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WORKSHOP ON RESEARCH & DEVELOPMENT NEEDS WATER SUPPLY AND SANITATION DECADE (1981-1990)

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Workshop on Research & Development Needs for Water Supply and Sanitation Decade : 1981 - 1991

Nagpur : November 21 - 22, 1979

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FOREWORD

The goal of international water supply and sanitation decade (1981–1990) to provide safe water and effective sanitation for all the people in the world as adopted by the United Nations Water Conference at Mar del Plata in 1977 is one of a series of basic needs along with food, health etc. which would lead to an improved quality of life. To achieve this goal with meagre resources, in a time frame of a decade as against a century or more taken by developed countries, needs political will, public support and administrative action at all levels in the developing countries. Bulk of the population in need of this are thinly spread out in vast rural areas as well as in densely populated urban squatter settlements. The strategies to be adopted would require planning of projects and programmes that are technologically appropriate, socially relevant and at reasonable cost affordable by member-conutries.

The conference on 'Technical Cooperation among developing countries' (TCDC) in Buenos Aires (1978) and U. N. Conference on Science and Technology, Vienna (1979) focussed attention on the need for relevant technology and suitable strategies among developing countries. The Government of India having actively participated and initiated actions in the above conferences is committed to programmes which will lead to achievement of these targets.

The World Health Organization, since its inception has, as its objective promotion of health, in which environmental sanitation has an important role to play. It has been actively supporting programmes of member-countries in relevant areas, particularly water supply and sanitation.

NEERI is one of the national laboratories under CSIR involved in the broad spectrum of R & D efforts in environmental engineering and sciences. World Health Organization had also provided assistance to NEERI in the form of equipments and consultants. It has been recognised by the World Health Organization as a regional focal point for community water supply and waste water disposal and global environmental monitoring systems programmes(GEMS). It is but natural that the Government of India represented by Central Public Health and Enviromental Engineering Organization, Ministry of Work & Housing, World Health Organization and NEERI should have jointly organised a workshop on "R & D Needs for the Water Supply and Sanitation Decade Programme".

In a programme of this magnitude, where large investments will be made, R & D effort becomes relevant for optimal utilization of the limited resources. NEERI will actively participate in all the programmes which are relevant to promote and further strengthen project activities leading to the fulfilment of set goals.

Several working papers were presented by experts chosen for their competence in the area in the workshop held during Nov. 21–22, 1979 at NEERI, Nagpur, to participants consisting of Chief Public Health Engineers from the states, research engineers/scientists, academacions and consultants. The deliberations among the professionals involved in a wide spectrum of activities led to identification of R & D projects of national, regional (sub-national) and local importance as well as possible linkages between user departments and research institutions. It is important that further follow-up actions are initiated by relevant agencies to fulfill the tasks and recommendations outlined in the workshop.

July 1980

(B. B. SUNDARESAN)
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INTRODUCTION

The decade 1981-1990 will be known as 'International Drinking Water Supply and Sanitation Decade' as resolved by the United Nations Water Conference held at Mar del Plata in March 1977 and approved by the 31st U. N. General Assembly. The Government of India and the State Governments in tune with the resolution of the U. N. are taking steps to achieve the targets of providing atleast (i) safe water to all the urban and rural population (ii) collection, treatment and disposal/utilisation of waste water systems to all class I cities and 80 percent of the remaining urban population with either complete sewerage or sanitary toilets connected to safe disposal systems and (iii) sanitary toilets to 25 per cent of the rural population. The requirements for total funds for meeting the target for the decade would be of the order of Rs. 15,000 crores. There is a need, therefore, to accept low unit cost and standards of service without sacrificing the hygienic aspects, and active involvement of the local community.

There is a considerable scope for research and development efforts to be directed in support of the fulfilment of the target set for the decade programme.

The objectives of R & D support would be :

i) determination of technical and social feasibility of various options which are available for water supply and basic sanitation (human excreta disposal);

ii) evaluation of economic and environmental system effects of technologies which provide for conservation of water, reclamation and re-use of wastewater ;

iii) development of devices to save energy and chemicals ;

iv) technological innovations at intermediate technology levels to improve efficiency and enhance appropriateness; and

v) evaluation of social attitudes, cultural patterns and community participation to improve health benefits.

Realising the need and role of R & D effort for the implementing the decade programme, NEERI in collaboration with World Health Organization, New Delhi and Central Public Health and Environmental Engineering Organization, New Delhi organised a Workshop at NEERI, Nagpur during November, 21-22, 1979 on "R & D Needs for Water Supply and Sanitation Dacade 1981-1990". Chief Public Health Engineers of states, research engineers/scintists, consultants and university professors were invited to discuss, deliberate and identify R & D projects of national, regional (sub-national) and local importance, suggest methods of funding and interaction between user departments and research institutions.

In order to guide and provide supporting material in the conduct of workshop, 14 working papers prepared by invited experts were presented in the workshop and grouped under three categories viz :

i) Planning and strategies, technology and methods.

ii) Professional development and manpower resources.

iii) Information system.

Prof. S. Subba Rao of All India Institute of Hygiene and Public Health, Calcutta chaired the plenary sessions, with Prof. V. Raman of NEERI as Technical Coordinator.

Four working groups under subject areas of (i) water (ii) sanitation (iii) manpower development and (iv) consultancy and information systems, discussed the following issues :

i) Identification of topics for R & D, institutions, resources, etc., takink into consideration the constraints of transfer of technology ;

ii) Criteria for setting up priorities; and

iii) National work plan with reference to subjects, strategies, materials, finance, institutions, etc.

It was emphasised that development of new knowledge should not be the sole criterion for identification of R & D projects. The application and extension of knowledge suitably modified to aid in the implementation of the decade programme, should be one of the guiding factors in the selection of projects, and the development of new knowledge should be in consonance with the main objectives.

The proceedings of the workshop contain the full text of the invited working papers and summary, brief resume of discussions, highlights the recommendations and R & D topics identified for support during the decade under the subject heading of water, sanitation, manpower development and information systems planning. The proceedings outline *national needs,* so that central and state level institutions could take up projects with active support from State Governments, Department of Science and Technology (DST), Council of Scientific and Industrial Research (CSIR), Central Public Health and Environmental Engineering Organisation (CPHEEO), University Grants Commission (UGC), Consultancy and manufacturing firms and public and private sector undertakings.

CONTENTS

WORKING PAPERS

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

R & D Strategy in Environmental Engineering and Sciences

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Appropriate technological innovations in environmental health programmes should be hygienically safe, scientifically sound, technologically feasible, environmentally compatible, economically viable, socially relevant and culturally acceptable. During the water supply and sanitation decade 1981-1990, more than ten thousand crores of rupees are likely to be invested in water supply and sanitation programmes in India. The technology options in implementing the schemes in different parts of the country with varying degrees of development, different hydro-geological conditions, in addition to the difference between rural and urban environment become highly complex to meet the requirements of appropriateness. The multi-disciplinary aspects of the profession add an additional dimension to develop appropriate technologies.

Environmental engineers and scientists exposed to American and European technological innovations have adhered to the line of least resistance in adopting technologies which were readily available. Such an approach has been useful in some cases, but have become irrelevant in a large number of cases. Research and development need of the country to meet the decade programme requirement should be viewed in this context.

Supply of safe water through closed conduits started several centuries earlier. For the first time in history, provision of adequate water supply through closed conduits brought the toilet next to the bedroom which was not thought of a few centuries earlier. This led to the demand for larger quantities of safe water for domestic consumption including bathing, cleaning and flushing of toilets. Treatment of water became necessary due to pollution of water from domestic discharges. The small volume of objectionable human excreta gets flushed out with relatively large volume of water produced at a high cost and conveyed through a system of complex network of underground sewers. After conveyance through long distances, utilising energy for pumping at different places, this small volume of human excreta and other objectionable matter need to be removed in conventional sewage treatment plants with primary, secondary and tertiary processes. This is typical of American and European technology. The economic status of the community demanding it was such that the high cost of such systems was acceptable to them.

In contrast, Asian and Middle-East countries had developed their own systems of waste disposal which were relevant to the respective society's needs. The Chinese method was to have ponds at the backyards in which human excreta and piggery waste were discharged. In this pond, fish was grown for human consumption. The total recycling of waste as a method appeared to meet their requirements. Rural population in India practise open defecation which gets cleaned up by pigs. Subjugation by foreign powers which destroyed all aspects of Indian science and technology led society to adopt ad-hoc means in small towns. This was supper-imposed on the caste structure prevalent in the society consisting of untouchables as a class of people. They, in turn, were conveying of human excreta.

Environmental sanitation had its own set back due to emphasis on personal cleanliness in India and complete and utter disregard for community hygiene. It might take several decades of sustained efforts with the help of sociologists, health education specialists and economists to break the barrier. Research and development in this context does not stop simply with unravelling the basic mechanisms through scientific efforts or technological adoptions through engineering skills. It must be supported by other disciplines such as sociology, economics and health education. Instances are not lacking where processes and technologies claimed to have been successful have failed to take off, because social relevance and cultural acceptance are overlooked.

The pollution taking place in surface waters led to the concept of water purification which earlier consisted of slow sand filters but later, replaced by rapid gravity filters. The rapid gravity filters, in turn, needed pre-treatment involving use of chemicals and energy. Thus, another technological innovation developed to suit a society which was willing to pay the high price for potable water was foisted on developing countries.

It should be recognised that science is universal and technology regional. The basic concepts of water purification, wastewater collection, treatment and disposal remain the same. But a technology which is appropriate in a developed country becomes inappropriate in a developing country due to social, cultural and economic aspects. The time has now come for scientists and technologists in India involved in environmental engineering practices to critically look at the technologies being adopted to meet the requirements of large percentage of population scattered over a larger area in the villages and urban squatter settlements.

The objectives of R & D effort should be :

i) determination of technical and economical feasibility of various options which are available for water supply and waste disposal;

ii) evaluation of economic and environmental system effects of technologies which provide for conservation of water, reclamation and reuse of wastewater;

iii) development of energy saving devices; and

iv) technological innovations at intermediate technology levels to improve efficiency and enhance appropriateness.

A World Bank report (1) based on review of 18,000 relevant publications revealed that :

a) less than 2% are of practical value in developing countries;

b) the conventional engineering wisdom indicating that there are no viable technological alternatives between the privy and sewerage system is invalid;

c) much information is available on septic tanks, but little on pit privies;

d) much information exists on treatment of dilute wastewater by oxidation ponds but little on the treatment of concentrated wastes (night-soil, solid wastes etc.) by composting or aquaculture.

In addition, alternative to underground sewers received very little consideration or no consideration at all. It is to be recognised that sewerage and sewage treatment cost 4-5 times that of providing safe potable water. The total annual cost per household (TACH) for various waste collection and disposal systems, collected from a study of 44 systems in 12 countries by World Bank is summarised in Table I. In a country where the average per capita annual income is about Rs. 1000/- as on 1975-76 (2) sewerage system disqualifies itself.

TABLE I–TOTAL ANNUAL COST PER HOUSEHOLD (TACH)
(Mean Values) (1978)

System	Rupees
Waterseal Pit Latrine	150
Pit Latrine	215
Communal Waterseal Latrine	272
Bucket Cartage	400
Composting Latrine	440
Aquaprivy	680
Vacuum Truck Cartage	835
Japanese	1500
Others	308
Sewered Aquaprivy	1440
Septic Tanks	1632
Japanese and Taiwanese	2785
Others	640
Sewerage	3165

(1) DeAnne S. Julius, " An Economic Appraisal of Sanitation Alternatives " Prog. Wat. Tech., Vol. 11, Nos. 1/2, pp. 251-258 (1979).

(2) India-A Reference Annual 1977-78

In 1971, a conference on R & D Needs w held at NEERI which outlined several topics for research. A perusal of the same indicates that the topics for research are grouped into areas of water treatment and supply, pollution survey, sewage treatment, industrial waste treatment, etc. This unfortunately has led to sectorial approach within environmental engineering and science. Scientists and technologists have started working in isolation with very little cross fertilisation of ideas and concepts. The total system concept has been relegated to the background. The depleting sourees of energy and high cost involved in production of energy has reached a point where energy saving devices become relevant to water supply and wastewater collection and disposal.

Water supply and sanitation programmes currently being undertaken in the country epmhasis the sectorial approach where the water supply and sanitation components are never integrated. The present method of providing water supply without adequate provision for collection, treatment and disposal of wastewater leads to public health hazards as well as unclean environment. Cess pools of wastewater around community taps, streets and houses in small communities are potential health hazards. Yet, schemes are being implemented unmindful of the consequences, taking shelter under the plea that no funds are made available for sanitation programmes. Simple methods of conveyance and low cost treatment systems should fill this gap in assisting operating agencies.

Waste either in liquid or solid form should be considerded as a resource to be put back into the ecological cycle. Microbiological pathway is more relevant in a tropical country like India where microorganisms grow and multiply at a faster rate than those in cold climatic regions. Energy intensive, mechanically contrived and skillfully operated system such as activated sludge or trickling filter, though relevant in Europe, America and in limited urban situations in India, appear to be irrelevant to meet the requirements of the majority of the communities. Recycling and reuse concepts using solar energy in stabilization ponds followed by aquaculture and agriculture are relevant. A technological innovation would thus be limited to the regional needs within the country such as choosing the type and variety of fish as well as crops to be adopted. This should further progress towards better linkage with the State Public Health Engineering Departments having their own R & D wing and research institutions.

Slow sand filters as a method of water treatment, though of European origin, has become relevant in India. Several large water treatment plants in Europe including those of London use slow sand filters. Several slow sand filters were constructed in India during pre-independence era. Subsequently it became a practice to go in for rapid gravity filters. High cost of energy and chemicals would make rapid gravity filters applicable to only a few selected metropolitan cities in India. The vast majority of smaller cities and towns and larger villages can adopt slow sand filters, with attendent advantages in case is required. Technological innovations should take the regional requirements and needs before a system is adopted.

Modern tools of data collection, storage and retrieval should be used rather than outmoded systems by operating agencies. Information collection, collation and dissemination should be improved to provide for continuous flow of information between operating agencies and research institutions. The R & D work to be undertaken to meet the decade programme requirements should thus take into consideration i) the total concept and system approach, ii) energy conservation, iii) waste reuse and recycling, iv) interaction with sociologists on aspects of community participation, v) economic analysis and cost effectiveness and vi) effective linkage between user departments and research organisations.

The possible set of benefits and indicators of benefit should be identified prior to embarking upon R & D work. Table II indicates a set of factors which could be considered in this regard.

A National Bureau of Water Supply and Sanitation could be set upto coordinate the country programme for effective implementation of the following specific tasks assigned to it :

i) Critical appraisal and evaluation of water supply and sanitation programmes currently under progress.

TABLE II — WEIGHTAGE FACTORS FOR BENEFITS ACCRUING FROM R & D PROJECTS

Benefits	Indicators for benefits	Weightage factor (fractions)
Economic benefit to the country	— addition to GNP	
Social benefits	— improved health status of community	
Employment generation	— additional jobs created in primary and secondary sectors	
Reduction in sickness rate	— increased working period	
Overall improvement in environment	— aesthetic appearance	
Competence building	— field experience	
	— availability of useful data	
	— opportunity to test technology	
Prestige value	— is this a long standing problem ?	
	— are other countries or institutions also working on it ?	
Motivating factor	— chance of promotions	
	— opportunities for visits	
Statutory obligation of the organisation	— can a question be asked in Parliament ' Why the Institution has not done this work ' ?	
	— there is no other institution in the country to do this work.	

ii) Critical evalution and development of design criteria for water supply and sanitation systems.

iii) Evaluation of equipment and materials and technology forecast.

iv) Provide an effective national information system on field and technological data through co-operative linkages at local, state and national level.

v) Assess manpower needs and develop training programmes at all levels.

vi) Support and coordinate R & D work.

In conclusion, this conference should discuss and bring out an effective guideline for the selection of R & D projects, priorities to be accorded, identify topics of national, regional and local importance, institutional arrangements, methods of funding, in addition to the linkages to be established between user departments and research institutions.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Research in the Development of Appropriate Technology for the Improvement of Environmental Health at the Village Level in the WHO South-East Asia Region

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Introduction

The 29th World Health Assembly confirmed the need for drawing up a comprehensive long-term programme for the development and coordination of biomedical and health service research in pursuance of the WHO constitutional mandate " to promote and conduct research in the field of health " (WHA29.64, May 1976). Further, the 29th, World Health Assembly specifically considered it necessary to promote research for the development of appropriate and effective methodologies and technologies (WHA29.74).

The WHO South-East Asia Regional Advisory committee on Medical Research (RACMR) selected the topic, Research in the Development of Appropriate Technology for the Improvement of Environmental Health at the Village Level, as the technical subject for discussion during its 4th Session in 1978. A background paper on this subject was prepared by the Environmental Health Unit of SEARO. During their 4th Session, the Regional ACMR recommended Research in the Development of Appropriate Technology for the Improvement of Environmental Health at the Village Level, be one of the priority areas for research in the South-East Asia Region, which was approved by the Regional Director.

A Concept of Appropriate Technology

A search of the literature revealed that there are many terminologies in use to classify/categorize technology, which may have given rise to some confusion. This confusion may be avoided if it is recognized that the various terminologies in use refer to subsets of technology. A classification based on qualitative characteristics of technology is suggested and given below :

a) *Origin*

- i) Indigenous technology
- ii) Imported/foreign technology, also
- i) Rural/village technology
- ii) Urban technology

b) *Age/Time*

- i) Old/primitive technology
- ii) Modern technology (often meant to involve the application of the scientific process)

c) *Cost*

- i) Low-cost technology
- ii) High-cost technology

d) *Major input or component*

- i) Labour-intensive technology
- ii) Capital-intensive technology

e) *Complexity*

- i) Simple technology
- ii) Intermediate technology
- iii) Advanced/sophisticated technology

f) *Appropriateness to local circumstances*

- i) Appropriate technology
- ii) Inappropriate technology

g) Other classifications may be added which are usually dichotomous.

Views expressed in this paper are those of the author and do not necessarily represent the official policies of the World Health Organization. The material presented in this paper were extracted from the documents listed under " References ".

The concept of appropriate technology has brought to focus the need to consider not only the efficiency of technology itself but also its social relevance to the society where it is applied with its social, cultural, political, economic and environmental elements. Technologies appropriate to a national setting will most probably be a "mix" of the various subsets of technology, which planners and decision-makers of a country have to carefully balance in order that optimal socio-economic development is attained.

With this focus, appropriate technology in environmental health is taken to refer to a product/tool/equipment (example : a type of water pump), a process/technique/methodology (example : a particular waste composting process) or a system with its various components (example : a water supply system) which has been successfully introduced, adapted and utilized in a particular setting with its social, cultural, political, economic and environmental elements to help solve environmental health problems.

Two components of appropriate technology may be brought up, namely : (a) appropriate technology "hardware", and (b) appropriate technology "software". The technology "hardware" refers to the products/tools/equipment, processes/techniques/methodologies or their combinations and associations in a system as discussed in para above. In the process of development and mass application of appropriate technology, certain approaches/strategies/methodologies which include organizational strategies, educational approaches, evaluation methodologies, etc. may be found more effective in a particular setting. These approaches/strategies/methodologies may be considered as appropriate technology "software".

Suggested criteria for appropriate technology in environmental health include :

a) Hygienically safe

- does not contribute to the spread of diseases;
- promotes health and healthful habits;
- prevents occupational hazards;
- ergonomically sound.

b) Technically and scientifically sound

- simple to operate and easy to maintain;
- technically effective and efficients;
- reasonably free from risks of accidents;
- flexible enough to fit changing conditions.

c) Socially and culturally acceptable

- meets basic needs of the people;
- local labour intensive;
- if possible, upgrades rather than supersedes traditional skills and crafts;
- aesthetically satisfactory.

d) Environmentally sound

- prevents pollution of the environment;
- does not disturb ecologic balance;
- helps conserve natural resources;
- economizes on the use of non-renewable resources;
- recycles by-products and other wastes;
- leads to enrichment rather than deprivation of the environment.

e) Economically viable

- cost-effective, preferably low-cost:
- financially feasible;
- helps develop local industry;
- utilizes local materials;
- economical in the use of energy.

The Need for Appropriate Technology in Environmental Health

The status of environmental health in the rural areas of the South-East Asia Region as of 1975 (mid-decade) shows that :

(a) Eight out of ten inhabitants of the rural areas in the Region did not have reasonable access to safe water supply. In absolute numbers, this proportion represents some 605 million out of an estimated total rural population of 760 million.

(b) Nearly 95 per cent or some 708 million of the rural population in the Region did not have adequate disposal of human excreta. A number of countries are reported to have less than 2 per cent of their rural population provided with adequate excreta disposal facilities.

(c) The actual percentage of the rural population who utilize the available water supply and excreta disposal facilities is much lower than the stated percentage coverage. This is due to a low level of public awareness of the importance of these facilities in the prevention of gastro-enteric infections and the frequents breakdown of the installed sanitary facilities.

It could be assumed that, should money, material or manpower be no constraint, currently available technology could provide an adequate level of environmental health service almost anywhere in the world. In reality in many countries money, material and manpower are major constraints; besides, environmental health is given relatively low priority. Hence it is important that the choice of technology is made appropriate in order that maximum benefit may accrue from the scarce resources invested in this field. The appropriateness of technology is particularly important during the coming years to ensure feasibility of implementation of the expanded programme of environmental health that is contemplated. The choice of technology appropriate to local circumstances to satisfy the suggested criteria would not only result in savings in capital cost but also in recurrent costs with the possible achievement of greater utilization and effect / impact.

Priority Research Topics in the Development of Appropriate Technology in Environmental Health

On the recommendation of Regional ACMR in its 4th Session in 1978, a Research Study Group (RSG) on " Appropriate Technology for Improvement of Environmental Health at the Village Level " was convened in New Delhi from 16 to 20 October 1978.

The RSG recommended criteria for evaluating research proposals in environmental health and include :

(a) the magnitude, importance and priority of the problem as perceived by Member countries of the Region;

(b) the problem has a demonstrable potential for solution or clarification; early implementation of the research project is possible within the Member country (ies) of the Region;

(c) the solution or clarification of the problem could lead to the development / strengthening of national enviromental health programme (s) including primary health care and have a beneficial effect on health and socio-economic development, especially of the rural poor;

(d) there is a strong likelihood of application of the findings at national level within a reasonable time frame and at an affordable cost;

(e) the research project would strengthen research capacities within the country;

(f) the research effort would encourage and promote multi-disciplinary and inter-institutional collaboration to bring about a " synergistic effect " at the national level;

(g) the research effort would encourage and promote the concept of " technical cooperation among developing countries (TCDC), by providing opportunities for pooling together resources of the Region in studying common research areas and in utilizing research findings, and

(h) that it takes into account past and current research being carried out elsewhere.

Based on the criteria identified, the RSG considered the following topics of regional interest which merit priority for WHO collaboration :

a) Hand-pumps

(1) Design and development - (including innovative designs and pumps made from plastic, bamboo and wood);

(2) Laboratory tests;

(3) Field trials /surveys;

(4) Development of capability for local manufacture;

(5) Studies to define the extent of pollution of hand-pump tubewells and to determine the influence of hydrogeological, socio-economic, engineering and health factors.

b) Related equipment/methods/materials for community water supply

(1) Survey and testing of tubewell strainers;

(2) Development, including field trials, of chlorinators for wells and surface water sources;

(3) Simple methods of collection, treatment and distribution or surface waters for village use;

(4) Development of more stable chlorine compounds;

(5) Field testing of methods for removing iron and fluorides from groundwater, and

(6) Study of costs and benefits or rainwater collection for individual / community water supply.

c) Excreta and waste-water disposal including integration of systems

(1) Studies on operation and maintenance problems of individual / community latrines;

(2) Composting household and/or community wastes including nightsoil;

(3) Optimization of biogas systems for the treatment of excreta and other wastes;

(4) Integrated waste (including excreta) and wastewater treatment and utilization with biogas - aquaculture - agricultural use systems.

(5) Studies on use of fish ponds for excreta and wastewater disposal;

(6) Studies on low-cost wastewater collection and disposal systems.

d) Operational, behavioural and other community aspects of appropriate technology

(1) Studies to develop and strengthen community capabilities (organizational forms, management and control mechanisms, etc., for priority setting, motivation, etc.) for community development including community water supply and sanitation projects;

(2) Studies to develop techniques / approaches to mobilize effectively community participation / efforts for community development in the field of community water supply and sanitation;

(3) Studies to determine local community priorities for water and sanitation in relation to other community priorities and potential for community participation within a primary health care approach or programme;

(4) Studies to develop effective approaches to introduce/transfer appropriate technological adaptations/innovations at the village level;

(5) In-depth study of village communities to determine existing social groupings and control systems/processes especially in relation to operation and maintenance of water and waste disposal systems, and

(6) Studies to develop effective ways of integrating, coordinating and strengthening extra-community support to community water supply and sanitation projects.

e) Impact on health of sanitary intervention

(1) Studies on impact on health of sanitary intervention utilizing professional researchers;

(2) Studies on impact on health of sanitary interventions utillzing villagers.

The Regional ACMR in its 5th Session in 1979 discussed the report of the RSG and while endorsing its findings in full, laid special emphasis on the following :

(a) Multi - disciplinary research aimed at identifying existing relevant social aspects in the community in order to discover ways of enabling the management processes to become more effective in installing, operating and maintaining adequate water and sanitation systems was of crucial interest and, therefore, worthy of research support on a priority basis.

(b) The need for development changes in environmental sanitation should be seen as an integral part of the total rural development process and in particular as a vital component of primary health care.

(c) The Study Group's concept of enlisting the active participation of the rural community in collecting information for research purposes relating to the simple, measurable studies of health status, existing water usage practices and attitudes and behaviours relating to excreta disposal systems deserves full support. This would facilitate not only collection of research data but also promotion of health education in the process.

(d) In view of the magnitude of the task, efforts would have to be devoted to identifying the special characteristics of the rural community, i. e., village size, population density, existing practices, morbidity patterns etc. which would determine the urgency and modality of implementing water and sanitation improvement measures in a particular locality.

The Regional ACMR recommended : (i) consideration should be given to studies that take into account the suggestions made in paras (a) to (d) above in the development, conduct, monitoring and evaluation of such studies and (ii) appropriate scientists including public health administrators. sociologists, anthropologists as well as community leaders should be involved in the programme.

Guidelines for Regional Workplan on Research

For the promotion of health and for the prevention and control of disease in rural areas, the concept of primary health care is appropriate. Primary health care should represent a harmonious balance of appropriate technologies of which rural sanitation is one. The group feels that there is a need for Member States and WHO re-examine the sectoral approaches and operations related to special programmes for disease control in order to ascertain whether various diseese (s) control programmes and the way they are carried out represent a well-balanced approach in harmony with the primary health care concept.

The group recognizes that there is scope for larger use of sanitation and hygiene in the prevention and control of many diseases such as cholera, enteric and diarrhoeal diseases and other food and water-borne infections in particular at the village level. In addition, the group considers that sanitation represent one of the effective tools for the promotion of positive health and therefore should never be forgotten in the planning and delivery of primary health care.

Suggested Objectives for a WHO Regional Research programme in Environmental Health

a) General objectives

These may be :

1) To promote the development and application of appropriate technology in environmental health at the village level, and

2) To support the environmental health component of primary health care and rural development programmes with technologies appropriate to the local conditions.

b) Specific objectives

These could be ;

1) To identify specific research needs in the development of appropriate technology for the improvement of environmental health at the village level;

2) To collaborate with Member States in undertaking research in the development of appropriate technologies in environmental health;

3) To collaborate with Member States in the development of national capability to undertake research on identified needs;

4) To collaborate with appropriate technology groups, institutions and organizations in Member States in the collection, assessment, compilation and dissemination of information related to identified research needs, and

5) To promote and support a feasible collaborative programme of research at national, regional and inter-regional levels with consideration to TCDC.

Activities to Support the Workplan

Technical cooperation with Member countries in the :

(a) Organization and development of a national research study panel to serve as focal point for the promotion, research and development and application of appropriate technology in environmental health;

(b) Development of national policies of research and development in this field;

(c) Development and strengthening of research institutions in this field including manpower development for effective multi-disciplinary collaboration in research projects;

(d) Development and strengthening of national information services for the collection, assessment and dissemination of information on appropriate technology in environmental health including promotion of information exchange in the Region;

(e) Development and strengthening of mechanisms for transfer of appropriate technologies in environmental health at the local, national and regional levels;

(f) Indentification/inventory of institutions and scientists undertaking research and development in appropriate technology in environmental health including assessment of their training needs;

(g) Preparation of research proposals including research protocols based on the outline developed by the Research Study Group;

(h) Promotion of collaborative research among different institutions in the country(ies) in the Region;

(i) Securing of financial support from bilateral and international agencies other than WHO, and

(j) Review of progress of national activities in this field.

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NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

R & D Needs for the Decade Rural Water Supply

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It is very timely that this workshop has been organised to look into the needs of the R & D for the Decade. In order, however, to determine the needs. It becomes essential to have a knowledge of the present design practices, experience in the field and the difficulties encountered in operation. There has been no proper evaluation of programmes and practices. Water Supply and sanitation is a State Subject and, therefore, every State is free to enunciate its own policies and carry out programmes accordingly. Under such conditions, it becomes necessary to have one Central Authority or focus for collection and dissemination of information. Unfortunately, today, there is no such effective Centre, or Organisation. The CPHEEO is a very weak Organisation and has been most ineffective and it is doubtful whether it will become a really effective Organisation. With this background, when we talk of R & D needs, we will have the handicap of lack of proper feed back and more or less it will depend on individual experience. I thought, I should mention this before we discuss this subject.

Rural Water Supply has gained some importance during recent years and in view of the decade, the work-load in this section of the sector is going to increase in the near future. A careful examination of the designs is, therefore, called for in order to maximise results within the available funds, so as to achieve the objective of providing minimum, water supply to all.

The design norms have come under criticism from various quarters, and at the same time there have been demands for further economy from some quarters. Here again, we grope in the dark and have to go by the experiences of international agencies in other countries. Had there been proper evaluation, we would have had much better data. I would, therefore, strongly urge that NEERI undertakes evaluation very quickly, so that we know where we are with reference to the design norms as adopted and whether we had public cooperation to make these designs effective and useful.

Another important field is water quality which could be important not only for rural but urban water supply. Are we satisfied with the present water standards ? Can these be followed satisfactorily and effectively ? Are these economically feasible standards ? The standards will not be important in normal average conditions but these become important when water is chemically not to the required standard. There are regions where excessive iron is present in water supplies. Are the designs adopted economical ? Can these be improved ? Do areas with salinity need an absolutely saline-free water ? Can there be a half way in all the treatments proposed ? Have water standards been followed in the plants after completion and when in operation ? Do the plants give the desired performance ? What is the tolerance limit of the population as regards these standards and in which area are the people sensitive ? Have we been able to prepare a national paper on water quality ? Here again, almost no evaluation or follow-up has been done or if carried out the Public Health Engineers in the country are not aware of it, which again points out to the need for an effective focal point. I hope, NEERI can take up this question of water quality.

The question of water treatment is closely related to water quality standards. If it is accepted that particular quality standards have to be maintained, then, specific treatments are required. It is encouraging to note that NEERI is actively involved in the slow sand filter project. It is, however, necessary to issue the guidelines regarding the designs as to where these should be adopted. It is also necessary to examine the economics of such plants. The economical studies should include not only the capital costs involved, but also the recurring costs. One of the major problems in case of rural water supply is that there are almost no recoveries made from the people either for the capital costs or for operation and maintenance, in quite a large number of areas. In case the rural water supply facility is to be extended to greater number of villeges every year, the total involvement of the State would considerably increase financial burdon on the State exchequer and it would become very difficult to operate and maintain these schemes. The economical aspect, therefore, needs to be studied and highlighted. In this connection, I would like to draw your attention to the various papers published by the World Bank wherein financial and economic analysis has been carried out for the various systems. I am not sure whether NEERI has a strong section of economists who examine each and every proposal and given an appreciation for such a proposal. I feel that there is an urgent necessity of creating such a unit in the NEERI, so that the Institute not merely examines proposal technically but also examines them from the point of view of financial involvement. This will not only give a better appreciation of the proposals of NEERI in the country, but it could also be valued by International Financing Agencies, such as, the World Bank.

In view of the fact that the operation and management for rural water supply schemes is financed by Government, it is necessary to examine whether these could be economically carried out. This would involve going into the details of the present practices of management and suggest methods by which the operational staff could be reduced. While this is not a matter for Research, it can certainly be called as an item for development.

In all water supply schemes-rural or urban-some sort of instrumentation becomes unavoidable. One of the areas in which we lack very badly is measuring instruments like flowmeters. There is almost a monopoly in this sector and the equipments available are far from satisfactory. While economy could be an important aspect, it should not be at the loss of efficiency. If NEERI could examine these instruments and suggest modifications. It could go a long way and meet an important requirement in the water supply system. In general, however, there is a need for examining standard of manufacture of appurtenances and instruments used in water supply schemes as these are far from satisfactory though they carry the mark of Indian Standards Institution. NEERI can examine the process adopted by I. S. I. and correct the same to obtain better results.

NEERI could also undertake development of hand-pumps to overcome the defects of the existing ones.

In conclusion, NEERI should get involved actively in the programme of rural water supply. So that it can examine the various designs and practices and suggest measures for improvement.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

R & D Support to Planning and Management of Urban Sewerage System

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Introduction-

Sewerage system works on water carriage system and waste water generated in households and factories is conveyed through underground drainage system to the point of treatment and disposal. The points of treatment and disposal are normally located at one or two places in a drainage zone and are likely to be away from the place of generation of wastewaters. This situation requires construction of intermediate pumping stations.

One of the important requirements of wastewater system is that it should transport the wastewater at the rate at which it is generated, and the system should not admit more than permissible quantities of underground water. The treatment plant and pumping stations with its accessories should deal efficiently all variations of loads. Due to unforeseen circumstances, wastewater loads both hydraulic and organic are likely to exceed the limits for which these units were designed. Under the circumstances there is a need to uprate the existing units by modification of existing processes. To undertake work of this nature, it will be necessary to have an R & D department. This will mostly deal with the requirements of public bodies like Municipal Corporations, Industrial Development Corporations etc.

Second type of waste treatment and disposal facilities will be relating to small plants such as those for housing colonies, which are not served by sewerage system, and those for industrial units which have to treat their waste waters before discharge into water courses or municipal sewers. These give enough scope to evolve treatment process and alternatives to study their performances.

Method of approach to the wastewater management problem

The first point is to identify the problem. R & D will come in the picture when it is desired to improve the working of existing unit and/or to increase its treatment capacity without much investment. Before finalising the programme of R & D for such a problem all the literature on the subject is to be reviewed. There are some journals which publish case studies describing how several similar problems were solved. That will give a clue to the solution. In these case studies it is important to know the characteristics of wastewater, why a particular method was adopted, what equipments were required for modifications and what is the importance of automation involved and availability of indegeneous equipments. Lastly the cost and the benefit derived need to studied. This kind of study should also be liniked up with value engineering so that R and D activities will be more useful. Value engineering branch involves identification of function of a particular unit and then weighing it for further work. Thus before undertaking any R and D project it is a basic necessity to find out how R & D is going to achieve the aim of cost reduction.

With these preliminary ideas, it is felt that there is considerable scope to subject the following problems to R & D work. Environmental engineering works in our country are in a state of development, primary attention being given to other public works like communications, housing etc. With legislative measures like Prevention and Control of Water Pollution Act, environmental engineering is going to achieve more and more importance, and perhaps works of sizeable magnitude will have compulsorily to be executed both in the urban and rural areas. The quantum of technological knowledge available in the mofussil areas being less, it is necessary that the works to be provided should be such as can be maintained with minimum day to day attention. It is from this angle that the R and D work will have to be of an applied character making the works simple so far as the design and construction features are concerned and should be capable of being maintained with minimum technical inputs during operations. The problems solved by developed countries and the solutions evolved by them in respect of material and equipment cannot therefore be straightaway applied in the context of Indian conditions unless the equipment and operating skills are indigenously available. The approach given hereafter is dealt specifically from this angle.

R & D PROBLEMS OF LARGE SEWERAGE SYSTEMS

CONVEYANCE SYSTEMS : Rising Mains.

Use of cement mortar lined M. S. pipes in rising main carrying sewage--

Particular emphasis being given to proper design for joints,

C. I. pipes are used generally for rising mains. This is on account of the fact that they are easy to be laid and are sufficiently robust. If jointed by use of lead, there are practically no problems of leakage. They can withstand corrosion much better than other known materials. However, C. I. pipes of large diameter are not manufactured in our country. When the flow to be handled is substantial, it becomes necessary to save on the diameter of C. I. pipes by ensuring a higher value of 'C' in William & Hazen's or any other formula used for finding out velocities and loss of head. This requirement attracts considerations of M. S. pipes which, in the context of the liquid they are expected to carry, are necessarily to be cement mortar lined. Simultaneously, this will pose a difficulty in designing a proper joint and avoiding effects of sulphide corrosion in these pipes. There is, therefore, a need to carry out proper development of the joints with necessary research in this field.

At present the sewers of larger diameters are constructed of R. C. C. pipes. The companies which manufacture these pipes, design them to the three edge bearing strengths specified in Indian Standards. These pipes are provided with full or half encasement of concrete depending on the load. Since cement is a scarce and costly commodity, there is a scope to replace cement concrete encasement by other suitable materials. Work on this aspect will be of vital and national importance needing substantial R & D inputs.

Flow measurement in a sewage pumping station using pumping station as Flow meter.

There are as many as 30 sewage pumping stations operated in the area under the jurisdiction of the Municipal Corporation of Greater Bombay. Some pumping stations are used as lift stations whereas the remaining as influent pumping stations to treatment plants. Many a time, need arises to find out the efficiency of a pumping system. This become difficult in the absence of a proper flow measuring equipment. Few organisations have installed meters to measure the flows, but they have not worked satisfactorily due to presence of large suspended solids in sewage It may be possible to measure flow pumped by a pumping system by knowing Electrical energy consumed for different combinations of the pumps. Few research workers have carried out studies with the method mentioned. However, more work is necessary in this field.

Electro-Magnetic flow measuring device is very efficient for accurate flow measurement in presence of even suspended solids. The cost of this is very high, R & D should be directed to evolve similar low-cost devices based on this principle.

PUMPING STATIONS :

The pumping stations installed for sewage are radically different from those contemplated for water, though here also centrifugal pumps are most commonly used. They are coupled to motors designed for constant speed (This is on account of the fact that variable speed motors are not available in this country). The liquid to be pumped is corrosive. It contains sizeable quantities of solid & grity matter. The flow arriving at the pumping station is variable and needs a judicious selection of individual pumps of variable discharges, but simultaneously operating in conjuction with other pumps pumping through the same rising main which results in substantial variation in the basic characteristics of 'total head'. For any sewage pumping station where the pumps operate through a common rising main it is customery to go in for choice of a pump with flat curves. It has been found that contribution of a single pump in the combined flow of two or more pumps connected to the same rising main is much less than that for which the pump has been initially selected. The problem is more pronounced when the length of the rising main is more when the frictional head is much more than the static head. If pumps are coupled to motor with variable speed, smaller number of pumps can effectively deal with all variations in flow and head. At present, variable speed drive motors are not available in India. In more developed countries, variable speed motors are invariably employed in combination with constant speed pumps. There is an R & D need to work on this problem.

TREATMENT PLANTS :

Grit removal devices :

Normally in our country grit chamber or detritus tanks are employed. In developed countries aerated grit chambers are employed at most of the plants. This not only aerates the sewage but occupies very small space and work efficiently at all variations of flow. R & D should make this unit popular by ensuring reduction in its cost. Developmental work is required to reduce the cost without sacrificing the efficiency.

Primary sedimentation tanks :

An overloaded primary settling tank can be rehabilitated by employing tube settlers which are available in the form of modules made of plastic. The tubes are set at an angle of 60^0 with the horizontal. Sewage rises from bottom to top and sludge settles down and flows in the reverse direction to the bottom of the tank. Such devices if employed, for new plants will occupy smaller space. This device need further development.

Multi-Bottom Settler : Some research work has been made by an engineer of Bombay Municipal Corporation to work deals with the study of performance of Multi-Bottom Settler as Primary settling unit for raw sewage. A pilot plant of 1.8 m×0.9 m×1.2 m (6′×3′×4′) which can handle sewage of 0.1 MLD (.024 MGD) was fabricated. The location chosen was Dadar Sewage Treatment plant of the Bombay Municipal Corporation where it was possible to install this unit parallel to Dortmund type Primary settling tank (P. S. T.) already existing at the above site. This discharge was varied to achieve different surface loadings and different horizontal velocities, to study their effect on the performance of the Multi-Bottom Settler. To study the effect of angle and spacing between the plates, different runs were conducted for to different spacings viz. 5 cm and 10 cm. for two inclinations of 30^0 and 45^0. In all thirty five runs were conducted. The results indicate that for same yield per unit occupied area, Multi-Bottom Settler gives superior performance as compared to conventional Dortmund type P. S. Tank. Multi-Bottom Settler gives efficiency for S. S. removal as high as 82% and B. O. D. removal as high as 50% for detention time of only forty minutes. It is more sensitive to horizontal velocity than to the surface loading. The angle and distance between plates also affect its performance. The work carried out shows that the Multi-Bottom Settler could be very conveniently used in place of conventional primary settling tank (P. S. T.). As it is more compact and needs no mechanical equipment, it will achieve economy in capital and operating cost and will also be easy for its maintenance. Further investigations are necessary.

Use of polyelectrolyte

The country has not started manufacturing of polyelectrolytes. Whatever manufacture has been done, the starting product viz.. the Monomer has always been an imported product. Polyelectrolytes improve settlement characteristics of small size particles by agglomerating them into bigger floc. For different situations, different types of polyelectrolytes will be found to be useful as the basic idea is to dislodge the bond between the various particles either positively or negatively charged. The sludge thus removed is the one which contains the organic matter and naturally has contributed to the total B. O. D. which is the measure of the nuisance value of the sewage or the industrial waste. The sludge needs stabilization which is best achieved through the anaerobic process in the digestion tanks. Behaviour of sludge where polyelectrolytes have been used needs to be studied for different situations and with different polyelectrolytes.

Secondary treatment process

Trickling filters of a depth of over 9 metres with plastic media are already developed in developed countries. These need performance data with studies on pilot plant scale.

In activated sludge treatment process, research is necessany to develop relations between plan dimensions of the aeration tank and those of aerators.

Sludge treatment devices.

Removal of Hydrogen Sulphide from Sludge Gas :— In the coastal towns like Bombay, there is every chance of infiltration of sea-water into the sewers resulting in increases of sulphate concentration in the sewage. Similarly the trade effluents which contain sulphates when discharged into sewer increase sulphates concentration in sewage. When the sewage is treated at the treatment plant this high percentage of sulphates creates problem of corrosion of gas holder units. Similarly, the higher contents of hydrogen sulphide in the sludge gas corrode the pipe lines in the gas distribution system. If the sludge gas is used for anything producing power e. g. truck engines, gas turbine etc. the hydrogen sulphide should not exceed 320 mq/m^3.

The elimination of H_2S from sludge gas can be achieved by reducing the infiltration of sea-water which is the main cause of trouble. However, this is very costly as the entire old sewerage system will be required to be combed & repaired. Thus, the preventive measures are left out of consideration and some corrective measures to remove H_2S from sludge gas are necessary. It is stated in the literature that one volume of water dissolves two or more volumes of H_2S at NTP. This particular aspect was used in the studies carried out by NEERI (Then CPHERI) at Colaba Plant of Bombay Municipal Corporation. The sludge gas is washed with effluent from the sewage treatment plant, which saves the cost & quantity of fresh water required. The study concluded that with gas to liquid ratio of 0.95 : 1 the reduction in H_2S contents observed was from average 925 grains/100 cft. in raw sludge gas to 25 grains/100 cft. in the gas scrubbed with the plant effluent. This is within tolerable limits. The study was carried out on a Pilot plant with set type scrubbers on two compartment. Thus, it can be concluded that if H_2S gas is removed from the sludge gas, the gas can be used as fuel, saving other precious fuels like L. P. G., coal etc. at least for domestic uses or for public uses as in municipal hospitals.

There is however a need for more R & D activity in this study of elemination of H_2S from sludge gas. Recovery of precious sulphur from removed H_2S can be a further field for R & D activity.

Tertiary treatments.

R & D for finding out a cheap adsorbent in place of activated carbon.

The cities, many times, experience shortage water supply and on such occasions any organisation supplying water tries to implement immediate cut in water supply to the industries. The reclamation of water by tertiary treatment is one of the possible ways to avoid cut in water supply to the industries. For the purpose of removal of trace organics 'Adsorbtion Unit' in a tertiary treatment is quite useful, however, high cost of effective adsorbent such as activated carbon prevents economical use of such a unit. Hence there is need to develop a cheap adsorbent.

RECOVERY FROM BACKWASH WATERS OF WATER TREATMENT PLANT.

Backwash waters are waste waters generated by water treatment plants. Advances in technology have led to rapid industrialization and this in turn increases the demand for water. To render water safe for human consumption, it is often necessary to treat it. Treatment of water produces certain wastes. These wastes contribute to the pollution of water resources. Therefore proper handling and management of these wastes is necessary.

These wastes like any other waste have recovery potential. The quantity of waste-water from a water treatment plants using alum as the coagulant may range from 2.5- 7 percent. However, it may be possible to recover water, chemicals and solids from it.

Municipal Corporation of Greater Bombay has undertaken the construction of 1910 Mld Bhandup water treatment plant. The work is nearing completion. The volume of the wastewater from backwash at the above plant is expected around 38-76 Mld. Since adequate waste management system for the above plant was to be evolved, it was decided to study the characteristics of wastes of the Pogaon water treatment plant and to predict characteristics of the waste that would result at the Bhandup water treatment plant. Study revealed that backwash water has high initial turbidity (145-520 JTU), suspended solids (236-1236 mg/l), BOD (9-101 mg/l), COD (24-176 mg/l) and substantial MPN count, and also traces of N and P contents. Therefore, their direct discharge to drinking water lake may not be desirable.

It may be possible to recover 90-95 percent water and 20 percent alum from these wastes by recycling the supernatant, which in terms of the Bhandup water treatment plant may mean a saving of 25-52 lakhs of rupees per year in the form of water and 1500 tonnes of alum per year.

Study also showed that it is possible to prepare building bricks from the sludge solids and earn a profit of rupee 1.2 lakhs per year. This will also eliminate the problem of sludge solids disposal.

A number of alternatives for waste treatment were analysed and an economical and efficient waste management system has been proposed, which consists of.

Allow one hour of settling time-using multi-bottom settlers.

Collect supernatant from the backwash waste water and recycle it to the plant inlet.

Thicken the sludge if necessary.

Put the sludge solids on concrete bottom and porous side drying beds with porous sides and lime to reduce drying period.

Utilize the sludge for brick making.

The capital investment on the approach suggested would be recovered in first two years of its operation, and would entail substantial saving of water, chemicals, and profitable use of solids, and would eliminate like water pollution.

SMALL SEWAGE TREATMENT PLANTS

As stated initially, quite a few plants installed in small areas where water supply has been duly provided will have hereafter to be provided with low cost treatment plants turning out effluents to conform to the requirements laid down by the State Boards for prevention for discharge of water into a natural water courses. Such plants will have to be robust, fool-proof in design, capable of being provided at minimum cost without involving serious construction difficulties and also capable of being maintained with minimum operating troubles. It is from this angle that this aspect assumes significant importance in the context of the development in the field of environmental engineering, especially for mofussil areas situated away from towns.

The plants in this category will be those required for treatment of domestic wastewater (sewage) from the housing colonies for staff of Government or Semi-Government bodies, large housing co-operative societies, housing board colonies which are not served by a functioning sewerage system. These colonies need a plant which will not give rise to a need for sludge treatment and will operate satisfactorily with least operator skill and attention.

Other category of waste water treatment plants are those set up by individual industries for treatment of their waste waters. In many cases, these treatment plants include units like equalisation tanks, neutralization unit and thereafter, biological treatment units.

Following unit processes are generally employed for the above categories.

Septic tanks – Indian Standards give comprehensive information on these and hence there is no need for further analysis of these units.

Extended aeration devices are very handy for such types of waste treatment. Standard sizes and equipments for these units may be devised by R and D for these tanks on the lines similar to the Indian Standard Specifications for septic tanks.

Bio-disc process is a very handy & compact device for waste water treatment. As flow increases the size of the plant can be easily increased by addition of one or more units of discs. Designs of the disc should be developed to facilitate their manufacture in the country.

Oxidation ditch : This is a very compact and handy unit. Different types of rotors for this unit process may be developed.

All known methods of waste water treatment ultimately go into the category of primary, secondary or tertiary treatment. The primary treatments are purely mechanical and those falling in the category of tertiary treatments utilize some biological and physico-chemical processes taking the help of micro-organisms fof hastening the process of stabilisation of the organic matter. Processes like trickling filters, bio filterers with recirculation or activated sludge utilise, nature's laws by creating conditions ideally suited for the development and growth of microorganisms responsible for stabilisation. Further work on the complex mechanism of stabilization, and ideal conditions for growth and development of particular species of micro-organisms be carried out. Various physico chemical metheds can be resorted to for the treatment of sewage. With a view to improve efficieney and accelerate the process and economize on energy consumption. Research should be diverted this aspect.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Conservation of Water with Reference to Water Supply and Sanitation Decade

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Introduction

The increasing demand and consumption of sweet water for domestic and industrial purposes, and the consequent production of wastewater with potential to pollute the water resources, and the limited resources of sweet water are factors to be given serious consideration towards economy in water use and conservation of water by various means. Quality and quantity considerations for water resources development have become inseperable. Rigorous measures are, therefore, required to carefully regulate the use of sweet water, save the precious commodity from undue wastage and to recycle the wastewater after treatment for industrial, agricultural and other pertinent uses.

About 35 percent of the utilisable water resources in India is being put to use at present. In another 50 years, full development of the water resources is expected. While the major use of water is for irrigation the quantum of usage for other purposes like irrigation, industries, thermal power generation, municipal and domestic uses would progressively increase in the future. Obviously, a rational, efficient and feasible management of water from the source to the user or 'consumer' is needed with respect to *quantity and quality*.

The thirteenth World Health Assembly (1) in May 1977 has rightly urged the Member States 'to formulate within the context of national development policies and plans by 1980 to programmes with the objectives of imporving and extending those facilities and services to all people by 1990 with particular attention to specific elements' of which the following elements are relevant viz. (i) the assessment of water resources and their conservation (ii) the prevention of pollution of water resources and spread of disease resulting from water resources exploitation and (iii) the improvement of the operation and maintenance facilities including the surveillance of drinking water quality.

Accordingly, the paper projects these aspects of proper mangement in domestic water supply system as a whole with respect to conservation of quality and quantity.

Identification :

Identification of sources of wastage and pollution (preventible and unavoidable) in a water supply system, and an approximate quantification of these can provide an insight into the magnitude of the problem, whether any scope exists of bringing down the wastage and improving the quality, and if so to bring out the feasible methods of preventing wastage to conserve water and maintain the quality of waters from deterioration. It may be noted that a figure of 10 to 20 percent of design per capita flow is provided in the design calculation as allowable wastage *in the whole system.* In water supply system, wastage and excessive consumption with reference to quantity and/or deterioration of quality of water can occur at the following points in the system, in decreasing order of magnitude viz., distribution system (including catchment and transmision), and Water treatment plant.

Water Distribution System (including consumer's end)

It has been variously reported that the wastage of water which can be considered as the total output of water which is not used and advertently or inadvertently misused by the consumers, will amount to as much as 30 to 40 percent of the flow in the system.

Waste of water due to leakages can occur due to following factors :

i) Leakage from reservoirs.

ii) Leakage from water mains due to faulty joints, corrosion of pipemains, fractures, ferrule connections, valves and hydrants.

iii) Leakage through abondoned or disused service pipes, broken pipes.

iv) Unduly high pressure in distribution system intensifying leakage and waste.

v) Leakages in service pipes and fittings inside the consumers' premises due to faulty joints, corrosion, faulty washers or glands in stop valves, taps etc.

vi) Undue consumption of water by consumers due to excessive garden watering, flushing, cleaning utensils etc.

vii) Failure to turn off taps inside or outside the premises (for public taps) wilfully or inadvertently or complete removal of taps.

viii) In intermittent water supply, emptying of stored water from a receptacle when the water supply recommences, and keeping the tap open throughout the day thus allowing water to waste.

ix) Misuse of water for miscellaneous purposes.

The quantum of waste of water under items (i) to (iv) can be categorised as 'unaccounted' for water, as the water consumed cannot be accounted for by systematic metering of consumers' premises.

The major points in a distribution system resulting in water going as waste are house service pipes and connections, public taps, disused connections and hydrants and the leaky plumbing fixtures and waste within the premises.

The status of leakages (2) (3) in distribution systems carried out by National Environmental Engineering Research Institute, Nagpur in different pilot zones of different cities of India are shown in Table I. Municipal Corporation of Greater Bombay (4) are systematically carrying out leak detection and control programme since 1971. In general, the waste level in the distribution system including the house service connections (upto house boundary) varies from 20 to 35 per cent of the total flow in the system. Expressing on per capita basis, the leakages in the system amounts to 25 to 85 litres per day. In some instances, there is noticeable deterioration in the quality of water in the distribution system as was found in Aurangabad (5), due to entry of extraneous pollution into the leaky pipes during non-supply hours. There is always the risk of back syphonage from water storage tank in the house and cattle water troughs through submerged inlets.

The leakage levels were brought down by systematic detection and control to 5 to 10 percent of the total flow in the system (vide Table I). The benefit cost factor for the detection and control of leakages is favourable. Such programme results in the improvement in quality and quantity of processed water delivered to the consumer. In Ahmedabad, it was possible for the house-owners to obtain water at practically double the rate at which it was delivered prior to leakage control by repairs or replacement of house service pipes. The main culprits are the corroded galvanised iron house service pipes and unsatisfactory house service connections (ferrules and joints). In humic soils, cost iron pipes are attacked resulting in graphitic corrosion. The lead joints in the cast iron pipes are normally water tight. But, there are reports elsewhere of the possible gradual deterioration of rubber ring joints in pipes resulting in leakages and deterioration of quality of water in the pipes; and these need detailed investigations.

Public taps or standposts are sources of waste. The measured wastage in public taps (when not in use) expressed as percentage of water usage for pilot zones in Calcutta (6) amounted to 20 to 25 percent of the total discharge from each tap or 5 to 7 percent of the flow in the zones; such wastage cannot be avoided unless there is public cooperation.

On the basis of findings, with a conservative estimate of *25 litres per capita* per day as

TABLE I : WASTE DUE LEAKS * IN THE DISTRIBUTION SYSTEMS IN SOME CITIES OF INDIA BEFORE AND AFTER CONTROL

Based on Field Studies in One or Two Pilot Zones

S. No.	Name of city	Population of each zone	No. of house connections in zone	Hours of supply	Percentage of waste flow		Percentage reduction in waste flow***	Initial per capita waste flow lit/day
					Initial	Final**		
1.	Bombay	8,000	241	15	28.5	8.5	66.0	60.0
		7,847	281	15	33.0	7.4	80.0	86.2
2.	Aurangabad	6,177	377	3.5	28.6	12.0	55.5	16.3
3.	Delhi	1,562	260	13	17.7	10.0	41.0	—
4.	Madras	2,000		6	36.0	7.0	84.0	75.6
		618	170	18	3.7	—	—	6.4
5.	Lucknow	1,517	149	24	19.0	6.0	64.0	24.7
6.	Calcutta	15,552	117	24 ++	24.6	6.0	75.0	34.0
		7,819	216	24 ++	25.0	3.1	87.0	33.1
7.	Ahmedabad	1,555	184	6	20.1	2.0	94.0	38.0
		1,703	—	5.5	25.5	2.5	90.0	27.5

* Leakages in pipes and ancillaries up to stop-cock (excluding plumbing within house), based on intermittent water supply.

++ 24 hours supply, but part of time under low pressure.

** After control measures.

Note— (i) Most of the leaks were observed at ferrule connections, coupling in service pipes, in house service pipes and in valves and joints.

(ii) *** Percentage of waste flow $= \dfrac{\text{Waste flow during supply hours}}{\text{Total average daily flow in the system}} \times 100$

wastage of treated water due to leakages in distribution system (which can be controlled) the 'apparent' loss of processed water in monetary terms would be Rs. 42 crores per year (assuming Rs. 0.50 per 1,000 litres for an urban population of 90.5 million served by piped water supply) or, additional 2250 million litres per day of treated water could be properly put to use in India.

The deterioration of the interior of pipelines with time reflected in the gradual reduction in carrying capacity (as reflected in friction coefficients like 'C' values), affects the quality of the waters with reference to taste, odour, biological organisms and aesthetics. The field studies carried out by NEERI have shown that the 'C' value ranges from 60 to 88 for cast iron pipes and steel pipes of 20 to 50 years old, and biological growth exist within the pipes (7). Systematic, scientific method of flushing and 'swabbing' can go a long way in maintaining the interior of the pipes clean (8).

There is a felt need for trained personnel for further extension work and development of techniques to manage and to carry out preventive maintenance of distribution system (which is a continuing programme), with reference to waste detection and control, and maintenance of capacity and cleaning of interior of pipes. Such programmes will definitely result in the conservation of water quantity and maintenance of hygienic water quality, even though such projects are labour intensive and time consuming. Simplified instrumentation and techniques for alignment of pipes, detection of leaks, flow and pressure measurements and cleaning of pipelines are needed. The behaviour of the materials of pipes and joints with reference to conveying water and surrounding soils and atmospheric conditions need further investigations, and this may lead to preventive measures and guidelines for choice of materials.

Treatment Plant

The dirt accumulated in a settling tank or clarifier and rapid sand filter have to be frequently removed by desludging and backwashing respectively. This entails loss of water which is inevitable. Usually, the total loss of water should not exceed about .5 per cent of the flow in the system. It is seen in practice, that loss of water due to indiscriminate desludging of settling tanks may go as high as 10 percent. Even with backwashing of filters, the losses exceed the prescribed norms and reach to the extent of 5 to 8 per cent.

By controlled desludging of settling tanks and back washing of filters, it is possible to bring down the total wastage to normal limits of 4 to 6 per cent. But, there is also scope to reclaim the backwash water from the filters and put it back to the treatment plant, there by conserving the water in water scarce areas. In this way, it is possible to conserve about 70 to 80 per cent of the back wash water and utilise as a processed water. In Detroit (9), the wash water was recycled back to the plant inlet, and the return was found to improve settling. Additionally, a holding sump and return pump are required. Similar experiments were also done on pilot scale at Madras (10). Pilot experiment were carried out in Jaipur (11) by settling the back wash water and putting back the settled water to the inlet of treatment plant. It is seen that the alum consumption only marginally increases, while 70-80 per cent of back wash water could be recycled back to use. Part of the water can be reclaimed from desludging by lagooning or settling.

Field studies on controlled operation for desludging and back washing may be useful with reference to saving of water. In water scare areas, the recycling of back wash water may be given due thought.

There are instances where the clear water sump is kept open, with the possibility of extraneous pollution entering. Even many of the clear water reservoirs are provided with vent shafts, and manhole covers (sometime with grating) kept open. These are the routes for entry of pollution in the form of dust, leaves or polluted water. Improved sanitary protection of these units are required to conserve the quality of the treated water at the source.

Source

Reservoirs and canals especially in aird and semi-arid lands are subject to heavy evaporation losses. Sometimes, evaporation losses exceed the amount of water used productively. In addition, many of the storage facilities and conveying systems suffer serious water losses through seepage.

Mean annual evaporation rate is 1.8 to 2.5 metres in arid and semi-arid regions of India. As an example, in the water supply system for

Madras (12), 73 million cubic metres of water is lost as evaporation in storage reservoirs supplying water to the city. Seepage losses is estimated at 27 million cubic metres per year. The actual supply to distribution is on the average 70 million cubic metres per year (192 mld). Only 41 per cent of the water stored in the reservoir system would be available for supply to distribution. With losses in transmission and distribution resulting from leakage and wastage, the net quantity of water available to the consumer will be much less. Similar situations occur also in arid regions in India with smaller reservoirs supplying to towns and villages. A practicable method need to be explored in reducing to the maximum extent losses due to evaporation and seepage in storage and transmission systems.

Generally, the method for reducing evaporation has been to cover the water surface with a barrier that inhibits vapourisation, but do not affect the quality characteristics of water. Aliphatic alcohols, e. g. cetyl alcohol (non toxic to fish and human) are sprayed on water surface to form a film of one molecule thickness. Considerable field studies were carried out in India (13, 14, 15) and elsewhere (16), and reduction of 30 to 40 percent in evaporation losses could be possible.

The monomolecular film is impossible to maintain because of wind and wave actions; for small water spreads, it may be considered. The usual application rate is about 60 to 150 gms of cetyl alcohol per hectare of surface area. A plastic net is tried to restrict the drift and disruption of alcohol layers. Floating materials (16) like special wax, solid blocks like light weight concrete, polysterene etc. to cover the water surface to reduce the evaporation area, are being tried. Another promising practical method for small storages, is by filling reservoirs with sand and rock, and water is stored in the pores between the particles. Small sand fill dams have also been used. Sand storage dams can be built where geology permits. Such methods could reduce the evaporation by 80 to 90 percent, but they have limitations in practical terms for large reservoirs and lakes.

Seepage losses in small and medium reservoirs can to some extent be controlled by treating soil bed with sodium salts and/or providing lining by plastic sheeting, butyl rubber sheeting and ferrocement lining.

Any reduction in seepage and evaporation losses provides additional water without major additional equipments or construction.

Field trials are needed to evaluate the feasibility of floating covers and sand storage dams. Cost effective methods and materials are to be explored to mitigate seepage. There is a major need for field studies in arid and semi-arid regions to develop and evaluate the efficacy of different systems for control of evaporation and seepage losses from practical and economic point of view.

Source, Catchment Area and Pollution

The catchment area of reservoirs supplying water to towns and cities are gradually becoming sources of extraneous pollution due to deforestation, human habitation, cattle grazing and industrial estates located nearby or within the area and also due to recreational activity. There are many cases in India where the 'clean' catchment areas are getting polluted e. g. Tansa Lake, Bombay, Ambazari Lake, Nagpur, Bhopal etc. Field studies (17) and surveys confirm such situation. Deforestation has also resulted in siltation of reservoirs, gradually reducing the capacity. Rigorous measures to protect the catchment areas and reservoirs from extraneous pollution are required to conserve the quality of water at source. Surveillance of catchment area, and of water quality followed by rigorous mersures to protect the catchment areas and reservoirs from extraneous pollution are required to conserve the quality of water at source. But, this is the most neglected part in a water supply system. Such action holds good also with reference to rivers and groundwater sources as well. A close collaboration and co-ordination with State Boards of Prevention and Control of Water Pollution are needed. With the possible switching over to onsite disposal of fecal wastes by water seal pit latrines and septic tanks as transitional methods for solving sanitation in semi-urban and even urban areas, the possibility of ground water pollution exists, and the ground water sources supplying to community may be affected. Field studies are required on the mechanics of travel of pollution underground in different soil conditions.

Transmission

The major sources of wastage in closed conduits are wastage by leakages through air valves, expansion joints and scour valves. This is approximately estimated to be around 5 to 10 percent. In open conveying channels, losses occur due to evaporation and seepage (eg. Madras). Pilferage of water on the way also takes place for agricultural purposes by farmers. Stricter vigilance is required to prevent pilferage of water and better maintenance of valves and joints.

Excessive Water Consumption at Users End—

There is growing concern amongst planners and designers, regarding the increased consumption of potable water for non-potable purposes and even domestic uses. Use of certain types of sanitary fixtures result in excessive water consumption. Bath tubs of European type necessitates large consumption of potable water compard to conventional bath by showers or buckets. The flushing tanks are provided with large capacity (upto 14 litres) which may not be needed. Consumption of water by flushing tanks for toilets, would amount to 15 to 30 per cent of average per capita consumption. Greater number of tap points in a house or greater number of water consuming installations, result in high consumption. But, measures to reduce water consumption should not go so far as to adversely affect public health. With reference to quality of water, it is paradoxical that the safe water is liable to become unsafe by storing water under unhygienic conditions in the houses especially in places where there is intermittent supply.

Use of smaller capacity flushing tanks, discouraging use of bath tubs, providing optimum number of tap points within house and optimum number of public standposts or taps can bring down the consumption to reasonable levels. Provision of continuous supply of water will in the long run ensure within premises saving of water and avoidance of unhygienic storage of water.

Conservation by Re-using Water

Wastewater from domestic and industrial activities should not be considered as a waste but as potential resource for utilisation for nonpotable uses like industries, agriculture, flushing etc. Domestic sewage is most amenable to re-use on a large scale. With careful planning, various agricultural and industrial demands may be met by well treated wastewater, thereby freeing fresh-water for municipalities, which require good quality water suitable for human consumption. Limitations from health and environmental aspects exist, but these have been overcome to some extent. Few advanced wastewater treatments for reclaiming sewage exist at Bombay (18). Pilot plant investigations were also carried out at Madras (19) (20) on the process and economic aspects of wastewater utilisation for industries. The cost of reclaimed water works-out to paise 55 to 100 per 1000 litres depending on the end use. In Madras (19), a water starved city, about 80 MLD of reclaimed sewage could be utilised by industries, thereby the equivalent amount of water from sources like ground water could be utilised for domestic purposes.

Daniel A. Okun (21) states "where there is insufficient potable water of high quality, growth of a community may be limited. Reclaimed water may be utilised for many of the nonpotable purposes ordinarily served by the high quality potable source, thereby permitting the high quality water to serve increasing populations. Extensive wastewater requirement imposed for the maintenance of the quality of receiving waters often results in the production of a water that is "too good to throw away". This water may serve many nonpotable purposes in the community.

In USA some agencies go in for dual water distribution system, wherein reclaimed water is used for sub potable purposes including toilet flushing. In India careful thought has to be given before launching on such projects.

Research should to be directed to develop treatments to reduce virological hazards and assess residual hazards, if any. Also, studies should be undertaken to reduce the cost of tertiary treatment and develop simple and economic processes for reclamation of wastewater.

Summary and Concluding Remarks

1. With the depleting resources of sweet water and the increasing demand for domestic use, industry, power generation, in addition to agriculture, there is felt need to conserve the water from the view point of quantity and quality.

2. A detailed assessment of the water losses and quality deterioration in a water supply system has been made. Water conservation

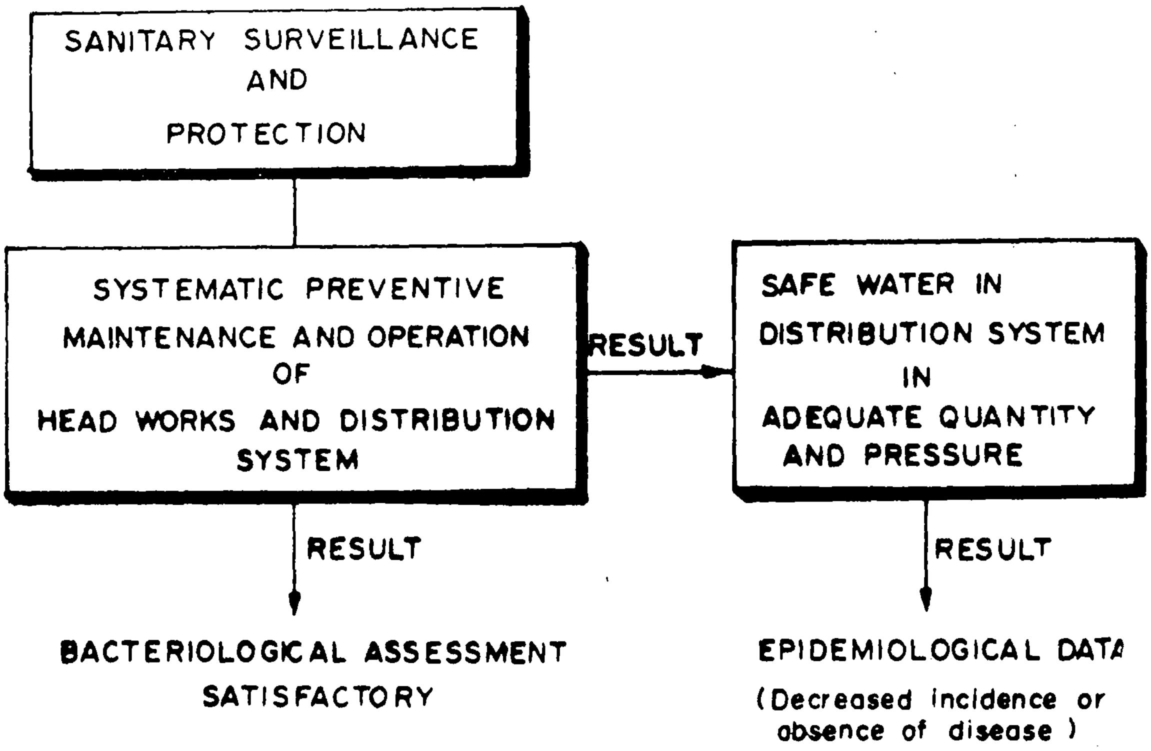

Fig. - 1

measures result in benefits like improved hygiene, and public health, and public good will in addition to the recovery of lost water (Fig. 1).

3. Experience supported by field data indicates that nearly 40 to 60 percent of the water that is lost, can be utilised in a water supply system at various points from the source to the consumer's end. Considerable quantum of waste of water, and the deterioration of water quality is preventible (Table II)

4. It is definitely feasible to recover the lost water to an extent of 50 to 60 per cent by judicious operation and management of the system, and indroducing preventive control measures.

5. One of the major factors in the system affecting the quality and loss of water, is the distribution system and the consumer's end. Systematic and routine programme for waste assessment detection, and control, capacity assessment of pipes and mains cleaning are required. Due to paucity of expertise and lack of appreciation of such work, much headway has not been made.

6. Detailed field studies on national basis on the behaviour of different soil conditions of various materials of pipe, the behaviour of water on materials of pipes and rubber ring joints and the status of house service connections should be made from the point of view of control of leakages and deterioration of water quality in the pipeline.

7. Field trials on use and behaviour of alternative materials which are more corrosion resistant than metallic pipes should be initiated for pipe mains and house service pipes.

8. Standard of house service connections need considerable improvement.

9. Detailed soil survey of the area of distribution system will be beneficial and useful for assessing the corrosive potential of under-

TABLE-II : WASTE AND CONSERVATION OF WATER IN WATER SUPPLY SYSTEMS

Component of water supply systems	Estimated loss as percentage of Utilisable water %	Likely waste after preventative measures, as percentage of utilisable water %	Equivalent per Capita Saving of Water lpcd**	Measures to Conserve Water	
				Quantity	Quality
Source	30-60*	15–30	15–30	Evaporation and seepage Control	Sanitary surveillance and protection.
Transmission	5	2	5	Maintenance of Scour valves, air valves, expansion joints	—
Water Treatment	10–15	5	5–10	Controlled desludging and back-washing, reclamation of wastewater.	Protection of sumps and clear water reservoirs.
Distribution system	20–35	5–10	15–25	Control of leaks, replacement of pipes, standard house service connections.	Control of leaks, layout of pipes vis-a-vis drains, continuous supply
Consumers end	10–15	5	10	Reduced number of taps and public standposts	Hygienic storage, continuous supply
Use for Industry	—	—	25–80	Reclaimed domestic sewage	

* Open surface reservoirs ** an average estimate, litres per capita per day

ground pipelines and specials, and to select suitable pipe materials or protective devices to prevent serious corrosion.

10. Number of tap points inside the premises, and the number of public stand posts need to be fixed at optimum level with a view to save wastage (more the number, more the chances of wastage).

11. Detailed study of the plumbing fixtures, and rational analysis of use of water by consumer for domestic purposes, can bring out the optimum water demand by the consumer. It is felt that an optimum limit should be set for per capita domestic demand.

12. Better control and operation with reference to desludging of settling tanks and back-washing of filters can bring down the wastage to the normal level of 5 percent.

13. In water scarce areas, the reclamation or return of backwash water from rapid sand filters and the sludge bleed from clarifiers can reduce considerably the loss of water. The usefulness of such methods for local conditions can be supplemented by pilot plant or field studies.

14. Sanitary serveillance and control of source and catchment area from extraneous pollution is necessary, and proper co-ordination with Central and State Boards for Prevention and Control of Water Pollution is necessary.

15. The evaporation and seepage losses in open surface reservoirs in arid and semi-arid regions may amout to 30 to 60 per cent of utilisable water. Evaporation control of small and medium sized reservoirs by use of chemicals, floating materials, sand dams and underground sand storage show promise; and further field studies can provide guidelines and data for effective and practical control measures in arid and semi-arid regions. Similar studies on the efficacy of chemicals to treat soil and lining materials for prevention of seepage in small reservoirs and canals should be tried.

16. Concerted efforts to reclaim domestic sewage for use for irrigation and industry should be made with due regard given to prevention of health and environmental hazards. The equivalent quantity of sweet water can be diverted for domestic purposes. Research and field studies tn the development of simple and economical methods of tertiary treatment methods suiting to the end use should be given priority.

17. Water quality control through abatement of pollution provides protection improvement of available data for domestic, municipal, industrial and agricultural and other uses. A plan for water quality management must be developed in consonance with the management of water supply systems.

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Water Quality Management in India : Problems Approach, and Areas of Investigation

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Three quarter of the earth is water. In the solar system, the earth is the only planet with water. All other planets are either too hot or too cold to have water in liquid stage. Even endowed with so bountifull water resources, the world communities are often facing water famine.

Nature is very temperamental, sometimes it pours causing so we have floods, sometimes dry spell continues, we end up in drought situation. There are only few countries around the equator which enjoy uniform pattern of rainfall throughout the year. But, most countries shuttle between flood and drought situation.

From the dawn of civilization, men always have been in the quest of fertile land, The fertile crescent half-encircling the Euphrates and the Tigris upto the eastern coast of the Mediterranean Sea had seen the rise and fall of many civilizations. It is in the quest of good water that most civilizations around the world grew along river banks such as the Nile in Egypt, Yangtso in China or the Indus in Indian sub-continent.

With the advancement of civilization, man started thinking how to even out the maldistribution of water which nature provides between seasons. Engineering innovations started getting introduced like dam, barrage, canal, etc. dam to protect against flood and also for power generation, and barrage to store water to run through canals for irrigation and navigation. Take the case of the Ganga-Brahmaputra-Meghna river system which drains an area of 1.76 million sq km. This is an extraordinarily rich natural endowment backed up by the inexhaustible Himalayan snow. Although one of the world's greatest water resource, only next to the Amazon in Latin America and the Congo in Africa, this water resource is generons but erratic and unevenly distributed in space and time. The total population living in this international basin is about 350 millions, of which 250 millions is in India, over 85 million in Bangladesh and around 12 million in Nepal.

Historically, all nations in the world in their attempt to harness water resources for the benefit of mankind always looked into the quantitative aspect of the resources. They measured the discharge to find out how much of this water may be utilised. They also measured the fluctuations of discharge between seasons, wanted to know the peak flow because that is the time when flood occurs. In short, people dealing with water resources remained busy with the quantitative management of water and never cared to look into the quality of water. Take the case of the river Nile in Egypt. Of all the rivers in the world, the river Nile has the longest and most extensive hydrological record. Ancient Egyptians installed river gauges, known as Nilometers, to determine the arrival and height of flood waters. The quantity of flow was so significant in the life of the Egyptians that the ancient Egyptain God Osiris symbolized in his death the Nile droughts and in his miraculous rebirth, the annual flooding and growth of the crops.

They should not be blamed because that was the need of that period. But, today in the age of intensive human activity in every sphere, be it in agriculture from one crop a year, to three crops a year, be it in industrial activity, be it in fisheries, be it in navigation, objective is to maximize all our products. And all the listed activities just mentioned are water intensive activities. It is natural that part of the fertilising chemicals and pest killing chemicals will flow back to the lakes and rivers; it is natural that industries would require water and the industrial waste would carry back residues of raw materials and the products and pour in the lakes and rivers; it is also natural the human settlements that are now present within the river basin will generate tremendous amount of sewage which would carry all chemicals, foodstuffs that are used in the households and in the industry. Imagine the pollutional stresses generated by the various activities of the 350 million people living in the International basin of the Ganga-Brahmaputra-Meghna. Half the present population of India today which may be taken as 700 million is living in the Ganga-Brahmaputra-Meghna river basin.

Take the case of Ganga alone, 48 class I cities of a total of 142 in India are in Ganga basin alone. Cities having more than 1,00,000 population are called class I cities, let them be termed as major cities. India has 14 major river basins. One hundred and twelve of the 142 major cities are distributed in these 14 major river basins. Out of the remaining 30 major cities, seventeen are coastal and thirteen are non-coastal and also not located in these 14 major river basins. The Ganga is carrying half the pollutional load of the 112 major cities spread between the 14 major river basins. The Krishna is the next populated river basin comprising major cities. Next in order is the river Cauvery accounting 10 major cities

In the backdrop of our national planning of water resources which is totally oriented towards the quantitative management of water the Water Supply and Sanitation Decade is introduced. In this Decade's programme also water supply will receive the priority and sanitation would go by default. The reason is obvious. In a country having 1,35,000 problem villages (as estimated in 1971, and the present estimate stands at 2,00,000) in a total 5,76,000 villages and having been able to provide drinking water sources to 1,00,000 villages, both planners and implementers would remain seized with the question of how to cover the remaining villages with drinking water sources.

By this process of downgrading the priorities for sanitation, the risk exists of providing water to every village and town without ensuring protection of water quality. Such sustained neglect of protection of water quality is endangering the very source of drinking water. If this is continued, it an anomolus situation like the sailor in a ship. It is for this reason we must take an integral approach of water supply and sanitation is necessary giving equal emphasis to both the components.

It is needless to dwell at length to establish the major sources of water pollution. Table 1 presents the water requirements of 2000 A. D. The water requirements for agriculture and power rank first and second in the list, pollution potential for these two sources are low when compared with the pollution potential of industrial and domestic wastewater. The pollution potential of agricultural runoff being nonpoint sources its pollution potential gets diluted and dispersed because of vast area-spread which is 140 million hectares or 1.4 million sq. km. Even then, there may be pockets of concern for which requisite alertness is to build up. The pollution potential of power plant emanates from the cooling water which is discharged into naturalwaters, introduces thermal stresses to aquatic life by raising the temperature of ambient waters. Technological innovations like cooling towers, cooling ponds are available to abate and control this pollutional hazard.

TABLE I – WATER USE (INDIA) 2000 A. D.
Available 1900

USE	In 1000 million Cu. M.		
	Taken	Consumed	Return
Irrigation and Livestock	869	783	86
Power	150	5	145
Industry	35	10	25
Domestic	38	8	30
	1092	806	286

Source : K. L. Rao, "India's Water Wealth", Orient Longman, P. 218

A look into the volume of wastewater discharged from industrial as well as domestic activities will indicate that both these sources are almost equal in volume to each other. The pollution potential of the combined wastewaters from industrial and domestic activities is reasonably high, and if discharged untreated may upset all the natural water resources in India as detailed below :

Total available water	1900 thousand million CULM.
Less Total water consumed	806 ,, ,,
Total remained in nature	1094 ,, ,,
Total wastewater (Industry + Domestic)	55 ,, ,,
Dilution available	55/1094 = 1 in 20

It the average BOD of wastewater is 300 mg/l, then BOD of ambient water becomes 300/20 = 15 mg/l. But with a view to keep the ambient water suitable for drinking, in some places after conventional treatment and disinfection and in some place after disinfection only, the average BOD of ambient water should be 2 mg/l or less. To satisfy this ambient water quality criteria all these wastewaters need to be treated to bring the BOD down from 300 mg/l to 40 mg/l and then only with 1 in 20 dilution the ambient water BOD should remain within 2 mg/l. This means all wastewaters should be treated to the extent of 87 to 90 per cent indicating requirement of secondary treatment.

Of course, the computation for treatment requirement may not be so straight-jacketted as shown above, still it indicates the extent of treatment required.

It is agreed that urban sewerage systems should find place in the presently conceived water supply and sanitation decade programme. Areas which are in dire needs of sewerage sector are dealt with. In author's opinion, urban sewerage systems, particularly in the class I cities would play a very vital role in water pollution control because this system, if properly planned, takes care of both domestic and industrial wastes. Most industries are characteristically located in the cities, and they continue to attract more industries in their neighbourhood. The process of industrialisation within cities is one of the primary causes of urban growth both in size and in population. In the absence of any programme for even dispersal of industrial growth, it is seen that the major industrial activities of India are confined to 142 class I cities, and there would be no appreciable change from this set pattern in foreseeable future. A recent survey has shown that the districts of Bombay, Pune, and Thane (covering 23 per cent population of the State) accounted for 82 per cent of the gross value output and 85 per cent of the value added by the manufacturing sector. The two of the nine metropolitan cities i. e. Bombay and Pune record the above output for the State of Maharashtra which stands first amongst all the States in the country in the manufacturing activity. Extending the above fact, it is believed that even more than three-fourth of industrial production of the country is generated from within the nine metropolitan cities. It is, therefore, suggested that such cities. should be with sewerage system in the first phase. The industries would then be in a position to utilise the sewerage system in the first phase. The industries would then be in a position to utilise the sewerage systems and the overall advantages are :

Industries located within the town or city area cannot provide separate arrangements for conveyance of waste even after treatment, upto the point af final disposal. They have got use the common effluent carrier sytem to be provided by the local body.

Industrial effluents when discharged into the common sewer get an advantage of dilution for the purpose of conditioning the waste, and thereby improving its treatablity in the common treatmemt plant.

Cost of treatment per unit of the volume of the waste can be kept to the minimum due to economics of scale.

Final disposal point or points for all the wastes generated within the town or city area can be chosen carefully in relation to the uses of receiving body of waters, and thereby, avoiding hapazard disposal of the waste by industries.

By allowing industrial waste waters into the seweres for the purpose of treatment and disposal, the local body owning the sewers can earn sizable revenue through a proper system of levy of industrial waste discharges, and thereby reducing its expenditure on the collection, treatment and disposal system.

This practice of allowing industrial waste discharges into the Municipal sewers is followed almost in all the developed countries of the world. In India too, this practice is followed in some cities like Bombay, Ahmedabad, Vadodara and Bangalore. However, the regulations under which this practice is followed in these cities do not appear to be uniform. In some of these cities, the industrial discharges are permitted into to the municipal sewers by the local authorities on some ad hoc basis. Bangalore and to some extent Ahmedabad and Vadodara Corporations have prepared systematic regulations in this regard. All the same, a need is felt to prepare comprehensive regulations about the aspects so that the same can be followed by all cities of the country subject to some local variations. Such regulations would have to provide not only for the levy of charges on industries for permitting them to make a discharge into the municipal sewers and for treating the waste in common municipal waste treatment plant, but also have to provide for certain conditions to be imposed on the industries in respect of pre-treatments to be provided by them for the industrial wastes before making discharge into the Municipal sewers, so that such discharges do not :

— damage the sewer fabric;

— affect the health of the people working in the sewers for its maintenance and operation;

— corrode equipment in the sewerage and treatment system;

- affect the common treatment processes;

- discharge toxic, explosive and certain types of persisting pollutants into the municipal sewers.

At this stage, it is worth while to look back and take a stock of the progress in urban water supply and sewerage systems.

Water : 1971 Census reports 3,113 towns housing 109 million people. Out of these 2,085 towns are having organized water supply. The coverage number-wise and population-wise is indicated in Table II.

TABLE II - COVERAGE BY WATER SUPPLY IN TOWNS 1971 CENSUS

Class of Towns	By Number	By Population
I	142/142	100
II	206/221	84.7
III	542/652	76.0
IV	649/988	60.8
V	423/821	51.2
VI	123/289	40.1
Total	2085/3113	93/109=85

Although the above table would convey a sense of significant progress in the field of water supply, there is enough scope for improvement in the existing system. The inadequacies are in spatial coverage, in population coverage, in daily per capita water supply, in inefficient distribution, and in overall ill-managed systems.

Wastewater : If progress with urban sewerage is distressing, the progress in sewage treatment is bashfully low. Hardly 105 towns are partly sewered covering about 25 per cent of urban population. The existence of sewage treatment plants is only marginal.

TABLE III - COVERAGE BY SEWERAGE

Class of Towns	By number	By population per cent
I	70/142	43
II	35/221	10
III	0/2750	0
Total	105/3113	28/109= 25

Findings

The Nationl Water Supply and Sanitation (NWSS) programme laid more emphasis on water supply and never emphasised the significance of integrated water supply and sewerage systems. A recent survey of 142 class I cities indicated the following findings in regard to collection, treatment, and disposal of wastewater

The proportion of sewered and unsewered population is 43 and 57 per cent respectively;

Only 59 per cent of the total wastewater generated is collected through sewerage;

Only 37 per cent of the wastewater generated received some form of treatment.

The Value of the above three factors are somewhat better in the case of nine urban agglomerations which have a population of more than one million.

The proportion of sewered and unsewered population is 56 and 44 per cent respectively;

Only 66 per cent of the total wastewater generated is collected through sewerage;

Only 57 per cent of the total wastewater generated is treated before disposal.

Recommendations

The total financial investment required to clear the backlog of under-development in regard to sewerage and sewage treatment facilities in 142 class I cities under survey is estimated to be about Rs. 1,200 crores (according to 1978 price index and 1978 population).

A time frame for investing this sum of Rs. 1,200 crores is desirable and it is also useful to ascertain the priorities between the class I cities. Considering various factors, an ordering of priorities is done as follows :

I	Cities producing large volume of wastewaters both of industrial and domestic nature are causing deterioration of watercourses at a rapid pace; all the 9 metropolitan citites should fall in this category except Ahmedabad and Bangalore, because these two are completely sewered and are provided with sewage treatment facilities; the cost estimate for this category will be......	Rs. 423.69 Crores
II	Cities where half of the population are sewered are obviously generating point discharges of wastewater causing rapid deterioration of water courses; the cost estimate for this category will be......	Rs. 309.76 Crores
III	a) The remaining cities are without sewerage and sewage treatment facilities; the estimated cost for these cities, will be......	Rs. 410.84 Crores
	b) Alongwith this phase of work, augementation work for cities which are completely sewered including treatment may be considered an additional outlay will be......	Rs. 25.34 Crores
		Total : Rs. 1,169.63 Crores

The time frame for the completion of the above quantum work may be spanned between 12-15 years requiring 4 to 5 years period for the completion of each phase.

To fulfill the target of sewerage coverage in major cities in India, the Public Health Engineering Departments in all States must orient themselves in the following facts finding activities along with the action plan :

Sewerage Regulation : It should be framed to facilitate industries to use the sewerage systems and municipalities to earn revenue thereby and optimise the cost of investment.

Sewerage Planning : It is becoming more and more evident that introduction of sewer lines on the roads only is not going to result in improving the sanitation unless the residents ean make a concomitant investment from their and to take advantage of this system through house connections. Besides, there is the question of availability of space for introduction of such systems, specially separate ones, for storm and and sanitary sewers. There is also the question of replacing large number of service privies with sanitary types before they can be connected to sewers. It is feared that the total cost of providing these services will be very high and the resultant improvement in sanitation will also not be in proportion to the investment because of the poor economic condition of a sizable number of house owners within the urban areas. In any case, a universal system of sewerage as prevalent in the developed countries, is not going to be the solution for these problems.

It is, therefore, suggested that the programme of introduction of sewerage and drainage shall have to be done after more rigorous planning exercise. In place of standard sewerage system for all the roads and lanes, it will be necessary to allow different types of systems for different areas with an ideal of gradual improvement of facilities as the standards of income for any particular group of residents improve and widening of roads and provision of other infrastructure take place. Places which are predominantly industrial should qualify for sewerage systems, for carrying both industrial and domestic sewage. Industries whould have no hesitation to pay the *prorata* levy for discharging their pretreated effluents into the sewerage systems. In view of all these, it is proposed that comprehensive sewerage and drainage programme is undertaken on an area wise basis after detailed study of the socio-economic conditions of the consumers, the site conditions, the existing land use pattern, and other incidental physical status on an area-wise basis. Such a system should consider provision of alternative systems of drainage through underground and surface drains, introduction of intermediate technology in wastewater collection and disposal for certain areas where water-born sewerage can not be immediately introduced and provision of sewerage system in the rest of the area. Such programmes can be drawn up on a municipal-wise basis starting from the areas which are nearest to the city core and, as a result, having a higher rate of development than the rest.

Standardising Intermediate Technology : Intermediate treatment systems like pit privies, septic tanks, with soakwells should be standardised for sizing, material of construction, and method of construction giving due regard to climatic and soil conditions, groundwater orientation and other safety factors.

Package plant : Attention is also drawn to package sewage treatment plant serving 10 to 20 thousand population. This would help dividing the cities in greater number of sewerage zones, and thereby reducing the cost of sewerage exponentially.

Case Studies : They should be immediately undertaken taking two or three such cities and developing various alternatives of solution mix for sewerage, treatment and disposal.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Optimization of Wastewater Collection Systems

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Introduction

The wastewater collection and disposal problem has assumed a large dimension in present times due to rapid urbanization, improved water supply facilities and concern for environmental quality. A major share of total expenditure on wastewater systems (60 to 70%) is spent on the collection and as such improvements in the design of these systems could result in substantial savings thereby serving a larger proportion of population in allocated funds.

The conventional design practice suffers from several limitations (1, 2) most prominent amongst these being a total disregard to economic factor. More often than not therefore, the designer arrives at an overdesign wasting substantial percentage of public funds. Notwithstanding sincere efforts on the part of some conscientious environmental engineers in obtaining economical solutions, it is practically impossible to incorporate all feasible design alternatives with the design practice in-vogue and only a recourse to mathematical programming in identifying the optimal solution could save the profession from the pitfalls of overdesign.

The problem

The optimization of wastewater collection system consists in the selection of optimal treatment and disposal sites, system layout and depth-diameter combination for each link of the system. In many problems the designer has little say in the selection of sites for treatment and disposal facilities, and system layout. The research so far on the selection of depth-diameter combination for wastewater links has been restricted to complete gravity systems whereas some pumping is indispensable in most systems. Also, with the exception of a few (2, 3) researchers have converted the nonlinear problem into simpler versions so as to employ available computer packages in seeking optimal solution to depth diameter optimization problem. Achievement of global optimum in such an approach is indeed doubtful.

Further, the relationship used in formulating hydraulic model has invariably been Manning's equation, which may result in an error of the order of 100-200 per cent in the estimation of velocity of flow (4). It is needless to point out that any optimization work with such an erroneous hydraulic model would be of little value.

The present paper presents a nonlinear optimization algorithm for a wastewater collection system including pumping. The cost model is based on total annual cash flow and includes the variation in the class of pipes used for varying overburden on the wastewater lines. The hydraulic model is based on Modified Hazen-Williams equation (5) which results in exact estimation of velocities of flow in wastewater lines. It also accounts for part and full conditions in wastewater lines obviating the limitation in research reported by Dajani *et al.* (1). The functional and structural constraints on the system have been converted into conditions in the process of identifying feasible solutions so that an indirect nonlinear optimization method (viz, univariate method) could be employed to seek an unconstrained optimum. The diameter and depth of excavation for each link constitute the two decision variables for minimizing the cumulative annual cash flow in the system. The convexity of the objective function has been checked to ensure identification of the global optimum solution.

Hydraulic Model

Wastewater lines are designed as open channels capable of accommodating peakflow at a partially filled section. The velociiy of flow is governed by hydraulic mean radius, slope of wastewater line invert and roughness of pipe material.

From the Modified Hazan-Williams equation (5) :

$$V = 143.534\ C_R\ R^{0.6575}\ S^{0.5525} \quad (1)$$

where

V = Velocity of flow in meter per second (mps)
R = Hydraulic mean radius in meter (m)
S = Slope of wastewater line
C_R = Coefficient of roughness

A regression analysis of C_R values for full flow conditions (7) as a function of diameter of wastewater line and velocity of flow results in :

$$C_R = 0.828\ D^{0.028}\ V^{-0.097}$$

where

D = Diameter of wastewater line in meter (m)

To account for variable C_R values for part full conditions a table of hydraulic elements presented by Mohan and Khanna (4) has been referred. Accordingly, for a depth of flow of 0.75 D :

$$C_R = 0.858\ (0.828\ D^{0.028}\ V^{-0.097}) \quad (2)$$

Accounting for variation in flow through wastewater lines and assuming

$$Q_{peak} = 2.5\ Q_{avi}$$

where

Q_{peak} = Maximum quantity of flow in the wastewater line in cubic meter per second (cumt/sec)
Q_{avi} = Average quantity of flow (cumt/sec)

From continuity relationship -

$$2.5\ Q_{avi} = VA$$
$$= 143.534\ C_R\ R^{0.6575}\ S^{0.5525}\ A \quad (3)$$

where

$$R = \frac{A}{P} \quad (4)$$

A = area of flow in square meter (sq. mt)
P = wetted perimeter (m)

A and P are related to depth of flow according to following expressions (2) :

$$A = 0.25\left[\cos^{-1}(1-\varrho) - (1-\varrho)\{\varrho(2-\varrho)\}^{0.5}\right]D^2$$
$$= a_r\ D^2 \quad (5)$$

$$P = \cos^{-1}(1-\varrho)\ D \quad (6)$$

where

$$\varrho = \frac{2d}{D}$$

d = depth of flow (m)

From equations (4), (5) and (6)

$$R = \frac{a_r}{\cos^{-1}(1 - \varrho)} \qquad (7)$$

= hr. D where

h_r and a_r = Constants for a given depth of flow

Substituting the values of A and R from equations (5) and (7)and expressing slope of wastewater link i in terms of invert levels and length of the link, in equation (3) :

$$2.5\, Q_{avi} = 143.534\ C_R(h_r.D_i)^{0.6575} \left(\frac{X_i - Y_i}{L_i}\right)^{0.5525} a_r D^2 \qquad (8)$$

where

X_i = invert elevation at upstream end of link i (m)

Y_i = invert elevation at downstream end of link i (m)

Rearranging equation (8) :

$$D_i = \left[0.0174 \frac{Q_{avi}}{C_R a_r} L_i^{0.5525} (X_i - Y_i)^{-0.5525} h_r^{-0.6575} \right]^{0.3736} \qquad (9)$$

Also substituting the values of R from equation (7), and expressing S in terms of invert levels, in equation (1) :

$$V_i = 143.534\ C_R\ (h_r.D_i)^{0.6575} \left(\frac{X_i - Y_i}{L_i}\right)^{0.5525} \qquad (10)$$

Another expression for velocity in link i incorporating the flow and diameter is

$V_i = 2.5\ Q_{avi}/A_i$

or, from equation (5),

$$V_i = \frac{2.5\ Q_{avi}}{a_r D_i^2} \qquad (11)$$

Cost Model

The cost of wastewater collection systems consists of the supply cost of pipes and accessories, laying and jointing cost of pipes at various depths and cost of pumping. The cost function is based on prevailing rates of material and labour at the site. The annual cash flow in various components of wastewater collection system is summed up to identify the objective function in the optimization process. The annual cost is related to capital cost by following relationship (6) :

$$A = C \left[i \left\{ \frac{(1+i)^n - K}{(1+i)^n -} \right\} + \frac{m}{100} \right] \qquad (12)$$

where

A = annual cost

C = capital cost

i = compound rate of interest

n = life of component under consideration

K = salvage factor

Twe cost data for supply of nonpressure concrete pipes, on regression analysis yields (7) :

$$C_1 = a + bD + cD^2 \qquad (13)$$

where

C_1 = cost of supply of pipes in Rupees/meter length (Rs/m)

a, b, c = regression coefficients

The cost of excavation, laying and jointing of wastewater lines is a function of diameter of line and depth of excavation. A regression analysis of data, similar to Gupta et al (2) gives :

$$C_2 = a + bd + cd^2 + ed\,D + fd^2\,D \qquad (14)$$

where

C_2 = cost of excavation, laying and jointing (Rs/mt)

d = depth of excavation (mt)

a, b, c, e, f = regression coefficients

Substituing values of capital cost from equations (13) and (14) in equation (12) alongwith appropriate values for i, n and k the annual expenses on pipes, laying and jointing could be calculated.

The cost of pumping equipment alongwith pump and sump house on regession analysis, gives (7)

$$C_3 = a + b(HP) + C\,(HP)^2 \qquad (15)$$

where

C_3 = cost of pumping equipment, pump and sump house (Rs)

HP = horse power of pumping equipment

a, b, c = regression coefficients

Substituting the value of capital cost of pumping station from equation (15) in equation (12), the annual expenses could be calculated.

The annual expenditure on energy and staff for maintenance could be expressed as :

$$A = aQH + b \qquad (16)$$

where

Q = rate of pumping (cum/sec)

H = lift of wastewater at the pumping station (m)

a, b = constants

CONSTRAINTS

Certain technological constraints need to be satisfied in order to fulfil functional requirements and structural safety of the system. In all seven constraints have been identified in this problem, viz. :

1. Minimum allowable diameter constraint

$$D_{min} - D_i \leqslant 0 \quad (17)$$

2. Diameter Progression Constraint

$$D_{i-1} - D_i \leqslant 0 \quad (18)$$

3. Minimum velocity constraint

$$V_{min} - V_i \leqslant 0 \quad (19)$$

4. Maximum velocity constraint

$$V_i - V_{max} \leqslant 0 \quad (20)$$

5. Invert progression constraint

$$X_i - Y_{i-1} \leqslant 0 \quad (21)$$

6. Minimum cover constraint

$$C_{min} - GL_{i+1} + Y_i + D_i \leqslant 0 \quad (22)$$

where

C_{min} = minimum allowable cover (m)

GL = ground level (m)

7. Maximum depth constraint

$$GL_{i+1} - Y_i - d_{max} \leqslant 0 \quad (23)$$

where

d_{max} = maximum allowable depth (m)

Thus the depth-diameter optimization problem for a wastewater collection system has been formulated as a constrained nonlinear mathematical programming problem.

Optimization Algorithm

In order to ensure the achievement of a global optimum solution it is imperative that the objective function and the constraints be convex in nature since the objective funtion is to be minimized. A check on the nature of objective function and constraints reveals (7) that except for minimum velocity constraint, Eq. (19), all other functions are either convex or linear in nature. The constraints have, accordingly been converted into conditions in the design part of the optimization programme and objective function minimized as an uncconstrained problem with recourse to Univariate method.

The search for the minima in the Univariate method proceeds in a manner defined by,

$$\overline{D}_{q+1} = \overline{D} + \propto \overline{S}_q$$

Where

$\overline{D}_{q+1}$ = $(q+1)^{th}$ value of decision variable

$\overline{D}_q$ = q^{th} value of decision variable

$\propto$ = step length chosen such that $F(\overline{D}_{q+1}) \leqslant F(\overline{D}_q)$

$\overline{S}_q$ = direction vector

The optimum step length in the present study has been determined by quadratic interpolation. The flow diagrams for the univariate method and quadratic interpolation are available in literature (8).

Optimal design of wastewater collection systems

The steps involved in the process of optimum design of wastewater collection systems are listed below :

1) The design data for the system including discharge at the nodes, length of the links, ground elevations and constraint value (viz. minimum and maximum velocities, minimum cover and diameter and maximum depth), step length and convergence criteria, is specified.

2) Each link of the system is designed as per conventional design procedure satisfying all constraints. The design part of the software is inbuilt in the optimization programme. The design values so obtained constitute the starting values for the decision variables in the optimization process.

3) The starting values of decision variables for the first link are improved by the Univariate algorithm alongwith quadratic fit for minimizing the objective function for total system. The process is continued till the convergence criteria is satisfied.

4) The procedure is repeated for all the links after deleting the links already optimized.

5) The optimal decision variables and costs are then printed.

The main programme for optimization has accordingly been prepared and used for optimal design of several wastewater Collection Schemes (2, 3, 9, 10) A perusal of information presented in Reference 2, 3, 9 and 10 brings out that the reduction in diameter and depth of excavation are conducive to reduced cos itn optimal design vis-a-vis conventional design, eg. the saving in 162 links, 5.53 km. long wastewater Collection System at IIT, Powai (10), works out over 18 percent as presented in Table 1. It is contended that the savings will be more pronounced for larger systems.

TABLE 1 SUMMARY OF COST COMPARISON BETWEEN CONVENTIONAL & OPTIMAL DESIGNS AT I. I. T., POWAI.

Area Sud-division	Cost Rupees	
	Conventional Design*	Optimal Design
Zone I	1,62,000	1,10,000
Zone II	6,60,000	5,35,000
Zone III	2,83,000	2,60,000
Total	11,05,000	9,05,000
	Saving ~ 18%	

* Conventional design consists in determining the diameter of wastewater lines for know discharges and a priorti fixed gradients.

The execution time for this case study was 10.5 minutes on an EC 1030 computer. The requirement of storage space was also small.

A sensitivity analysis around the optimal design was carried out in some case studies (2,7) with a view to assess the cost implications of variations in optimal decision variables.

Conclusions

The computer software developed for the optimization of wastewater collection systems employing Univariate method is fast converging, requires small computer memory, selects the diameter of wastewater lines from a discrete set of commercially available sizes and leads to a global optimum design. It is also based on an exact mathematical simulation of real world systems.

Notwithstanding the consideration of each link separately (two decision variables at a time) in the optimization process, the totality of the system has been incorporated in this work to some extent by optimizing the total cost of the system. Further research is, however, underway to obviate the limitation of sequential optimization.

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Use of Mathematical Models in Water Distribution System Design

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Introduction

It has been estimated that in India an investment of the order of Rs. 9200 crores might be needed if the laudable objective of "water for all" of the 1977 Mar del plata conference is to be implemented successfully during the International Water Supply and Sanitation Decade 1980-1990. In view of the massive investment, it becomes imperative that all professional engineers concerned with the investigation, design and construction of water supply and sanitation schemes become familiar with the efficient tools and techniques of economic analysis applicable to such systems and apply them for effective use of the resources. During the last two decades, considerable progress has been made in identifying, developing and applying suitable techniques such as linear and some classes of non-linear programming, dynamic programming and simulation to a variety of well-known design problems such as

- Optimal capacity allocation and water release policy formulation in a multi-reservoir water resource system,
- Capacity expansion policy of water and wastewater treatment plants,
- Discharge allocation and sizing of regional treatment plants in river basin water quality management,
- Minimum-cost design of water distribution networks including pipes, reservoirs, pumps and appurtenances,
- Economic sizing of individual units in treatment plants, and
- Selecting optimal routes and sizes in long-distance transmission of water

and several others. For long, the decisions of engineers and planners in collecting and evaluating data and formulating rules for their use in design have been made in the context of objectives that often have been conflicting, poorly defined and imperfectly connected with external economy. Some of the design methodology and empiricism of earlier eras contain assumptions, now no longer tenable under close scrutiny. Many of these rules have stood the test of time, however, and are valid even today despite shifts in public objectives and private desires. It is necessary to distinguish between them and improve the design methodology and data base using the modern tools of systems analysis. The recent and rapid development of the logic of planning and advances in digital computer capabilities have encouraged a new generation of engineers to aspire to create methods of systems analysis of ever widening scope. It is the endeavour in this presentation only to illustrate the application of mathematical modelling and Systems Analysis with special reference to the design of water distribution networks.

At the outset, it may be noted that not all problems are suitable candidates for Systems Analysis studies. From the view point of the formal system analyst, some of the properties of the ideal problem are :

i) the objective of the system should be clearly defined;

ii) it should be possible to represent the essential characteristics of the system in terms of a reasonably tractable mathematical model;

iii) it should be possible to estimate the parameters of such models from readily available data;

iv) current practice should leave plenty of room for improvement.
From a practical point of view, one could add :

v) the problem should be one of high priority, and

vi) the problem should be common enough to make reuse of such models likely, or extension of their applicability to other types of problem convenient*.

These characteristic are not wholly compatible with one another. For example the fourth tends to conflict with several of the others. However, in the problem under discussion that there is a wide scope for the application of systems analysis techniques has been amply demonstrated.

Mathematical Models and Mathematical Programming :

The use of formal mathematical models as an aid to design or managerial decision making is an integral part of the techniques applicable. Four necessary steps in such use are :

i) Construct a model that satisfies the conditions of the available mathematical and computational techniques, and that at the same time adequately represents the important features of system performance. It usually makes little sense to formulate systems models that cannot be solved.

ii) Define a criterion function, or 'measure of merit' that enables all of the possible designs or plans to be arranged in order of preference. This must be expressed formally and quantitatively as a function of the system variables and parameters. The principal purpose of this 'objective' function is to reduce the indeterminacy of the model. Stated differently, the objective function is used to eliminate all the less desirable, but technically possible, systems designs.

It is often difficult to quantify and agree upon the formal objective function. It is precisely at this point that value judgement enter prominently, and disciplines other than engineering — particularly economics and other social sciences — become especially important. Traditionally, engineers have used the (minimizing of the) "Cost function" as the objectives or criterion function.

iii) Obtain empirical estimates of the parameters of the model for the given situation. Almost inevitably this will involve the use of conventional or advanced statistical techniques.

iv) Solve the model, using mathematical and computational techniques to select values of decision or design variable that minimize (if cost is the objective) — or, more generally, optimize — the objective function. In this process modern computing facilites are increasingly necessary.

The construction of a valid mathematical model of a water distribution network design situation generally results in a ' mathematical programming ' problem. Mathematical programming implies that an objective function representing the criterion to be optimized has been specified and a set of constraints which the system variables have to meet has been prescribed. The set of conistraints may portray the physical laws such as flow formulas, non-negativity of the veriables, operational requirements such as commercially available pipe sizes or maximum permissible limits of pollutants, and others. The constraints may be equations or inequalities; they may be linear or nonlinear. Once the mathematical programming problem has been completely specified to reflect the system performance as close to reality as possible, we can recognize its kind : whether it is an unconstrained or constrained optimization, linear programming, nonlinear programming or dynamic programming situation, etc. For each class, either well-established techniques are available or it might be necessary to develop a technique using the power of the high-speed digital computer. A typical water distribution network design problem involving the sizing of pipes is presented.

* For the explicit identification of such characteristics and related feature, and indeed for a further exposition of the concepts outlined here, see reference 1.

Minimum-Cost Pipe Sizing in Distribution Systems

The problem of analysis and design of water distribution systems has been existing for a long time. It is still a fertile subject for investigation, the various levels of complexity or dimensions of the problem can be recognised such as—

- balancing for one demand pattern,
- sizing of pipes in network,
- sizing of total system, steady-state,
- sizing of total system, time-varying supply and demand, and others.

Here, only some of the well established parts of the problem are considered. Specifically, the problem of minimum cost design of a distribution pipe network taken up subject to

i) the provision of required domestic and fire flows at specified draw-off junctions

and

ii) the maintenance of minimum residual pressure at critical junctions

which can be examined using the mathematical techniques of simulation and optimization. The problem can be cast as one of non-linear, integer programming. Such a model and an engineering approach to its solution are briefly discussed. More detailed exposition and reference to earlier works on the topic can be found in literature (2), (3), (4).

Formulation of the Objective Function

The principal part of the total cost function of a distribution pipe network is the cost of pipes. The installed first costs of pipes can be related to their diameter by an empirical exponential function of the form,

$$C' = \alpha \, l \, D^{\eta} \quad \ldots . \text{Eq. (1)}$$

where C′ is in Rupees, l is the length of pipe and D is the diameter. α and η are parameters to be determined locally. Then, the total installed cost of all the pipes in the network, is

$$C_p = \sum_{all(i,j)} \alpha \, l_{i,j} \, D_{i,j}^{\eta} \quad \ldots . \text{Eq. (2)}$$

where the paired subscript (i, j) denotes the jth pipe in loop i (Fig. 1).

In addition to pipe cost, the cost of friction losses in the pipe network constitutes another important component of the total cost. In pumped systems, it represents the cost of energy required to overcome pipe friction; in gravity systems, the same is an indirect cost on the system if one considers that higher pressures are desirable at the draw-of points. As such, the energy cost of pipe friction losses can be incorporated in the objective function for all supplies. Relating this cost to motive power prices (here assumed as electricity), the present value of cost associated with pipe friction losses in the system can be

$$C_T = \alpha \sum_{(i,j)} l_{i,j} \, D_{i,j}^{\eta} + \gamma \left(\frac{P_v \, w \, b \, E}{e} \right) \sum_{(i,j)} Q_{i,j} \, H_{i,j} \quad .. \text{Eq. (3)}$$

computed and incorporated in the objective function to be minimized. Such a total cost function is where $Q_{i,j}$ and $H_{i,j}$ stand for the flow and head loss in pipe (i, j), Pv is the present value of an annuity of 1 Rupee discounted at rate r over the economic time horizon T, w is the unit weight of water, b is a load building factor, E is the unit cost of electricity, e is the wire-to-water efficiency of pumping and γ is a constant derived from units employed.

Formulation of the Constraints

The diameters, flows and head losses in the pipe network must meet certain constraints in the from of hydraulic flow formulae, Kircholf laws for nodes and loops, and certain operational constraints regarding minimum pipe sizes, commercially available pipe sizes and minimum permissible residual pressures. Such constraints can be represented by the following set :

$$(a)\ H_{i,j} - \left[0.08435 f \, l_{i,j} (D_{i,j})^{-5} (|Q_{i,j}|)\right] Q_{i,j} = 0$$
for all pipes

$$(b)\ \left(\sum_{some(i,j)} Q_{i,j}\right)_m + q_m = 0 \text{ for all nodes}$$

$$(c)\ \left(\sum H_{i,j}\right)_i + S_i = 0 \text{ for all loops}$$

$$(d)\ D_{i,j} \geq D_{min}, \text{ for all pipes} \quad \ldots\ldots \text{Eq. (4)}$$

$$(e)\ D_{i,j} \in \{D_A\} = \{D1, D2, \ldots D_a\}, \text{ for all pipes}$$

$$(f)\ \left(\sum_{(some(i,j))} H_{i,j}\right)_k \leq h_k, \text{ over all specified paths}$$

$$(g)\ g_p(\text{relevant } q_m, S_i) = 0, \text{ for all pumps, if any}$$

In the constraints set, (a) is a version of D'arcy-Weisbach formula for flow in pipes;* (b) and (c) are Kirchoffs' node and loop laws respectively; (d) ensures that all pipes are not smaller than prescribed minimum size D_{min} (e) specifies that the sizes shall correspond to commercially available ones D_1, D_2 ...... D_a; (f) is the equivalent of maintaining minimum permissible residual pressures at draw-off nodes, by requiring that along specified pathways in the network, the sum of headlosses shall not exceed preset magnitudes; and (g), guarantees that the inflow and pressure at pump nodes shall correspond to the specified characteristic curves of pumps. The quantities q_m, S_i and h_k stand for inflow (or outflow) at node m, unbalanced head+ at loop i, and maximum pressure difference permissible over path k, respectively.

The Integer-programming Problem

This mathematical model for cost minimization of pipe networks assumes that the layout and lengths of pipes are known, and, for the moment, only one demand pattern is considered. The problem can now be seen to be one of non-linear constrained minimization in numerous variables. The constraint set (e) restricts the domain of feasible diameters to a few specific values thereby discretizing the objective function and the set of feasible diameters. In this analysis, it is assumd that α, η, Pv, b, E, e and f are known, non-negative parameters and $l_{i,j}$, q_m, S_i, D_{min}, D_A, and h_k^- are given in put vectors. The three sets of variables $D_{i,j}$, $Q_{i,j}$ and $H_{i,j}$ are treated as decision variable: i.e., the solution seeks that that set of feasible $D_{i,j}$, $Q_{i,j}$ and $H_{i,j}$ which minimizes the total cost of the pipe network (equation 3).

Attempts have been made in past investigations to treat the diameters as continuous variables, arrive at a minimum cost solution on that basis, and select the next larger or nearest available commercial size for each pipe as the solution for diameter set. However, the fact that headloss is inversely dependent on the fifth power of the diameters should caution the analyst that the solution so obtained could be far from "optimal". That such an approach is suboptimal has been pointed out (5). Also, even under greatly simplifying assumptions, convexity tests of the objective function do not show promise. For this non-linear, integer programming problem, an iterative, sequential search procedure has been developed (2) and it is briefly described here.

+ The unbalanced head is usually zero in real loops. However, in synthetic loops connecting reservoirs or pumps, this is non-zero.

* Others could be used.

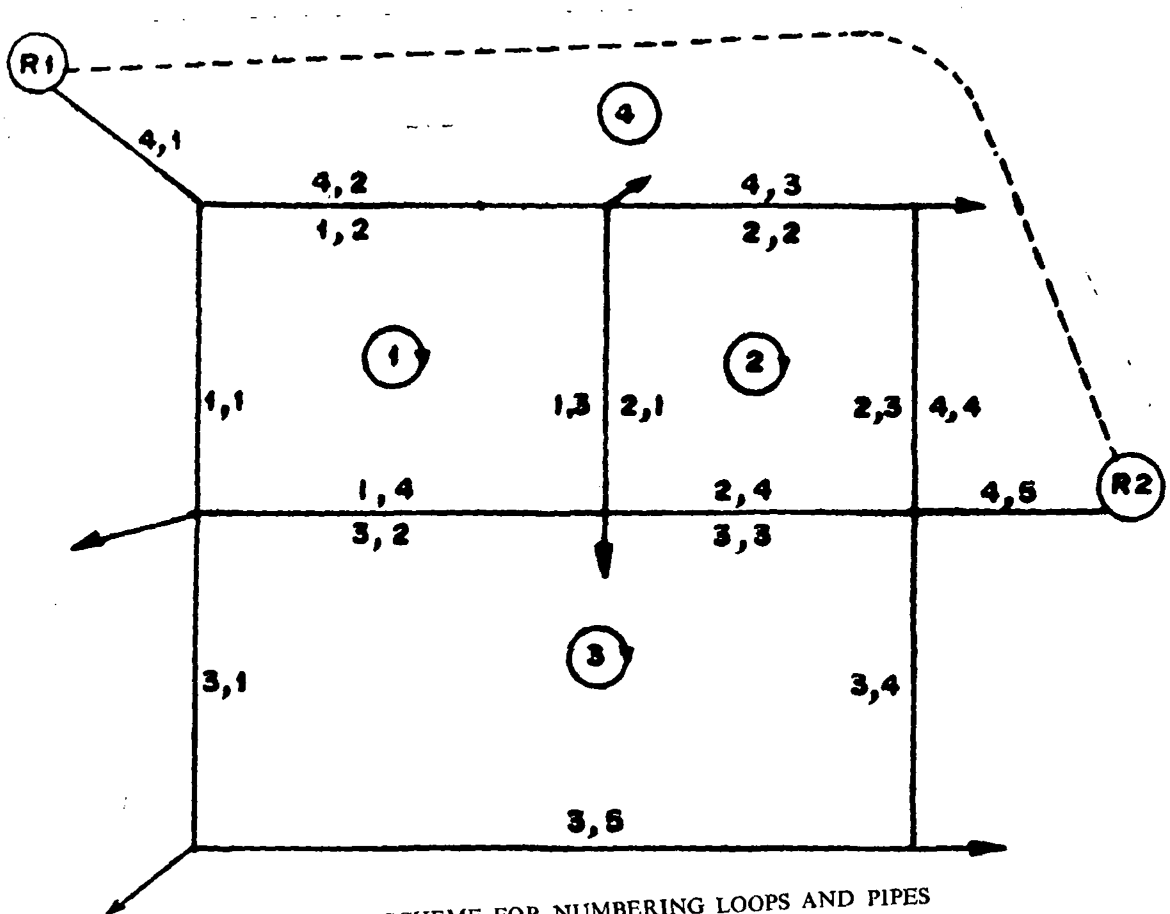

FIG. 1. SCHEME FOR NUMBERING LOOPS AND PIPES

1, 2, 3, REAL, PRIMARY LOOPS

4 - SYNTHETIC LOOPS

(i, j) - j^{th} PIPE OF LOOP i

DRAW-OFFS AT JUNCTIONS AND WATER ELEVATIONS AT RESERVOIRS ARE KNOWN.

Constructing a Starting Solution

The most direct way of meeting constraint sets (d) and (e) is to choose diameters as the variables to be set for a trial, and derive other decision variables (Q), and (H), therefrom. Then, while selecting the diameters, only those feasible with respect to (d) and (e) may be chosen. Such diameter selection is a significant step which eliminates the trial and error procedures otherwise required. The setting of such a diameter vector ($D_{i,j}$) leaves the flows and headlosses to be determined. Solving for $Q_{i,j}$ and $H_{i,j}$ with given $D_{i,j}$ from constraint sets (a), (b) and (c) is the familiar problem of hydraulic network balancing.

Balancing the Network with a Trial set of Diameters

Traditionally, engineers have used the iterative Hardy cross relaxation technique to solve this balancing problem. However, more powerful, rapidly converging methods such as the Newton-Raphson technique have been developed and employed towards this end (2) (3).

Constructing a Penalty Function

If the constraints system is now examined, the method of starting with a feasible diameter vector and balancing the network to obtain feasible flows and head losses has given rise to a solution feasible with respect to all constraints except set (f). The resulting head losses may either satisfy or fail to satisfy set (f); i. e. , headlosses summed over specified paths may or may not be less than the permissible limits set. A rational approach to the treatment of these consraints is to weight them and blend them into the objective function in such a form that the violation of these constraints will penalize the causative design while ranking alternative designs. Such is the penalty function approach. This penalty function can be related to the extent of violation of the (f) constraints. Blending this penalty function with the earlier total cost function produces a new, more complete function for ranking. Such a function is

Total cost of a design, $s = C_s = C_T +$ Penalty . . . Eq. (5).

Note that designs which meet constraints (f) are favoured in the ranking since the penalty will be accordingly zero. A minimal solution with the above ranking function will normally be a feasible one with respect to (f).

Sequential Random Search Procedure

Having established the model and formulated a function to rank alternative designs, a sequential random search can be conducted starting with a trial design (set of diameters) and improving it in successive iterations until a terminal design very low probability of improvement results. The rationale of this method differs from that of classical optimization in that it does not attempt to identify the global optimum with complete certainty; rather, *it provides a statistical estimator of the best design.* The technique can be summarised as follows:

1. Select a starting design from a specified population of starting designs. It could be master-plan design or existing design in practical problems.

2. Proceed sequentially from the starting design to an improved Terminal Design (T. D) according to a set of rules involving random sampling (sweetening). This involves searching in the neighbourhood of successive central designs and pegging the best in the neighbourhood as the central design for subsequent (next) cast.

3. Repeat the above steps until several T. D' are obtained. This provides a sample of, say n Terminal Designs.

4. Identify the least costly of the n Terminal Design as the current estimator of the global optimum (to be termed) "Optimal desing'' hereafter). Steps 1 to 4 constitute a "Search''.

5. Examine the optimal design in detail and a scertain whether it is satisfactory from engineering experience. If so, the search is terminated. Otherwise, repeat from step 1, with a new set of rules for sampling (i e. new population of starting designs and new rules for 'sweetening'). This 5 step procedure is the core of the method developed and applied.

An example of a real-world water distribution system design problem for which a computer model was developed on the lines described and the technique applied to arrive at a minimum-cost solution is presented.

The Jullundur Example (6)

Skeletonization of the Network

For purpose of computer analysis, a skeletonised version of the distribution network map was prepared consisting of all pipe sizes equal to to or larger than 15 cm indicated in the Master plan. To a large extent, the existing pipe sizes in the present system were retained in the initial assignment of diameters. The skeletonised network thus prepared consisted of 139 loops and more then 500 pipes. For purposes of design, the network was divided into four parts with each part consisting of not more than 50 loops. The material of the pipe chosen was cast-iron, class LA, as indicated by the user agency and a Hazen-William's "C" value of 100 was adopted for all pipes. Any pipe size selected had to be one of the eight commercially available diameters ranging from 15 to 50 cm.

Load and Demand Computation

The city was divided into 20 zones according to the Master Plan and each zone was further sub divided into several sectors. Based on the ultimate population, hours of supply, per capita rate of supply and the demand for other uses, the actual water demand of each sector was estimated. The average per capita demand was specified as 205 lpcd. The peak load factor was given as 2.1 times the average daily demand. The nodal demands accordingly derived were the basic load on the network; they were used for further analysis as the steady-state draw-off from the system at all the nodes.

Analysis

The scope of the analysis was to determine the minium cost combination of pipe sizes and reservoirs, both overhead and underground so that adequate amounts of water will be available over the entire urbanisable area of the city at adequate pressures at all points in the distribution system, the minimum residual pressure required being specified as 17 m. Two alternative input conditions were investigated, one with 25 reservoirs and the other with 15 reservoirs for the 1991 loading condition. The Zone commanded by the reservoirs, their capacities, heights and costs were determined outside the computer by a rigorous analysis based on economic zoning and mass-curve concepts. Once the computer program based on the stochastic, sequential search procedure was updated and checked out, and the basic data for running the computer program was made ready, one hundred alternative designs in 10 casts of 10 each were tested for each of the four parts of the network for each of the two input conditions. The *best design* resulting from this search (with minor modifications necessitated by practical considerations) was retained as the 'Optimum' design for the 1991 condition. Further elaborate search could theoretically lead to a better design, but the probability of such an improvement would be minimal and the utility or worth of such an improvement was not commensurate with the cost of further search. Hence the total number of alternatives was *Set at 100.*

For the network *balancing* problem (to determine flows and head losses for a set of given diameters), either Kirchhoff's node equations or loop equation can be solved. In solving a system of simultaneous equations on the computer, the time of computation and therefore the cost are directly related to the *number* of equation to be solved. In any real-world network, the number of nodes is usually much larger than the number of loops. Hence, in order to minimize the cost of computer time and increase the efficiency of computation, *the lop equation* approach (of balancing heads by correcting assumed flows) was followed. *The Newton-Raphson* method of network balancing was programmed and used as a subroutine towards this end.

Results

The results of the computer run indicated the combination of the pipe sizes leading to minimum cost for the two input conditions indentified earlier. The balanced flows and head losses corresponding to the minimum cost solution were also obtained simultaneously. The residual pressures at all the nodal points fulfilled the minimum pressure requirement specified. The cost of reservoirs and pumpsets in each case was added to the total pipe and power costs arrived at from the computer results. According to the Master plan estimates, the total cost of the distribution system for the urbanisable area was about Rs. 11.00 crores whereas according to the design based on the computer model, the minimun cost turned out to be only about Rs. 7.16 crores with 25 reservoirs and 7.08 crores with 15 reservoirs (6). The marginal difference in costs between the 25- and 15- reservoirs alternatives also brought home the point that as long as the minimum-cost design by rigorous computer-based methods is sought, the choice between the number of reservoirs could well be based on the other dimensioas of feasibility such as ease of land acquisition, ease of operation and maintenance and social acceptability of the solution. Including pipes of sizes less than 150 mm, the total cost of the design obtained from the computer—based method was not likely to exceed Rs. 9.00 crores, thus representing a saving of about 20% on master plan estimates, which is quite significant.

Similar application of the model and technique for designing the extensions and improvements to the distribution networks of some other cities (such as Srinagar and Jammu) are now in progress.

Mathematical Model for a 'Tree' System Design

Where the distribution system consists of a long distance transmission main with 'trees' fanning out from branches the minimum cost problem can be conceived as

i) the minimum—cost design of a long, large main subject to several intermediate draw—off points, and

ii) the minimum-cost design of a 'tree' system involving no loops where the inlet and exit pressures are known and all pipe flows are explicitly known.

A model based on the classical Lagrangian undetermined multiplier technique can be developed and applied to the first part and a modified version of the same can be adopted and applied for the second part.

Just to illustrate the minimum cost sizing of a long-distance gravity main subject to several intermediate draw – offs, let L_i, D_i, f_i and Q_i represent the length, Diameter, friction factor and discharge of section] i of the compound pipe. Only D_i is the unknown decision variable. If H_i is the headloss due to friction in pipe section i, the minimum-cost pipe sizing problem can be represented by the model

$$\text{Minimize } C(D) \equiv \alpha \sum_i L_i D_i^{\eta}$$

$$\text{subject to } H_i = f'_i L_i D_i^{-5} Q_i^2 \text{ for all } i \quad \ldots\text{Eq.}(6)$$

$$\text{and } \sum_i H_i \leq h_k,$$

the maximum permissible headloss along the entire length of the pipe line.

were α and η are parameters derivable from pipe cost data and f_i is the Darcy - Weisbach friction factor multiplied by a constant depending upon the units employed which will be 0.2296 when Q is in lpm, D is in cm, g is in m/sec² and L and H are in meters. The Lagrangian function

$$L(D,\lambda) \equiv \alpha \sum_i L_i D_i^{\eta} + \lambda\left(\sum_i f'_i L_i Q_i^2 D_i^{-5} - h_k\right) \ldots\text{Eq.}(7)$$

can now be written as and if all the f_i can be assumed to be equal, the classical solution to the diameter in section i can be derived as

$$D_i = \left[\frac{f'}{h_k} \sum_i L_i Q_i^{2\eta/(5+\eta)}\right]^{0.2} Q_i^{2/(5+\eta)} \quad \ldots\text{Eq.}(8)$$

This is an explicit closed-form expression for the minimum cost pipe size of a compound gravity main. The diameters arrived at can be adjusted to the commercially available sizes by an iterative application of the expression for a progressively decreasing number of segments. Expressions for minimum-cost pipe sizing of pumping mains with intermediate draw-offs are similarly obtainable.

These examples are meant only to illustrate the range of problems in water distribution system design for which computer-based techniques can provide adequate solutions. Other examples of application are possible.

Epilogue

Water distribution and the design of pipe networks are not new to environmental or hydraulic engineers. Over the past two decades, considerble progress has been made in the design and analysis of such systems employing the advances made in quantitative optimization techniques and computer technology. Even complicated systems including a variety of boundary conditions such as multiple reservoirs and pumps and multiple demand patterns can now be handled without resorting to empiricism. Similarly, the range of choice in materials, laying and jointing techniques and maintenance procedures has widened giving an opportunity for the engineers in charge of water distiibution systems to provide ample returns for the large public investment involved in such systems. With a progressive outlook and a willingness to apply tested and proved modern tools, he can creditably fulfil his obligation in this direction.

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Simplified Water Treatment System

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Introduction

More than eighty per cent of population in Inda constitute communities with less than 10,000 people. Many of these communities have population less than 500. To keep down the cost and to make optimum use of available water resources, schemes for such communities are designed for consumption rate of 50 to 60 litres per capita per day. Many housing complexes, small scale industrial units, tourist centres. etc., also need small capacity water supply schemes. Many of the water supply schemes need, therefore, capacities in the range of 2,500 litres per day to about 3 million litres per day.

Many of these small communities are located in remote places, some time at hill tops or in thick jungles or at places which are not even accessible by roads. At such places, no skilled labour or repairs and maintenance facilities are available. Electrical power also may not be available and if available, cannot be fully relied upon.

At many places ground water sources are not available and surface sources have to be used. Many rivers and canals carry very heavy silt and colloidal clay load during rains. The discharge of small rivulets may be very large during rains but may be very low in other months. At some places, ground water available contains either excessive fluorides, or hardness, or iron and manganese or total dissolved solids. And if no surface source is available at a reasonable distance, these sources have to be used. In all such cases, a suitable treatment plant has to be incorporated in the scheme. The Central and State Governments are very keen to provide this basic need of safe and adequate drinking water to these communities. The work is massive, and unless these schemes are executed with enough speed, it will be impossible to reach the target in near future. To attain this speed and to keep down the capital costs, the plants should be able to be designed, constructed or fabricated at the district level with the use of local materials and labour.

The problems, therefore, are:

1. Are suitable small capacity water treatment plants easily available?
2. Are they sturdy, easy to install, maintain and operate?
3. Can they run without electrical or fuel power?
4. Are their capital and running costs reasonable?
5. Can they be designed and fabricated or constructed at district level and easily transported?

Even for large capacity, the conventional water treatment plants are not always able to give the desirable service. Their capital and maintenance costs are also quite high. For removal of hardness, dissolved solids, fluorides, iron and manganese, suitable treament plants are feasible. However, they are difficult to procure to suit the local conditions. Therefore, solutions to most of the problems raised need to be found out. R & D work on priority basis has to be undertaken.

The first and essential step is to categorise and quantify the needs. The needs of the other developing countries also will have to be kept in mind when doing the exercise so that solutions obtained can have wider applications. Field engineers, manufacturers and research scientists have to get together to achieve this. Once this is done, priorities could be worked out.

Considerable research work has been carried out by scientists in this country and other countries and some approaches have been developed. Suitability of these approaches could be studied and treatment units to suit the identified categories could be developed. Research work could also be undertaken to develop new treatment plants suitable to our needs.

To initiate thinking on these lines and to illustrate the concept, some categorisation is suggested (Appendix 'A'). It is no way an effort to make an exhaustive list, but to suggest a possible approach only.

Suggested Approaches

1. Low Rate Filters

Conventional rapid sand filters oprate at flow rate of 5 to 6 $M^3/M^2/hr$. To achieve economy, high rate filters have been developed (8-10 $M^3/M^2/hr$). But higher rate reduces efficiency, increases head loss and gives shorter length of runs. The effluent quality is likely to deteriorate with time and skilled operation is needed. To achieve desired results pre-treatment should also be of higher order. In many cases depth of media has also to be increased as higher rates cause deeper penetration of impurities. Low rate filters give higher removal efficiency (specially bacterial),lesser headloss and longer length of runs. Effluent quality does not deteriorate with time and lesser media depth could be adopted.

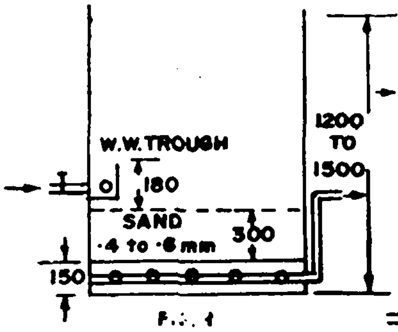
The experimental work carried out by the author (1) and some (2) other workers indicates that 1.5-2.5 $M^3/M^2/hr$ rate of filtration with sand media of 0.45-0.6 mm sizes gives optimum advantages. The sand depth could be 0.2 to 0.3 M and the headloss seldom exceeds 0.6 M. in 24 hours. This enables to reduce the height of the filter tank to 1 to 1.2 M. Therefore, brick, stone, R. C. C. ferrocrete, M. S. G. I. or fibre glass etc. could be conveniently used to construct or fabricate the filter units. Lesser head for back wash or using surface jets for cleaning media are other advantages. For small capacities, a pre-fabricated pressure unit could be used which can be transported through a bullock cart or carried on head-load or which could be air-dropped. It could be designed to treat directly water of low turbidity making the treatment unit compact, simple and considerably cheaper. For higher capacities, multi-inlet and multioutlet filters developed by the author could be used (Figure 1, 2).

2. Double Layer Filters

In this filter, influent water first passes through a coarser medium and then through a finer medium (Fig. 3). This enables the filter to accommodate more impurities with comparatively lesser head-loss. If suitable sizes and depths of media are used higher flow rates could also be used. With lower rates, it could be used to treat directly waters of low to moderate turbidity. The double layer could be obtained by using anthracite, suitable hard coal, coconut kernels, etc., over a sand bed. If the size of both the layers are chosen in accordance with their specific gravities both the layers could be conveniently back-washed. If coarse and fine sand is to be used to constitute the two layers an upflow filter, or stage filter (Fig 4) or horizontal filter (Fig. 5) could be used. Stage filter and horizontal filter offer more flexibility in design and are more suitable to treat waters of moderate turbidity. As depth of filter tank could be much smaller in these two cases, local materials could be used conveniently and the construction cost could be brought down. To achieve compactness multi-inlet and mul i-outlet approach could also be adopted in double layer filters.

3. Simple Mixing and Coagulation Units

Alum is commonly used coagulant, In conventional unit 2% to 5% alum solution tanks (each of 8 hours capacity) are used. These are interconnected by valves and pipes to a constant level dosing tank with a ball valve. To vary the dose with discharge, lever and float arrangements with special orifice valves or weirs are used. Alum is added to a coagulation chamber (flash mixing) with 45 to 90 secs detention capacity. A mechanical mixer is used to mix alum does uniformly with raw water. Also stirrers have to be provided in alum solution tanks to keep uniform concentration in these tanks. Alum is corrosive and in diluted solutions it gives suspensions. The temperature being higher in India, the corrsion rate also is high. The pipes and valves get blocked and due to corrosion not only accuracy in dosing is affected but the levers and valves do not work properly and the arrangements fail. Thus, much simpler, reliable and economical coagulant dosing and mixing arrangements have to be evolved. Author has evolved parallel flow dosers (Fig. 6). These are simpler, reliable and have much less maintenance troubles. If effluent alum solution is directly used to determine optimum dose, the flow to be adjusted is directly obtained. These dosers are in use at a few places in the country and are giving satisfactory performances.



F. 1
LOW RATE FILTER

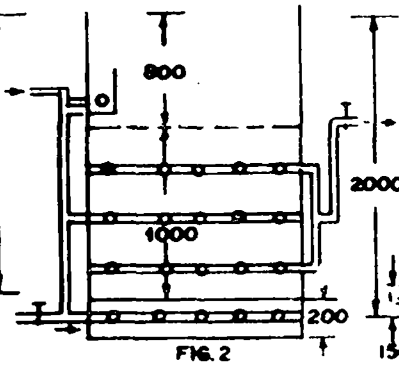


FIG. 2
LOW RATE FILTER (MINI)

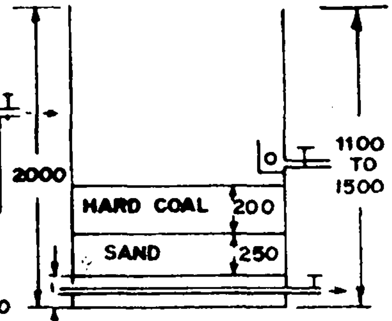


FIG. 3
DOUBLE LAYER FILTER

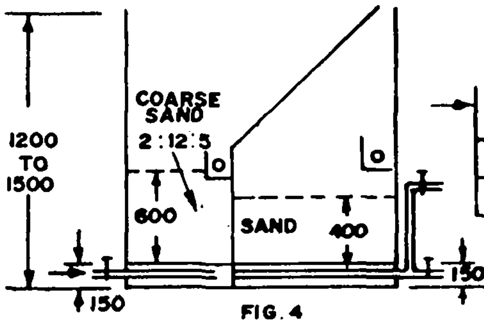


FIG. 4
STAGE FILTER

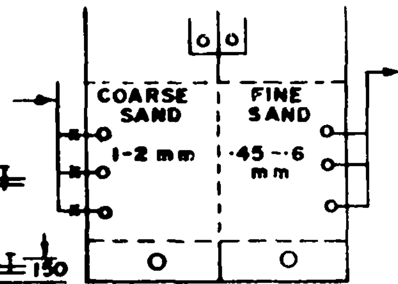


FIG. 5
HORIZONTAL FILTER

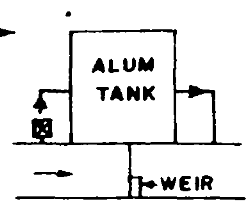


FIG. 6
PARALLEL FLOW DOSER

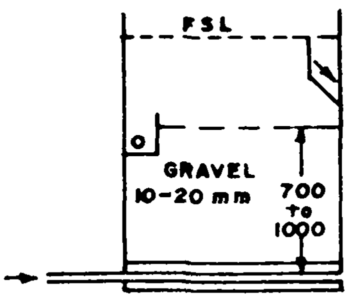


FIG. 7
GRAVEL FLOCCULATORS

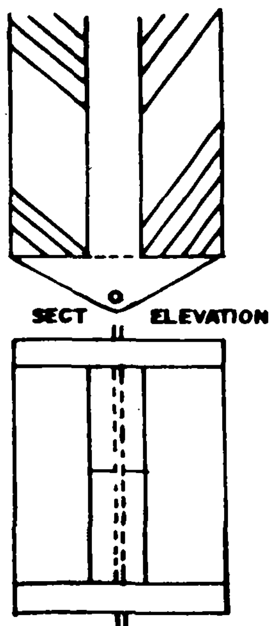


FIG. 8
PLAN
M.B. SETTLER

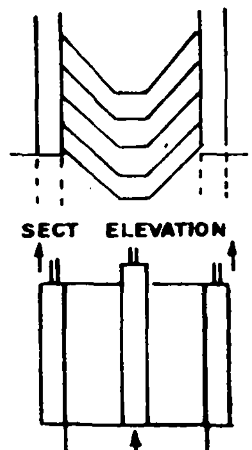


FIG. 9
PLAN
CHANNEL SETTLERS

The chemical reaction of alum solution is quite rapid and it is necessary only to distribute the alum solution uniformly in the incoming raw water. Simple devices like tangential tragectory funnels, vortex formation at inlet of a pipe or a ventury neck and many other simpler hydraulic devices could be used to achieve this. Thus much simpler, reliable and cheaper dosing and mixing arrangements could be evolved, which will be very useful specially in small capacity plants.

4. Simple Flocculation Methods

Microflocs collide to form large flocks if controlled contact opportunity is available. In conventional flocculator this is achieved by using machanically operated paddle flocculators. In such flocculators power distribution is not uniform and rate of contacts per unit time is not adequate. Due to this detention time as large as 30 to 40 minutes is required. This increases the cost and total power requirements.

It is possible to use simple arrangements to create controlled contact opportunities. With better understanding of mechanism of floc formation, simple baffle flocculators could be designed to suit small capacity plants. These flocculators need less time of detention as rate of contact could be increased. Flocculators based on compressed air are also possible. Kinetic energy of incoming water could be used to rotate paddles. Gravel flocculators (Fig. 7) developed by the author are much simpler and can give good flocs within few minutes. In such flocculators backwash arrangements are required to be provided as they are likely to get clogged. During high turbid periods, such flocculators can serve as pre-filters also. More research work needs to be carried out to improve upon these new approaches and to standardize the design parameters. This important unit in pre-treatment could be simplified and its capital and running cost could be considerably brought down. Baffle flocculators and gravel flocculators are giving satisfactory services at the plants where they have been installed.

5. Shallow Depth Settling Units

The time required for settling depends upon the depth of the settling unit. Conventional settling units are 2.5 to 4 M deep and need about two to three hours detention time. Due to large diameters, it is not possible to give adequate slope (30 to 45°) to the bottoms for sludge collection; so mechanical scrapers are used. To reduce the cost, it is necessary to reduce the depth and the detention time. Some modifications are also necessary to avoid scrapers.

Three types of modifications have been tried. These are the tube settlers, multi bottom settlers and channel settlers. In tube settlers, flocculated waters are allowed to pass through a number of 40 to 50 mm tubes inclined at a suitable angle. The sludge flows downwards, while clear water leaves the tube at other end. Tube settlers have been used successfully at one of the treatment plants in Maharashtra. More research work is needed to standardize the design and arrangements. The multi-bottom settlers have been successfully used in many plants in the country. As the M. B. settler uses a verticle sludge core re-suspension of sludge is avoided and thicker sludge gets collected at the bottom. Well arranged channels placed one over the other could also be used to give a compact settling unit (Fig. 9). The effluent can emerge through the sides of the channels. This is expected to give decreased surface loading and flow through velocity as the influent reaches the other end of the channel. More research work is required to be taken up to evolve simpler and cheaper units. But with the available information also considerable simplicity and cost reduction could be achieved by using any one of the above approaches.

6. Control of Chemical Impurities

Rain water during its travel over the earth's surface or through the underground strata picks up certain chemical impurities. Increased industrial activity, and production of new materials and increased quantity of wastewaters are also responsible for addition of chemical impurities in natural waters. But still, commonly encountered chemical impurities in small capacity schemes are, hardness, iron and mangenese, fluorides and dissolved solids. If these are present beyond permissible or tolerable limits, suitable treatment plants have to be provided for.

Usually pressure units are used for controlling hardness or dissolved solids. The resins used for this purpose are quite costly. Skilled personnel are required to operate them. Simpler and cheaper units are not available. For treating brackish waters, a process based on reverse osmosis has been developed but still considerable R & D work needs to be planned.

Some of the approaches that can be tried are :

(i) Development of gravity softners–It is possible to select suitable type and size of resins. The rate of flow and depth of resins could be suitably adjusted to bring down the head loss. This will then enable to use gravity units made in brick, stone, RCC, ferroconcrete, fibre glass, etc. The gravity units will need much less piping and control valves reducing the cost and bringing simplicity in operation. Certain easy tests (like litmus paper) could be developed to assess the hardness of the effluent.

(ii) Development of resins from indigenous materials–It is possible to obtain resins by controlled oxidation of cellulose materials like weeds, or grass or woods. IIT, Delhi Rural Development Centre has taken up a research project for production of such resins and the results obtained so far are quite encouraging. Such resins may not be only cheaper but can be prepared at the district level by a simple process. If the cost could be brought down substantially, these resins could be used as throw away resins and instead of regenerating them after use, they could be used in agriculture. Such resins may be used for not only removal of hardness, but of iron and manganese, fluorides and dissolved solids, considerable R & D work is needed in this regard.

7. *Compact Layouts and Package Plants*

The compactness of layout not only reduces the cost, the land requirements, but also gives convenience in maintenance. Adequate attention is needed to be paid in this regard. The distance between two units, the choice of type size and shape of the units, its depth, etc. has to be given due consideration. For sizes between 1–3 MLD units, rectangular units with depth ranging from 2 to 3 metres may give optimum economy. For plants less than 1 MLD, the depth should be kept to 1.2 to 1.5 M, so that local materials could be used. If these are needed at remote places, circular compact package plants may be desirable. The filter unit may be kept open to the sky to reduce the height of buildings and the cost. If filtered effluent is obtained at a level of 1 to 1. 5 M above the ground, considerable savings result in clear water reservior and clear water pumping. Thus, more information needs to be collected after suitable investigations to give guidelines for selection of plant, the sizes, depths and layouts.

8. *Process and Quality Control*

Many water treatment plants do not have adequate quality control. Adequate laboratory facilities are not available, neither trained personnel. At some other places, costly equipments which do not find adequate use by the staff are provided for. It is, therefore, necessary to carry out research and development work to develop simple and cheaper equipment. For example, instead of turbidity meter, a turbidity comparator could be developed. At many plants, flows meter, gauges have been provided which get out of order very soon. It is also difficult to say whether these are giving desired accuracy, as no provisions are made for measuring their accuracy when in use. Considerable saving could be effected if suitable simpler equipment and gauges are developed.

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APPENDIX 'A'

SUGGESTED CATEGORISATION

A. *Capacity-wise (in MLD)*

1.	Below 0.01	Inspection houses, farm houses, villages below 100 population, small railway stations, small canteens, clubs.
2.	0.01 to 0.1	Tourist centres, restaurants, housing colonies, small villages (200-1000), small dairies and other industries.
3.	0.1 to 1	Small villages (200-5000), small industries, small railway stations, three star hotel, small swimming pools.
4.	1 to 5	Small group of villages, small towns (1000-20,000 population), small industries, five star restaurants, swimming pools, small military cantts.
5.	5 to 25	Medium towns (10,000), medium to large industries, railway stations, military cantonments.
6.	25 to 100	Big towns, big industries.
7.	Above	Large cities, large industries, power houses.

B. *Quality - wise*

	Turbidity Av. Max.	Algal Load	Objectionable chemical impurities	Pollution	Sources
1.	5-100	Negligible	Nil	Low	Shallow walls, springs, inf. galleries, swimmming posts.
2.	50-500	Medium	Nil	Medium	Reservoirs, rivers receiving tail water
3.	50-500	Appreciable	Nil	Medium	Lakes, ponds.
4.	300-5000	Negligible	Nil	Medium	Rivers, canals
5.	1-5	Nii	Hardness about 500	Nil	Deep tube wells in certain areas
6.	1-5	Nil	Fluoride	Nil	Springs, shallow wells, deep wells
7.	1-5	- - -	Iron & Manganese	Nil	Tube well in certain areas

	Turbidity Av.	Algal Load Max.	Objectionable chemical impurities	Pollution	Sources
8.	1–5	– – –	Dissolved solids above 1000 but below 5000	– – –	Brackish walls sources
9		– – –	8000 to 15000	– – –	Saltish waters, wells near sea

C. *Power System*

1. Hydraulic Head 0.6 – 1 M (Gravity flow)
2. Hydraulic Head above 3 M (Pressure unit/Gravity unit)
3. Diesel set
4. Electricity

D. *Manufacturing*

1. Cast in Situ
2. Fully pre-fabricated
3. With pre – fabricated units to be assembled at site

E. *Materials of Construction*

1. Brick
2. Stone
3. Ferrocement
4. R. C. C.
5. G. I.
6. M. S. Plates

F. *Transport System*

1. By truck
2. Head-load
3. To be air-dropped

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Relevance of the Current Curricula for the Graduate and Post-Graduate Training in Environmental Engineering Towards Research and Development Needs and Proposed Improvements

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Introduction

Man power planning consists of planning, development and utilisation. Although some sort of planning for future is always carried out, it has often failed to take proper account of the complexities of present and future situations, the connection between the set goals and required resources of money, material and man power. Therefore, the success of man power planning depends on the ability of the planners to project the changing nature of the demand and development of right types of personnel to meet these demands. This requires a step wise evaluation of the following :

(i) Surveying and analysing both present and anticipated future environmental conditions.

(ii) Taking stock of present availability of man power including an analysis of its pattern of utilisation and effectiveness.

(iii) Determining future goals of development within a comprehensive national environmental health plan.

(iv) Determining the research and development needs to meet the set goals of development.

(v) Initiating and augmenting training programmes to produce different categories of personnel who can, not only implement the programmes, but also undertake research and development work to solve the problems and help in the implementation of programmes both effectively and economically. Such sequential steps in man power development in environmental engineering has rarely been undertaken even in advanced countries.

Curriculum development

After identifying the categories of personnel required for implementation of current and future programmes, the first step in man power development is drawing up curriculum for each category of man power required. This is, perhaps, the most vital step in man power development, which requires a careful analysis of the existing environmental conditions and the proposed current and future activity to improve these conditions. Besides critical evaluation of existing physical environmental conditions, the curriculum planning should also take into account the socioeconomic situation, the health status and the cultural pattern of the community for which the proposed environmental improvement programmes are meant for. Therefore, engineers in general, and environmental engineers in particular need to know enough of humanities and social sciences in order to apply their engineering skills to the solution of broad social problems. The environmental engineer of today should not merely be ' work oriented ' but ' well-being ' oriented to serve the community. Besides, environmental health programmes particularly in the developing countries, are components of a comprehensive health programme, and their planning should therefore be an integral part of national health planning. In fact, the economic development is itself dependent to some degree on the improvement of environment, as for example, prevention of soil pollution, malaria control through proper engineering measures, both leading to better agricultural production. Hence, the curricula in environmental engineering should include health related medical subjects, such as, medical entomology the concept of vectors and the role of environment in the transmission of diseases, which concerns with communicable disease control and a laige number of environmental factors that affect both the parasite and the host. Besides, health education is a subject of particular importance to the environmental engineer. It is essential that the Environmental Health Engineer learns to establish contact with the population among whom he has to work and be able to persuade them to cooperate and participate in the programme in a country where illiteracy and ignorance is rampant in the rural areas. Health education plays a vital role in motivating and accepting the environmental health services and to look after them with adequate care. The concept of environmental engineering is also fast changing. It does not merely concern with the well being of human beings but also, deals with the delicate balance to be maintained with all other living beings in the whole of ecosystem, and the repercussions of man's development activity on the whole of biosphere. Therefore, the future envirnomental engineer should not be a traditional sanitary engineer but also should know how to solve his problems without disturbing the balance in the nature's ecosystems. He must approcach his problem from a resource point of view and learn how best to utilise each of the natural resources to the maximum benefit of mankind without disturbing the equilibrium in nature. This requires a new concept of systems approach and systems analysis with or without the help of computer technology to be included in the curriculum development. the systems approach enables engineers and administrators, both decision making and evaluation of alternatives to be more rational. Besides environmental health engineer of future should receive education and training in management, national policy. sanitary laws, administration and financing. One of the lacunae in environmental. studies is the cost-benefit evaluation. Until adequate methods are developed for quantifying benefits in social and economic terms, investment on environmental improvement programmes continue to receive low priority from the planners and administrators. Hence, basic knowledge on economics and project evaluation should be included in the curricula in specialisation studies. In the context of research and development to solve the basic problems, certain foundation courses, such as, mathematics biology, physics and computer science should be taught at the graduate level. But the post-graduate training should provide advanced knowledge in these basic foundation courses. At the post-graduate level, scope for specialisation in certain aspects of environmental engineering should be provided. This will also help in meeting the research and development needs These specialities should be carefully chosen in the order of priority for the current and future development programmes. Otherwise, it will lead to under utilisation and wastage of man-power.

CURRENT CURRICULA IN ENVIRONMANTAL ENGINEERING AT GRADUATE AND POST-GRADUATE LEVELS :

GRADUATE LEVEL

At graduate level, environmental engineering or sanitary engineering is taught only in the Bachelor's degree in civil engineering. In most of the universities and colleges, the subject is introduced as a compulsory course in the 3rd or 4th year of the study. Elementary principles of water supply, water treatment, sewerage and sewage treatments are taught as compulsory subjects. Many colleges have also introduced environmental engineering as an elective subject in the fourth or the final year of the civil engineering degree course which a student can opt for. As an elective subject, the subject is taught sufficiently in depth covering some detailed aspects of designs of water treatment plants, sewerage, sewage treatment plant, water pollution, solid waste disposal, etc. and a few laboratory exercises in water and sewage analysis. In this curriculum the students are not oriented to the community health needs, nor do they learn to appreciate the environmental impact on community health and the trainee's future role in solving the problems of environmental health. It is true that at this stage, the trainee is not sure whether he will opt to choose environmental engineering as his career. But, it is a fact that a large number of basic civil engineering and mechanical engineering graduates are recruited in both governmental and non-governmental agencies. to work on environmental engineering programmes and the fresh civil/mechanical engineering graduate is not found productive, unless and until he undergoes practical training for a considerable period under trained senior engineers or undergoes an in-service postgraduate training in environmental engineering for a further period of 1 - 2 years. With the existing facilities for post-graduate training in the country, the back-log of training in service graduate engineers working on environmental engineering, is increasing every year and could never be met, with the increased tempo of activity in environmental engineering in the years ahead. These graduate engineers will not have gained adequate knowledge in depth to be productive in research and development. They have no exposure to community at all. Nor can they appreciate the social and economic conditions of the community to whom they are expected to work for the betterment of the environmental conditions. They have very little or no exposure at all to rural environmental conditions and rural environmental engineering practices. During the International Drinking Water Supply and Sanitation Decade and subsequently also, we need have to employ larger numbers of graduate engineers (civil, mechanical and chemical) to accelerate the coverage of water supply and sanitation both in urban and particularly, in rural sector. The coverage so far in rural water supply is only about 10% of the population and the coverage rural sanitation is negligible (statistics indicate 2% coverage in rural sanitation). Hence, rural water supply and sanitation, and urban water supply and waste disposal will continue to require many engineers to plan, design and implement projects providing services to human settlements not only during ensuing International Water Supply and Sanitation Decade (1980-1990) but also beyond this period. Besides, rural water supply problem alone will call for innovative solutions to reach the set goals of developments with the financial and material constraints, These basic graduate engineers have to be better oriented to environmental engineering at the graduate leavel if they are to be productive towards and development needs, particularly in the rural sector.

(a) Proposed revisions or change in graduate curriculum : A suggested curriculum revision is given below:

(i) Civil, mechanical as well as chemical engineers should receive foundation courses in basic sciences, viz.. mathematics, statistics, physics, chemistry, biology and systems analysis including elementary knowledge on computer science, social sciences and economics.

(ii) Students belonging to any of the above three branches, who wants to choose environmental engineering as their career should have the option to choose environmental engineering as an elective subject in the final years.

(iii) The civil engineering students will have elementary environmental engineering as a compulsory subject in the 3rd or 4th year of graduate study. The students in mechanical or chemical engineering branch who choose environmental engineering as an elective, should have attended the elementary course along with the counterpart civil engineering as an additional subject for which they need not have taken an examination.

(iv) Environmental engineering as an elective subject in the final year open to all three branches should have two parts, viz., **Advanced Environmental Engineering and Environmental Health**. **In** advanced environmental engineering detailed design of urban and rural water supply systems, pumping, sewerage and waste-water treatment, analysis of water and wastewater, solid waste management, rural sanitation, general sanitation including ventilation, lighting, housing, etc. should be included. The course in environmental health should orient the students towards the relationship between environment and health, epidemiology of communicable diseases, role of environment in transmission of diseases, vector borne diseases and their environmental control, etc. These rather expanded electives in environmental engineering could be offered, perhaps only at the cost of curtailing certain other portions in civil/mechanical/chemical engineering curricula which the student has to forego if he has a mind to work in environmental engineering field. Besides, the candidates opting for elective in environmental engineering should be given designs, and laboratory exercises and field exposure to rural and urban environmental health problems by field visits and demonstrations. Both in the compulsory as well as in the elective course more emphasis should be laid on rural environmental health problems and appropriate technological development needed to solve these problems. A graduate engineer better oriented to environmental engineering in this manner will serve short term objectives of how to meet the set goals, particularly in view of the difficulty of providing in-service post-graduate training to all the new entrants because of the limited training facility available in the country and also practical difficulty of sparing large number of in-service engineers even if facilities are expanded. Such remodelling of graduate curriculum, will not induct a sense of uncertainty in the minds of the trainees about the job-market in any of the three disciplines, as they still can remain in their main stream in case, they do not find employment opportunities in the field of environmental engineering. But this is not likely to happen in view of the fast expanding environmental engineering field. With such orientation to public health and environmental engineering, some contribution in respect of research and development could be expected from the graduate engineers even without a post-graduate degree or diploma. Many of our present problems in environmental engineering being towards improving environment in human settlements, particularly in the rural sector, which call for simple, low cost and appropriate technological development we can expect some contribution by these graduate engineers towards research and development needs. Even if such contribution is doubtful, at least, they will not make a negative contribution by way of unsound and uneconomical excution of schemes defeating the objectives and set goals.

(b) The other alternative to improve effectiveness of graduate engineers entering environmental engineering field, both in service, research and development is to introduce a complete graduate programme in environmental health engineering leading to a bachelor's degree in environmental engineering (or equivalent) to allow a greater breadth and depth of coverage of material in environmental health and should include the basic engineering training common to other engineering degrees. The W. H. O. Expert Committee (1) (1967) suggested a format to make up an under-graduate curriculum for environmental engineering in terms of desirable subject areas as follows :

FOUNDATION OF PROGRAMME

(a) Basic Sciences : Mathematics, Mathematical Statistics, Physics, Chemistry, Biology and Computer Science.

(b) Engineering Sciences : Thermodynamics, fluid and solid mechanics, materials, electrical science, engineering analysis and design, instrumentation and systems analysis.

(c) Social Sciences : Economics, Sociology, Political Science and Planning.

ENVIRONMENTAL ENGINEERING SPECIALISATION

Here there are three main areas of specialisation, viz., (1) human settlement orientation, (ii) industry and environment and (iii) resources and environment. It is not necessary to include all the three areas in a particular country or region. The curricula of specialisation should be problem oriented to meet the set objectives of training programme. In most of the developing countries, the major problem area still being related to human settlements, curriculum development should include primarily subjects like epidemiology, parasitology, human ecology, water and waste water analysis, unit operations and processes in environmental engineering, solid wastes and gradually expanded to cover other two problem areas of industries and environment, and resource development and environment as and when need arises.

POST-GRADUATE LEVEL

With the introduction of proposed modifications in the graduate curricula, as suggested in the earlier paragraphs or alternately introducing a seprate graduate programme in environmental engineering, the pressure on post-graduate training could be reduced and the post-graduate training programme, could be developed purely as specilisation courses in specific problem areas to meet the changing needs. The curriculum could be well developed to provide specialists in specific areas to accept pressing and challenging problems which are indigenous in nature and be able to solve the problems through research and development. By this does not imply that all the post graduates be employed only in research and development organisations. This advanced training provides them necessary skills to apply their minds even in the implementation of schemes, to improve upon the existing know-how and to develop an appropriate technology to render the schemes econo–

mical, effective and more acceptable to the community. In other words, research and development should form a part of their activity irrespective whether the post-graduate environmental engineer is employed on planning, execution or research in the field of envtronmental scienees. It is only them one one could expect quicker solution to many of the problems faced in the actual implementation of the accelerated programme for development of water supply and sanitation, industrial water supply and waste water disposal, solid waste management, etc.

(a) Current curriculum in post-graduate courses:

Although it was not possible to obtain details of curricula from all institutions and universities are now offering a post-graduate degree programme, by an analysis of data collected a few years back from eight of the institutions, it is observed, that curricula widely varied (vide Appendix 1). Some institutions teach background subjects (foundation courses) and some do not. Some have provision of electives to choose specific areas of specialisation, but others provide for a general type of specialisation, in all aspects of environmental engineering. Considering the variations, the Government of India in the Ministry of Works and Housing, set up a Committee on Public Health Engineering Curricula, to review the existing pattern and to make suitable recommendations to modify or set a standard pattern to meet the objectives of the post-graduate training. The scope of the committee also included other short terms and refresher courses, to train all categories of environmental engineering personnel to meet the man-power required for the expanded National Water Supply and Sanitation Programme.

(b) Proposed curriculum for post-graduate courses in environmental engineering:

In the report (2) submitted by the curricula committee, the committee has recommended a two tier post-graduate training in environmental engineering, viz., (a) a diploma course of one year's duration for training in-service graduate engineers and (b) a master's degree course of two years duration for attainment of a higher degree of specialisation. The curricula proposed for the above two courses are shown in Appendix II. Although it is not within the scope of this paper to review the proposed curriculum for both diploma and degree level of post-graduate training, yet it is necessary to look into the curricula from the point of view of research and development needs of the sanitation decade and the period thereafter. The committee has identified, besides five compulsory subjects, eight principal areas of electives for specialisation, in both the diploma and degree programme. Our research and development needs, during the sanitation decade and perhaps even during the subsequent decade will be mainly in the problems related to areas of human settlement and industrial environment. Therefore, while modifying existing curricula in any institution or university one should set priorities in the choice of electives, so that the speciatists are really contributive to research and development efforts. In this context, it may not be relevant to adopt block areas of specialisation. As for examples if one omits Block VIII, namely, 'Environmental Planning and Control' which is really not our priority area of research, he will omit two main subjects like solid waste management and rural environmental engineering included in this block which is our immediate concern in research and development. Besides, Block VI may be required only for a few candidates for further pursuit of knowledge leading to a doctoral programme. On the other hand, if in the graduate curricula environmental health, as discussed under proposed graduate curriculum is not taught, courses listed under Block IV, i.e. Epidemiology and control of communicable diseases and public health entomology and parasitology should be made compulsory both for the diploma and the degree programmes and in any case could never be omitted from the diploma programme where we intend to train a generalised type of post-graduate student. If these subjects related to health are omitted, the trainee will fail to appreciate the relationship between environment and health, and often overlooks health aspects in lieu of economy. Besides, basic principles of health education, social sciences should also be taught in order that the trainee will work to fulfill the social aspirations of the community and to elucidate their cooperation and participation in the programmes. Besides, the trainees should be given for their thesis work such problems, for which economic solutions are needed using indigenous material leading to development of appropriate technologies useful to the country. In this connection, the recommendations of the Research Study Group organised by W. H. O. in October 1978

(3) which identified areas of research studies on appropriate technology for improvement of environmental health at the village level should form the basic needs of research in rural water supply and sanitation. Each institution besides having wellequipped chemical and bacteriological laboratories, should also set up a *field research centre* in an urban-rural situation, where research projects based on needs should be developed by teaching staff and post-graduate students following doctoral and post-doctoral research programmes. With the national and international agencies such as, WHO, IRC, IDRC, UNEP, UGC, ICMR now offering assistance to research on environmental engineering, funding of research projects in any of these institutions should not be a constraint. Where students are allowed to take up a project work for dissertation, projects should be so chosen to be field oriented to solve some of the pressing problems in environmental health. Guidance and supervision of such project work for candidates who are permitted to work under their own employers is generally lacking and as such should be under the full control of the faculty members. The main areas of research and development of appropriate technology in rural sector as identified by the W. H. O. Expert Committee Group are :

(1) Simple protection of well and water sources.

(2) Hand pump construction and maintenance and evaluation.

(3) Studies on community participation, operational and behavioural problems and constraints.

(4) Studies on excreta and waste water disposal.

(5) Studies on integrated water supply and excreta disposal systems.

(6) Studies on impact on health of water supply excreta disposal.

(7) Simple methods of water purification and disinfection.

(8) Effectiveness of various methods and techniques in the involvement of the community and the assessment of their impact on their peoples knowledge, attitude and practice (K. A. P.)

Both post-graduate and doctor students should be encouraged to undertake research for their thesis work in these priority areas of research in the rural sector, as our main thrust during the next decade is on rural environment. In this connection, attention is drawn to the paper (9) on Impact of Water Supply and Sanitation on Health by Prof. B. Cvjetanovic, of the Institute of Immunology, Zagreb, who states " in search of new and more appropriate technology for rural areas, the common man can greatly assist in particularly enlisting peoples cooperation and finding solutions suitable to the community and acceptable to it ". This is highly relevant to our research and development efforts and the students in post-graduate training should be exposed to the community in solving their problem.

Summary of Recommendations

(a) The graduate curricula should be suitably modified to provide opportunities for civil, chemical as well as mechanical engineers, to be better oriented in environmental engineering.

(b) There should be both compulsory and elective in environmental engineering which any of the candidates in the above three streams in graduate course, should study in order to be employed in environmental engineering field.

(c) The elective subject in environmental engineering now offered in civil engineering branch only, should be split into two parts, viz., environmental health and advanced environmental engineering.

(d) All the three disciplines should study basic science courses, viz., mathematics, statistics, physics, chemistry and biology, social sciences, economics, systems analysis.

(e) More emphasis should be laid on rural water supply and rural sanitation in the graduate curricula and the students should be exposed to community health problems.

(f) As an alternative to expanded teaching in environmental engineering in the graduate curricula, a separate graduate programme in environmental engineering [B. E. (Env. Engg.)] be introduced to reduce the pressure on in-service post graduate training and to be more effective in research and development efforts.

(g) To introduce certain uniformity and to meet the objectives and set goals of post-graduate training, two tier post-graduate training as recommended by the Curricula Committee be adopted.

(h) A post-graduate diploma course of one year duration mainly to cater to in-service personnel be introduced in all institutions now conducting 2-year degree programme. The curriculum for this course may be broadly adopted as per curricula committee's recommendations except for the choice of electives, which should be relevant to the objectives and set goals of development.

(i) The post-graduate degree course of 2 years duration now conducted by several institutions be revised or remodelled to meet the research and development needs of International Water Supply and Sanitation Decade and thereafter. In this context, electives as suggested in blocks of several areas of environmental aspects, need not be strictly adhered to. Electives should be offered in the order of priority of national environmental engineering development programmes and the research needs to implement those programmes.

(j) Both the diploma and degree curricula should include compulsory subjects on 'Environmental Heath', if not covered in the graduate programme.

(k) A field research-cum-demonstration centre should be set up by each of the institution conducting the post-graduate programme and active research be carried out by staff and doctoral and post-doctoral students; on priority areas, specially in rural water supply and sanitation.

(l) Post-graduate students should be encouraged to take up field oriented type of research projects, to facilitate finding solutions to some of the urgent and pressing problems of environmental engineering in the country. Similarly, they should be encouraged to take up projects of an extension nature to involve them in community participation and to elucidate their cooperation in translating laboratory research findings to field practice.

(m) The curriculum should be dynamic and flexible to modify to the changing needs of research and development in a vast country like ours where there is wide variations both in the nature of problems and the socio-economic structure of the community.

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Background Subject	Compulsory/ Principal Subjects	Elective Subjects
ALL INDIA INSTITUTE OF HYGIENE & PUBLIC HEALTH, CALCUTTA		
1. Hydraulics & Applied Hydraulics	A. *Non-Engineering*	
	1. San. Microbiology	
2. Computer Programmeing Application in Environmental Engineering	2. Communicable disease	
3. Systems analysis	3. Public health Practice & Health Education	
	4. Statistics	
	5. Industrial Hygiene & Air Pollution Control	
	B. *Engineering*	
	1. Water supply (urban & rural)	
	2. Sewerage	
	3. Water Purification	
	4. Domestic and industrial waste water disposal, including water Pollution control	
	5. Sanitary chemistry and Biology	
	6. General sanitation including Solid waste management and rural sanitation.	
	7. Design of Public Health Engineering Works	
	8. Seminar	
	9. Field training in rural water supply and sanitation	
UNIVERSITY VISVESWARAYA COLLEGE OF ENGINEERING, BANGALORE		
	1. Statistics-I & II	
	2. Hydraulic & Hydraulics of Water Supply & Waste Disposal	

Background Subject	Compulsory/ Principal Subjects	Elective Subjects
	3. Sanitary Chemistry	
	4. Advances Water Treatment	
	5. San. Microbiology	
	6. Advances in Sewage Treatment	
	7. Advances Hydraulics.	
	8. Epidemiology & public health administration	
	9. Industrial Waste Treatment	
	10. Environmental Sanitation.	
	11. Special Prob. in Public Health Engineering	
	12. Seminar & Dissertation	
	M. S. UNIVERSITY, BARODA	
1. Engineering Geology	1. Statistics	
2. Instrumentation	2. Public Health Engineering	
3. Measurements.	3. Sanitary Chemistry	
4. Material Sciences	4. Sanitary Microbiology	
5. Structural Engineering	5. Advances in Water Supply	
	6. Advances in Sanitary Engineering	
	7. Industrial Waste Treatment	
	8. Disseratation	

Background Subjects	Comulsory/ Principal Subjects	Elective Subjects

CENTRE FOR ENVIRONMENTAL ENGG., COLLEGE OF ENGG.,
PERARINGAR ANNA UNIVERSITY OF TECHNOLOGY, MADRAS

Background Subjects	Comulsory/ Principal Subjects	Elective Subjects
1. Maths - I	1. Numerical Methods & Computor application	
2. Sanitary Chemistry	2. Statistical Theory	
3. Sanitary Microbiology	3. Engineering Measurement & Instrumentation	
4. Advances in Water Treatment	4. Material Science & Technology	
5. Advances Waste Treatment and Disposal	5. Unit Operation of Sanitary Engineering	
	6. Water Resources & Supply	
	7. Environmental health Engineering - I	
	8. Environmental Health Engineering - II	
	9. Industrial Health Engineering	
	10. Epidemiology & Control of Communicable Disease	
	11. River Pollution & Industrial Waste Treatment	
	12. Sanitary Engineering Machinery and Operation	
	13. Design of Sanitary Engineering Systems	
	14. Air Pollution & Radiology of Health	
	15. Public Health Engineering Structures	

Background Subjects	Compulsory/ Principal Subjects	Elective Subjects
	16. Fluid Mechanics	
	17. Hydrobiology	
	18. Porous Medis	
	19. Site Investigation and Soil sampling	

WALCHAND COLLEGE OF ENGG., SANGLI

1. Maths.	1. Environmental Sanitation	
2. Material Science	2. Sanitary Chemistry &	
3. Instrumentation	3. Advances in Water Supply & Waste Treatment	
	4. Disseratation	

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

1. Water Supply & Treatment	(Any one)	
2. Waste Water Disposal	1. Concrete Technology	
3. Pumping Machinery	2. Applied Hydrology	
4. General Sanitation	3. Ground Water Geology	
5. Laboratory	4. Prestressed Concrete	
6. Chemistry for Water Supply & Sewage	5. Earthen Dam	
7. Epidemology & Air Pollution	6. Open Channel Flow	
8. Statistics	7. Soil Mechanics	
	8. Numerical Analysis	
	9. Planning Principles	

Background Subject	Compulsory/ Principal Subject	Elcetive Subject
	ANDHRA UNIVERSITY	
1. Applied Math 2. Sanitary Microbiology 3. Sanitary Chemistry 4. Material Technology & Instrumentation	1. Environmental Sanitation – I 2. Environmental Sanitation – II 3. Epidemiology, Public Health Administrative Parasitology & Entomology	1. Design & Drawing 2. Advances in Water Supply Purification 3. Industrial Hygiene & Waste Disposal 4. Radiological Health (Any Two) 1. Stream Sanitation 2. Public Health Structure 3. Unit Operation in Sanitary Engineering 4. Applied Hydrology & Soil Mechanics One from other field of specialisation (Structures and Soil Mechanics) related to Public Health Engineering
	JADAVPUR UNIVERSITY, CENTRE FOR ENVIRONMENTAL STUDIES, CIVIL ENGG. DEPARTMENT	
(Any three) 1. Advanced Engineering Math 2. Engineering Material Science 3. Instrumentation 4. Sanitary Biochemistry 5. Special Problems in Civil Engineering 6. Sanitary Microbiology 7. Process design in Sanitary Engineering 8. Industrial Wastes Water Treatment	1. Water supply & Treatment 2. Sewerage and Sewage Treatment 3. Disposal of Solid & gaseous wastes. 4. Research and demonstration 5. Seminar, Laboratory and Project work	

APPENDIX II

OUTLINE OF CURRICULA FOR THE POST-GRADUATE DEGREE AND DIPLOMA COURSES/M. E. OR M. Sc. (ENGG.)/ IN ENVIRONMENTAL ENGINEERING

A. DEGREE COURSE

All candidates for the post-graduate [(M.E. or M.Sc. (Engineering)] Degree in Environmental Engineering should have successfully gone through the compulsory subjects listed in part 'A' below. In choosing the electives, it is recommended that the grouped courses be taken together to cover two or three principal areas of specialisation within Environmental Engineering. The Post-Graduate Degree Programme shall cover a total period of two years or four semesters, of which the first three semesters should be spent in the college undertaking course work. The Fourth semester or last six months should be spent in completing a research thesis, project work or dissertation under the guidance of the Head of the Department (or his colleagues) of the Institution where the course work was done. If found necessary, the candidates deputed by State/Local Governments. Public Undertakings, etc. may be permitted to return to their parent organisations for completing the research, project work or dissertation. However, the same shall be carried out only under the guidance of the Faculty of the Institution where course work was done. The course work should be supplemented by field visits, seminars and assignments and adequate weightage should be given for sessional work in final evaluation of candidate's performance. Use of new teaching aids, such as film strips, as appropriate, should be encouraged. The students should be brought in close contact with the latest developments in the field.

B. DIPLOMA COURSE

All the candidates for the post-graduate Diploma Course in Environmental Engineering should have successfully gone through the compulsory subjects, and course on (i) " Design of Treatment Systems" and (ii) "Groundwater Development". There will be only three further electives to complete all the course requirements. In choosing the electives, it is recommended that the grouped courses be taken together in consultation with the Head of the Department. The Post-Graduate Diploma Programme shall cover a total period of one year. Two semesters should be spent in the college undertaking course work. The last two or three months of the year (usually summer vacation time in the colleges) should be spent in completing a project work under the guidance of the Head of the Department (or his colleagues) of the Institution where the course work was done. The course work should be supplemented by field visits, seminars and assignments and adequate weightage should be given for sessional work in final evaluation of candidates' performance. Use of new teaching aids, such as, film strips, as appropriate, should be encouraged. The students should be brought in close contact with the latest developments in the field.

Eligibility (for both courses)

i) B.E. (Civil or Chemical)

ii) B.E. (Electrical or Mechanical) with three years experience in Public Health Engineering/Environmental Engineering.

Part "A" – Compulsory Subjects

1. Advanced Mathematics :
   - 1.1 Advanced calculus
   - one of 1.2 Statistical theory and methodology
   - 1.3 Numerical methods and computer programming
2. Applied chemistry
3. Ecosystems and Applied microbiology
4. Transportation of Water and Wastewater
5. Unit Operations and Processes in Water & Waste Treatment

Part "B" — Elective Subjects

I. Water Quality Management

Design of Treatment Systems
Water Quality Models
Water Quality Planning
Public Health Engineering Structures

II. Industrial Water and Wastes

Water for Industry
Industrial Wastes Treatment

III. Water Resource Systems

Water Resource Systems Analysis
Hydrogeology
Groundwater development
Public Health Engineering Structures
Flow through Porous Media

IV. Public Health

Epidemiology & Control of Communicable Diseases
Public Health Entomology and Parasitology

V. Management, Measurement and Materials

Engineering Management of Public Utilities
Engineering Measurements and Instrumentation
Radiotracer Technology
Materials Science and Technology
Machinery & Equipment for Public Health Engineering works

VI. Applied Mathematics (one of the following, other than the one taken under compulsory subjects)

Advanced calculus
Statistical Theory and Methodology
Numerical Methods and Computer Programming

VII. Air Quality Management

Air Pollution Control
Air Quality Models
Industrial Hygiene
Radiological Health

VIII. Environmental Planning and Control

Environmental Engineering Systems
Comprehensive Environmental Planning
Solid Wastes Management
Waste Utilisation and Recycling
Rural Environmental Engineering

M. TECH. (PHE), NAGPUR UNIVERSITY COURSE CONDUCTED AT VISVESVARYA REGIONAL COLLEGE OF ENGINEERING NAGPUR.

1 st Semester :

1. Mathematics
2. Instrumentation.
3. Material Science.
4. Sanitary Chemistry.
5. Applied Hydrology.

2 nd Semester :

6. Sani Biology & Microbiology.
7. Water Supply Engineering.
8. Sewerage System.
9. Advanced Sewage Treatment.
10. Advanced Water Treatment I.

3 rd Semester :

11. Advanced Water Treatment II.
12. Stream Sanitation & Industrial Waste
13. Environmental Sanitation
14. Applied Structure ()
    OR ()
    Air Pollution, Radiological Health & Industrial Hygiene ()
    OR
    Public Health Administration & Management ()
15. Project Design and Seminar.

4 th Semester :

16. Dissertation and Defence.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Inservice Training Needs for Water and Waste Water Engineering Personnel

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Introduction

The branch of environmental engineering is expanding at rapid stride in India. Water supply and wastewater disposal are the two major aspects of environmental engineering, rather the two major problems which could not be solved satisfactorily so far. There are numerous reasons why the problems remained severe and almost unsloved even to-day. Some of the major reasons are :

a) Vastness of the country and over-population and relatively meagre funds to solve the above problems.

b) Lack of research to develop the low cost and easy to operate plants suitable for Indian conditions and lack of implementations of the useful researches, if at all, by various organisations because of absence of coordination between the government organization, research institutes and universities.

c) Lack of concept about the importance of maintenance of the treatment plants.

The last two aspects are directly coneerned with the environmental engineers. The pattern of education and training in environmental engineering should be oriented to solve the above two major problems.

Present Status of Environmental Studies in India

The 1972 Stockholm conference of Human Environment highlighted the man's concern for the environment and its growing problems. One of the recommendations of that Conference made was for a programme in environmental education involving interdisciplinary approach, encompassing all levels of education in school and out of school.

Later, the International Environmental Education Workshop held at Belgrade during October 1975, laid down the principles and established the guidelines for an environmental education programme. The Belgrade Charter defined the environmental education goal as 'to develop a world population that is aware of, and concerned abou, the environment and its associated problems and which has the knowledge, skills, attitudes, motivations and commitments to work individually and collectively towards solutions of current problems and the prevention of new ones'.

In India the environmental education is fat off from its goal. The environmental education is mostly confined only to the universities. It musr extend to primary and secondary education, professional education like medicine and law apart from engineering and technology and the education of social scientists, administrators, planners and decision-makers. The status of environmental education at various levels in India is discussed briefly below :

Environmental Education in School Curiculum

For a majority of the country's population, school education marks the end of the formal education. In fact, more than about half the children that enrol in primary classes drop out by the end of the primary education level and to be more realistic; the primary education is likely to set the level of general literacy in our country.

The National Council of Education Research and Training (NCERT) has given due importance to ecology and environmental sciences and has introduced these topics at the various levels of school education. The modernized syllabi set by N C E R T, with adequate bias in favour of the environmental concerns of our time will soon spread to all parts of the country. The N C E R T syllabus has now introduced the environmental education course very carefully at various levels from primary level to higher secondary level. Some of the important topics in the syllabi are – i) Man's dependence on plants and animals and the balance of nature, ii) inter-dependence of plants and animals and their interactions with the environmental factors, iii) water, iv) energy, v) population and pollution which includes pollution of water, air and noise, vi) conservation of natural resources and vii) man and environment.

The courses are of basic nature and do not contain any engineering aspects.

Environmental Education at University Level

Ecology and environmental sciences are of recent introduction in the teaching of life sciences in our country. The concepts of these subjects have rapidly changed during the last two decades. However, all the Indian Universities have not yet fully recognized its importance. Even in those universites where the subject is taught, it is more or less incomplete. This warrants a total and thorough reorientation in the basic approach and teaching methodology at the university level.

Teaching of ecology and environmental sciences can be divided in two groups :

a) Teaching basic subject like botany, zoology, microbiology, etc. These subjects are taught mainly in the science colleges.

b) Teaching applied aspects which includes the measures to prevent environmental pollution.

These aspects are taught in engineering and technological institutes where courses on environmental engineering are run.

TEACHING BASIC SUBJECTS-

Basic subjects like botany, zoology, microbiology are included in ecology and ecosystems.

Remarks : The subjects should stress on the topics like behavioural sciences, cell biology, developmental biology, molecular and microbiology, bio-physics, biochemistry, bio-statistics and bio-engineering.

Major ecosystems like plants and grass-lands and fresh water, their interdependence, aquatic, ecosytems, environmental pollution should also find place.

Due emphasis should be given to field studies and practical aspects. Provision of a mobile ecology laboratory with necessary field equipments to study the various ecosytems will be helpful.

TRAINING IN APPLIED ASPECTS AT COLLEGE LEVEL

This can be broadly be classifield in four gro-ups

i) Training at under-graduate level
ii) Training at post-graduate level :
   a) Post-graduate Diploma
   b) Post-graduate Degree
iii) Training at Certificate level
iv) Short-term courses

i) Environmental Engineering at under-graduate level : Present status–The public health engineering subject is taught at all the colleges and institutes where B. E. degree in Civil Engineering is offered.

Normally there is one compulsory paper in the pre-final semester or year of the Civil Engineering degree course. At the final semester or year, this subject is offered as one of the electives.

ii) Environmental Engineering at Post-graduate Level: At present Environmental Engineering training at post-graduate level is of two types. They are as follows :

a) Post graduate Diploma Course
b) Post-graduate Degree Course.

iii) Certificate Course: Present status–At present the certificate course is run at a few engineering colleges. One of the colleges where such a facility is available is V. Regional College of Engineering, Nagpur. Here the course is of six months' duration and the minimum qualifications for admission are either B. Sc or Diploma in Civil Engineering. The course contents are of higher standard than that diploma but less than under graduate level. In the present course subjects like water chemistry, water treatment, effluent disposal, and solid waste disposal are included. The certificate is awarded by College and not by University.

iv) Short-term Courses at the University Level: There are a number of short-term courses conducted by various universities and I. I. Ts. but most of them are under "quantity improvement programme' (QIP) for which only college teacher are permitted to attend. Those courses cover theoretical apsects in more details and has less emphasis on practical aspects. The duration of such courses varies from 2 weeks to 2 months.

Remarks : Although the short term courses conducted at university level are not directly concerned with the people serving in the field, these courses serve the purpose indirectly because the teachers who are benefitted by these courses can in turn impart the same to the persons from the field at the time of government sponsored courses. The response for these courses is satisfactory. The teachers get travelling expenses, free boarding and lodging during the course period and also useful reference books concerned with subject. At present the Q I P programme is conducted mainly by all I. I. Ts., Roorkee University, Indian Institute of Science, Bangalore and similar Institutions. More institutions should be permitted to conduct the short-term courses under Q I P so that more teachers could take its advantage. Although at present the Q I P are arranged, keeping in view the teachers of the colleges, some Q I Ps could be specially designed keeping in view the various catagories of the personnel in the field, although such field personnel cannot participate directly in such programmes, as a matter of Q I P policy. The teachers attending these programmes would then know the correct requirements of the field personnel.

CPHEEO Aided Public Health Engineering Training Programme for Water and Wastewater

The training programme was started in 1956 as a Central Programme as part of the National Water Supply and Sanitation Programme in the Ministry of Health and Family Planning and continued in the Ministry of Works & Housing when the subject was transfered to it in February 1973.

Details of Courses

The courses are conducted at the following institutions :

1) All India Institute of Hygiene and Public Health, Calcutta

2) Roorkee University, Roorkee

3) V. J. T. I., Bombay

4) Guindy Engineering College, Madras

The courses conducted are mainly of three types :

a) Post-graduate courses leading to Master's degree in Public Health Engineering

b) Short-term courses

c) Refresher courses

The details of the short-term and refresher courses are briefly discussed below :

SHORT-TERM COURSES

The short-term course was started by the Central Government in 1956 to cater to the needs of engineers who could not be spared by the State Departments for a period of ten months required for the post-graduate course at Calcutta and for subordinate engineers to give them an orientation in Public Health Engineering. Three institutions, viz., All India Institute of Hygiene and Public Health, Calcutta, Guindy Engineering College, Madras, and Roorkee University, Roorkee were offering these courses. At present this course is being offered only in the Guindy Engineering College, Madras. The course of three months' duration is conducted three times every year. The syllabus for the course covers almost the entire range of subjects under public health engineering and is formulated with practical bias. This is the only course which gives orientation in PHE to the large number of diploma holders in the departments who could not find admission to the Post-graduate courses. Monetary support for this course has been extended by CPHEEO in the form of stipends, examination and tuition fees for the participants.

Fifty per cent of the salary for the staff sanctioned for the course subject is reimbursed by the Ministry at present and the remaining 50% by Tamil Nadu Government. The total number of candidates trained till December 1978 since 1977, the year of inception, at the College of Engineering, Guindy is 910. Candidates from all the States of India participated in this course.

REFRESHER COURSE

CPHEEO is running several refresher courses through various institutes and State Departments to cover in elaborate detail certain aspects of design, planning, management and maintenance of water supply and sewerage systems so that microlevel training is possible, the course duration varying from about a week to six weeks and the categories of personnel who take advantage of the courses, ranges from senior enginieers to operators. Stipends are limited to some of the courses but for majority of the courses the State themselves bear the travel expenses and the daily allowances of the trainees.

Some of the important courses conducted under PHE training programme for water and wastewater are :

1. Water Works Supervisors course
2. Water and Sewage Analysts course
3. Water Treatment Plant design
4. Sewage Treatment Plant design
5. Industrial Waste Treatment
6. Preventive Maintenance of Distribution System
7. Distribution system network analysis using computers
8. Public Health Engineering Structures
9. Waste Stabilization Pond Practices
10. Water Supply System Management
11. Filter Operator's Course
12. Workshop of Chief Engineers and Senior Public Health Engineers
13. Conduits and Pipes
14. Rural Sanitation and Handpump Maintenance
15. Well Drillers' Course
16. Care and use of Chlorinators
17. Operation and Maintenance of Motors and Pumps
18. Sewage Works Supervisor's Course
19. Waste Recycling - Utilization for Agriculture
20. New Developments in Water and Wastewater Treatment
21. Corrosion Control

These courses have proved quite informative and useful to the personnel at various levels, i. e., right from Chief Engineers to Operators.

Evaluation of CPHEEO Aided Training programme for Short-term and Refresher Courses :

The various courses which are run with the aid of CPHEEO serve a great purpose, but there is a scope for further improvement. The possible improvements are suggested below :

(a) Comments on Short - term Courses by CPHEEO :

The short-term course is the only course for providing the subordinate public health engineers at ' field level ' some insight into the scope of public health engineering and also in exposing them to the advancements in this field, hence the author suggests that not only the present short-term course at Engineering College, Guindy (i. e., Perargnar Anna University of Technology) should be continued but more institutions should be requested to conduct such courses, so that a greater number of inservice subordinate engineers could be trained. Short-term courses could be easily conducted in all the institutions where post-graduate courses are run. Normally a large number of diploma holders in the departments take advantage of this short-term course since they cannot take advantage of post-graduate courses. But three months' duration of this course is little too short compared to the two years post-graduate course. Hence the author feels that the duration of this short term course could be increased to six months specially for persons with diploma. This could be phased out between two years, 3 months in the first year and remaining 3 months in the next year.

The State Governments should have the facility either in the department or in an institution to give inservice training for a period of three months to all the new graduate entrants.

Apart from the short-term course in public health engineering being conducted at the Engineering College. Guindy, Madras the following short-term courses of three months' duration should be started :

1. Water treatment plant design, operation and maintenance
2. Sewage treatment plant design, operation and maintenance
3. Water and sewage analysis
4. Well drilling
5. PERT/CPM
6. Project investigation and planning
7. Management information system development including legal aspects of contract system.

The Central Ministry should prepare manuals on all these courses after constituting a committee of experts for each topic. This will ensure uniform standard at the various centres where these courses are conducted. The manuals dealing with operators' courses, should also contain a check list (i. e., list of significant aspetcs to be checked daiiy) for the operator. For example, some of the important aspects the water works supervisor has to check daily are :

1) Analysis of raw water (i. e., PH, turbidity, alkalinity. etc.)
2) Alum does required.
3) Turbidity of clarified water
4) Head loss in rapid sand filters per day
5) Quantity of back wash water
6) Turbidity of filtered water
7) Chlorine demand and residual chlorine after 30 min. contact time.

Any operator whether for water works, sewage treatment or pumps or for similar purpose, should maintain a diary which has to be monthly countersigned by his superior officer. The manuals should be in various regional languages. The instrucctions should be in simple language so that the operator can easily understand it. The manual should include adequate number of diagrams and sketches. The other important point is that the manual should be easily available to the operator at a reasonable price.

Comments on CPHEEO Aided Resresher Courses :

The various refresher courses conducted by CPHEEO expose the field engineers to modern advancements in environmental engineering and and hence these courses thould continue.

As far as manuals are concerned, the same comments hold good here also, which are for short-term courses.

Additional refresher courses could be initiated to cover new topics such as–

i) Industrial waste treatment
ii) River pollution control
iii) Hydrology and ground water techniques
iv) Water and wastewater quality criteria, significance and public health standards.

Some refresher courses relating to management and administration could be thought of for high and middle level engineers. Certain approprate institutions could be identified for teaching these courses.

Since there is an urgency of training of personnal who are 'on-the-job' such as pump operators, drillers, etc., the responsibility of their training should be at the State level. However. limited central financial support should be made available to activate the training programme.

Comments in general about CPHEEO Aided Courses :

The Central Govt. should continue to help financially and otherwise to conduct the various courses. This adds to the status and stature of the course and the institute which runs that course.

Careful and detailed assessment and redrafting of the course contents for various short-term and refresher courses is necessary. Experts committee should be constituted by CPHEEO to go into the details of each course and to prepare a detailed manual for each course.

It is necessary to form a 'Course Examination Committee' for yearly evaluation of the course and for continuous monitoring and updating the course contents. The Committee also can see if the standard of existing courses attain the adequate training at all centres where it is run, and if the facilities have been made up in case they are wanting in any particular institution.

A coordination between the centre and the organizations running various courses is equally essential.

Adequate number of copies of the manual should be available in advance with the organization conducting that particular course. A committee could be set up for printing the manuals and sending them in advance to the concerned organization.

Training Courses at NEERI for Water and Wastewater

So far 67 training courses in 17 areas of environmentel sciences and engineering have been conducted. About 1100 scientists and engineers and technicians have been benefitted by these programmes. The training programmes are reviewed periodically to fail in line with the country's needs keeping in view the demands of the profession.

Present Training Programmes

In the coming decade senior engineers and scientists responsible for planning of environmental pollution control in their respective organizations need to be exposed to the latest developments. NEERI proposes to organise 3 core training programmes as under for water and wastewater engineering personnel.

(i) Preventive Maintenance of Water Distribution Assessment

This course consists of field training on leak detection and waste prevention in distribution system. It is preceded by a project of about three months and envisages prevention of loss of treated water through defective mains, avoid cross connections and maintain proper pressures in the distribution system. In addition field studies on carrying capacity and cleaning by flushing and swabbing of pipelines are demonstrated.

The duration of the course is ten days.

(ii) Unit processes in Wastewater Treatment

This course highlights the processes involved in wastewater treatment with presentation of appropriate case studies and modern design concepts, The performance evaluation of the processes, reuse and recycling of wastes, operation and maintenance aspects of waste treatment systems is covered in this course.

The duration of the course is three weeks.

(iii) Analytical Instrumentation in Environmental Engineering

The course covers information on and use of various instruments in analytical work in environmental sciences and engineering.

The duration of the course is ten days.

(iv) The Institute also undertakes to organise refresher course to suit the specific requirements of industrial undertaking in air and water quality monitoring and control programmes.

The various courses conducted by NEERI serve useful purpose. The courses which are not normally run either by State Government or CPHEEO are conducted by NEERI. Hence short-term course for water works supervisors is not conducted by NEERI. The courses could be conducted at least twice a year and at different places in India so that more persons can take its advantage. Short-term course on " Chlorination and Use of Chlorinators " should be conducted. The manuals published for such courses should be made available on payment for those who are unable to attend the courses.

Indian Water Works Association (IWWA) Short-Term Courses for Water Works Personnel

The Indian Water Works Association has started conducting short-term courses. The course on " Water Supply System Management " which is sponsored by Union Ministry of Works and Housing has been conducted by I W W A seven times. The course has become quite popular. It includes 1) responsibilities of the undertaking, 2) water rights and rules relating to water services, 3) water rates and finance, 4) maintenance of head works, pipe lines, treatment plants, pumping stations, meters and workshop, 5) waste detection and prevention, 6) quality control, 7) Public relations, 8) personnel and inservice training, 9) safety in water works, 10) billing and accounting procedures, 11) application of O & M techniques in water works and 12) rural water supply. The other courses run by IWWA were - Water Pollution Control Methods and design at Pune Centre, " Pump Operators Course " at Ahmedabad and Bombay, " Pumps and Pumping Machinery for Water Supply and Sewage" at Pune.

These courses should be on numerous subjects and should be conducted throughout India so that advantage could be taken by a larger number of persons, Detailed manuals should be readily available at low price. The courses are of direct benefit to the operators since they deal practical aspects.

Institution of Engineers Short-Term Courses

The Institution of Engineers has also recognised the significance of short-term courses and has started conducting them. Some of the courses it has conducted so far are :

i) Water pollution control methods and design

ii) Pumps and pumping machinery

iii) Treatment of sewage and industrial effluents-design operation and maintenance.

These courses are conducted by local centres of the Institution of Engineers. The normal duration of courses are from 1 to 4 weeks

The short-term courses conducted and frequency of courses could be increased. Although course is conducted by certain local centre, experts from all over India could be invited for delivering lectures. Course content could be made available in the form of a manual.

Workshops on various aspects of water and wasterwater could be conducted by the centres where persons of the rank of Chief Engineer, Chairman of Water Pollution Boards, Chief Administrative Officers, eminent professors could be invited for group discussions.

State Level Public Health Engineering Training

At present various States conduct their short-term and refresher courses for their personnel apart from the CPHEEO Aided courses. Some States conduct courses only for the persons of operator level, some conduct the courses for junior and assistant engineers a few States conduct courses for executive engineers.

Improvement in the present nature of training can be made in the following ways :

Tnree-tier Training System - There should be a 'three-tier' training system at state level. Three tiers can be as follows :

i) Training for executive engineers

ii) Traning for deputy and assistant engineers

iii) Training for operators and similar personnel.

(i) Executive Engineers' Training : An executive engineer is a vital person in the field because he is the highest person under whose supervison the construction work of a project is executed. Similary, operation and maintenance of a plant is under his supervision. So the executive engineer not only has to know 'How' but 'Why' of a question. He has to know the precise solutions of the problems met in the field. His knowledge should be so thorough that he should be able to guide his juniors and solve their problems in the right way, on the spot, so that delay can be avoided. The training should include not only the theory lectures but also the actual operation of the plant. Facilities should be made available to actually handle and operate the plant rather than to see the operation from a distance.

This will enable him to check whether the juniors are fulfilling or failing their duties and thus will give better control on the operation and maintenance of plant or for that matter any system.

The lectures for the executive engineers during the training programme could be arranged not only by the senior persons of the department and the teaching institutes but also by the recently retired chief engineers and the superintending enneers from the various States. The retired persons can devote more time for systematic preparation of the lectures and also can find time to deliver the same. The senior persons yet in service are so much preoccupied in their works that they hardly find time for preparing and even delivering the lectures. Other advantage of the retired persons is that their experience being maximum compared to others, can do better justice. The retired persons can discuss the problems more freely and can even criticise the Government policies more openly. If the senior persons are from different States, naturally the trainees get opportunity to hear more varied experience, problems and their solutions.

The assessment of the trainees at the end of the course is necessary. The practical training period could be of two weeks apart from the lectures for the course.

(ii) *Deputy and Assistant Engineers' Training:* The nature of training can be very much similar to that of executive engineers but with less emphasis on the theoretical aspects and more emphasis on practical aspects, the training programme of this group can be conducted by the trained executive engineer and other expert persons from teaching and research institutes from the State.

Facilities should be available to handle a water works plant for initially one week under supervision and for next one week independently, the total practical training period being of two weeks. This is in addition to the lecture course.

(iii) *Operators' Training :* Operators are key persons for operation and maintenance of plants. Operetor training is one of the vital aspects of operation and maintenance. State Environmental Engineering Department should recruit persons with minimum qualifications such as H. S. S. C. Certificate and preferably, Science graduates. If possible pay-scales could be revised for getting better qualified persons. Training period should normally be of three months.

Each State should maintain one ideal plant and the operators' training should be conducted at that plant rather than at any Institute. In fact, a fullpledged training centre should be constructed at the ideally maintained plant. Such a training will be more beneficial for the operators since this would be the direct method of teaching and training.

Apart from the manuals other effective teaching method would be through use of audio-visual aids. This will include informative films on plant operation and similar aspects. The audio-visial technique helps the operator for better understanding of the subject.

The actual certificate of training will be awarded two years after training. The first certificate will be called certificate D and will be awarded to the operator who will look after the plants for population less than 5000. The condition of award for varions types of certificates can be briefly mentioned as follows :

TABLE I – CONDITIONS OF AWARD OF CERTIFICATE

Type of Certificate		Population	Mini period served for that population by the operator
Certificate	D	Less than 5000	2 years
Certificate	C	5000 - 20000	2 years
Certificate	B	20000 to 2 Lakhs	3 years
Certificate	A	More than 2 lakhs	4 years

The operator, after obtaining Certificate D, will be sent to plants serving for larger population. After successfully completion of his two years at that plant, he will be examined and if successful, then would be awarded Certificate C and will be sent to plant for larger population (i. e., between 20000 to 2 lakhs). Every time he will have to successfully operate the plant and also face the departmental assessment (the assessment could be even in the form of an oral examination). Thus in elevan years' period, the operator can get Certificate A. Two advanced increments could be awarded to the operator after successful passing of each Certificate assessment. The operator will thus get incentives. Good house-keeping is another important aspect to be looked after by the operator.

Health Education for Masses

This is the aspect which has not been given due care. People are very much ignorant about the significance of clean water. They could be educated in this direction by social workers. Free pamphlets and documentary films describing the importance of clean water, likely causes of pollution and how to prevent them, will serve a long way. The mass education reduces the river pollution problem and help to improve the sanitation standards of an individual.

Conclusion

There is scope to improve the present status of training for environmental engineering personnel by :

a) achieving uniformity of standard;

b) introducing 3-tier system of courses;

c) updating the technical information improving teaching methods with the help of audiovisual aids;

d) maintaining one ideal treatment plant per State where courses could be conducted and where facilities for operating the plant by the trainees could be made available;

e) publishing manuals in regional languages and easy to understand language with sufficient number of sketches and diagrams and making the manuals available readily at low price;

f) giving incentives to the operators for satisfactory maintainence of the plants; and

g) constituting a Central Expert Committee for constantly reviewing the standard of the various course contents and other facilities to be provided for conducting the courses.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Role of Consultants and Their Contribution to R & D in Environmental Engineering

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Introduction

With a view to arrest the growing deterioration in the quality of waters in streams and other receiving bodies of water and maintaining or restoring the wholesomeness of water, the Government of India introduced Legislation in 1974. The Water (Prevention and Control of Pollution) Act received the Presidential assent on 23rd March 1974. Under the provisions of the Act, the Central Board was constituted on 22nd September 1974 by the Central Government and the State Boards were constituted by the many State Governments at about the same time, so that by now only the States of Tamil Nadu and Orissa have to pursue action on the Act and set up State Boards. The Central Board and each of the State Boards have prepared and approved lists of consultants based on competence and experience in the field of water pollution control and wastewater treatment and disposal. Whenever an industry intends to pursue action in accordance with the directions issued by the Board, the industry can choose a suitable consultant from the approved list of consultants.

Consultancy services in the field of water supply and water pollution control and especially industrial waste treatment are, therefore, a relatively recent development, in this country. Most of the available services are of recent origin and many of them have been set up on the model of international collaborators of these service organisations. The efficacy of these service organisations in successfully solving water pollution problems is yet to be assessed in its entirety by the industry on the one hand and by the Pollution Control Boards on the other. This is due not only to the comparatively recent origin of these services, but also to the fact that pollution control has become obligatory.

Services Offered

The services offered by consultants in the field of water pollution control generally are in three phases :

i) Laboratory Studies

ii) Feasibility Report

iii) Detailed Engineering

i) Laboratory Studies : The laboratory investigations and pilot plant studies (if needed) are aimed to identify the problem, to arrive at appropriate treatment method and its economic viability.

The problem definition is the most challenging part of the contract with the client, involving not only genuine technical expertise, but a professional approach. For, this is the base on which further actions follow, which include the commitment of finance for the actions. Unfortunately, problem definition is complicated by a degree of vagueness regarding the objectives. To begin with, the quality requirements for effluents spelled out by the enforcing authority are either too stringent or tentative. The pollution control Boards rely completely on the Indian Standards and quote them freely in their stipulation of standards for effluents. The Indian Standards Institution, New Delhi, has laid down effluent standards for effluents from industries discharged to sewerage systems, into inland surface waters, into the sea and on land for utilisation for irrigation. The formulation of these standards is based on the present status of knowledge on the pollutional and toxic effects produced from time to time. The ISI standards are intended to serve as guidance to the Pollution Control Boards in controlling pollution. They are not intended to be applied in every case without modifications, as the degree of treatment imposed on a small industry with a small waste volume would be the same as would be required for a large installation of the same type in the same location. Such application of standards would cause a great deal of hardship to small industries, Further, the function of a State Board shall be :

17(x) to lay down standars of treatment of sawcge and trade effluents to be discharged into any particular stream taking into account the minimum fair weather dilution available in the stream and the tolerance limits of pollution permissible in the water of the stream, after discharge of such effluents.

The clause implies that the pollution assimilating capacity of the stream must be taken into consideration in fixing the standards for effluents and further that each case has to be considered separately and appropriate standards laid down for each case. Finally, the effluent quality should be looked at from a process point of view, treating it as an other product of the process rather than looking at it in an isolated manner.

It is important that the consultant initiates steps towards a study of pre-treatment of wastes, which covers all steps preliminary to actual treatment operations and includes collection and segregation of wastes and the processes of equalisation such as storage, blending and self-neutralisation. For this purpose he has to extend his study of pretreatment back into the manufacturing plant, since it is by considering the waste before it is formed that the greatest opportunities for savings and for economical treatment occur.

An important step in the study of pretreatment is the determination of the quantity of waste that is economically unavoidable which may be considerably less than the quantity of waste normally produced in the plant. Unavoidable liquid waste produced by an industrial plant must be disposed of ultimately by discharge to a natural body of water, but should be prepared for such dlscharge by proper treatment processes. Hence the consultant is properly concerned with elimination of all avoidable waste ahead of his treatment plant. Reduction of waste in this manner may at times involve actual changes in the manufacturing process. More frequently it is achieved by salvage of materials or recovery of by-products. Substantial waste reduction can often be obtained by improved house-keeping in the plant area.

Every manufacturing plant is interested in process changes that reduce or eliminate waste, not only from the point of view of preventing stream pollution but also because waste reduction rerpesents economies in the manufacturing process. Authorisation of process changes is not usually a responsibility of the consultant, but, since industrial plants are operated as co-operative enterprises, there is generally an opportunity to recommend changes and to work with the process engineers on their evaluation. Major process changes for the sole purpose of reducing quantity of waste are not often possible or practical, but should be considered since substantial economics occasionally result. Even product redesign may be possible at times. Process changes for the purpose of reducing waste may result in decreased flow of equal higher concentration than the original, or may lead to reduction in quantity of pollutional constituents discharged and hence to weaker wastes or decreased flow. With more drastic process changes, the nature of the waste may be changed, resulting in an effluent that is more susceptible to treatment. Each manufacturing plant requires an individual study with respect to process changes.

In all process industries there is some loss of raw materials and intermediate materials throughout the manufacturing operations. When these lost materials enter the plant effluent stream, they become a source of stream pollution as well as an economic loss to the manufacturer. Frequently, recovery is possible and practical. It should always be investigated since material salvage not only eases the disposal job but provides a saving to the company.

The recovery of by-products from a waste material is not often practical but such techniques should always be considered in planning for industrial waste disposal. The quantity of recoverable by-products is likely to be small, even though the degree of stream pollution would be considerable. In investigating the economy of by product recovery, consideration should be given to improvement in plant effluent quality or to reduced treatment facilities required for the waste, as well as the manufacturing economy of the new product.

Many industrial plants have accomplished outstanding reductions in the quantity of waste requiring disposal by adoption of good house-keeping practices in the plant. The daily and the meat-packing industries in particular, have accomplished a great deal by these techniques. Waste reductions achieved in this manner represent not only an easing of the disposal problem, but also economy in process operation. The task of good house-keeping in an industrial plant must be a cooperative job among managment, the maintenance crews and plant operators.

The next step under laboratory studies is the characterisation of wastes. The quantity as well as the characteristics of industrial waste waters vary from industry to industry and in the same industry from day-to-day. In some industries-fruit canning industry, these will vary from season to season depending upon the type of fruits processed during different seasons. Hence it is important that a fairly long term-two three months-characterisation study should be carried out. The average characteristics of the wastes should be determined on composite samples collected at suitable intervals determined based on the judgment of the consultant. In the case of an industry such as the fruit canning industry characterisation studies should be carried out during all the sessons with a view to determine the range of variation in quantities and characteristics. Such a sudy will then provide a valid basis for the design of the treatment system.

The most important aspect of laboratory studies is the treatability studies. Various physical, chemical and biological unit operations and their co-ordination to attain wanted plant performance and effluent quality are studied in the laboratory to determine their applicability and efficiency in the treatment of the specific wastewater. Such a study will lead to the development of basic design criteria for the various unit processes. A consultant with his varied experience will set up a suitable sampling programs, decide on significant pollution parameters and develop laboratory or pilot plant scale studies for treatabitity.

The treatability studies are an exercise which is best done jointly with the client. The consultant techninical service men must be prepared to work with the client in the plant and in the laboratories where the experimentation is performed. This ensures that no relevant factor is omitted from consideration. The consultant gets to know the plant operation and layout which will facilitate an assessment of the treatment processes considered from the point of integration of the same with the main process. Selection of a treatment process should not only take into consideration the efficacy of the treamcnt in bringing the quality of the effiuent to desired level, but also such considerations as cost of treatment, availability of other water effluents from the plant which could be used as diluents and thus reduce the severity of treatment, potential for the recovery of the constituents of the effluents for possible reuse in the precess or for sale as a by-product, adaptability of the process with the main process. nature of the effluents discharged by neighbouring industries, location of ground water sources in the plant premises and the vicinity and any common treatment facilities set up to handle the area's effluents. These considerations will not come into play if a joint study between the client and the consultant is not carried out.

The evaluation and testing step is in fact an integral part of the treatability studies. Every alternative process conceived and experimented upon will have to be put through an evaluation programme. The design of the evaluation and testing programme is an extremely important step. Whether it is done in plant or a pilot or bench scale, the interpretation of results can make or may make the success of the selected process, depending on the soundness with which the interpretation is made. The client, in fact, leans heavily on the consultants' experience, developed out of the letter's diverse experties. The client is naturally eager to avoid the evaluation stage in large scale because of the costs involved. What is then the optimum scale at which the evaluation has to be carried out which would give a reasonable assurance on the validity of results at a minimum cost ? There is no formula answer for this question. The consultant is expected to develop this answer out of literally his sixth sense developed from his experience.

ii) *Feasibility Report:* The logical second step after collection of basic data from laboratory studies is the preparation of the feasibility report. For industries which are not in production or are at project planning stage, it is not possible to carry out laboratory studies. In such cases, the feasibility report is based on the data available in the literature and experience of the consultant.

In the case of industries on which data is not available in the literature, a feasibility report cannot be prepared at the project planning stage. In such cases permission should be obtained from the concerned pollution control agency for the industry to be commissioned and produce the wastes. After data is obtained on the characteristics of the wastewaters, a feasibility report can be prepared.

Feasibility report is the translation of basic laboratory data into an engineering design, with the objective of selecting an optimum system. A feasibility report generally considers various alternative treatment systems and completes preliminary design of each of the alternative systems. Preliminary estimates of capital and operating costs are prepared and preliminary area requirements are estimated. Then based on technical and economic considerations the optimum system is selected.

A consultant will in close association with his client select a system which meets the requirements laid down by the pollution control agency at minimum overall cost.

The basic for process design is naturally the data obtained from the evaluation and testing programmes, appropriately scaled up. While this feeling on the part of industry may not be entirely justified, its mention is necessary to impress that there is a need for an optimum design so that the cost data that is obtained is realistic. There is an exercise of selection of equipment which follows and the consultant can take the opportunity of suggesting suitable equipment.

iii) *Detailed Engineering :* After the selection of the optimum system, the third step is to complete the detailed engineering. Here the consultants' services include detailed process design of the units of the selected system and preparation of civil and structural drawings, civil and mechanical specifications, detailed layout and piping drawings and hydraulic profiles. The civil and structural drawings should be prepared by the consultant in such details as to enable the client to get the works executed through any agency he chooses. The consultant should select, for the treatment plant, equipment available in the country or which can be manufactured. If necessary, the consultant should provide shop drawings for some of the equipment fabricated.

It is relevant to mention here that there are a few consultants who just supply a flow sheet and advise the clinct to execute the treatment plant. It is needless to mention that the work of the consultant is incomplete and that the treatment plant cannot be executed for want of details.

If desired by the client, the consultant will also invite tenders on behalf of the client and provide services for supervision during construction and commissioning the plant.

The consultants' role in the commissioning of the facilities installed needs some consideration here. To what extent does the consultant's obligation exist in the successful implementation of the process is a question that cannot be answered only from legal aspects but from the point of view of professional ethics. This does not mean that the client expects the consultant to own up a failure in the efficacy of the designed facility. It is easy to determine and agree to obvious defects in the project, whether in the design or in execution; and contractually agreed penal clauses can be imposed. It is not easy to determine the accountability of the party in the case of a failure of the process chosen to meet the objectives, which because it involves basic decisions theoritically, the client alone makes. At the same time the consultant cannot be absolved entirely of the contribution he makes in arriving at a decision. After all, the client has relied on the consultant's expertise in initially engaging him and subsequently arriving at a decision based on the consultants' recommendations. This faith on the part of the client has to be honoured by the consultant. No contractual provision can protect the client from a consultant who does not observe professional ethics. While this tricky situation exists commonly in any kind of consultancy contract, it is accentuated in a contract involving pollution abatement in an industry, in view of the complexity of the subject and a degree of innovation approach required in solving pollutiom problems. It is common knowledge that pollution abatement technology will have to be tailor-made to suit an industry or municipality, the raw materials used, processes employed, the location and quality stipulations.

Monitoring: Another additional services that could be provided by a consultant is the monitoring of an existing treatment plant to evaluate its efficiency and recommend modifications for improvement.

Case Studies

Author has conducted the following consultation projects to evolve optimum treatment systems on the basis of transfer of research findings to treatment and disposal of wastewaters.

i) Treatment and disposal of wastewaters produced by M/s Kissan Products Limited, Bangalore.

ii) Treatment and Disposal of Wastewaters produced by M/s Mysore Acetate and Chemicals Company Limited, Mandya.

NATIONAL WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR THE DRINKING WATER SUPPLY AND SANITATION DECADE; 1981-1990, NEERI, NAGPUR : 21-22 NOVEMBER 1979

Water Supply & Sanitation Information Bureau (WATSSIB) - An Outline

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Introduction

During the recent years there has been a growing awareness about water supply & sanitation activities in the country. As a result, a broad based R & D programme in water supply & sanitation is now under way. A basic element of planning at all levels of human endeavour is the acquisition and maintenance of an adequate information base from which rational plans and decisions can be made. This has proved to be true in the development of plans for water supply and sanitation also. A universal concern of the people involved in R & D activities pertaining to water supply and sanitation is that adequate information has not been available to do their jobs properly. These are the people who are never given the means to satisfy their needs or are geographically cut off from the centres of information, the people are not aware of the available information. It is worthwhile to mention here that one of the recommendations of the UN Water Conference held in 1977 is of particular interest from an information point of view. It was recommended that an effective clearing house mechanism should be developed by strengthening existing mechanisms if available to provide for the communication of selected information concerning all elements of community water supply and sanitation.

The WHO Expert committee on community water supply in 1968 noted the almost complete absence of reliable and relevant technical, economic and financial data emanating from national goverments about their community water supply programmes and their progress. Such data have to be relevant to the needs of the government planning agencies, and also suitable for onward transmission to international agencies to enable them to promote improved organisation, financing and planning of national water supply programmes. It was further advocated that energetic steps need to be taken to ensure the collection of these data by the establishment of systematic registry, For creating such a data base as well as for implementing a water supply & sanitation programme a strong information centre needs to be developed.

Nature of the Problem

Although no systematic studies have been carried out to know the exact needs of the R & D workers in this area, apparently the need is of two kinds viz. (i) Data, which is quantified information and (ii) Documentary information. Besides this, much relevant and potentially useful data pertaining to rural water supply & sanitation is collected at some place, but it is officially not published and as such not avalable. Many internal reports, state of the art reports are compiled; however, their existance is many a times not known. Last but not the least, much useful information which is hidden in published literature existing in diversified publications makes literature survey expensive, burdensome and often inadequate, and a paradoxical state has been reached when the appropriate infor mation cannot be traced, out of ocean of information. It is generally found that most of the institutions and organisations work in isolation, and they lack of co-ordination in their activities. There is no access to information which is available in an organisation in the same or at a nearby station. Moreover, whatever information is available, it is not collected, collated, analysed, stored, retrieved and disseminated in a systematic manner.

Therefore, an information system has to be established which would try to gather the knowledge or information available at various places and disseminate the information to the proper place where it is required. In other words, the system should be capable of providing right type of information at the right place at the time and in a right or appropriate manner. If activities at various institutions are properly co-ordinated by co-operative efforts, it would not only prevent duplication and wastage, but would also help to determine areas in which a more balanced programme would be desirable. All this call for establishing a strong information system for ' water supply & sanitation.

Objectives of Information System

Information system has to be developed in such a way so that it would not only accelerate R and D efforts in this important field, but also would endeavour to eliminate various difficulties faced by all concerned.

Main objectives of the information systems should be to reduce the gap between generation of knowledge and its use. In general, the objectives of the system should be :

(a) to serve the R & D needs of the persons involved in water supply and related disciplines by collecting, collating, organising & storing pertinent information,

(b) to disseminate information about new and better techniques for handling of water supply & sanitation schemes,

(c) to provide for an input/ output mechanisms for the information concerning water supply and sanitation,

(d) to seek, select and acquire both published and unpublished literature pertaining to the field,

(e) to prepare periodical directories of R & D personnel in water supply & sanitation organisation as well as registry for ongoing research projects,

(f) to provide the three 'R' services (Reference, Reprography & Referral),

(g) to co-operate with other information services and systems in the field of water supply, sanitation and related topics,

(h) to design, develop and establish services appropriate to different kinds and levels of users in R& D and other sectors,

(i) to establish bilateral exchange programme with (a) International, (b) Regional, (c) National and (d) Local, agencies,

(j) to establish necessary equipment and facilities like audiovisual, reprographic and Information Retrieval System equipment & tools for processing of information and dissemination,

(k) to promote cohesiveness,co-operation and coordination among the various agencies enumerated at (i) above,

(l) to establish feedback channels internally and with users individually and collectively to correct, orient and introduce services of maximum effectiveness to users.

The objectives of the system could be achieved by establishing a Central Information Bureau which can act as input–output centre of information. This bureau may be named as Water Supply and Sanitation Information Bureau, (WATSSIB).

Need For A Spade Work

Before establishing the Bureau, it would be helpful to make a survey of the potential useres of water supply & sanitation information as well as various aspects of information system. These are detailed as follows :

i) Indentification of the requirement of infornation of all the agencies working in the field

ii) Information soures available

iii) Information outputs of different institutions at local, national, regional and international level

iv) Expertise and skills available

v) Finance and other physical facilities available

vi) Selection and development of suitable for collection, storage and retrieval of information

vii) Impediments and barriers to the effective communication of ideas such as over abundance of information, occurrence of unwanted, redundant and erroneous information, language barriers,

viii) Time required for processing and dissemination of information,

ix) Extent of secrecy, i. e. classified or unclassified information,

x) Subject interest, the variety of data and information requirements at different organisations

These would also help to study whether they fulfill the criteria required for establishing an information bureau.

Outputs of the Information Centre

Before establishing the centre it would be worthwhile to know the expectations of the Bureau which would be its output.

The following will form the major outputs.

i) Registry of ongoing research pertaining to water supply & sanitation

ii) Inventory of completed and current programmes in the field of water supply and sanitation

iii) Data Bank for rendering data service-technical and economic

iv) Publication of digests, reports/news bulletin

v) Abstracting bulletin

vi) Package information service

vii) Publication of Reference tools

viii) Bibliographies-Adhoc, current, subject oriented

ix) National catalogue of serials in the field

x) Products & Processes Index for Water Supply and Sanitation facilities

xi) Current awareness bulletin

xii) Selective dissemination of information

xiii) User Orientation Training Programmes

xiv) Developing of other appropriate services for R & D as well as other agencies concerned with water supply

Pre-requisites for Establing a Bureau

In view of the multifarious activities which are to be handled by the bureau it should be established at a place which should have following facilities.

i) Strong data base in form of well organised Library having rich collection of literature both in core as well as peripheral areas

ii) Experience expertise in the technique of collection storage and dissemination of information

iii) Established linkages with organizations doing similiar work both in country and abroad

iv) Should have inbuilt mechanism for providing services

v) Accessibility and acceptibility of the centre

vi) Availability of reprographic equipments for quick dissemination of information

vii) Demonstrated ability to take up the work of a Switching Centre

The centre should collect relevant information through acquisition of materials and the establishment of co-operative links with existing institutions or centres in the country and throughout the world active in the field of water supply and sanitation. It should disseminate water supply and sanitation information enumerated earlier under 'output' of the system.

Role of the Centre

The enclosed schematic diagram (Appendix 1) will show the mechanism of the information system vis-a-vis the role of Information Bureau and its relation with other agencies.

Organisational Structure of WATSSIB

The WATSSIB would consist of a large central facility at one place complemented with facilities in various zones of the country. The plan envisages four functional divisions of the central facility of WATSSIB as shown in the organisational chart below :

WATSSIB

* Document & Data acquisition and Procession
* Document & Data Selection
* Document Procurement including reprographic copies & translation
* Technical Processing
* Document & Data Dissemination
* Inter Library Loan
* Maintenance

* Documentation & Data Service and Facilities
* Reference Service
* Referral Service
* Documentation Work & Services
* Data Bank
* Research in Documentation & Data Processing
* Training and Refresher courses

* Promotion of Information Use
* Contact with uses organisations to identfy potential users of information service
* Users Profile Preparation
* Reference Tools Compilation
* Advisory Services for establishing small Information facilities

* Reprography
* Document Copying & storing
* Production of Information. Dissemination Devices

Methodology

In meeting its objectives, WATSSIB will undertake the following activities under phased programme.

1) draft a detailed subject scope definition for water supplies and sanitation to serve as the scope of the information bureau.

2) prepare an inventory of important instiutions (government, academic, professional) in India working in the field of water supplies and sanitation. The directory, to be published will include institutions and their programmes and projects, past, present and future (1960 to 1990) in to field.

3) establish regular exchanges of information with institutitons identified above.

4) prepare and publish an inventory of existing information sources (e. g. information units, libraries) supporting water supplies and sanitation activities in India.

5) identify a basic set of information materials and information sources that will then be made available to individuals or centres in India working in the field of water supplies and sanitation with little or no information resources.

6) Co-operate with other institutions such as the Environmental Sanitation Information Centre ENSIC of the Asian Institute of Technology, Bangkok in the collection, exchange and dissemination of information materials relavent to the field.

7) print a quarterly newsletter giving information such as new publications, forthcoming event, news of the informatinn centre's activities, user notes on-going projects, sources of information and generally speaking any type of news relevent to water supplies and sanitation.

8) collect data pertaining to water supply and sanitation in India and establish a data bank for its processing, storage and retrieval.

9) compile selected bibliographies on subject such as :

   a) rural water supply systems (e. g. hand-pumps, standpipes wells) utilized in Indian rural development programmes;

   b) sewage farming;

   c) wastewater disposal techniques and sanitation systems (e. g. sewage systems, sedimentation ponds, privies, treatment) utilized in Indian development programmes:

   d) biogas utilization

10) provide a reprographic service. Bureau will supply to users on their request copies of documents available at the centre.

11) provide a reference service. The Bureau will perform bibliographic searches on request and provide advisory services where possible.

The work for this project will begin by preparing a detailed subject scope definition for water supplies and sanitation. This will be followed by the preparation and testing of a questionaire, and its distribution to all potentially relevant institutions in India and follow-up visits. This work will greatly benefit from an earlier project carried out by NEERI in the identification of environmental institutions in India. Institution program and user information will be collected, exchange agreements arranged and relevant documentary information identified. Wherever possible, copies of documentary material will be collected for storage and dissemination by proposed bureau. As these activities are being carried out, a newsletter a reprographic and reference service and a current awareness system will be established. Subsequently, specialized reviews and bibliographies will be developed. Arrangements will have to be made for regular exchanges of information between centres in other regions of the world, such as the Asian Institute of Technology, Bangkok, the Pan American Centre for Environmental Engineering and Sanitation in Peru, the Inter-African Committee for Hydraulic Research in Upper Volta and the Companhia Estadual de Tecnologia de Saneamento Basico de Controle de Poluicao das Aguas in Brazil.

Summary

The paper presents a tentative plant of the proposed information bureau and details will have to be worked out. The system would also establish linkages with other information systems existing in related fields in India as well abroad so that a strong linkage is established.

(APPENDIX I)

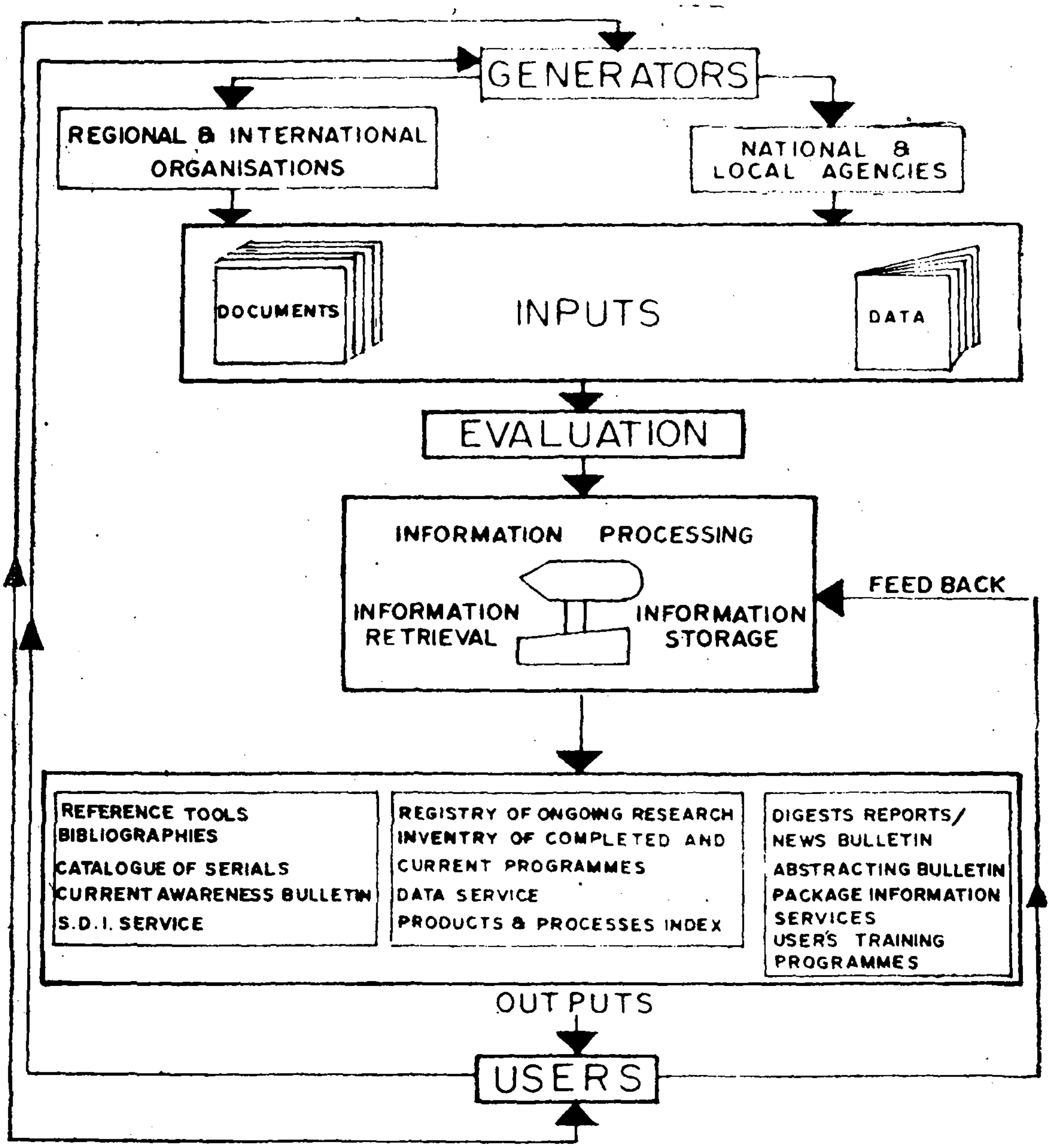

Fig.-1. Schematic Diagram of Information System

RECOMMENDATIONS

Recommendations

General

1) In order to coordinate and help the State efforts and formulate national policies and provide guidance, the organisational set-up at the national level is grossly inadequate. A strong organisation similar to the Central Water Commission should be created which might be designated 'National Commission for Water Supply and Sanitation'.

2) Work plan for water supply and sanitation should be taken on priority basis for completion during the decade.

3) Each State should have a research and development laboratory attached to the Public Health Engineering Departments/Board and initiate programmes to meet the local needs.

4) CPHEEO, NEERI and other organisations at national level should coordinate the R & D Programmes with States, universities and engineering colleges to avoid duplication of efforts.

5) At least 2 per cent of the total investment for the projects in the decade programme should be earmarked for strengthening infrastructual facilities of research institutions and undertaking R & D programmes.

Topics for Research

The R & D topics identified for support during the decade have been grouped under

a) Water,
b) Sanitation,
c) Manpower Development, and
d) Information Systems Planning.

WATER

It is envisaged that the entire population of India should be provided with reliable water supply by 1991. Conventional approaches, systems and design criteria need be reviewed against the background of community participation and acceptance, and low cost technological options. The topics for research and development have been identified as indicated below in the order of priority :

1. Community Participation, Behavioural Pattern and Technology Transfer Aspects of Water Supply

   Study the effectiveneess of various methods and techniques to involve the communities for effective participation and assess their impact on the people's knowledge, attitude and practice.

2. Evaluation and Assessment of Rural Water Supply Systems

   Evaluate critically and asses the design, construction, performance and operation of rural water supply schemes inlcuding the impact on health, social and economic status of community and suggest measures for improvement.

3. Optimum Number of Public Stand Posts vis-a-vis House Connections for Rural Water Supplies

   Suggest guidelines for provision of number of standposts and house connections taking into accout socio-economic conditions, financial constraints, community participation etc.

4. Field Studies on Preventive Maintenance of Water Distribution Systems with reference to Leakages & Carrying Capacities of Mains

   Assess the wastage of water in distributiou system due to leakages, undertake projects for control of wastages and to assess the efficacy of control measures, to measure in the field the carrying capacity of mains as basic input data for design and operation, and evalute errors associated with estimation thereof.

5. Hydraulic Analysis and Optimum Design of Water Distribution Systems

   Develop indigenous electric pipe line network analysers, and follow optimisation techniques and systems approach (use of computers) for analysis and design of distributiou systems.

6. Design Norms for Intermittent Water Supply

Work out norms for design and operation of systems with intermittent water supply.

7. Recharge of Groundwater and Conjuctive Use of Ground and Surface Waters
Undertake studies on feasibility of recharge of groundwater with surface runoff especially in water scarce regions.

8. Simple, Continuous and Effective Method(s) of Disinfection for Rural Water Supply
Study, assess and develop, if need be, the various simple disinfection devices suitable for small water supplies.

9. Extension of Rapid Bacteriological Techniques

Undertake field trials and inter-laboratory studies of some of the newly developed rapid techniques for bacteriological analysis.

10. Development of Spring far Water Supplies
Study and gather information on effective utilisation of springs.

11. Simple and Effective Water treatment Methods for Surface Water

Develop systems without or with minimum use of chemicals and mechanical gadgets.

12. Use of Filters without Rate of Flow Controllers and other Sophisticated Equipment

Carry out field and pilot scale studies on design and operation of filters without gadgets and using alternative simple devices, if need be.

13. Development and Field Testing of Methods for Residual Chlorine Determination

Compare various methods and develop suitable alternative methods to orthotolidine tests for determination of residual chlorine.

14. Development of Natural and Inorganic Coagulants

Indentify and develop alternate materials for use as coagulants in place of conventional ones.

15. Use of Solar Energy in Rural Water Supply
Investigate the feasibility of using solar enegry for rural water supply schemes especially with reference to removal of dissolved solids from brackish water and for pumping.

16. Use of Wind Mills
Carry out field studies on use of wind energy for pumping and for mixing.

17. Studies on Tube and Plate Settlers
Investigate application of tube/plate settlers to upgrade existing plants and develop compact units.

18. Handpumps, Strainers and Substitute Materials

Identify the components of handpumps that need attention, improve the performance, and use of alternate materials.

19. Alternate Materials for Pipes and Specials in Water Supply System (to suit different soil conditions to resist chemical action)

Prepare soil maps with reference to corrosivity in different cities and towns, identify materials to suit various soil conditions, and develop inexpensive protective coatings and linings and their field testing.

20. Evaluation and Development of Reliable Rubber Ring Joints & Jointing Materials for Pipes

Develop standards for rubber ring and other jointing materials, and evaluate and assess the existing status of rubber ring and jointing materials with reference to leakages, effect on water quality, life, etc.

21. Infiltration Wells, Galleries and Intake Structures

Study the hydraulics of flow through porous media, and develop suitable designs and code of practice for infiltration galleries and wells.

22. Water Meters, Flow-rate and Water Level Measuring Devices

    Develop simple, sturdy and reliable instruments for recording (without use of electricity

23. Tube Well Construction and Development Evolve proper rational design for tube well, gravel filter pack and strainers and methods for reconditioning derelict tube wells, and explore use of alternate materials for strainers.

24. Electronic Leak Detectors, Pipe Locators and Valve Box Locators

    Develop simple devices including electronic methods for underground leak detection, location of buried pipes and valve box covers

25. Hydraulic Rams for Rural Water Supply in Hilly Areas

    Develop and standardise designs and materials of construction of Hydraulic rams with respect to discharge and high heads for small population in hilly areas.

26. Reclamation of Backwash Water and Sludge Bleed from Water Treatment Plants

    Carry out field studies on the feasibility of reclamation and reuse of backwash water and sludge bleed from filters and clarifiers respectively

27. Reduction in Volume of Waste of Water from Water Treatment Plants

    Evaluate the wastage from existing treatment units, and recommend measures for reduction of waste by proper operation and control

28. Control of Evaporation and Seepage

    Evolve practicable cost effective methods for reduction of losses in open storage reservoirs due to evaporation and seepage

29. Water Quality Management with respect to Water Supply Systems

    Assess, rationalise and manage the water quality in the water supply systems.

30. Development of Package Water Treatment Plants

    Conduct studies on development of simple package type water treatment plants for hilly areas, and for removal of specific constituents like iron, fluorides, hardness, brackishness, etc.

SANITATION

The target set for the decade programme in India is to provide sanitary latrines to 50 per cent of the households. With high investment costs in conventional water carriage sewerage systems it will be prudent to adopt low cost, low energy, simplified collection and treatment systems like pit privies, septic tank followed by secondary treat ment/disposal units. Acceptance and active involvement of community essential for successful implementation of sanitation programmes. The topics for research and development have been identified under two categories, namely, Rural/ Semi-Urban/Urban/Urban fringe in the order of priority.

a) Rural

1. Development of Sanitary Latrines

   Develop simple inexpensive techniques with different materials for W. C. pan and trap, superstructure, lining of pit, etc.

2. Operation and Maintenance of Individual/ Community Latrines

   Study community attitude and engineering aspects regarding operation and maintenance of individual/community latrines.

3. Composting of Household Wastes and Night-soil

   Develop simple and hygienic methods of making compost with household waste and night-soil.

4. Integrated Bio-gas System for Treatment of Excreta and Animal Wastes and Utilisation of Gas

   Develop and undertake field studies on integrated approach for the treatment of excreta, use of biogas and utilisation of effluent for agriculture and aquaculture.

5. Low Cost Waste Water Collection & Disposal System

   Evaluate and assess simplified collection and disposal system.

6. Package Wastewater Collection and Treatment Units for Small Communities

Develop low cost and simplified package wastewater collection and treatment systems for small communities.

7. Community Latrines Attached to Bio-gas Plants

Evaluate the performance of communal latrines directly connected to bio-gas plants.

8. Community Organisation Patterns

Study and develop sociological and health education methods for community acceptance and participation for maintenance and operation of sanitary facilities.

9. Sanitary Latrines Suitable for Rocky/Impervious/Water Logged Areas

Evolve suitable sanitary pit type latrine or alternate devices suitable to rocky and water logged areas.

10. Impact on Human Health

Epidemiological studies on the impact of sanitary facilities on human health.

11. Water Pollution due to Pit Privies

Make detailed field studies on travel of groundwater pollution due to pit privies for different soil conditions.

12. Mechanisms for Removal of Human Excreta/Sludge

Develop simple systems, vacuum tankers, etc. for cleaning cess pools and septic tank desludging.

13. Utilisation and Disposal of Sullage

Investigate and study inexpensive methods of collection, disposal of sullage by soak pits, dispersion trench, etc. and treatment by stabilisation ponds and utilisation for aquaculture and agriculture

b) Urban

14. Evaluation and Rational Design of Bio-Filters

Conduct pilot plant and field studies on evaluation and formulation of design models for bio-filters for secondary treatment of sewage.

15. Energy Consumption in Sewage Treatment and Collection System

Study and assess the energy consumption in sewage collection and treatment with a view to conserve energy.

16. Package Treatment Unit and Innovative Treatment Systems

Carry out detailed pilot plant and field performance studies on biodisc or rotating biological contactor, anaerobic (upflow) filter followed by grass plot and aeration systems to evolve standard designs, design criteria, materials of construction, cost reduction, etc.

17. Reclamation of Domestic Sewage for Industrial and Agricultural Use

Undertake studies on treatment aspects for reuse of domestic sewage for various purpose

18. Cost Aspects of Collection, Treatment and Disposal of Sewage

Cost analysis (capital and O & M) of collection, treatment and disposal of sewage for different sized communities under different systems.

19. Design, Development and Evaluation of Surface Aerators

Undertake model studies, develop and evaluate prototype units for their performance.

20. Performance of Polishing Ponds

Evaluate the polishing pond performance with reference to nutrient and pathogen removal.

21. Upgrading of Existing Treatment Plant for Increased Loads

Study the practicability of upgrading of the existing treatment plants to take up increased loads.

22. Evaluation of Existing Sewage Treatment Plants

    Critical evaluation and assessment of sewage treatment plants of different capacities.

23. Development of Suitable Mechanical Equipments for Collection and Treatment Works

    Develop variable speed pumps, and equipments for sewage treatment plant from the point of view of ruggedness, simplicity of operation and economy.

24. Control and/ or Removal of Hydrogen Sulphide

    Evaluate critically and assess the extent of corrosion of sewers and sludge digesters and suggest methods of control and/or removal of hydrogen sulphide.

25. Water Hyacinths for Nutrient Removal

    Explore the use of water hyacinths for removal of nutrients and metal ions from wastewaters.

26. Sludge Treatment and simple techniques for conditioning and dewatering of sludge.

27. Field Evaluation of Pipes and Ancillary Structures in Sewerage Systems

    Field studies on the behaviour of various materials of pipes and ancillary structures with regard to sewage or combined sewage and industrial wastewaters.

28. Status Report on the Discharge of Industrial Wastes into Municipal Sewers.

    Prepare the status report regarding the discharge of industrial wastes into municipal sewers with reference to norms, charges, effects, etc.

29. Feasibility of Sludge Gas Utilisation

    Carry out feasibility studies on the gas utilisation by digestion of sludge/night-soil for communities.

MANPOWER DEVELOPMENT

Research and development support by itself will not provide all the required information for the field engineers but it can be a valuable tool if the research iustitutions as well as engineering colleges involve themselves with implementing departments at the State level through proper linkage. The professional development and manpower needs for the decade programme to be provided from the teaching and research institutions need careful consideration. It has been estimated that about 2000 post-graduate and 40,000 graduate engineers and an equal number of diploma hooders in environmental engineering would be required for the decade programme. There are sufficient number of engineering colleges and polytechnics in the country which can train engineers at under-graduate and diploma levels. However, all are trained basically as civil engineers, who need further re-training for one to two years.

The PHE departments rely essentially on the civil engineering graduate who is a generalist for all practical purposes. It is desirable to embark upon environmental engineering as a specialised branch at the under-graduate level. The existing institutions offering Master's degree courses will not be able to provide all the post-graduates needed for the decade. The advances that have taken place in environmental sciences and engineering are so much that specialised training could be provided at the post-graduate level also. At the under-graduate level, it could be suitably oriented so that more subjects are covered and the degree is awarded in environmental engineering. The subjects to be included should have theory and design aspects in water supply and wastewater engineering, sanitary microbiology, sanitary chemistry, solid wastes management, liquid and gaseous industrial wastes and environmental sanitation. Other subjects which are not essential in environmental engineering practice should be replaced by the ones which are relevant. It will be prudent to train more environmental engineers at the end of 4 or 5 year under-graduate programme to meet the increasing demand.

A good stream of students could be diverted to environmental engineering through proper counselling at the under-graduate level as the country needs such a large number for the decade programme. A large number of them will be required in air and water pollution control programmes. Only one course in water supply and sanitation is being offered in bachelor's degree course in civil engineering. Academicians in engineerieg colleges and universities as well as field engineers should give a lead to let environmental engineering emerge as a professional discipline, backed up with solid under-graduate programme. It is heartening to note that several universities have already started courses in environmental chemistry, environmetal biology and microbiology to provide adequate professional support in environmental management.

The curriculum and the mechanics of conducting in-service training and continuing education for water and sewage works managers, supervisors, operators and laboratory personnel should be properly geared to the job requirements and job specifications with proper apprortionment of theoretical laboratory and field aspects. Machanics, pump drivers, rig operators could be trained in the industrial training institutes. Specific professional categories such as financial analysts, hydrologists, geohydrologists, system analysts, etc. need be trained.

There is need for consultancy services for the planning and design of water and sanitation systems during the decade. Consultants should have proper competency, qualifications and experience in the field of environmental engineering.

INFORMATION SYSTEMS

Information services in environmental sciences and engineering being provided in the country to the field engineer as well as research worker are inadequate. Such a system is essential to have the right type of information at the right time; and helps reduce the gap between the generators and users of information. It is required primarily for selection of alternative technologies–technology available, case studies to show experiences on projects executed earlier, substitution of materials, impact of projects on society and community participation, directory of expertise, and indicators of cost-effectiveness of the projects.

The tasks required for generation of information are listed below :

i) Identify sources of information in terms of organisations, experise and users, both at the national and international levels.

ii) Create information sources and motivate them to generate relevant information.

iii) Document available information.

iv) Acquire useful data such as rainfall, water quality, water and wastwater treatment data, population trends, health statistics.

v) Prepare briefs of various documents.

It is desirable to have cells at the State and national levels for organising such activities with special emphasis on the the following :

i) Information on assistance available from national and international organisations and procedures to be followed in this regard.

ii) Identifying experts for satisfying specific requirements of different member cells.

iii) Identifying the organisations who can arrange demonstration and extension services for various technical innovations. It should disseminate information regarding the seminars, conferences and exhibitions organised within and outside the country in the field of water supply and sanitation.

It should also manitain directory of specialised personnel and inventory of important equipments available at different places and organisations in the country.

DISCUSSIONS

DISCUSSIONS

Paper-2	Research in the Development of Appropriate Technology for the Improvement of Environmental Health at the Village Level in the WHO South East Asia Region.
Author	W. L Reyes
Participants	S. R. Kshirsagar, D. R. Jagannath Rao C. E. S. Rao, K. P. Krishnamurty
Highlights	1. Appropriate technology should be acceptable and relevant to social and economic cultural pattern of the rural areas 2. It is advisable to evolve and utilise locally available technology instead of adopting any appropriate technology.

Paper-3	R & D Needs for the Decade Rural Water Supply
Author	S. T. Khare
Presented by	S. T. Khare
Participants	D. N. Singhdeo, A. K. Poddar, Y. N. Nanjundiah H. S. Puri, D. R. Jaggannatha Rao, K. R. Bulusu, R. Krishnaswamy, A. B. Mishra, M. G. Vaidya, P. K. Chatterjee, S. Daivamani
Highlights	I. Role of human behaviour during implementation of water supply and sanitation schemes to be considered. 2. Without use of hand pumps, rural water supply schemes will fail; and handpumps have to be properly designed; and facilities for their maintenance have to be provided. 3. Water supply standards should not be relaxed at the cost of health and safety. 4. Design criteria for intermittant water supply schemes, hydraulic raw and infiltration galleries should be evolved. 5. Methods to assess revenue and collection should be standardised for the public water supplies. 6. Development of water meters which record only water flow should be thought of. 7. Study in depth on the economic and financial aspects of water supply systems should be taken up.

Paper - 4	R & D Support to Planning and Management of Urban Sewerage Systems
Author	V. D. Desai
Presented by	G. F. Khambatti
Participants	M. S. Sandhu, C. E. S. Rao, A. K. Poddar, S. R. Algarswamy, D. Kantawala, R. Natrajan, V. H. Kulkarni and K. R. Bulusu

Highlights

1. Work is desired on chemical treatment of sewage and sludge.
2. Recycle of treated sewage effluents for irrigation & flushing should be given priority.
3. Maintenance and cleaning of sewers should be given proper attention and appropriate devices should be developed for the same.
4. Use of variable speed motors for pumps to pump at varying rates of flow should be developed.
5. Use of chitosan for sewage treatment and algal harvesting can be considered.
6. Study on the efficiency and optimum spacing of ventilating shafts in sewerage system is required. Provision of vent shafts are expensive.
7. Development of simple package plants for treatment of sewage for small communities, should be explored.

Paper - 5

Conservation of Water with Reference to Water Supply and Sanitation Decade

Author: V. Raman

Presented by: V. Raman

Participants: C. E. S. Rao, S. D. Badrinath, Y. N. Nanjundiah, M. S. Kachawah, D. Kantawala, M. S. Sandhu, A. H. Gandhi, P. Arunachalam, P. Khanna, S. Daivamani

Highlights

1. Proper pretreatment of Water should be emphasied.

2. A device is necessary for differential flushing of WC for urination and defecation.

3. Survey and methods are necessary to check prilfrage of water.

4. R & D on reactor classifier, should be thought of.

5. Necessity to consider soil conditions before widespread of sanitary latrines, is necessary from ground water pollution point of view.

6. Reuse of treated wastewater for flushing purposes and air conditioning may be considered.

7. Deterioration of rubber ring joints, eating of rubber rings by white ants are reported. Therefore critical field evaluation of rubber ring joints is necessary.

8. Creation of leak detector cell in major water works to carry out assessment and control programme for prevention of waste potable water should be given priority.

9. The wastage at public stand posts present an insurmountable problem.

10. Studies on water harvesting by prevention of seepage evaporation suppression should be carried out.

Paper-7	Optimisation in Waste Water Collection Systems
Author	P. Khanna
Highlights	1. Limitations of Hazen Williams flow formula should be considered. It is worthwhile using Prataral flow formula.
	2. Optimisation of water distribution system can also be done for rural water supply schemes.
	3. Realities of the situation should be taken into account (identification of constraints) when optimisation of waste water collection systems are employed.

Paper-9	Simplified Water Treatment Systems
Author	S. V. Patwardhan
Participants	C. E. S. Rao A. K. Poddar Virendra Kumar V. R. Bhave
Highlights	1. Decentralisation smaller package plants for rural water supply be preferred to a centralised large plant.
	2. Accent should be on simplified treatment methods. Too much simplification at the cost of deserved performance is not warranted.
	3. Provision should be made for repairs and maintenance of small treament plants.

Paper-10 & 11	(a) Relevance of the Current Curricula for the Graduate and Post-graduate Training in Environmental Engineering Towards Research and Development Needs and proposed Improvements. (b) Inservice Training Needs for Water and Wastewater Engineering Personnel.
Author	(a) A. G. Bhole (b) S. Subba Rao
Participants	S. V. Patwardhan, S. Subba Rao, M. S. Kachawaha, D. R. Jagannathrao, P. Khanna, B. B. Sundaresan, K. K. Das, D. Kantawala, S. R. Kshirsagar, Y. N. Nanjundiah, W. L. Reyes N. S. Bhaivravan, Chaudhuri.
Highlights	1. Environmental engineering education will get importance to provide job potential during the decade programme. 2. Field training in public health engineering works at the undergraduate course is necessary for acclimatisation. 3. Three years field experience is preferred before admission to a post-graduate course in environmental engineering. 4. Two different courses in environmental sciences leading to post-graduate diploma are useful. 5. Environmental engineering museums should be installed in every state wherein the demonstration plants and models and appertenances with pictorial presentation are included. 6. Rules to recruit engineers to public health engineering departments should be revised. in case undergraduate courses on environmental engineering are to start. 7. Environmental education is socially oriented and in addition to being health oriented. As such, the engineer should have grounding as humanities and social sciences.

8. Time is ripe for starting undergraduates courses in environmental engineering leading to Bachelor's degree. There will be good demand for such engineering from public health engineering departments, water pollution control boards, consultancy firms, etc.

9. Proper planning and management of manpower is required for the research programme. This can provide guidelines for the necessity of expansion of environmental engineering education.

10. Conventional civil engineering undergraduates coming out of the college do not have basic concepts of environmental engineering.

11. The senior engineers in environmental engineering field should have proper appreciation of aspects of environmental impact assessment.

Paper-13 — Water Supply and Sanitation Information Bureau (WATSSIB)-An Outline

Author — S. G. Bhat
S. K. Kesarwani

Participants — B. B. Sundaresan, V. Raman, S. V. Patwardhan, S. Subba Rao.

Highlights — A centrally located organisation may be ideal for collection and dissemination of information with respect to various aspects of water supply system.

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