NIVA - REPORT

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Abstract: This report gives an overview over the Water Supply and Sanitation Sector in Tanzania, the educational possibilities within this Sector, the on-going water research activities and NIVA's assessment of the demand for water research and research cooperation with Tanzania institutions.

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Norwegian Institute for Water Research NIVA

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THE NEED FOR WATER RESEARCH IN TANZANIA

Oslo, May 1984
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FOREWORD

The Norwegian Institute for Water Research, NIVA, would like to thank the Norwegian Agency for International Development, NORAD, for sponsoring NIVA to undertake this study regarding the need for water research and research cooperation in three of the main partner countries of Norway; Zambia, Kenya and Tanzania.

We would also thank the institutions, civil servants and individuals with whom we have had fruitful discussions.

We do feel we have got relevant information of the water research situation in these countries and that we have got a base for recommending cooperation between Norwegian water research institutions and these developing countries in

- *training the scientists and technologists both through the provision of study abroad and through training programmes in developing countries,*
- *the implementation of major research programmes relating to water development,*
- *establishing a direct linkage through cooperation arrangements including joint research and developing programmes.*

Since the water development situations in Zambia, Kenya and Tanzania are different, we have chosen to write separate reports for each country. However, some of the chapters are very similar as these countries have almost the same water research requirements.

Oslo, May 1984

Svein Stene Johansen
Research Manager

CONTENT

List of content cont.. Page

RECOMMENDATION

This report gives and overview over the Water Supply and Sanitation Sector in Tanzania, the educational possibilities within this Sector, the on-going water research activities if any, and NIVA's assessment of the demand for water research and research cooperation with Tanzanian institutions.

1. There is an acute shortage of experienced professionals. The output from the University is too low. The situation is serious, and in connection with NORAD's technical assistance programme, this issue should be discussed thoroughly. As a short term measure, NORAD should offer scholarship for Tanzanians to study Public Health Engineering abroad.

2. There is an immediate need for water research activities in order to strengthen the Decade programme.

   NIVA thus recommends water research activities which are short and long term in nature.

   The short term research should be carried out on a contract basis using both consulting engineers and water research institutions.

   The short term research projects are listed in table 7.1.

   The long term research should be based on cooperation arrangements during the initial phase in order to build up and strengthen the national institutions.

3. Direct links should be established between The Ministry of Water and Energy (MAJI) and Norwegian water research institutions through co-operation arrangements. Such arrangements should provide for the undertaking of joint research and development programmes, including personnel and funds to establish a water research unit as well as funds for operating research programmes.

   The research and development programmes should be carried out to the maximum extent possible in Tanzania.

1. INTRODUCTION

The need for water research as part of water development is fully recognized in the developed countries, and water research institutions are working in close cooperation with the water authorities and ministries. Thus water research results are an important basis for decision-making in water management.

The same applies to the developing countries, but organized water research activities on national basis are only to some degree implemented.

In order to get an overview over the situation, The Norwegian Institute for Water Research, NIVA, applied to the Norwegian Agency for International Development, NORAD, for research founds to undertake a study regarding the water research situation in developing countries, particularly in NORAD's main partner countries.

The study was limited to a desk study and was carried out in 1980. The study should investigate:

a) the need for water research in the main partner countries of Norway
b) ongoing and planned research activities in water development for developing countries including a brief description of the research projects.

The aim of the study was to give NORAD a base for considering a cooperation between Norwegian water research institutions and developing countries in:

- training scientists and technologists both through the provision of study abroad and through training programmes in developing countries,
- the implementation of major research programmes relating to water developing,
- establishing a direct linkage through cooperation arrangements including joint research and developing programmes.

In order to carry out the desk survey NIVA sent out questionnaires to organizations, firms and institutions involved in water development programmes in the developing countries.

Based on the desk study, NIVA put forward the following recommendation to NORAD:

1. Direct linkage should be established between the Norwegian research base and intitutions in the developing countries. Such arrangements should provide for the undertaking of joint research and developing programmes.

2. The research should to the maximum extent be carried out in the developing countries.

3. The development of human resources is an important part of the research activities. The Norwegian research base should cooperate with developing countries in training their scientists and technologists both through the provision of fellowships for the study in Norway and through training programmes in developing countries involving scientists and technologists from the countries.

4. NORAD should devote more resources to water research relevant to the developing countries in connection with the water development programmes financed by NORAD.

   Water development programmes are long term in nature and will always include important water research activities which should be part of the programmes.

In 1982 we were asked by NORAD to follow up the above mentioned desk survey of 1980 by visiting relevant water development institutions in the following three main partner countries of NORAD; Kenya, Tanzania and Zambia.

The findings and recommendations should be reported to NORAD and the report should cover, but not be limited to the following items:

1. Brief description of the current national water development programmes, the related water research activities and educational possibilities within the water sector.

2. The need for water research and social studies in view of paragraph 1 above. Relevant research activities should be listed and given a priority ranking.

3. A list of the relevant institutions and the Governments' interest in cooperation.

4. Detailed description of relevant institutions, especially the part of the organizations for which a cooperation could be possible.

5. Recommendations to NORAD with regards to:

   a) Project related research which could be undertaken on consultancy basis
   b) Institutional arrangements, i.e. direct linkages between the proposed research systems of the developing countries and the Norwegian research institutions through cooperative arrangements. Such arrangements should provide for the undertaking of joint research and development programmes (a above) and the development and strengthening of the process of restructuring and improving existing systems to meet the water research requirements.

This study was carried out during February and March, 1983.

2. CURRENT NATIONAL WATER DEVELOPMENT PROGRAMMES

2.1. Historic

The history of Water Supply Development in Tanzania has its beginning well before Independence. Nevertheless, only towns and few major settlements had the privilege of getting this important service at that time.

After Independence, the programme of water supply development was extended to cover rural areas as well.

However, the real emphasis on the development of water supply for use by the people and livestock started in 1971. In that year the ruling Party made a major policy decision which committed the Government to the task; by the year 1991 every Tanzanian gets an access to a drinkable water tap of source within a walking distance of 400 metres. The Ministry of Water and Power, at that time, was given the directive to implement the decision. This was the beginning of the 20 years water development programme.

At the beginning of the programme it became evident that several factors would impede the timely implementation of the programme. One of them was the manpower issue. The need for people with right expertise in planning, preparation, construction, operation, and maintenance of water supply system is one of the key factors in the successful implementation of water programmes.

At the beginning of the programme, there were hardly any people with enough expertise to carry out the programme. There were only a few expatriates working as Engineers and some as Technicians supported by a few local experts, mostly technicians. In all, there were no more than 10 local Engineers throughout the country engaged in the water sector. At craftsman level, they were mostly skilled labourers without any or with very little basic training on how to handle the job.

This situation necessitated the Ministry to draw up a programme of obtaining the required personnel for the implementation of the programme as follows:- First were the immediate and short term plans for the recruitment of experts from outside the country. This was planned and implemented.

The second step was to draw up a short and long term training programme for Tanzanians. This requirement was worked out and submitted to the Government for approval in 1973. Though the requirement was inevitably beyond the Government is capability to train within the country, they were nevertheless approved as a requisite manpower requirement for the implementation of the programme. The strategies to achieve it were left to the Ministry of Water to work out.

The figures were based on the Ministry's objective of supplying every Tanzanian with water within 20 years from 1971.

The Decade target in Tanzania of a water supply for all by 1991 within 400 meters of the house is apparently no longer considered feasible by many senior Tanzanian officials or by the donor agencies. It nevertheless remains the official goal of the Government and Party.

As yet no sanitation targets for the Decade have been set.

If and when an integrated water supply-sanitation policy is formulated it could be expected that some of the money allocated for rural supply might be transferred to sanitation projects but it is also to be expected that such a policy would attract additional donor support to the overall water supply-sanitation sector.

2.2. Water Supplies in Tanzania

Table 1 shows the coverage for both water supply and sanitation in 1975 and 1980. Actual coverage is much lower in both cases. In the case of water supply, more than 50 percent and up to 75 percent of the water supply systems are periodically not working, due to problems of fuel, maintenance and repair capability and management deficiencies. It is suspected that many are not adequately treating the water.

Until recently the emphasis in rural areas has been on diesel pumped systems and, where feasible, gravity fed systems. Now the much more economical schemes which rely on shallow wells and handpumps are being introduced where hydrogeological conditions exist.

No charges are made for water in rural areas. Revenues from metered urban water supplies (house connections) cover an estimated 75 percent of the operating expenses for urban and rural water supplies. Approximately TSh.40 million are required for annual operation and maintenance. The operation of piped systems are estimated to cost TSh.30 per capita per year while shallow wells with handpumps cost TSh.3 per capita per year. The capital costs of piped systems in rural areas vary from 100 - 500 TSh. per capita per year.

In 1978-79 the budget for water supply was TSh. 311 million, of which 72 percent was in foreign exchange and 28 percent local currency.

For the structure of the MAJI Ministry see Figure 1. For the structure in the regions, see Figure 2.

2.3. On-Going Water and Sanitation Projects

A brief summary of the enormous on-going activity in the water supply sector on the part of donors is presented in Table 2.

In the absence of a National Water Master Plan, the strategy pursued by each of the donors varies considerably. The Finns have implementation units linked to specific projects. The Danes, Norwegians and Swedes have implementation units which are more closely linked to the office of the Regional Water Engineer. the Dutch operate with minimal connections to the Regional Development Director of the Regional Water Engineer. An important and different project is the Dutch-financed IRC Project for community education and participation. This is a 16-month project whose objective is to provide support to community water supply and sanitation agencies for developing and field-testing a community education and participation component. The project will work through the Community Development Department of the PMO, a department which will ultimately be staffed to the ward level.

Table 1. <u>Community water supply</u>. Comparison of Services 1975 and 1980.

		1975		1980	
		No. of systems in thousands	%	No. of systems in thousands	%
URBAN POPULATION SERVED	By House Connections	264	14	546	25
	By Public Standpost	1,054	54	1,274	57
	Sub Total	1,318	68	1,820	82
RURAL POPULATION SERVED		2,416	17	4,500	28
GRAND TOTAL		3,734	23	6,320	34

Source: World Bank Technical Advisory Group Report.

Figure 1: Organization Chart for MAJI Ministry.

DEPUTY MINISTER

PRINCIPAL SECRETARY

INTERNAL AUDIT

PROJECT PREPARATION DIVISION	CONSTRUCTION AND MAINTENANCE	MANPOWER DEVELOPMENT AND AMINISTR.	PLANNING
HYDROLOGY	CONSTRUCTION	FINANCE	WATER
GEOPHYSICS	PLANNING AND CONTACTS	ESTABLISHMENT	ENERGY
RESEARCH	DRILLING	RECRUITMENT	
DESIGN	EARTH MOVING	TRAINING	
	WATER WORKS	WATER OFFICE	TANECSO
WMPCU	MAINTENANCE		RUBADA
	WORKSHOPS	SUPPLY	TPDC
	PLANT AND TRANSPORT		NUWA
	WORKS AND MAINTENANCE		

Source: MAJI Official Report

Figure 2. <u>Organization of MAJI - Regional level</u>

MAJI Headquarters --- Prime ministers office

Presidents office

Regional commissioner

Regional development director

Regional financial officer

Regional planning officer

MAJI regional water eng.

Other decintr. tech. ministries

Planning and project preparation

Water resource

Construction

Operation and maintenance

Administration

Area commissioner chairman of DDC

District planning officer

MAJI district water engineer

Other dec. tech. ministries

Water resource

Construction

Operation and maintenance

Administration

Source: MAJI Official Report.

Table 2. Bilateral and international organizations involved in the water supply sector.

AGENCY	PROJECT REGION(S)	STAGE OF IMPLEMENTATION AND REMARKS
Australian Government	Singida	Project under implementation
British High Commission	Lindi and Mtwara	Project under implementation only financial materials
Canada Government	Coast & Dar es Salaam	Study and survey phase
DANIDA	Irringa, Mbeya and Ruvuma	Project started implementation
Federal Republic of Germany	Tanga	Almost completed
Finland Government	Lindi and Mtwara	Project under implementation
Japanese Government	Kilimanjaro	Study and survey phase
Norway Government	Kigoma and Rukwa	Started implementation
Royal Netherland Govt.	Morogoro & Chinyanga	Completed Shinyanga and started implementation in Morogoro
SIDA	Mwanza, Mara and Kagera	Implementation stages
World Bank	Tabora	Also financing some rural integrated projects

Sources: UNDP/WHO Report by Hassan

3. MANPOWER REQUIREMENTS IN THE MINISTRY OF WATER AND ENERGY (MAJI)

3.1. Manpower Projections

At present about 35 percent of the population of Tanzania is served by an improved water supply system. While the goal of water for all by 1991 is still officially sanctioned it is clear that this goal will not be met.

For the purpose of making reasonable manpower projections WASH assumed that 70 % of the population of Tanzania will have access to clean water by 1991. The population to be served will be about 18 million.

In deriving projections for the numbers of different categories of personnel which may be needed in the water sector in Tanzania by 1991 the following sources were used:

- WHO guidelines on total required staff derived from detailed manpower assessments in other developing countries
- A detailed recent anaysis of the manpower needed in the water sector of Mozambique
- A World Bank analysis of the mix of different personnel in the water sector of developing countries.

The WHO guidelines suggest that in a stable, well-developed rural water undertaking a ratio of one employee to 1,600 population can be expected. Assuming that 70 percent of the population of 25 million will be served in 1991, this implies a total water sector staff of 10,000 people. The World Bank presents data on the mix of personnel to be found in the water sector of rather more developed developing countries (Iran and Brazil). Adapting these data to the Tanzanian situation we suggest that a likely make-up of the water sector labour force may be:

Engineers	4 %
Technicians	14 %
Skilled Labour	28 %
Admin. and Accounting	22 %
Unskilled Labour	30 %
Total	100 %

These data suggest that by 1991 Tanzania will need about 400 engineers, 1,400 technicians, and 2,800 skilled labourers in the water sector.

In a detailed analysis of the manpower needs in Mozambique it was concluded that about one engineer will be needed for each 50,000 people served and about one technician for each 12,500 people served. These give a slightly lower, but quite similar figure to those derived from the WHO and World Bank data above. It may be concluded, therefore, that the projections made for Tanzania are valid estimates.

3.2. Present Production of Manpower

There are at present about 150 Tanzanian engineers working the regional water supply schemes. This number will increase to about 220 with the return of the 75 mechanical and electrical engineering students from India. Each year approximately 10 engineers who specialize in water engineering will graduate from the University of Dar Es Salaam (of a total of 60 graduates in civil engineering). Similarly about five of the 20 diploma graduates from the Technical College may be expected to work in the water sector.

By the end of the decade, therefore, it may be expected that a total of about 355 engineers (220 + 9(15)) will enter the water sector. It is thus necessary to increase somewhat the production of water engineers from Tanzanian institutes.

There are about 500 technicians at present in the water sector. By 1991 the WASH team estimates the requirement to be 1,400 technicians.

The MAJI Institute plans call for an annual production of 120 water sector technicians, or a production of 1,080 more technicians by 1991. Thus by 1991 a total of about 1,580 technicians will have graduated into service in the water sector. If the attrition rate from this cadre remains relatively low (about 12 percent overall) by 1991 the sector will have required 1,400 technicians.

For each technician about two skilled workers will be required. That is, by 1991 about 2,800 skilled workers will be required in the sector (by 1991). There are at present about 600 such workers in the sector, while each region plans to produce about 20 such workers per year. At this production rate, a total of about 4,200 skilled workers will have entered the sector by 1991. This implies that even at an overall attrition rate of 30 percent there would be sufficient skilled workers if present training levels were maintained.

In summary, an analysis of the manpower needs in quantitative terms alone, suggests that present training programmes are sufficient to meet the manpower needs for the Decade in the water supply sector.

4. RELEVANT INSTITUTION FOR COOPERATION

4.1. Ministry of Water and Energy

According to fig. 1, Organization Chart for MAJI Ministry, a research section exists in the Project Preparation Division.

However, the Research Section is not operational due to lack of funds and skilled personnel.

The Water Master Planning Coordination Unit, WMPCU, is within the same division and is supposed to coordinate the regional master water plans currently carried out by different Consulting Engineering Firms. The WMPCU should be in the position to initiate and coordinate water research connected to the regional master water plans.

4.2. University of Dar Es Salaam

4.2.1. Faculty of Engineering

The Faculty of Engineering has got some facilities to carry out a limited amount of water research, especially through post-graduate students.

However, the research work is hampered because of the lack of funds and transport.

4.2.2. Institute of Resource Assessment

The Institute of Resource Assessment, previously called BRALUP, has for more than a decade been involved in social studies related to water and sanitation development. The institute has thus been involved in the NORAD financed water and sanitation programmes in Rukwa and Kigoma regions.

5. CURRENT WATER RESEARCH ACTIVITIES

5.1. Ministry of Water and Energy (MAJI)

5.1.1. Water Research Section

This section was not in operation during the time the field survey took place.

The Consultants engaged in the Regional Master Water Plans were to some extent involved in Pilot Projects and R & D Projects. However, the WMPCU could not give details.

5.2. University of Dar Es Salaam

5.2.1. Faculty of Engineering

The Faculty of Engineering was at the time of the visit not involved in water and sanitation research projects. They had, however, research plans and project proposals on pre-treatment in connection with slow sandfiltration in connection with the regional master water plans.

5.2.2. Institute of Resource Assessment

The institute is engaged in several research projects related to water and sanitation development.

6. THE NEED FOR WATER RESEARCH AND SOCIAL SERVICES

6.1 General

In the industrialized countries water research is orientated towards their own needs. Thus it is imperative that developing countries should develop their own expertise. To be self-sufficient in water research requires positive moves to invest. Since the governments are the largest investors in the water sector in developing countries, the governments should also bear the major costs.

There is a need for action on the part of developed countries to support and facilitate the internal costs of developing countries to achieve development through establishment of endogenous scientific and technological capacities.

However, it will take time to achieve research potential in new water institutions in developing countries, and it will in the meantime be necessary to contract-out water research projects. It will probably take more than a decade to establish sufficient self operation activities on water management.

There are no obvious institutions to handle water research in the developing countries visited. Normally the Universities have the skilled manpower and the basic facilities. This is not always the case in developing countries. The Universities in developing countries are mostly short of qualified staff, funds and facilities.

The type of water research which is needed in developing countries is at present definitely applied research rather than research in the purest sense. There seems to be little space for fundamental research. The application of known technological principles and techniques to existing problems is the approach needed.

Water research projects supporting the national water programmes for the Decade should in our opinion have the highest priority and start immediately. These kind of R & D-projects are likely on an ad-hoc basis. This type of projects could be contracted out to project teams consisting of researchers and consulting engineers, but in close cooperation with the clients, local technical and scientific staff.

Water research is, however, long term in nature and it is important to build up competent local staff in order to make continuously evaluation and revisions to the research policy and priorities. Both research establishments and the Government must constantly be evaluating effectiveness of research investments by measuring the impact of research findings on water and sanitation development.

One major problem is the translation of successful research into practice. The researchers should do a continuous "state of the art review".

6.2 Water Resources

Water Resources Assessment requires knowledge of suitable water resources, surface water supplies as well as ground water resources. In order to assess these resources for human and livestock consumption, small-scale gardening supply, fishing, as well as for other user categories, it is important to;

a) study and evaluate existing hydrological and hydrogeological data,
b) identify and execute possible additional field investigation required in order to assess the water resources,
c) assess the suitability of the water resources,
d) prepare hydrological and hydrogeological maps of the country,
e) evaluate continuously existing data collection system in respect of water resources and propose eventual improvements of the system,
f) make suggestions with regard to the improvements in the control of water quality by setting up and implementing adequate water monitoring systems.

The paragraphs above are part of the Regional Master Water Plan. The drawback is, however, that a Master Water Plan is normally done on an ad-hoc basis which in the long term, is not sufficient for a proper management and the utilization of the water resources.

6.3 Standardization

6.3.1 Introduction

Norwegian Institute for Water Research, NIVA, has years ago applied to NORAD for R & D funds in order to assist the Water Authorities in the Main Partner Countries of NORAD to enable them to develop necessary standards.

The need for design standardization has increased considerably due to the prevailing economic situation which calls for more economical designs and more effective utilization of the design resources which are available in the developing countries.

6.3.2 Criteria and Guidelines

It is pertinent to look into the present set of criteria and guidelines for the design of water supplies and sanitation schemes. These need to undergo frequent revisions in order;

- to incorporate new policy decisions in particular regarding the service level and relevant new technology,
- to introduce criteria for more appropriate and cheaper technology,
- to make changes of the criteria or guidelines shown necessary from experience of design construction and operation & maintenance during the last years.

6.3.3 Design Manuals

The manuals shall contain general and detailed criteria and guidelines necessary for the design of water supply sanitation and sewerage projects.

It is envisaged that in the future more design work will be taken over by the developing countries and that the number of projects designed by expatriate consulting engineers will be reduced. A pre-requisite for such a development is that a number of type and standard drawings and descriptions are available, such as intake structures, various treatment units, storage tanks, staff houses, office buildings, etc. and a large number of detail drawings of various structures. Without such drawings it will not be possible to keep an acceptably high design standard at the same time as the work load of the design offices increases.

The current trend towards the use of appropriate technology for rural water supplies and sanitation will increase the need for drawings of simple structures such as wells, springs or rainwater catchment installations, etc. which can be used directly by the people building the structures without the assistance of a design engineer. Much effort has to be put into this kind of standard drawings to make them easy to understand for the laymen.

Standard Drawings and Type Drawings should be included in the Design Manual or appended to it. The Standard Drawings shall be used whenever applicable while the Type Drawings will only give examples of recommended solutions.

6.4 Water Supply Engineering

6.4.1 Operation and Maintenance Research

Operation and Maintenance (O & M) create crucial problems in developing countries. The reasons are manifold, thus not limited to only lack of skilled local manpower and funds.

Proper O & M-routines have to be worked out and implemented. This will, however, require major training programmes.

Some water works will require special attention in order to get an effective operation. Improvements to the present design will be necessary in order to solve the problems.

Some water works need rehabilitation, augmentation or up-grading. During NIVA's visits to water supplies in Africa, we have many times experienced that consulting engineers have proposed new supplies in stead of improving the existing systems. The local water authorities have not got the manpower required to critically examine the proposals or to suggest other solutions.

O & M-research will in this respect be of greatest importance in respect of up-dating and rehabilitating existing supplies.

O & M-research will most probably result in proposals which in term lower the O & M-costs tremendously. Many water supplies are, f.ex. based on coagulation by dosing chemicals into the water. Without proper dosing, a huge amount of chemicals are wasted.

6.4.2 Materials

The choice of materials in the different components of a water supply may be accidental or based on other criteria than the water quality. Choice of the materials of the pipes used for water distribution will similarly depend on the quality of soil. One has experienced many catastrophical examples of the consequences by neglecting the importance to consider the water qualities when selecting the materials.

Some components may be manufactured in the developing countries, however, proper test-procedures are of outmost importance, independently of the country of manufacture.

6.4.3 Distribution

Some of the problems related to distribution are mentioned in the above paragraphs 6.3.1 - 6.3.3.

A distribution system may depend on intake structures, pumps, pipes, storage tanks, etc. or buckets to be carried home.

Pumps

A world-wide research programme with regard to handpumps is going on. It is important that each country is selecting a limited number of different handpumps for their future requirements. The selection must be based on a proper test-programme. The programme is presently mostly carried out by expatriates because of lack of local research staff.

Pumps based on solar energy are under development. These pumps are still very costly, and a lot of research would be needed before these pumps are competitive.

Pumps based on windmills have been in operation for years, but through research, the efficiency of these pumps has been improved during the last year. However, the use of windmills depends on the local situation and must be adapted accordingly.

Pumping systems which use human power more efficiently should be developed further, besides improvements to existing animal lift systems need more research.

6.4.4 Treatment

i) General

New trends in water treatment need to be evaluated in respect to existing plants. Studies of the breakdowns may indicate that other systems and processes should have been chosen in the first place. Learning from mistakes is of major importance.

Up to date knowledge of existing low cost, appropriate technology will be another important aspect. The most promising systems should be followed up through pilot plant studies.

The possibilities of using local available media in filters, and local available coagulation and disinfection chemicals should be given high priority.

Realistic criteria or guidelines for drinking water quality should be worked out, based on health aspects, technical options and economy.

ii) Electrocoagulation

The project deals with the basic ideas and preliminary results from a developing project "Development of a Package Plant for Potable Water Treatment in Developing Countries" developed at NIVA. The treatment processes included in the package plant are; coagulation, flotation, alkalization, filtration and UV-disinfection, in other words, advanced potable water treatment. The coagulation, flotation and alkalization process is combined in one unit, the electrocoagulation process, which has proved effective for removal of organic matter and which is being tested with other parameters. This method is a simplification of the traditional coagulation process. The maintenance and operation of this system is simple. No handling of chemicals is required by the operator, and the change of the electrodes used in the unit is necessary only once a year.

The electrodes must be connected to a power plant, only 24 V are required. If the treatment plant is located far from an electricity distribution system, small solar cells should be used.

In order to simplify the conventional coagulation method, electrocoagulation using soluble aluminium electrodes could be used (Vik, 1982). The quality of the water available as source of supply varies considerably. In areas where only surface water is available, the water quality is often poor with great impurity. The sources can be shallow wells, streams or ponds. These sources are dependent on rainfall and surface runoff, and the water quality has enormous seasonal variations.

The coagulation process removes effectively various impurities from water. The objective of the research is to simplify the conventional coagulation process. A simplification of the conventional coagulation process will have a great potential in developing countries where the water must be treated to provide safe drinking water. Avoiding chemical handling is of major importance. A combination of electrocoagulation, granual-media filtration, and disinfection is studied in order to develop a package plant producing adequate water quality. UV-disinfection is used instead of the conventional chlorination process. This simple operating disinfection process (UV lamps must be changed once a year) can only be used for treated water or water with low turbidity and colour. The objective of this development project is to simplify the operation and maintenance of small scale treatment plants.

iii) Desalination

Hundreds of boreholes in Africa have got saline water and can not be used for human and livestock consumption.

Saline groundwater may be the only reliable water source in many areas. Many lakes are also saline. Thus it is of greatest importance to develop low-cost methods for renovation of saline waters for various uses.

NIVA proposed to NORAD some years ago to develop desalination cells based on solar energy. The development should take into consideration local manufacturing.

We are still of the opinion that the development of desalination cells should have high priority.

We also propose to use water-hyacinths to remove chlorides. Desalination and purification of slightly saline waters can be accomplished effectively by water hyacinth ponds.

iv) <u>Development of Low Technology Defluoriation Systems</u>

In special areas in Africa ground water and surface water have got a too high content of fluorides which make the water unsuitable as drinking water.

The limit set by WHO for acceptable fluoride concentrations in drinking water ranges from 0.7-1.5 mg/l. It is thought that human beings consuming water of fluoride concentration greater than 1.5 mg/l during their first 8 years of their life, suffer from dental fluoration or mottled enamel.

The actual effects of consuming water containing fluoride are not just confirmed to the teeth. The effects go deeper into the whole skeletal framework and in particular the backbone, resulting in backaches, bending and weakness of the skeleton.

Many African states are not in a position to adopt the WHO figure as they have no other alternative than using the water sources available. The development of low technology defluoridaton systems is thus of greatest importance. The first stage in such a research and development project will be as follows:

Laboratory investigations should be done to identify an absorbent which can be used in a low technology defluoridation system suitable for household or small community use in developing countries. The effectiveness of a variety of materials, including locally available plant and soil materials, will initially be tested using jar tests. Substances which exhibit ability to remove fluoride will then be tested in columns to determine removal capacity in water of various compositions. Components to be varied will include fluoride, alkalinity, turbidity, organics, and salinity, with the test concentrations to be based on maximum and minimum concentrations occurring in the target area.

Suitability of a defluoridation system will be evaluated based on the following criteria:

- Reduction of fluoride concentration from 10-20 mg/l to less than 1 mg/l.
- Fluoride removal capacity of media
- Operation and maintenance of system by local people possible
- Capital and operation/maintenance costs low
- Increase in toxicity of water due to improper operation of system unlikely.

During the evaluation of a proposed defluoridation system, media regeneration and disposal of waste products will also be considered.

v) <u>Pre-treatment - Slow Sand Filtration</u>

Slow Sand Filtration is used throughout Africa and is a simple but efficient treatment process to produce a hygienically safe drinking water. However, its application is limited and depends on the turbidity and suspended solids concentration in the raw water.

During the execution of the Water Pricing Study in Zambia, one experienced that of all the slow sandfilters visited, no one was in a proper working condition. There was no pre-treatment, the sand was dirty and so was the "clean water". The same problem may occur in Tanzania as well.

The objective of this proposal is to develop a simple, selfreliant pre-treatment method for use in connection with the existing slow sand filters.

vi) Low-Cost Household Water Treatment

Until public water supply systems actually deliver safe water to the consumer, it may be advisable to encourage the use of household water treatment.

In parts of the developing world one has used traditional water treatment methods for decades. These methods need to be further developed and improved. Due to the introduction of piped supplies, the traditional water treatment methods have been neglected without considering the water quality in the new supplies which may not be satisfactory.

Household water treatment units should be developed. The following options should be looked into:

1. Modified slow sand filter followed by disinfection by copper ions. The filtered water may be stored in a clean copper container for 24-48 hours. Alternatively cheaper specially designed copper-plate elements may be used along with other types of containers which are cheaper and locally produced.

   Clay pots are traditionally used as containers for transporting and storing water. Experiments carried out with clay pots show that clay has a purificational effect. Further investigations should be carried out.

2. Optimal Storage Tanks designed for households should be developed. During Storage, two main processes occur which improve water quality. These are the death of micro-organisms and sedimentation of solid particles. These particles may be the eggs or cysts of parasites, or inorganic particles.

The mineral particles will by adsorption remove a significant portion of bacteria and viruses, which will thus be dicearded by sedimentation by sedimentation.

3. The use of Rainwater Cisterns as a catchment system should be designed, developed and operated as an alternative or supplemental water supply. The cisterns should be designed with screens, sandfilters, activated carbon or membranes.

4. The principal disinfection agents used in water treatment are chlorine, chloramine, chlorine dioxide, silver and ozone.

   Chlorination remains the most widely used process at the present time.

   However, the use of chlorine in household water supply is for the time being not practiced in the developing countries. Electrolytical chlorination should be evaluated.

5. Artificial ultraviolet radiation (UV) is an effective way of disinfecting drinking water. (In combination with oxydants UV also removes organic matter). The use of natural UV as a disinfectant on tanked water (eventually in combination with oxydant) should be investigated.

6.4.5 Water Consumption Restricting Devices

One has experienced great problems with regard to reading, operation and maintenance of water meters. In addition come the problems of billing, collecting revenue and in many cases the disconnection procedure.

To simplify the revenue collection and to avoid the problems mentioned above, a water consumption restricting device (wcrd) should be developed.

The wcrd should allow a certain amount of water to the consumer equal to i.e. one month's average consumption. When that amount of water has been used, the wcrd has to be replaced by a new one to be bought from a store, public office, etc.

The wcrd must be cheap, reliable and easy to replace.

6.5 Sanitation

6.5.1 Water Borne Sanitation

i) Sewage Quantities and Composition

The need for information regarding the quantities and composition of the sewage is obvious.

Without a proper metering and sampling programme, further planning, design or cost estimates will be speculative and is not recommended.

Quantities

To get information of the sewage quantities - total and per capita - water measuring programmes should be implemented. Gauging stations should be installed on the inlet of existing waste-water treatment plants and the flow recorded continuously. The measuring will take place during a typical dry-season period and a typical wet season period.

To calculate the per capita flow a counting of the houses and inhabitants within the conntected area has to be done.

Composition

To find out the composition of the sewage, samples will be taken and analyzed. It is recommended to gather composite samples - both on incoming and outgoing flow - during the same periods as mentioned above and analyze them on the following parameters:

- BOD_7 (Biochemical Oxygen Demand)
- COD (Chemical Oxygen Demand)
- TS (Total Solids)

- TVS (Total Volatile Solids)
- TSS (Total Suspended Solids)
- TVSS (Total Volatile Suspended Solids)
- N (Total Nitrogen)
- NH_4-N (Ammonia Nitrogen)
- P (Total Phosphorus)

In addition it is recommended to analyze the samples on some bacteria, viruses and hook worms.

ii) Aquaculture System for Waste Water Treatment in Developing Countries

Introduction

Aquatic systems employing plants and animals are proposed as alternatives to conventional wastewater treatment system. The fundamental difference between conventional and aquatic systems is that in the former, wastewater is treated rapidly in highly managed environments, whereas in the latter, natural self-purification processes are utilized by establishing suitable combinations of aquatic organisms in more or less unmanaged natural environments. The consequences of this difference are

1) conventional systems require more construction and mechanization but less land than aquatic systems

2) conventional processes are subject to greater operational control and less environmental influence than aquatic processes.

The major stimulus for further research into the fundamentals, design, and management of aquatic systems is the potential for reducing the construction and operation and maintenance costs for wastewater treatment. Furthermore aquaculture systems may provide protein or other exploitable products.

These aspects are very promising with regards to the utilization in developing countries. The general concepts involved in the design and use of aquatic systems are presented and the implications are discussed in the following.

Wastewater characteristics and treatment (see also i) above)
The characteristics of the wastewater to be treated are of fundamental importance in the selection of design of treatment systems whether conventional or aquatic, employing plants and animals. Further, the performance, reliability, and cost of conventional treatment systems have become the standard against which other treatment systems must be compared. For these reasons, each of these topics is considered in the following discussion.

The principal contaminants of concern in wastewater are shown in paragraph i) above.

At the concentrations found in domestic wastewater, the contaminants of greatest concern are biodegradable organics, suspended solids, and pathogens. Problems stemming from the other contaminants are of a more subtle, long-term nature and are neither well understood nor closely regulated at this time.

The principal removal mechanisms for the contaminants of concern in wastewater in aquatic systems employing plants and animals are known. The removal mechanisms have been identified on the basis of observations of:

- natural systems such as marshes and wetlands

- laboratory and pilot scale studies of aquatic systems employing one or more plant and/or animal species.

An understanding of these mechanisms is important because the selection of plants and animals for use in aquatic systems will depend on the contaminants to be removed and the removal mechanisms that must be used for their removal.

In aquatic systems, the plants and animals themselves bring about very little actual treatment. The major treatment in these systems is accomplished by bacterial metabolism. In effect water hyacinth or wetland systems are similar to a large, slow-rate trickling filter with built-in secondary clarification.

Aquatic Processing Units: A Conceptual Model

An aquatic processing unit (APU) is defined as the assemblage of aquatic plants and animals grouped together to achieve a specific treatment objective (e.g. removal of nutrients and heavy metals). In this context, an APU is a definable physical entity that represents some discrete step in the treatment of a wastewater. For example, one or more APU's could be used in conjunction with conventional treatment methods to achieve a desired degree of wastewater treatment or several APU's could be used together to form an entirely aquatic treatment system.

The Need for Research

At present, very little is known about the use of plants and animals for the treatment of wastewater. Our knowledge is primarily related to the removal of nutrients, refactory organics and heavy metals.

Research is needed to define the conditions under which various types and compositions of aquatic species may be used in the tropics, and with special regards to the O & M aspects in developing countries.

6.5.2 Low Cost Sanitation

i) "State of the Art Review"

As complement to the sanitation programmes that are being carried out in developing countries, a number of multilateral and bilateral agencies have done and continue to do research in the sanitation sector. This is especially motivated by the "Water and Sanitation Decade". A State of the Art Review is highly recommended, and agencies of special interest are:

- The World Bank Technology Advisory Group (TAG)
- The International Development Research Centre of Canada

- UNICEF
- WHO/International Reference Centre
- USAID - Water and Sanitation for Health Programme (WASH)
- Asian Institute for Technology Bangkok/ENSIC (Environmental Sanitation Information Centre)
- B.I.E. - Bouwcentrum for International Education, the Netherlands
- Intermediate Technology Group, London

  etc.

ii) Composting of human wastes

General and experiences gained

Composting the wastes is an old method of reclaiming the substances in the wastes. Very little, however, has been done on composting fecal material in a container. During the last 10 years more than 25 different methods for composting fecal material have been produced in Scandinavia.

A biological toilet consists of a container that collects the feces and urine. This container is ventilated above the roof. After a certain period the composted material may be removed. During the composting, microorganisms decompose the organic materials into "soil" and CO_2. The compost contains a harmless "Soil flora". The Department of Microbiology at the Agricultural University of Norway has tested all the biological toilets on the Scandinavian market (45 tests) in their laboratory. They were tested with regards to capacity, strength and hygiene. From this experiment a few models were chosen for further testing in practical use. The Department of Microbiology has installed and continuously controlled about 150 toilets, in different parts of Norway.

Research requirements

The climate, price and method of use make it impossible to transfer our technology directly. We know that some experiments have been done in this field in Africa, and a number of problems have emerged:

- Many of the users are reluctant to handle excreta even in its composted form.
- The users have difficulty in providing the necessary maintenance inputs of adding carbonaceous material and thereby maintaining the correct carbon nitrogen ration required which results in the composts becoming aerobic.

To resolve these problems it is proposed that the composting latrines constructed in Tanzania and in Botswana during the middle 70's be visited to assess the operational difficulties before embarking on better development work in other African countries. This should be contracted against the very successful biological latrine programmes that operate in Thailand and Vietnam.

iii) The Ventilated Improved Pit Latrine (VIP)

General

The major problems associated with a traditionally constructed pit latrine are usually:

1) Short lift due to the pit collapsing and/or the pit becoming full.
2) They are malodorous
3) They are a focus of insect breeding especially flies which are a major vector of fecal oral disease transmission links and also in some instances are a focus of mosquito breeding.
4) The squatting plate is often foulded with feces and is difficult to clean and can be reservoir of hook worm larvae.

Over the past few years research projects in Botswana and Zimbabwe have developed on improved pit latrine in order to overcome these problems. The main features of the improved pit latrine are that it is relatively easier to clean, foul odours and fly breeding are controlled.

Permanence is ensured by providing a structural lining of the pit either for the full depth or partially. Sufficient volume is provided to give a useful life of 10 years or more.

The most important modification is the addition of a ventilation pipe or chimney, screened at the top with a mosquito gauze. This has the effect of controlled both odour and fly breeding which are inter linked.

Wind shear across the top of the chimney or ventilated pipe creates a strong updraft which vents out the foul odours. Gravid or egg laying flies who are attracted to their egg laying site by foul odour, follow the smell to the top of the vent-pipe, but cannot enter into the pit because of the gauze. Secondarily the few flies that do emerge from larvae in the pit are strongly phototactic and fly toward light, the greatest source of light into the pits is via the vent-pipe; therefore the young emergent flies travel up the vent, but are prevented from leaving by the gauze. The flies remain trapped until they dehydrate, die and fall back into the pit. This mechanism is reinforced by adopting a superstructure design that provides low light intensity in the interior of the superstructure.

The odour/fly control mechanism in ventilated pit latrines is well researched and established.

A variety of materials may be used to construct the superstructure. We suggest the following options to be included in a Pilot Project:

a) Concrete blocks, with tile or corrugated iron or asbestos cement roof.
b) Mud and water walls with thatch roof.
c) Thatch walls with thatch roof.

A variety of materials can be used to construct the squatting plate. We suggest the following to be included in a Pilot Project:

a) Timber with plastic cover
b) Reinforced concrete
c) Glass reinforced plastic
d) Ferrocement.

Pit Lining

It is not unusual that the pits collapse after 5-6 months in average due to the soil condition.

The pits have to be protected and different solutions should be considered.

The following options should be tested in a Pilot Project:

a) Timber used in the same way as framework for pillars.
b) Framework in basked material and produced by local basketmakers.
c) Cement/grass sheets.
d) Concrete or sand/cement blocks.

6.6 Water Related Research - Social Studies

6.6.1 General

Improvements to health through water supply and sanitation is a long term goal whose effectiveness is not easily measured. The provision of appropriate technology is in itself insufficient to achieve this aim.

The main requirements for a good water supply and sanitation programme are a full understanding of local conditions and practices, promotion and provision of appropriate facilities combined with a health education programme that can bring about behavioural changes in order to gain full benefit from the improved facilities.

In connection with Water Supply and Sanitation Development Programmes, it is recommended to undertake series of indepth studies that will enable the correct implementation strategy to be formulated.

6.6.2 Anthropological Study

Indepth national or regional studies to determine behavioural patterns to personal and domestic hygiene, water use and sanitary practices are recommended.

Specific regards shall be given to traditional customs and attitudes concerning excreta disposal and knowledge of disease transmission.

Such surveys will provide basic information as to what (if any) improvements can be made in domestic and sanitation practices in order to improve health.

It is important that such a study also provide data that will determine the form and level of education

a) in rural populations
b) in health personnel

required to bring about these changes and improvements.

Such studies could be carried out on a sample basis by enumerators in both rural and peri urban areas supervised and trained by social-anthropologists.

6.6.3 Socio-Economic Study

Indepth socio-economic studies to determine social and economic opportunity of the rural people and rural communities i.e. the money, skill, time available and willingness to participate in a sanitation programme are recommended.

Such studies shall provide data and information as to the most appropriate strategy to be accepted during physical implementation, minimum standards, and the scale of technical and/or financial subsidy that may be required and to what degree self help and self reliance may be utilized. Data collection will be part of the anthropologial study.

6.6.4 Health Education and Promotion

In the educational/promotional sector there are three major initiatives to be undertaken:

i) A promotion campaign to persuade communities and individuals to provide for themselves (perhaps with assistance) good water supply and sanitation facilities.

ii) A demonstration/technical help campaign to show how to build and help communities construct these facilities.

iii) A health education programme to support and reinforce the above investments by ensuring proper use and associated good hygiene practice.

The study shall propose and design the most effective methods, "media mixes", and programmes for delivering these messages. Emphasis will be placed on utilizing existing institutions and organizations within the country.

6.6.5 Community Participation and Implementation Strategy

The key to success in projects which demand social and behavioural change is to promote willing and active community and individual participation in both planning and implementing a project, this creates a sense of ownership and pride which reinforce continued use, operation and maintenance of any facility thereby provided.

Community participation strategies that have been successfully used in other countries undertaking similar projects are:

i) The community assists in planning and organizing a project (and perhaps provides some materials).

ii) The individual provides labour (and perhaps provides some materials).

iii) The donor/investigator provides financial or material assistance, technical assistance, education and training.

6.7 Development of Human Resources

Tanzania should co-operate with Norway in training their scientists and technologists both through the provision of fellowships for study in Norway and through training programmes in Tanzania involving Norwegian scientists and technologists. Such exposure and training should be undertaken in conformity with the needs, priorities and specific conditions agreed upon and proposed in this report.

7. PROPOSED WATER RESEARCH PRIORITIES FOR TANZANIA

7.1 General

NIVA is not in a position to give firm recommendations with regard to priorities on water research projects as the selection of projects depends to a great extent on the availability of economic and human resources.

The priority list NIVA is suggesting is divided into two parts.

The first part contains research activities which are long term in nature and require proper planning.

The second part contains R & D-projects which initially should be done on an ad-hoc basis by contracting out the work. These projects are directly linked to the International Decade for Drinking Water Supply and Sanitation and should have immediate priorities. It would of course be a great advantage if the activities of these two levels could advance in close contact.

7.2 Long Term Water Research Activities

The National Water Research Section under the Ministry of Water and Energy (MAJI) should be established. During the initial years, MAJI should be strengthened by a multidisciplinary water research team consisting of

1 hydrochemist
1 hydrobiologist
2 public health engineers/sampling engineers
1 hydrologist

and funds to upgrade existing facilities and to renew equipment.

MAJI has a good relationship to the University and both institutions and will cover all relevant aspects of water research if strengthened. The water research activities may be divided into:

1) Public Health Engineering Research
2) Water Resources Research.

i) Public Health Engineering Research:

The short term water research projects mentioned in chapter 7.3 need to be followed up and revised from time to time. Some of the proposed projects may prove to be long term in nature and will require considerable time to complete. It is important to have continuation in research and to develop human resources for research. A continuous state of the art review should be undertaken.

The choice of materials based on proper test-procedure will be of great importance. The demand for low cost and appropriate technology will be a main subject of interest. New trends in water treatment and disinfection should be followed up through pilot plant research.

ii) Water Resources Research

Some investigations have been carried out and some are in the implementation phase. However, there is an urgent need to get a water resource research programme properly organized and coordinated by MAJI. Such a programme should cover all the lakes, rivers and groundwater resources.

7.3 Short Term R & D-projects

In the table below we have indentified some R & D-projects which are very important to be carried out at our early stage of the Decade in order to select the best technical options taken into consideration aspects like economy, health, benefits, etc.

In the table we have given a brief description of the projects and proposed teams to carry them out. Terms of reference for these projects will be forwarded at a later stage.

Social studies should be part of the planning and implementation strategies for both water supply and sanitation.

SHORT TERM R & D-PROJECTS

No	Brief description of water research projects to be contracted out.	Ref. to chapter in this report	To be carried out by	Remarks
I	Development of design criterions and quidelines i) Water supply engineering ii) High cost sanitation iii) Low cost sanitation		CE/R/SA	The research projects I-III are all very important at an early state of development. Based on experience the criteria will have to be revized from time to time.
II	Standardization and the development of Design Manuals including Standard and Type Drawings for the items listed under I above.		CE/R	
III	Drinking water quality criteria or guidelines.		R	
IV	Pilot Project on Low Cost Sanitation.		CE/SA/R	Pilot Project
V	Pilot Project on the development of low cost water supply projects in the rural areas.		CF/R/SA	Should be part of the NORAD financed Water Supply Programme in Rukwa and Kigoma.
VI	Testing of handpumps in order to select and/or to manufacture locally		CE	
VII	Operation and maintenance research in order to upgrade existing facilities and to solve current O & M-problems including the reduction of costs.		R/CE	Many water supplies need rehabilitation, augementation or up-grading. For some of these projects Consulting Engineers have proposed new expensive designs which in some cases could have been avoided.
VIII	Treatment Electrocoagulation	6.4.4	R	The research projects listed under VIII are all very important as they are appropriate and cheap. They have all a great potential.
	Low-Cost Household Water Treatment	"	R	
	Optimal Storage Tanks Design	"	R/CF	
	Disinfection by using natural UV-radiation	"	R	
IX	Water Consumption Restricting Devices (wcrd)	6.4.5	R	The development of a wcrd which could simplify the revenue collection would be of great benefit.
X	Pre-treatment - Slow Sand Filtration	6.4.4	R	The development of a pre-treatment plant to use in connection with existing slow sand filters would be of greatest importance.

CE = Consulting Engineers
SA = Socialanthropologist
R = Researcher