NIVA – REPORT

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Report No.: 0-83014

Sub-No.: I

Serial No.: 1552

Limited distribution:

Report title:
The Need for Water Research in Kenya.
VA - 18/83

Date: September 1983

Project No: 0-83014

Author(s):
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Topic group: SEKVAT

Geographical area: AFRICA

Number of pages (incl. app.) 50

Contractor:
NORAD
NORWEGIAN AGENCY FOR INTERNATIONAL DEVELOPMENT

Contractors ref. (or NTNF - No):

Abstract:
This report gives an overview over the Water Supply and Sanitation Sector in Kenya, 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 Kenya institutions.

4 keywords, Norwegian
1. Vannforskning
2. Utviklings-land
3. Forsknings-samarbeid
4. Kenya
VA-18/83

4 keywords, English
1. Water Research
2. Developing Countries
3. Research Cooperation
4. Kenya
VA-18/83

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ISBN 82-577-0698-1

NORWEGIAN INSTITUTE FOR WATER RESEARCH
OSLO

O-83014

THE NEED FOR WATER RESEARCH IN KENYA

Oslo, September 1983
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F O R E W O R D

The Norwegian Institute for Water Research, NIVA, would like to thank the Norwegian Agency for International Development, NORAD, for sponsering 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, September, 1983

Svein Stene Johansen
Research Manager

C O N T E N T

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RECOMMENDATION

This report gives an overview over the Water Supply and Sanitation Sector in Kenya, 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 Kenyan institutions.

1. There is an accute shortage of 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 Kenyans to study Public Health Engineering abroad.

2. The Diploma Course now partly financed by NORAD should be strengthened by NORAD providing staff equipment and funds.

   The equipment bought for the Diploma Course and sent to Kenya should be handed over to the University and not be kept by others.

3. 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.

4. Direct links should be established between The Ministry of Water Development (MWD) and Norwegian water research institutions through cooperation arrangements. Such arrangements should provide for the undertaking of joint research and development programmes, including personnel and funds to establish a water research institute as well as funds for operating research programmes.

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

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 co-operations 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 funds 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 co-operation between Norwegian water research institutions and developing countries in

- training scientists and technologists both through the provision of study abroad and through training progammes in developing countries,
- the implementation of major research programmes relating to water developing,
- establishing a direct linkage through co-operation 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 institutions 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 co-operate 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 developing 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 follwoing 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 co-operation.

4. Detailed description of relevant institutions, especially the part of the organizations for which a co-operation 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 co-operative arrangements. Such arrangements should provide for the undertaking of joint research and development programmes (a above) and the development and strenghtening 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 The International Water Supply and Sanitation Decade in Kenya

Of Kenya's estimated 15.7 million people about 3.5 million, or roughly 22 percent, have access to safe water supply. Average urban coverage is estimated between 50 and 75 percent. In rural areas, only about 15 percent of the population have safe drinking water. Kenya has currently about 26 water-borne sewerage systems which are completed or under construction. Overall urban sanitation coverage (piped systems, septic tanks and pit latrines) is estimated at about 40 percent. Countrywide rural coverage is estimated between 20 and 30 percent.

Since 1970, the Government has had the intention of providing a safe potable water supply for all by the year 2000. The Government has subscribed to the goals of the international drinking water supply and sanitation decade (1981-90) (IDWSSD). The targets to be achieved by 1990 are for water supply coverage of 100 percent of the population in urban areas, 75 percent in rural areas, and sanitation coverage of 90 percent in urban areas and 50 percent in rural areas. These ambitious targets will make a heavy demand on available financial and human resources. It is estimated that capital expenditure to meet decade requirements would almost double the average annual amount of about US $ 48 million invested over the past few years. This will mean a sharp increase in the number of professional, technical and skilled operation staff needed for the planning, design, construction, operation, maintenance and rehabilitation or water supply and sanitation schemes. There are current staffing problems and shortages in many categories. These will have to be overcome if decade targets are to be met, and if new and revitalized schemes are to achieve the purposes for which they were financed and built.

Provision of adequately skilled manpower during the decade period has high priority in the plans of the national action committee.

2.2 Sectorial Organizations Involved

The Ministry of Water Development (MWD) was formed from a department of the Agriculture Ministry in 1974. Initially about 1,455 staff were transferred to the new Ministry. Under the Water Act, the Ministry controls all national water resources. It is also the sole agency of Government with technical expertise in water affairs as well as the largest undertaker. Major irrigation developments are the responsibility of the National Irrigation Board under the Ministry of Agriculture. The development of hydro-electric power is concentrated in the Ministry of Power and Communications. Several ministries and agencies are involved in development and operation of water supply facilities. The Nairobi City Council is responsible for the city's water supply and sewerage systems. Eight municipal and country authorities operate their urban water supply systems under the Ministry of Local Government. Many small rural schemes are operated by county councils. Kenya Railways operate about a hundred schemes, and the Ministry of Lands and Settlement plans and budgets water supply for new settlement areas. The Ministry of Co-operatives and Social Services administers grant to "self-help" schemes in rural areas, and the Ministry of Health is responsible for potable water quality surveillance and the promotion of community health and health education.

It was recommended in 1978 that municipalities and possibly the stronger townships should run their own water supply and sewerage facilities subject to formal safeguards. This recommendation has not been implemented, and the Ministry of Water Development retains responsibility for operation and maintenance of most schemes in the country. There are proposals to decentralize many of its functions to the provincial and district level, but responsibility for the major part of sectoral recurrent expenditure on staff, materials and services is likely to rest with the Ministry for the time being.

Many non-governmental organizations contribute both funds and technical help for the voluntary development of community water resources. The UNICEF assisted (NGO) Water for Health project supports these

activities in close co-operaton with government, and operates pilot development projects and training courses in the community.

2.3 Manpower Requirements in Ministry of Water Development (MWD)

In preparation for implementation of the fourth rural water supply programme, a management study was conducted in the Ministry with the assistance of Messrs. Coopers and Lybrand. The study indicated a total staff of 5,700 in post in 1978 or 7,200 including casual labour. Excluding casuals, it was estimated that this would rise to a total of 12,800 by 1982/3, and 17,900 by 1987/8. The total of existing staff used as a base for projections in the Ministry's master water plan was estimated "using consensus values from several sources because manning tables for the principal MWD departments were not available".

It is estimated that there are currently 11,350 staff in Ministry service. This included consolidated totals for "headquarters paid" and "works paid" staff, who were amalgamated this year. The total does not include an estimated 1,600 casual staff, mainly engaged in project implementation since casual employment in operation and maintenance of schemes was recently discontinued.

Of the total of 11,350, subordinate staff (job groups A and B) account for 5,650, skilled operational staff (C - F) for 3,370, and administrative staff from clerical to executive level (D - K) for 1,150. There are 45 senior ministry officials (including senior engineers and professional staff) in job group L and above. Other professionals total 230, including 98 water engineers. There are 22 senior and chief technicians (K - L) and 865 sub-professional technicians and assistants (G - J).

The Ministry's professional staff included 79 expatriates which represent an increase of 23 over 1978. Of the present expatriate complement, 59 are water engineers.

There is no clear mechanism in the Ministry to predict staff requirements for implementation, operation and maintenance of an expanding national system. This should be quickly rectified to ensure that man-

power needs, especially for organized decentralization, are properly foreseen.

Decade coverage targets have been variously estimated to entail a capital investment requirement of K£ 459 million (US$ 891 million) or K£ 609 million (US$ 1.2 billion) at 1981 prices, or (for 100 percent of rural sector alone) US$ 500 million at 1977 prices. The most modest of these conflicting estimates, if translated directly into staffing needs, would impose a quite unrealistic rise in staff over the plan period. Neither the budgetary resources, traning facilities, nor the absorptive capacity of the Ministry's structures to deploy, train and supervise the additional manpower are likely to be adequate. The Ministry's present operation and maintenance activities cannot keep pace with its existing rapidly expanding construction programme.

Projections made in this study reflect likely maximum increased staff availability and absorptive capacity in the sector over the plan period. A mathematical extrapolation from very ambitious investment targets has been avoided. Even so, by 1988 a doubling of staff is foreseen in some critical categories. If it is true that investments required to meet Government targets and design standards would be far beyond available resources, unless there is a major shift in choice of technology, this would have further implications for the types and levels of required staff.

The present projections, if achieved, will be a major step towards the structure needed to reach Government targets for the end of the century.

It is estimated that about 7,5000 new staff (excluding casual labour) will be required to the Ministry between 1982 and 1988. This is made up of an additional staff requirement of 4,000 and a further 3,500 replacements for people who leave. The total includes 259 water engineers (it is expected that all expatriates will leave by 1988), 146 other professionals, 980 technicians and 2,100 skilled operational staff. These estimates would bring the total of Ministry staff to 15,300 costing in 1988 (at 1981 prices) an estimated K£ 9.2 million

(US$ 16.7 million) per annum. Including casual labour for implementation of projects, the staff total would be 18,100. It is assumed that all new staff require training, though in some cases (e.g. University courses for professionals) this procedes entry to Ministry service. It is further assumed that in service training will be required for a variable percentage of existing staff, and of new staff (expecially some categories of technicians and skilled operational grades) who will undergo refresher training during the plan period. On average in each year, 1,270 non-casual staff will be engaged and will require pre-service training. At 1981 prices, and assuming an average renumeration (all grades) of (say) K£ 600 per annum, this represents an additional annual recurrent cost burden of K£ 762,000 (US$ 1.4 million) equivalent to 13 percent of the total estimate of recurrent expenditure for the Ministry of Water Development, 1982/83. A further 1,680 staff should participate in refresher programmes.

There is an annual need for 44 new civil engineering graduates to be trained as water engineers, and for 28 graduates of various disciplines (including mathematics, physics, geology, geography, economics, meteorology, engineering) to become electrical and mechanical engineers, drilling engineers, economists, surveyors, geologists, hydrologists and chemists.

It is estimated that about 170 new technicians will be needed annually, but they should be trained for a longer period to a higher standard than is currently possible. About a further 170 annually will require in-service upgrading or refresher training.

About 360 new skilled operational staff need training each year and there should be refresher training for about 550.

Turnover among subordinate staff (labourers, line patrol men, plant attendants) is low, but their training should be improved. There will be an estimated 530 new entrants annually, and 760 candidates for skill upgrading courses.

2.4 Other Requirements

The Ministry of Water Development is the country's principal source of technical expertise in water supply and sanitation. This expertise is made available to a wide range of schemes initiated through other governmental and non-governmental agencies. Engineering staff who leave Ministry service are generally absorbed elsewhere in the sector, and often rejoin Ministry service later. Experience is not normally lost to the Country, but the Ministry incurs a substantial cost by effectively offering on-the-job training to meet all national requirements. In order to meet this wider need, both university training and the Ministry's internal rotational programme for engineers will need to be expanded and intensified during the plan period.

This study has not extended to an estimate of detailed requirements of technical and operational staff for schemes under development and operation in other ministries and urban water and sanitation undertakings, which include Nairobi City Council. As the recommended manpower planning acitivity gets under way in the Ministry, the wider national requirement ought to be properly quantified.

The growing policy emphasis on rural water supply and sanitation, and provision in marginal urban areas creates manpower development needs in the community. The Ministry of Health operates a community health and health education programme, which has an important out-reach capability. Integrated district health which includes clinical officers, public health officers and technicians, public health nurses, enrolled community nurses and family field health educators. There is a public health educator in each district.

Several indications are that the Ministry's present programme is understaffed.

3. EDUCATIONAL AND TRAINING PROVISION

3.1 Civil Engineer

About 60 graduates take a first degree in civil engineering from the University of NAIROBI each year. An estimated 20-30 of these are recruited annually by the Ministry of Water Development and undergo a two-year rotational graduate training programme. The University expects that 70 to 80 percent of the graduates will remain in Ministry service after one year. About 30 percent of the current civil engineering course deals with water-related subjects, and 8 staff (of a civil engineering department of 19) specialize in areas such as hydraulics, water resources, hydrology and public health engineering. A part-practical post-graduate diploma in water engineering is offered to between 12 and 15 students each year, but a two-year masters programme has not operated since 1980. Both NORAD and WHO have assisted the past development of postgraduate programmes, but resources are not inadequate to meet sectoral demand. The University does not expect to satisfy demand before 1995. A shift in emphasis is foreseen over this period from construction towards sanitation, operation and maintenance, rehabilitation and augmentation. A scheme to extend University facilities in Kenya proposes a new faculty of technology, with a total enrolment of 1,120 undergraduates, which would offer courses in water engineering. It is unlikely that this specialized civil engineering course will begin until at least 1990. Meanwhile, the University of Nairobi is anxious to reinstate a full programme of postgraduates studies.

Donor assistance is received by the Government for civil engineers to undergo training abroad. NORAD, SIDA and GTZ, who provide expatriate engineers to the Ministry, all regard training of Kenyan engineers as a major element of their assistance programmes.

3.2 Technicians

Staff enter MWD service as school-leaver technician trainees. The SIDA-assisted Staff Training School has trained 1,470 students since

1973. Each year, about 190 students undergo a six-month period of preselection training in water engineering subjects. Trainees are then distributed within the Ministry for on-the-job training as water supply inspectors, water bailiffs or assistant hydrologists. About 90 students are selected each year to undertake further polytechnic training as engineering assistants, draftsmen and technicians. At the end of a three-year period, students submit a record of their work to the Prinical, and their training concludes.

Facilities at the Staff Training School are inadequate to meet future sectoral manpower requirements. A Kenya Water Resources Training Institute (KWRTI) is currently under development by MWD at Kajiado, with World Bank assistance. The Institute will have 400 training places and will offer a 5-month pre-selecton introductory course for technicians, and Ordinary Diploma course in water engineering for an annual intake of 60 trainees, short courses for 200 operators, mechanics and other skilled operational workers annually, and in-service training for 800 trainees each year on 4-week courses. The project foresees 25 man-years of fellowships abroad for staff development, and estimates that 32 man-years of technical assistance will be needed to establish the programme.

Physical implementation of the project is well in hand, and bids for construction work are due in November 1982. Implementation of a staff development plan will soon become urgent and plans for donor technical assistance in staffing and staff training will need to be finalized so that courses can begin by the agreed dates.

The existing staff training school will principally be utilized for training lower grade staff when the KWRTI becomes fully operational in 1984/85.

These facilities, which will operate in co-ordination with programmes of the Kenya polytechnic, will be adequate to meet sectoral institutional training needs at technician level over the plan period, and no additional provision is proposed.

3.3 Skilled operational staff

Each year, about 40 apprentices are sponsored by MWD to participate in Industrial Training Centre programmes in sector-related trades (including general fitters, diesel engine mechanics, pipe fitters, etc.). By 1982, 182 pre-service trainees had taken part in this scheme and in-service training introduced in 1981 had trained 41 staff. The scheme meets about a quarter of the Ministry's recruitment needs in the relevant trades, and will expand as far as limited resources permit. Additional needs will continue to be met informally from the labour market, and through on-the-job training at Ministry facilities. While some further systematization of training may be useful, these trades are cross-sectoral, and the general labour market can continue to meet most requirements.

4. RELEVANT INSTITUTION FOR COOPERATION

4.1 Ministry of Water Development

The Ministry of Water Development (MWD) was formed from a department of the Ministry Agriculture in 1974. Under the Water Act, MWD controls all national water resources. It is also the sole agency of Government with technical expertise in water affairs as well as the largest water undertaker.

In 1978 MWD was reorganized. Under the Water Engineering Department two Research Sections are established, one in the Planning and Design Branch, one in the Sewerage Division.

However, very little research has been undertaken due to lack of manpower, identified water research policy and funds.

In the Water Resources Department a Water Quality and Pollution Control Division has been in operation for years. A water laboratory with equipment funded through NORAD is in operation within the Division.

The Water laboratory is situated at the old premises of the MWD in the Industrial Area.

Except for the water laboratory no research facilities are in existence. However, existing buildings could be easily utilized for research activities.

4.2 University of Nairobi

4.2.1 Civil Engineering Department

The Department offers a 3-year course which leads to a B.Sc. in Civil Engineering.

Facilities are available in the Department for qualified graduates to pursue postgraduate programmes under the supervision of specialist staff for a diploma course and for the degrees of M.Sc. and Ph.D.

The Department offers an M.Sc. Programme by coursework, examination and thesis in Environmental Health Engineering and a Diploma postgraduate Programme in Water and Waste-Water Engineering.

The candidates in the M.Sc. course are required to carry out an Environmental Health Engineering Research Project under the supervision of the staff while in residence at the University and the project shall normally be completed by the end of the sixth term of the course.

The M.Sc. course has not been in operation the last years due to lack of financial support and scholarships. That means that no research is carried out by students.

The Diploma Course is still in operation and supported by NORAD through scholarships. However, the equipment and teaching aids bought by NORAD and skipped to Kenya have never been received by the University.

There are for the time being four full time lecturers and two part time lecturers running the course.

The lecturers are part time working for Ph.D. and some research in this connection is carried out.

Their progress is however humpered due to lack of funds and facilities.

The current water research interests are as follows:

1. Solar distillation.
2. Treatment and disposal of sisal wastes.
3. Treatment of industrial wastes using various free floating waste plants.
4. Field investigation of waste stabilization ponds in Kenya.
5. Model studies of ponds using synthetic sewage.
6. Sedimentation of soil particles using as settling column.
7. Non-water borne sanitation systems.
8. Distribution and concentration levels in Kenyan waters
9. Appropriate defluoridation techniques for water supplies in Kenya.
10. Slow sand filtration.
11. Deep-well disposal of waste waters.
12. Composite roughness in open channels.

4.2.2 Institute for Development Studies (IDS)

The University of Nairobi, as a major national institution in Kenya, has the opportunity and the responsibility of contributing significantly to all aspects of national development. In line with this important role, the Institute for Development Studies was created as an integral part of the University to initiate and carry out a programme of applied inter-disciplinary research concentrating on high-priority social and economic issues of development in Kenya and the rest of Africa. This programme is carried out in co-operation with other departments and institutes of the University and in conjunction with Kenyan Government ministries and other agencies concerned with development.

The Institute for Development Studies' broad mandate includes the provision of research opportunities, facilities and professional guidance to enable a rapidly expanding number of Kenyan scholars to study the problems of development. In addition, research papers issued by the Institute for Development Studies are widely used as University teaching materials, as they are based on the analysis of

relevant issues in their own society and related to national development. Finally, visiting scholars from all over the world whose work is directly relevant to the research priorities of the Institute may carry out studies in Kenya as research associates, and in this way make their own contribution to an understanding of the processes and problems of development in Kenya.

The Institute for Development Studies was created in 1965 as an integral part of the University of Nairobi, on par with the faculties. It is a multi-disciplinary research institution set up in response to the strongly felt need for organized, full-time research on urgent social and economical problems of development.

Most of the staff time and resources of the Institute are devoted to research. The research programme is designed to mirror the high priority social and economic problems of development. The emphasis is on Kenya, but the broader problems of the African continent are also considered. The research is concerned both with basic-term development problems and with more immediately pressing policy issues.

In most parts of the world broad concept of human welfare has replaced per capita economic growth as the defining characteristic of "development". Reflecting this recognition the country's Development Plan for the period 1979-1983 has alleviation of poverty as its paramount stated objective. It proposes a strategy aimed at creating conditions which can meet a set of basic needs for all Kenyans. Among the most important of such needs are adequate food, health, shelter, employment and education.

Work at IDS in this Plan period will be guided by these national objectives and will aim to assist their implementation. In particular IDS will be concerned to assess the extent to which these basic needs are being met and to propose ways in which they can be more speedily and effectively achieved in the future.

In line with this broad objective IDS have identified four areas within which IDS work will be carried out. These are: Rural and Agricultural Development; Industrialization; Human Resources and Development, and

Natural Resource Management and the Environment. For the next Plan period emphasises will also be given to "water related research".

Broconsult A/B is through SIDA undertaking a Water Demand Study in Kenya.

Some Pilot Projects on Shallow Wells and Handpumps are going on at the Coast and in western Kenya financed by SIDA and FINNIDA.

Research Section in the Sewerage Division

The Division has proposed a Low Cost Sanitation Pilot Project to be financed through NORAD.

5. CURRENT WATER RESEARCH ACTIVITIES

5.1 Ministry of Water Development

5.1.1 Water Research Section

Standardization is undertaken by the section which consists of one experienced engineer recruited through NORAD. He is for the time being revising the Design Manual.

A Water Tariff Study and a Water Consumption Study are undertaken by Consulting Engineers.

5.1.2 University of Nairobi

Except for research undertaken in connection with Ph.D. studies, no water research is going on.

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 continuously "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 National 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 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 paragraph 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 pumpes are competitive.

Pumps based on windmills has 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 enormously 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 Kenya 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) Development of Low Technology Defluoriation Systems

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 is 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) Pre-treatment - Slow Sand Filtration

Slow Sand Filtration is used throughout Zambia 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 Kenya 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 discarded 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 there 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 main-

taining 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 mal odorous
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 basket-makers.
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 hygine, 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 reinforces 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 provide 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

Kenya 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 Kenya involving Norwegian scientists and technologists. Such exposure and training should be undertaken in conformity with the needs, priorites and specific conditions agreed upon and proposed in this report.

7. PROPOSED WATER RESEARCH PRIORITIES FOR KENYA

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 devided 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 Institute under the Ministry of Water Development (MWD) should be established. During the initial years, MWD 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.

MWD has a good relationship to the University and both institutions are represented in the National Action Committee for the Decade. MWD has assisted the University by providing part-time lectures.

MWD 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 MWD. 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.

With regard to Western Province, social studies should have a major part of the Mongu Sanitation Programme.

Table 7.1. 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 criteria and guidelines 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 Tinkana.
VI	Testing of handpumps in order to select and/or to manufacture locally		CE	
VII	Operation and maintenance research in order to up-grade 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