chemicals or compounds from various sources including domestic areas, industries and hospitals. The lack of proper management technologies of these hazardous wastes contributes to their slipping into water sources either by deliberately or unknowingly disposal. Most of hazardous chemicals and compounds which are commonly present in various household products normally used in the country and that may be found in water resources (surface and ground water) are given in Table 2.9.

The lack of proper management technologies of these hazardous waste chemicals indicates the importance of their analysis to detect their presence in country's water. Most of these hazardous wastes originate from urban areas and some along the road network and therefore their impacts can be significant at the basin scale. It is therefore recommended that all parameters (Table 2.7 and 2.10) are of basin importance and should always be analysed in any water samples.

Table 2.9: Sources of hazardous chemicals and compounds normally present in various household products in Tanzania.

Source	
Antifreeze	Batteries
Brake fluid	Chemical strippers
Chlorine bleach	Contact cement
Drain cleaners	Fire extinguishers
Flea collars and sprays	Herbicides
Insecticides and insect repellent	Kerosene
Lawn chemicals	Lighter fluid
Lye	Mothballs
Nail polish remover	Old propane tanks
Paints	Pesticides
Pool chemicals	Prescription drugs
Solvents	Spot removers
Stains and finishes	Toilet cleaners
Used motor oil	Oven cleaners

At the transboundary spatial scale, the main activities that contribute to water pollution include agriculture, mining and industrial production. Unfortunately, most of the transboundary rivers in Tanzania drain into water bodies in Tanzania. These include

i) River Mara with headwaters in the Mau escarpment in Kenya drains through the Maasai Mara and Serengeti ecosystems into Lake Victoria

ii) River Kagera with headwaters in the northern Mitumba Chain Mountains in Burundi drains through Burundi and Rwanda to discharge into Lake Victoria.

iii) River Lumi drains the Taita hills into Lake Jipe whose outlet River Kifaru/Ruvu drains into the Nyumba ya Mungu reservoir whose water flows through River Pangani to the Indian Ocean.

iv) River Ruvuma drains parts of the Livingstone Mountains in Ruvuma region and nothern part of Mozambique to discharge its water into the Indian Ocean.

The fertile upper catchments on the headwaters of these transboundary rivers are the areas of extensive agricultural activities, human habitat as well as mining activities. They are therefore, the main sources areas of pollutants which enter rivers although wildlife in parks and game reserves also contribute some pollutants found in the trans-boundary rivers. It is therefore recommended to analyse all WQ parameters that originate from agricultural and mining activities (Table 2.10). They mainly include

i) physical parameters related to sedimentation, organic and inorganic contamination.
ii) chemical parameters related to fertilizers, herbicides, pesticides and mining operations.

It should be remembered that some of these parameters including those from agricultural and mining activities can be seen as of importance at the basin scale, their multiplier effects render them important at the trans-boundary scale. Excessive nutrients loads into Lake Victoria resulted in excessive growth of waterweeds which affected fisheries within the three countries of Tanzania, Uganda and Kenya sharing the lake. Some of the nutrients could have originated from the extensively cultivated Mau escarpment on the Kenya side of Mara River basin and from the catchment of River Simiyu in Tanzania. Recently, there is an increase of mercury levels at the downstream reaches of River Mara and in the Mara wetlands (McClain, Personal communication) probably from gold mining activities in Mara Region. Although this situation can be seen to affect immediately communities along the river reaches and those surrounding the wetlands, its multiplier effects related to its discharge into Lake Victoria could be felt in many Nile basin countries. Similarly, there are substantial mining activities in Rwanda and Burundi which extract ores of Tin, Tungsten, Colombium-tantalum and gold. Moreover, there are huge potentials for the development of Nickel, phosphate, vanadium and uranium mines in Burundi which might bring significant impacts of surface (rivers and lakes Victoria and Tanganyika) and ground water resources.

Table 2.10: Water quality parameters of transboundary importance.

Other parameters	Inorganic chemicals	Organic chemicals
Physical	Naturally occurring	From agriculture
Turbidity	Aluminium	Alachlor
Colour	Antimony	Aldicarb
	Arsenic	Aldrin and dieldrin
Chemical	Barium	Atrazine
Monochloramine	Boron	Carbofuran
Chlorine	Cadmium	Chlordane
Bromate	Calcium	Chlorotoluron
Bromodichloromethane	Carbonate	Cyanazine
Bromoform	Chromium	2,4-D
Chloral hydrate	Copper	2,4-DB
(trichloroacetaldehyde)	Cyanide	1,2-Dibromo-3-chloropropane
Chlorate	Fluoride	1,2-Dibromoethane
Chlorite	Iron	1,2-Dichloropropane
Chloroform	Lead	1,3-Dichloropropene
Cyanogen chloride	Magnesium	Dichlorprop (2,4-DP)
Dibromoacetonitrile	Manganese	Dimethoate
Dibromochloromethane	Mercury	Endrin
Dichloroacetate	Molybdenium	Fenoprop
Dichloroacetonitrile	Nickel	Isoproturon
Formaldehyde	Nitrate	Lindane
Monochloroacetate	Nitrite	MCPA
Trichloroacetate	Phenolphthalein	Mecoprop
2,4,6-Trichlorophenol	Phosphate	Methoxychlor
Trihalomethanesb	Potassium	Metolachlor
Acrylamide	Selenium	Molinate
Epichlorohydrin	Sodium	Pendimethalin
Benzo[*a*]pyrene	Uranium	Simazine
Vinyl chloride	Zink	2,4,5-T
		Terbuthylazine (TBA)
		Trifluralin

2.4.4 Problems

The operational WQ analysis in Tanzania is facing a number of shortfalls mainly related to

i) availability of WQ testing facilities (laboratories, portable testing equipment, etc)
ii) instrumentation capacities of testing laboratories
iii) limited number of qualified WQ personnel
iv) limited nature of WQ analyses.

The availability of WQ testing facilities and their instrumentation are the major two factors which hinder the spatial development of adequate WQ analysis in the country. Only MoW laboratories are located in many regions most of which have limited analysis capacities due to limited availability of WQ analysis equipment and human resources. Therefore, despite the a fairly good regional distribution of MoW and other institutions laboratories across mainland Tanzania, only laboratories in Dar es Salaam can, in combination, analyse the full range of WQ parameters. Moreover, it is the GCLA laboratories which are fully equipped for WQ and other analyses.

The limited number and instrumentation capacities of WQ laboratories are similarly reflected in the limited number of qualified personnel and nature of performed analyses. There is a close relationship between the number of qualified personnel and laboratory analysis capacity in a way that either the presence of qualified staff initiates improvement of laboratory instrumentation (provided funds are available) or vice versa. Highly qualified personnel are essential for high level managerial and analysis results interpretations and consequently are required in laboratories which analyse full range of WQ parameters. The limited number of these laboratories in the country is reflected to their absence in many regions. Therefore, to improve the number and distribution of these highly qualified WQ personnel across the country, it is recommended to

i) improve the number and instrumentation of WQ laboratories in the country

ii) upgrade the education of existing technicians to graduate level

iii) introduce specialised WQ training (modules) at graduate levels to enhance human resources for WQ research and development

Whilst the improvement of human resources and instrumentation capacities of WQ laboratories is expected to enhance WQ analyses, specialised training at graduate and post-graduate (Master's and doctorate) levels will enhance innovative WQ research. This is essential for the development of appropriate WQ analysis and monitoring methodologies and programmes.

SECTION 3
WATER QUALITY TRAINING

3.1 INTRODUCTION

In order to ensure sustainability of the quality of drinking and receiving water, it is important to provide training to communities on quality management and pollution prevention. The training should target different levels within the communities depending on the activities each level will be required to perform. Local communities, for example, can receive training to prevent water pollution, carry out simple routine measurements and reporting of water quality parameters (such as water colour, turbidity, odour, pH, etc). At high levels, the need for appropriate technical personnel to carry out water quality testing, analysis and drafting of policies and quality assurance programmes requires specialised training at technician to research levels. Moreover, water quality training involves preparation of training personnel, training materials and development of training facilities prior to conducting proper training. This section, therefore,

i) reviews the capacity existing water quality training institutions in Tanzania in terms of human resources and courses offered and
ii) designs training modules for different levels, for local communities and schools, for middle level technicians and engineers and for high level researchers.

3.2 EXISTING WQ TRAINING SITUATION IN TANZANIA

The training in WQ sampling, analysis, modelling and monitoring are conducted both locally and abroad. In-country training modules that essentially integrate various aspects of WQ are mainly taught at the following institutions

i) Rwegarulila Water Resources Institute (RWRI)
ii) University of Dar es Salaam (UDSM)
iii) University College of Lands and Architectural Studies (UCLAS)
iv) Sokoine University of Agriculture (SUA)
v) Medical and pharmacy institutions (MUCHS, Bugando Medical University, Tumaini University KCMC Campus, IMTU, Paramedical and nursing institutes, etc)

The academic level to be attained distinguishes the level and nature of training in these institutions. Whilst, specialised training for prospective WQ laboratory technicians is offered at RWRI, the training at graduate and post-graduate levels is broad in which courses on aspects of water quality form a part of the overall degree programmes (Table 3.1). For example, while the FTC (WLT) course at RWRI is mainly to prepare water quality laboratory technicians, WQ aspects are studied only in few courses at the Bachelor's and Master's degree levels at the universities and university colleges.

The RWRI is specialised in technical training of middle level technicians in Water Resources Engineering (WRE) and Water Laboratory Technology (WLT) at the Full Technician Certificate (FTC) level. The WLT programme accepts Form IV leavers with passes in appropriate subjects and has the objective to train water technicians in water quality to carry out water quality analysis required in the planning and operation of water supply works. This programme is targeting to providing capacity in WQ analysis and quality assurance. The programme technical modules related directly to WQ are given in Table 3.2. The institute has contributed more than 95% of WQ laboratory technicians in the country.

Table 3.1: WQ related courses offered by Tanzanian institutions and their WQ technical human capacities.

Institution (Dept/Fac)	Course offered	Duration (Months)
RWRI	Full Technician Certificate in Water Laboratory Technology	24
UDSM (WRE)	Bachelor of Science Degree in Civil (and Water Resources Engineering)	48
	Master of Science in Water Resources Engineering	18
	Master in Integrated Water Resources Management	18
UDSM (CPE)	Bachelor of Science in Chemical and Process Engineering	48
	Bachelor of Science in Food and Biochemical Engineering	48
	Master of Science in Environmental Engineering	18
UDSM (Chemistry, Zoology, Botany)	Bachelor of Science (General)	36
	Master of Science (Biology)	18
	Master of Science (Chemistry)	18
	Master of Science (Wildlife and Terrestrial Ecology)	18
	Master of Science (Applied Zoology)	18
	Master of Science (Fisheries and Aquatic Sciences)	18
	Master of Science (Environmental Science)	18
UCLAS (EE)	Bachelor of Science in Environmental Engineering	48
	Postgraduate Diploma in Environmental Technology and Management	12
	Master of Science in Environmental Technology and Management	24
SUA (Fac Sc)	Bachelor of Science in Environmental Sciences and Management	36
SUA (Fac Agr)	Bachelor of Science in Agriculture General	36
	Bachelor of Science in Agronomy	36
	Bachelor of Science in Food Science and Technology	36
	Bachelor of Science in Animal Science	36
	Bachelor of Science in Aquaculture	36
	Master of Science in Agriculture General	24
	Master of Science in Soil Science and Land Management	24
	Master of Science in Food Science	24
SUA (Fac Vet Med)	Bachelor of Veterinary Medicine	36
	Bachelor of Science in Biotechnology and Laboratory Science	36
	Master in Veterinary Medicine	24
	Master in Preventive Veterinary Medicine	24

The University of Dar es Salaam (UDSM) is conducting undergraduate and postgraduate training in water resources engineering, chemical and process engineering, environmental engineering as well as in various science specialisation including microbiology and water chemistry. WQ is part of the broad Bachelor's and Master's degree programmes. The various departments which offer such graduate training include

i) The departments of Water Resources Engineering (WRE) and Chemical and Process Engineering (CPE) (College of Engineering and Technology)

ii) The Departments of Botany, Chemistry and Zoology (Faculty of Science, UDSM)

iii) The Department of Environmental Engineering (Faculty of Lands and Environmental Engineering, UCLAS)

iv) Faculties of Agriculture, Veterinary Medicine and Science (SUA)

Table 3.2: WQ relevant training modules and topics for FTC (WLT) at RWRI.

Module	Objectives
Mathematics (I, II, III)	To acquire knowledge and skills for making mathematical computations required by a water technician.
Water Treatment Operations	To acquire knowledge and skills for municipal water treatment plant operations in relation to desired water quality standards.
Measuring and Monitoring Groundwater	To acquire and apply the principles and practices involved in groundwater monitoring.
Documenting and Analysing Groundwater Prospecting Data	To provide knowledge on procedures for documenting and analysing groundwater prospecting data
Laboratory techniques	To acquire appropriate knowledge and skills in laboratory procedures and practices sufficient to carry out laboratory activities.
Health, Sanitation and Water	To participate in activities for promoting health through improved sanitation.
Water Quality Surveillance	To acquire knowledge and skill on the design of water quality surveillance scheme.
Analytical Chemistry	To acquire knowledge and skill in the fundamental principles and practices of chemical analysis used in water quality laboratories as a basis for solving analytical problems in chemistry.
Introduction to Water Analysis	To acquire basic principles required to perform water quality analysis.
Applied Water Analysis (I, II, III)	To acquire knowledgeand skill required to perform routine laboratory analysis.
Bacteriological Analysis of Water	To acquire knowledge of microbiology and bacteriology of water and skill for bacteriological analysis of water.
Laboratory Organisation Procedures	To outline principles and procedures for proper organisation and management of a water quality laboratory.

The degree programmes and course modules relevant for specialisation in some areas related to water microbiology and chemistry are given in Table 3.3. The fundamental objective of undergraduate courses is to enable graduate engineers and scientists to interpret results of analysis and plan, design and conduct WQ related experiments (scientists) and supervision and maintenance of water treatment plants (engineers). The objective of post-graduate courses is to create competence in the analysis of WQ problems, provide appropriate technical solutions and conduct researches in the field of WQ.

It is not surprising that the largest number of undergraduate and postgraduate courses is offered at the University of Dar es Salaam (Table 3.1), which is the largest and oldest of the academic institutions. The undergraduate courses are extensively taught in the departments of Botany, Chemistry and Zoology of the Faculty of Science. Those related to microbiology and chemistry of water and the environment intend to provide fundamental knowledge of general water chemistry and microbiological characteristics essentially required in analysis and remediating pollution problems.as well as in quality monitoring and assurance.

Table 3.3: Modules relevant for WQ offered in academic institutions in Tanzania.

Instit.	Depart.	Programme	Module
UDSM	WRE	BSc (Civil&WRE)	• Introduction to water chemistry and microbiology • Management of solid and hazardous wastes • Epidemiology and wastewater engineering
		MSc (WRE)	• Unit operation in water treatment • Water quality modelling • Unit operation in wastewater treatment • Water pollution prevention and control • Water, sanitation and diseases
		M (IWRM)	• Hydro-geochemistry • Water quality modelling • Water quality management • Wastewater management
UDSM	CPE	BSc (CPE)	• Chemical engineering laboratory • Elements of environmental engineering • Environmental management and cleaner technology • Biological treatment of industrial wastes
		BSc (FBE)	• Fundamentals of microbiology • Food and biochemical engineering laboratory • Applied food microbiology • Environmental protection and industrial hygiene • Environmental management and cleaner technology
		MSc (EE)	• Solid waste management • Soil and groundwater pollution from agro-activities • Water pollution prevention and control • Water quality modelling
UDSM	Science	BSc (General)	• Environmental science • Fundamentals of microbiology • Algal ecology and systematics • Plant ecology and phytogeography • Applied ecology and biodiversity • Microbial nutrition and metabolism • Food microbiology and processing • Applied microbiology and biotechnology • Microbiology ecology and environmental microbiology • Soil microbiology • Aquatic microbiology • Basic analytical chemistry • Organic chemistry • Industrial organic chemistry • Inorganic chemistry • Chemistry practicals • Advanced food microbiology and bioprocessing • Instrumental methods in analytical chemistry • Industrial biotechnology • Environmental biotechnology • Environmental chemistry • Agricultural biotechnology • Invertebrate zoology • Environmental physiology • Aquatic biology • Advanced spectroscopy • Applied geochemistry • Fisheries biology • Aquatic pollution
		MSc (Biology)	• Freshwater ecology
		MSc (Chemistry)	• Advanced organic chemistry

Instit.	Depart.	Programme	Module
			• Photochemistry • Advanced analytical chemistry and instrumental methods • Organic chemical of industrial, agricultural and medicinal application
		MSc (Wildlife and Terrestrial Ecology)	• Environmental science • Fauna and flora of Africa • Ecological monitoring • Wildlife diseases and parasitology • Invertebrates ecology
		MSc (App Zoology)	• Protozoology
		MSc (Fisheries and Aquatic Sciences)	• Fish ecology and population dynamics • Aquatic pollution
		MSc (Envir Science)	• Environmental chemistry • Atmospheric and soil quality management • Environmental toxicology • Environmental pollution and public health • Environmental modelling • Indistrial development and pollution • Treatment and recycling of waste products • Chemical pollutants in the environment
UCLAS	EE	BSc (EE)	• Environmental microbiology • Environmental health and epidemiology • Environmental chemistry • Water treatment engineering • Land and water pollution prevention and control • Industrial wastewater treatment • Wastewater treatment technology
		PGr Dip (ETM)	• Environmental microbiology • Environmental chemistry • Wastewater treatment • Land and water pollution prevention and control
		MSc (ETM)	• Toxicology and risk assessment • Soil and groundwater quality management • Hazardous waste management and technology • Advanced topics in environmental health and epidermiology • Advanced environmental modeling • Ecological modelling • Aquatic chemistry • Surface water pollution prevention and control • Advanced wastewater treatment • Advanced industrial wastewater treatment • Natural waste treatment system • Sludge and septage management technology
SUA	Science	BSc (EnvirSc& Mgt)	• Introduction to ecology • General chemistry • Biochemistry • General microbiology • Environmental chemistry • Environmental microbiology • Land and water pollution and control • Waste management • Biotechnology and the environment • Methods in environmental health management and ecology restoration • Environmental toxicology

Instit.	Depart.	Programme	Module
SUA	Agric	BSc (Agr Gen)	• Weed biology and management • Environmental pollution and management of agricultural wastes • Soil water management and conservation
		BSc (Agron)	• General microbiology • Soil chemistry • Environmental chemistry • Weed biology • Land and water pollution control • Introduction to agrochemicals • Environmental pollution and management of agricultural wastes
		BSc (Food Sc & Tech)	• General microbiology • Food microbiology • Food contaminants and analytical microscopy
		BSc (Animal Sc)	• General microbiology
		BSc (Aquaculture)	• General microbiology • Environmental chemistry • Environmental microbiology • Food microbiology • Environmental toxicology and health hazards
		MSc (Agr Gen)	• Weeds and weed control
		MSc (Soil Sc & Land Mgt)	• Soil and water pollution
		MSc (Food Sc)	• Food microbiology
SUA	Vet Med	BVM	• Microbiology • Environmental microbiology • Pharmacology and toxicology • Technology and the environment • Biotechnology and the environment
		BSc (Biotech & Lab Sc)	• Fundamental microbiology • Toxicology • Food microbiology • Diagnostic microbiology • Environmental toxicology and health hazards
		MVM	• Environmental physiology • Toxicological methods • Laboratory technology in biochemistry • Diagnostic bacteriology and mycology • Diagnostic virology • Bacteriology • Virology • Food microbiology and hygiene • Environmental hygiene and water quality control
		MPVM	• Ecology and control of infectious diseases • Toxicology • Bacteriology • Virology

The postgraduate courses are more specialised and target at producing highly qualified scientists and engineers who can, in one way or another, be involved in the analysis and design of environmental systems as well as the research for their improved performances. It is the Faculty of Science which offers the largest number of postgraduate (Master's degree) courses in areas of water microbiology and chemistry in relation to human, ecology and the environment. These courses are geared to provide indepth understanding of the biology of various organisms (mammals, birds, fish, etc) and chemistry of the environment.

3.3 PROPOSED WQ TRAINING

3.3.1 Weaknesses of existing WQ training

According to the predominance of science-related courses relevant for water quality, the largest number of qualified academic staff who teach WQ related courses are concentrated in the Faculty of Science and Department of Chemical and Process Engineering of the University of Dar es Salaam (Table 3.4). Owing to their nature as academic departments, the majority of staffs are highly qualified doctorates and Master's degree holders (79%) capable of teaching and conducting researches. Only a few technicians work alongside these experts as supporting staff for various laboratories.

Table 3.4: Available WQ human resources in training institutions in Tanzania.

	Academic qualification							
Institution	PhD	Masters	Bachelors	Advance Diploma	Diploma	FTC	Grade Tests	**Total**
UDSM (WRED)	5	1		1				**7**
UDSM (CPE)	16	2				2		**20**
UDSM (Chemistry)	22	6	1	2		3	1	**35**
UDSM (Zoology)	3	1	2			1		**7**
UCLAS (EE)	1	1				1		**3**
RWRI	1	1	1				1	**4**
SUA (Science)	4	4	1			2		**11**
SUA (Vet Medicine)	42	5	8	3	16	1	6	**81**
SUA (Agriculture)	60	11	2		9	10	3	**95**
Total	**154**	**32**	**15**	**6**	**25**	**20**	**11**	**263**

Despite the development of advanced training, the development of water quality testing, analysis and monitoring programmes in Tanzania is substantially lagging behind. This is attributed, among other factors, by

i) limited number of qualified personnel for WQ analysis

ii) limited laboratory instrumentation

iii) biased training at various academic levels

iv) little community involvement in WQ monitoring

Apart from highly qualified academic staff within the academic institutions, only very few WQ scientists and engineers are actually working in WQ related laboratories in the country (Table 2.4). Majority of WQ staff in the MoW, for example, are laboratory technicians with only an FTC qualification from RWRI and other overseas institutions. Among the major problems hindering academic upgrading of these technicians is the lack of Water Laboratory specialist courses and modules in the universities, colleges and institutes.

Another factor which retards the development of WQ programmes is the demand-driven WQ assessments in which testing for drinking water quality is predominant. This has been contributed by the requirement for any development activity that would potentially generate wastes to discharge effluents that comply with standard drinking water recommendations. It has been a no man's duty to protect the environment and ecology of receiving water once requirements for drinking water are met. Since our industries had been light industries generating heavy metals and non-hazardous wastes, this situation has led to selective equipment of WQ laboratories with emphasis on equipment and apparatus for analysing drinking water parameters.

However, the alarming increase of environmental degradation from evergrowing agricultural, industrial and mining activities is creating the need for maintenance of unpolluted water resources and restoring polluted water resources at their ecological functioning states. This requires an input of WQ expertise for both sampling, testing and analysis of WQ data as well as monitoring programmes to control water pollution. It requires widening the range of parameters that are actually tested in country's laboratories and therefore calls for further training of WQ specialists to perform specific tasks.

The majority of modules are related to WQ aspects are science based and do not concretely cater for WQ monitoring as part of general environmental monitoring. The exceptions are water quality modelling modules at the Master's level in the Departments of Environmental Engineering (UCLAS), Chemical and Process Engineering and Water Resources Engineering (UDSM). Most courses in the faculties of science at UDSM and SUA are dealing with the biology of living (micro)organisms and chemistry of water. The application courses for WQ like water quality and environmental modelling are taught only at the College of Engineering and Technology and UCLAS at the post-graduate levels. Since very few proceed to post-graduate engineering levels (Table 3.3), only a few graduates are actually receiving this specialised training and only a small part ends up in WQ analysis institutions. It is therefore important to include some aspects of WQ analysis and monitoring techniques at the technician and undergraduate levels to promote their improved understanding of the importance of WQ monitoring and pollution prevention.

Accessibility difficulties for routine collection of water samples for laboratory analysis, particularly in remote areas of the country, indicate the need for community involvement in WQ monitoring. Therefore, there is a need for training of school children and local communities to carry out simple measurement. However, such training will require a prior development of community training staff and training materials. They can handle all aspects of WQ analysis, monitoring and reporting within the given environments.

3.3.2 Proposed improvement on existing WQ training

3.3.2.1 Institutional training

In order to undertake water quality assurance and quality monitoring programmes successfully, it is important to have a number of qualified WQ trained personnel to carry out community awareness creation, community training, routine sampling and testing. From the existing course modules in different academic institutions in the country, modules related to community WQ awareness and monitoring are missing while others need to be provided for other levels. At the technician level, it is important to introduce two modules related to hazardous wastes examination (module 1) and community water quality monitoring (module 2) (Table 3.5). The modules can be stand-alone modules which can be taught for short courses aimed at improving technical capacity of existing WQ technicians. The modules are expected to provide technicians who are capable of providing demostration training to communities and engaging in field works in remote areas of the country.

Similarly, modules 2 – 6 are suitable for undergraduate trainees in engineering and science targeting at advocating understanding of WQ aspects of monitoring and training of communities to improve their participation in the WQ monitoring programmes. Modules 2, 4, 5 and 6 can be included in post-graduate curricula so that researches can be conducted to improve our understanding of the role of communities in WQ monitoring in Tanzania and provide advanced methods and techniques for WQ analysis and monitoring.

Table 3.5: Proposed water quality training modules for institutions, schools and communities.

Module 1: Hazardous Wastes Examination
Objective: To promote better knowledge of sampling and examining hazardous waste chemicals present in water. **General topics**: • Introduction to hazardous wastes • Hazardous wastes characteristics • Hazardous wastes generation and spread • Hazardous wastes and water pollution • Sampling and testing for hazardous chemicals
Module 2: Community Water Quality Monitoring
Objective: To enhance communityunderstanding of their environment, water quality and the need to monitor their quality for their protection. **General topics**: • Introduction to environmental and water quality protection • Water quality aspects (physical, chemical and microbiological) • Community activities and water quality pollution • Water quality monitoring: Importance of macro-invertebrates and fish as indicators of water pollution • Water quality monitoring: Simple methods for water quality sampling and testing • Water quality data analysis, interpretation and reporting • Water pollution prevention and control • Designing community water quality monitoring programmes
Module 3: Communities and Hazardous Wastes
Objective: To provide better understanding of the roles of communities on the generation, spread, storage, treatment and disposal of hazardous wastes. **General topics**: • Introduction to hazardous wastes • Hazardous waste characteristics • Identification of hazardous wastes • Management of hazardous wastes: Reduced consumption • Management of hazardous wastes: Community recycling • Management of hazardous wastes: Community treatment and disposal technologies
Module 4: Chemical Pollution and Water Microbiology
Objective: To promote understanding of the role of different water chemical contaminants on the decay of micro-organisms present in water. **General topics**: • Introduction to water micro-biology • Microbial growth and decay in water • Pathogenic micro-organisms decay and water chemical pollutants • Indicator micro-organisms decay and water chemical pollutants

Table 3.5 (*Cont'd*)

Module 5: Remediation of Chemically Polluted Waters
Objective: To promote understanding of technologies available for remediation of chemically contaminated waters **General topics**: • Sources of chemical water pollutants • Kinetics of chemical water pollutions • Remediation of polluted waters: metals recovery technologies • Remediation of polluted waters: recovery technologies for solvents and liquid chemicals • Community recovery technologies
Module 6: Water Quality Mapping and Data Management
Objective: To provide relevant techniques for mapping WQ parameters to promote spatial analysis of the health of water resources for WQ monitoring. **General topics**: • Introduction to GIS • Database creation and management • Application of GIS in water resources mapping • WQ parameters spatial analysis

3.3.2.2 School and community WQ training

Although emphasis is always given to training of specialists of middle and high levels, the sustainability of health and quality water resources depends on the level of involvement of the communities and all polluters and potential polluters of the environment. The community involvement is among the major component of any successful WQ monitoring programme as communities are among the major polluters of water and the environment.

In most cases, the members of the communities have little knowledge of the relationships between their socio-economic activities and environmental and water pollution. This situation suggests that, in order to effectively involve local communities in the maintenance of good water quality, it is important to provide education on environmental and water pollution and the role of communities in preventing quality deterioration and restoring quality of polluted waters. This education is necessary and always facilitates community participation in water quality monitoring programmes. Several methods can be used in providing such education to the community and include

i) public awareness meeting,
ii) seminars,
iii) volunteers training sessions,
iv) books and notes,
v) posters, banners and leaflets,
vi) community environmental days, etc.

The topics may include those indicated in modules 2, 3 and 5 (Table 3.5) and should be selected depending on the community group that is targeted. It is strongly recommended that, for communities to appreciate the importance of environmental and water quality protection, lectures should be supplemented by field demonstrations to concretise the knowledge. During these demostration visits, trainees can be asked to perform some few activities following actual demostrations from the trainers. This may include

i) identifying and listing down all activities (at sight) that they think may be depleting the quality of water at that particular place,
ii) listinging down major and minor water pollutants at that particular place,
iii) indicating things which can be used as indicators for water quality monitoring,
iv) carrying out water sampling and measuring exercises.

During the field demostrations, trainers can demonstrate on how to calibrate and use simple sampling and testing equipment as well as monitoring techniques and indicators. Some of these equipment and indicators are given in Table 3.6. This process always works with school children and community members. It has often led to rapid acceptability of community water quality monitoring programmes.

Table 3.6: WQ parameters to monitor, monitoring equipment and indicators for community use.

Parameter	Indication	Equipment/Tool/Indicator
Turbidity	Sediments, inorganics	Turbidimeter
Colour	Organic and mental contamination	Colour scale
Odour	Organic contamination	Odour type scale
pH	Water acidity or alkalinity	pH meter
Temperature	Water stress for aquatic life, DO concentrations, lake stratification	Thermometers
Conductivity	Extent of dissolved salts in water	Conductivity/TDS meter
Phosphate	Nutrients status	
Nitrate	Nutrient status	
DO	Organic pollution, over-enriched water	DO meter
Fish	State of water pollution	Number of fish

SECTION 4
A WATER QUALITY ASSURANCE AND MONITORING PROGRAMME

4.1 INTRODUCTION

The emphasis is always given to high level monitoring of WQ through sampling and analysis of major parameters of concern by regulatory authorities. However, the sustainability of health and quality water resources depends on the level of involvement of the communities and all polluters and potential polluters of the environment in the whole pollution prevention and remediation process. This requires establishment of a comprehensive water quality assurance and quality monitoring programme that take on board all actors including regulatory authorities (e.g. NEMC), WQ testers (WQ laboratories), polluters (local communities, industries, commercial outlets, mines, etc) and policy makers (MoW, MAFS, etc). Therefore, this section presents the proposed WQ assurance and quality monitoring programme and its implementability.

4.2 WQ ASSURANCE PROGRAMME

4.2.1 Existing WQ assurance situation

WQ assurance requires quality analyses to provide good results. The quality of analysis results is significantly affected by several factors including i) sampling and analysis methods, ii) quality of testing equipment and iii) education and experience of analysts. Technicians in various laboratories in thecountry are well-trained to accurately carry out water sampling for analysis. It was observed that the quality of results of laboratory and field WQ analysis was affected mainly by the quality of testing equipment, testing method used and level of education and experience of the analyst. Despite the fact that most laboratories use established standard methods and procedures like that of AWWA of the USA for water quality testing, results of laboratory analyses were sometimes different between laboratories. This was contributed by either the use of modern against old equipment, the different analysis methods, the different level of analysis experience of laboratory personnel incharge or a combination of them.

The differences of results of WQ analysis between laboratories were significant for certain parameters compared to others and sometimes led difficulties in providing conclusions. In order to avoid such post-analysis difficulties, it is usually recommended to have a classification of laboratories according to commonly agreed criteria for quality analyses. The criteria may include i) overall quality of analysis, ii) quality of physical analysis, iii) quality of chemical analysis and iv) quality of microbiological analysis. Thereafter, laboratories can be categorised into various classes based on any of these criteria in which, for example, Class A laboratories in chemical analysis provide the best quality results of chemical analysis. Such categorisation will facilitate inter-comparison of laboratories and ultimately facilitates recommendation of laboratories for different WQ analyses. If for example, high quality results are required, then Class A laboratories will be recommended and client will have a list of all Class A laboratories in the country for selection. This is expected to improve the quality of WQ analysis from the current practise of clients going for cheaper WQ testing laboratories whose quality of results is doubtful.

Despite the importance of laboratory accreditation with respect to the quality of laboratory analyses, there is no any such water quality assurance programme in Tanzania. Laboratories are simply carrying out WQ analyses in accordance to available standard analysis methods and the quality of the results relies on the accuracy of the analyst and expert interpretation. Moreover, only TBS and four (4) MoW laboratories in Dar es Salaam, Mbeya, Mwanza and Tanga are actually participating in different inter-laboratory proficiency testing in which laboratories are guided in the quality management and analytical proficiency. Whilst MoW laboratories are participating in Global Environmental Monitoring System (GEMS)/Water global netowork of WQ laboratories, TBS participates in a similar programme within the SADC region through the committee of Experts for standards, quality assurance, accreditation and metrology.

4.2.2 Proposed WQ assurance programme

Therefore, in order to esatablish an appropriate and sustainable in-country WQ assurance programme, it is important to introduce a programme coordination unit and thereafter formulate a WQ assurance programme. The programme coordination unit can be located within any of Ministry of Environment, Ministry of Water or regulatory authorities (e.g. NEMC) which are responsible for environmental and water management and form part of the broad Environmental Monitoring Division (Fig 4.1). It will consist of the principal coordinator or director and tthree main sections, the Programme Development and Implementation (PDI) section, Quality Assurance (QA) section and the Central Database section. Its overall duties may include, but not limited to,

i) establishment of WQ assurance programme,
ii) recommending appropriate standard methods for WQ analysis,
iii) carrying out laboratory classification and
iv) periodic evaluation of the quality of laboratory analyses.

The PDI section will deal with the design of the WQ assurance programme and supervise its implementation across the country while the QA section will be involved in the categorisation of laboratories and carrying out periodic evaluation of laboratories testing quality. The QA section will be responsible for the review of all methods of analysis currently used in different laboratories in the country. The review will form the basis for recommending a few methods which most appropriate suit Tanzanian environment. The section will then be involved in supervising the implementation of selected methods so as to create a common platform for periodic evaluation of laboratory analysis capacity.

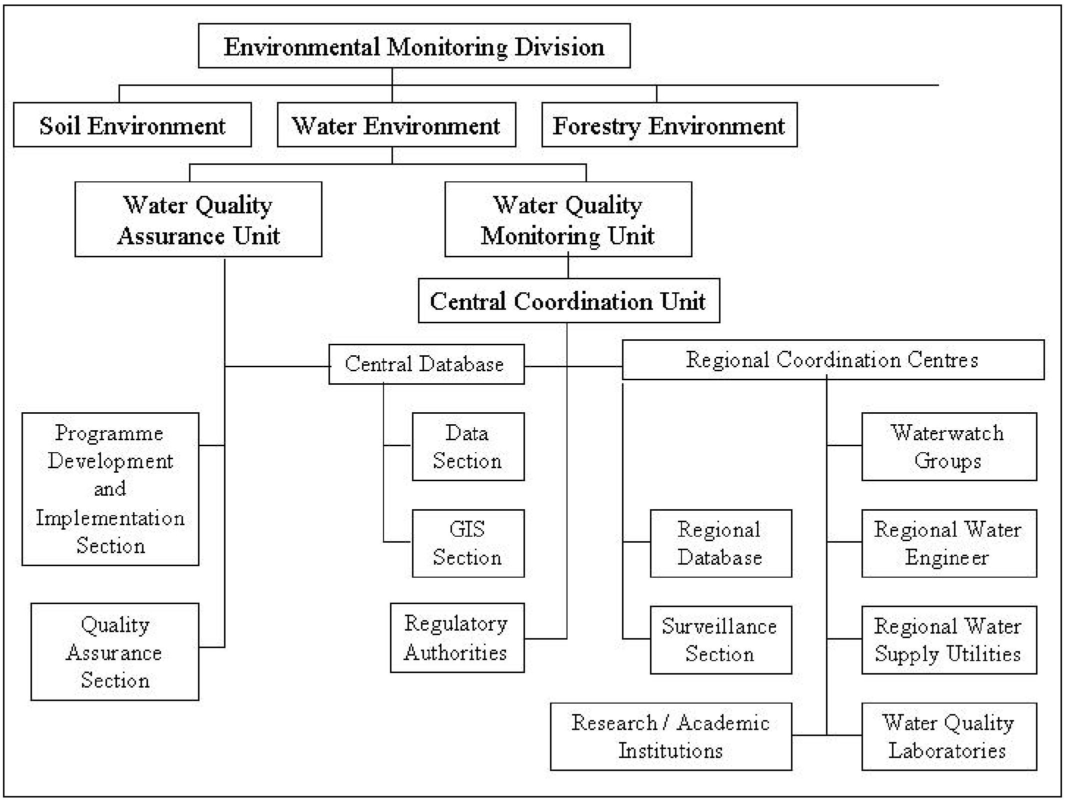

Fig 4.1: Proposed organisation of technical WQ Assurance and Monitoring Programme coordination.

4.3 WQ MONITORING PROGRAMME

It is a common practice in Tanzania to rely on enforcement of environmental compliance through legal processes involving sampling and testing of water samples collected from industrial effluents and receiving waters to ensure safety of water resources. However, most of production facilities in urban areas of the country cannot attain the most economic profit margins while ensuring meeting environmental standards for their effluent discharges due to their outdated production technologies.

Moreover, pollutants from domestic and agricultural areas are usually not monitored. This situation has led to widespread of pollution across the country and consequently to decline of water resources in the country from pollution problems including waterweeds in several lakes including lakes Victoria and Jipe.

4.2.1 WQ monitoring programme coordination

Therefore, for any successful water quality monitoring programme, it is important to involve all stakeholders within the communities including industrialists, traders and local people. This creates the community water quality monitoring programme which, through education and awareness raising campaigns, will ultimately ensure maintenance of better quality of surface and ground water resources. The programme will essentially coordinate environmental monitoring activities performed by established community "*water watch*" groups and linked with regulatory authorities including the National Environmental Monitoring Council (NEMC) and WQ laboratories and research institutions. The programme will therefore comprise

i) The central (country) coordination unit,
ii) Regional coordination centres and
iii) Surveillance programmes

The central coordination unit and regional coordination centres include within its departments, the *database* and *field surveillance* sections. The latter section will be responsible for designing and implementation of the surveillance programme that includes awareness campaigns, community *waterwatch* volunteers training and fields sampling and testing and collection of available WQ information from *waterwatch* groups. The proposed technical organisation structure of the central unit and regional coordination units is given in Fig 4.1.

The information will then be georeferenced and archived in databases at regional centres and central coordination unit. From these georeferenced WQ information, the performance of each water body within a small geographic unit represented by a single *waterwatch* group can be compared to those in other regions across the country. However, it is important to ensure that data of reasonable or high quality from *waterwatch* groups is archived. This could be achieved through design of a surveillance training programme that incorporates required community training, measurement equipment and measurement frequency while taking into consideration local geographical factors.

The surveillance programme for water quality will aim at

i) raising awareness and knowledge of communities on the importance of maintaining water resources at good quality.
ii) enhancing community understanding of its roles on water pollution.
iii) providing community training on water quality monitoring through sampling, analysis and reporting.
iv) providing platform for all stakeholders involved in the maintenance of required water quality level.

The programme will generally involve monitoring and assessing the i) regulated contaminants and ii) unregulated contaminants that are found and suspected to be found in surface and ground water resources. The unregulated contaminants are referred to those which do not have preset health-based standards.

4.3.2 Implementation of WQ monitoring programme

The daily implementation of the programme will be coordinated by regional coordinators at regional coordination centres. They will be responsible for supervising i) collection and archiving WQ data from various sources within the region, ii) enhancement of working partnerships between institutions and communities and iii) community training on WQ issues. Regional coordination centres will link directly and regularly with the central coordination unit and provide data to the central database for country evaluation of water quality monitoring.

For a proper implementation of the WQ monitoring programme to ensure maintenance of quality water resources, the roles of each participant must clearly be outlined with respect to WQ monitoring level. The criteria for delineation of responsibilities may include

i) the accessbility problem of remote sites,
ii) the expertise required,
iii) availability of measurement equipment and competence in using them,
iv) working environment of WQ experts (e.g. laboratories, training institutions, etc) and
v) the type of works performed by institutions

The allocation of roles could generally depend on the type of works performed by various institutions while communities can volunteer WQ monitoring in their places. This will therefore distinguish between quality monitoring for drinking water and for water resources in general. The water supply utilities, regulatory authorities and WQ laboratories can effectively carry out such monitoring from the water supply intake to the consumer end points. In remote areas of the country where water quality laboratories are distant, volunteer communities *waterwatch* groups can be trained to monitor the state of the quality of water resources in their vicinity and carry out water quality measurements. Periodically, members of *waterwatch* groups can be asked to provide samples for laboratory testing and subsequent archiving. On the other hand, laboratory personnel could be the reliable sources of WQ information from their data while research institutions could be responsible for undertaking improvements on WQ technologies and training materials and facilities.

Owing to limited spatial distribution of WQ laboratories in Tanzania and few types of equipment for analysis of all WQ parameters, the following parameters are considered most indicative of the health water resources and which can be easily measured and tested (Table 4.1).

Table 4.1: Water quality parameters for community monitoring.

Main purpose	Comments	Critical things to test or survey						Locating your sites			When do you test?	
		Physical/chemical tests			Macro-invertebrates	Algae	Habitat	Reference, impact and recovery sites	Sample in paired catchments	Other areas to test	Regular	Other times
Establish a baseline	Essential if condition of waterway is not known	pH turbidity temp flow	PO_4(o) nitrate DO	PO_4 (t) conductivity velocity	✔	✔	✔	✔ reference site		Choose representative sites, bottom of main tributaries	Weekly – monthly for physical/ chemical site tests during base flow conditions Twice yearly for macro-invertebrates	
Determine suitability for particular uses:												
Protection of aquatic ecosystems	Ecosystems are affected by many contaminants and by clearing of riparian vegetation	turbidity temp pH	PO_4 (o) nitrate DO	PO_4 (t) conductivity	✔	✔	✔			Sample within waterbody to be protected	As above	
Drinking water	Quality determined by chemicals, bacteria and taste	turbidity pH	nitrate taste	conductivity		✔	✔			Sample drinking water	Weekly to monthly for physical/ chemical tests	
Recreation	Bacteria and aesthetics are main problems	turbidity				✔	✔			Sample at recreation site		During times of recreational use
Agriculture	Farm productivity may be affected by poor water quality	conductivity pH	nitrate	pesticides	✔	✔	✔	✔	✔	Sample water used for agriculture	Weekly to monthly for physical/ chemical tests	Sample water used for irrigation during summer
Assess effect of land uses/contamination sources:												
Forest practices	Roading, clearing and fires can lead to soil erosion and algal growth Herbicides may be used	turbidity velocity	PO_4 (o) nitrate	flow	✔		✔	✔	✔			During rain

Main purpose	Comments	Critical things to test or survey					Locating your sites			When do you test?	
		Physical/chemical tests	Macro-invertebrates	Algae	Habitat	Reference, impact and recovery sites	Sample in paired catchments	Other areas to test	Regular	Other times
Urbanisation/ stormwater	Runoff contamination and flooding are common problems	pH, turbidity, flow, PO_4 (o), nitrate, velocity, DO	✔	✔	✔	✔	✔	Sample at run-off points	✔	During rain and discharge events
Livestock operations	Manure, bacteria and nutrients from feedlots affect waterways	turbidity, DO, PO_4 (o), nitrate	✔	✔	✔	✔			✔	Per discharge from feedlot and rain
Cropland/ pastures	Soil erosion from heavy grazing. Fertiliser or herbicide runoff and salinity problems.	turbidity, velocity, PO_4 (o), nitrate, flow, conductivity, PO4(t)	✔	✔	✔	✔	✔	Sample within cropping areas Sample ground water	✔	During rain and after fertilising
Mining operations	Sediment, tailings, dust, chemicals can have very long-term effect	turbidity, conductivity, DO, flow, pH, velocity	✔		✔	✔	✔	Sample at single point discharge sites		During rain and discharge events
Construction sites	High sediment and chemical runoff from poorly managed sites	turbidity, velocity, pH, flow, conductivity	✔		✔	✔	✔	Sample at run-off points		During rain and discharge events
Septic systems	Leaks, overflows and leachate can have severe effect on quality and cause health problems	nitrate, PO_4 (o)	✔	✔		✔	✔	For lakes, sample near and away from contamination source	✔	During times of high demand, rain and recreational use of waterway
Golf courses and playing fields	Runoff carries nutrients and pesticides	NO_3, PO_4 (o)	✔	✔	✔	✔	✔	Sample at runoff points	✔	During rain
Dams	Changes in flow rates during filling or releases stress aquatic ecosystem. Low DO release water is a problem.	turbidity, temp, DO, flow, pH, velocity	✔		✔	✔	✔	Profile temp and DO from top to bottom	✔	During filling of dam or release of stored water

SECTION 5
REFERENCES

AWWA (1985) Standard methods for the examination of water and wastewater, AWWA, 15th Edition, 1268p.

MoW (1988) Draft syllabus for the Full Technician Certificate Course in Water Resources Engineering and Water Laboratory Technology, Rwegarulila Water Resources Institute, 236p.

SUA (2001) Semester curriculum for Bachelor of Science Degree in Environmental Sciences and Management, 34p.

SUA (2004) Prospectus under the semester system 2004/2005, Mzumbe Book Project, 358p.

TBS (1997) Finalized Tanzania Standards: Specification for Drinking Water-Part-1, TZS 574. Dar es Salaam

UCLAS (2003) Postgraduate programme in Environmental Technology and Management, 85p.

UCLAS (2004) Curriculum for Bachelor of Science Degree in Environmental Engineering, 2nd Edition, 76p.

UDSM (2004) Prospectus, Directorate of Research and Publications, 558p.

US EPA (2003) List of contaminants and their maximum contaminant levels, EPA 816-F-03-016 June 2003.

US EPA (2004) National primary drinking water regulations.

US EPA (2004) National secondary drinking water regulations.

WHO (2006) Guideline for drinking water quality, Vol 1, 3rd Edition: Recommendations, First Addendum to Vol 1, WHO Press (Geneva), 595p.

WHO (2004) Guideline for drinking water quality, Vol 1, 3rd Edition: Recommendations, Sun Fung (China), 540p.

WHO (1997) Guideline for drinking water quality, Vol 3, 2nd Edition: Surveillance and control of community supplies, Best set/Interprint (Malta), 250p.

WHO (1998) Guideline for drinking water quality, Vol 2, 2nd Edition, Addendum to Vol 2: Health criteria and other supporting information, WHO Press (Geneva), 127p.