AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 52

1. SUBJECT CLASSIFICATION	A. PRIMARY	TEMPORARY
	B. SECONDARY	

2. TITLE AND SUBTITLE
Rural water supply in developing countries

3. AUTHOR(S)
Gorkum, Willem van; Kempenaar, Kees

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	116p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Okla.

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

(ENGINEERING--HYDRAULICS R&D)

Urban and industrial growth in developing countries has increased the demand for water and the related need for more information on water and sewage treatment. This project, conducted by the University of Oklahoma, focuses on that need by developing a global network of adaptive and innovative technologies based on economic, social, political and cultural factors. A series of detailed reports have been produced that are designed to assist planners in their selection of suitable water and wastewater treatment processes appropriate to the material and manpower resource capabilities of particular countries at particular times.

"Prediction Methodology for Suitable Water and Wastewater Processes," George W. Reid and Richard Discenza.
PN-AAB-491 English
PN-AAD-291 Spanish

"Prediction Methodology for Suitable Water and Wastewater Processes. Supplement I: Manual Computation Methods," George W. Reid and Richard Discenza.
PN-AAD-292

10. CONTROL NUMBER PN-AAD-285	11. PRICE OF DOCUMENT
12. DESCRIPTORS	13. PROJECT NUMBER
	14. CONTRACT NUMBER AID/CM/ta-C-73-13 Res.
	15. TYPE OF DOCUMENT

"Prediction Methodology for Suitable Water and Wastewater Processes. Supplement II: Computer Program," George W. Reid and Richard Discenza.
PN-AAD-293

"Data Requirement," University of Oklahoma Bureau of Water and Environmental Resources Research.
PN-AAD-295

"A Mathematical Model for Predicting Water Demand, Wastewater Disposal and Cost of Water and Wastewater Treatment Systems in Developing Countries," George W. Reid and Michael I. Muiga.
PN-AAD-294

"Treatment Methods for Water Supplies in Rural Areas of Developing Countries," Ir. L. Huisman.
PN-AAD-284
PN-AAD-285

"Sewage Treatment in Developing Countries," L.W. Canter and J.F. Malina.
PN-AAD-286

"Contributions to a Mail Survey on Practical Solutions in Drinking Water Supply and Wastes Disposal for Developing Countries," International Reference Centre for Community Water Supplies, The Hague.
PN-AAD-287

"A Catalog of Water Supply and Waste Disposal Methods for Individual Units," George W. Reid.
PN-AAD-283

"Historic Implication for Developing Countries of Developed Countries' Water and Wastewater Technology," George W. Reid and Kay Coffey.
PN-AAD-288

"Evaluation of Lower Cost Methods of Water Treatment in Latin America," Odyer A. Sperandio and Jose Perez C.
PN-AAD-289

"Socio-Economic Conditions which Pertain to Cost of Construction and Operation of Water and Sewage Treatment Facilities and Quality of Water Consumption in Kenya," Erasto Muga.
PN-AAD-290

"A Water Sterilization Study in the Philippines," Reynaldo M. Lesaca.
PN-AAD-282

"The Study of Microbial Treatment of Nightsoil," Taiwan Institute of Environmental Sanitation.
PN-AAD-281

"Study of an Existing Water Treatment Plant on Simple Design and Operating System for Supplying Drinking Water to Rural Communities in the Lower Mekong Basin Countries," Thailand Ministry of Public Health, Department of Health, Rural Water Supply Division.
PN-AAD-280

RURAL WATER SUPPLY
IN
DEVELOPING COUNTRIES

volume I

Willem van Gorkum
Kees Kempenaar

november 1975

F. Annex
1. roof catchments 70
2. ground catchments 72
3. recovery of spring water 77
4. construction of dug well 81
5. surface water intakes 83
6. induced recharge 88
7. artificial recharge 89
8. coagulation and flocculating chemicals 91
9. dosing of chemicals 94
10. slow sand filters 97
11. activated carbon 101
12. disinfection 103
13. bamboo distribution system 108

G. Bibliography (see volume II of this report) 116

INTRODUCTION

Many people in the developing countries have to drink unreliable water, especially in rural areas. The first investigation to estimate the proportion of the population supplied with reliable water of seventy-five developing countries was done by Dieterich and Henderson in 1973. They estimated that less than 10% of this population has piped water in their homes. The World Health Organization gave a survey in 1972 of ninety countries with a rural population of 1672 million people. About 12% of this rural population had reliable water in 1970.

This data shows the necessity of further development of community water supply in developing countries.

We have tried to give a state-of-the-art review and a bibliography (volume II) in the field of development of community water supply in developing countries, with the accent on the rural circumstances.

The difficulty in gathering the material needed toget a good impression of this subject, was that quite a lot of our investigated publications are articles or journals and short reports, which are difficult to obtain and in many cases published in small quantities.

As far as various countries are concerned, the publications of the People Republic of China and the Soviet Union are missing. This could possibly be a great shortcoming in the information as China's singular development and the extensive rural regions of the Soviet Union must provide a great deal of experience on community water supply. Because of the language barrier posed by Spanish, the biggest part of the literature available form the Latin American countries is missing. This is an exceptional shortcoming as it seems that the experiences of the development of Latin America could be put to good use in other developing countries.

We thank everyone who has helped us in gathering material and who has given advice during the research on this work.

Willem van Gorkum
Kees Kempenaar

A. PLANNING AND DESIGN

In general one can state that there are no populated regions without water because of people's natural instinct to settle in a region with water. The problem of many regions is the shortage of really reliable drinking water. This problem leads to direct action by various people, institutes, etc. The disadvantage or danger of these actions could be that they are not tuned in to each other and this can give double work or lead to bad consequences for a region. For this reason there is a growing demand for the planning of drinking water supply for a region or country. An article which shows the bad consequences caused by almost no communication between voluntary water supply organizations is "Sahel Drought" written by A. Brett-Young. In the Sahel too many wells have caused overgrazing by cattle so that plants and trees were eaten which leads to erosion and together with an abnormal long dry time this gave a distressing situation.

"Quantity" and "quality" can be in contrast. For example with a lack of quality control you can give the people water from a new raw water source without any investigation of the reliability because of the lack of money and/or research possibilities. Alternatively one waits for money and/or research possibilities, starts the research plan followed by a treatment of a sort and gives reliable water. Neither of these solutions are good; the first can cause an epidemic, which can not be cleaned up quickly and in the later case a long waiting time retards or even stops any other development. A solution could be a kind of simple treatment plant which can be constructed by locally available materials and/or manpower which improves the quality of water. Examples of these treatments are explained in "Village Technology handbook", edited by VITA.

To return to the question of planning, a drinking water supply planning programme for a whole region or country seems to be the best. The advantages of such a planning programme are that in a survey of all drinking water projects in one region, one could start with cooperate data collection necessary for each water project, one could use the experiences of former projects and one would need probably less investigational equipment as the cooperational action would mostly save a lot of mony. All these advantages show and accent the importance of total drinking water planning programmes for a region.

The usual time for such a programme is different and could be five, ten or even twenty years you also can have, for example, a twenty year programm as a long term programme which is divided in five year programmes. To advis "Which is best?" is dependable on the situation and could not be given. An advice could be: don't forget the starting data may be out of date after a long period.
A long term programme has more disadvantages. It soon can be very bureaucratic or unsurveyable and the difficulties that are experienced during the current programma have to be integrated into the programme itself during the succeeding time. Problems of this kind were discussed at the East-African conferende, 5 - 18 April 1971, which is described by G. Tschannerl.

Finance is usually a difficult item in the planning and designing of drinking water projects in developing countries. Many water project can be started by international bilateral or multilateral aid. For example instintutes such as the World Bank, UNESCO, UNICEF, WHO, FAO, etc. give funds and/or advice for water projects just as many developed countries do. A lot of the institutes and countries call for claer developent programmes of the water projects before giving financial aid. This factor is also a reason to have a total water planning programme.

A disadvantage of this finance system is the dependence of the developing countries on the fund giving country. For example, it is usually the practice that developing countries have to buy the materials and equipment which they need for the project from the country giving the support. So the developing countries are not free in their own choice.

Another disadvantage can be that some developing countries think too lightly about funds and spend it on too expensive, and overly-sophisticated supply plants. The difficulties of complicated and sophisticated constructions and treatment plants, such as operation, repair and replacement of foreign-made parts and accessoiries are described in chapters C and D, "Technology " and "Management" respectively.

A good finance system for village drinking water projects seems to be a system applied in South America. The first village sets up a drinking water project, from outside funding, and after the start of the water delivery the village starts to pay the funds back little by little. Then a second village uses the funds returned by the first village to start its own drinking water project and so on which means that the funds needed to start only one programme can be used for a whole region.

A less expensive self-help water scheme in Kenya is also a good example to be less financially dependent. This method is described bij I.D. Carruthers in his book "Impact and Economics of Community Water Supply".

To get the involvement of the local people for a project is not easy but quite indispensable. Without the involvement of local people the continuation of the water project has no real chance. Important in this field is to get a good communication with the local people, especially with the political, village and religious leaders because of their, usually, great influence on the population. An involvement of the population also gives more possibilities for the above mentioned self-help water scheme system. In "Drawers of Water" (White e.a) and "A report on the condition of UNICEF-assisted demonstration rural water supplied in Kenya", (Wignot) these problems are discussed.

Low cost appropriate water projects tune in to both of the last mentioned problems,finance and involvement. It is a good way of self-help water schemes and so a cheaper possibility.

The large difference between cultures of completely different origin causes a lack of technical feeling in many developing countries. This produces difficulties when building and operating western constructions and techniques, which have a great negative influence on the involvement of the people. Appropriate water scheme systems should be uncomplicated and use locally available materials and native man power. These may be a stimulation for more involvement and so give a better chance for a good follow-up of the drinking water supply. The cartridge disinfection system and the rainwater catchment methods in Sudan and Botswana are good examples of appropriate technology; see chapters C and D.

When starting planning and designing one needs data on the population, the region and the raw water sources. The importance of data collecting in the field of quality and capacity of the raw water sources is stressed accented in Chapter B.

The knowledge of historical consumption patterns as peak demands, average total and personnal demand, etc. of the population is important. Also for the as good as possible estimate of the consumption in the future. Moving of population have a great influence on the total consumption, just as agriculture (irrigation) and industrial development. A new or improved water supply mostly gives better tap facilities so a higher consumption can be expected. An example which presents data about water supply and population with projections in the future is the report of B.H. Dieterich and J.M. Henderson.

The daily consumption is an important factor in the design. Beyond the minimum required for bodily survival, man's household use of water varies tremendously.

In the New Guinea Highlands a total water use of 0.68 liters per capita daily is measured from which an average of 0.54 liters per capita is drunk daily (Feachum, R.) Otherwise in some countries water uses up to 1000 liters daily are measured. Often there are great variations even within one region. It points out the need for a realistic assesment of the demand in each case. According to White, Bradley and White, there are least seven factors affecting the amounts of water withdrawn by individual households.

- the size of the family
- income level
- education
- cultural heritage
- character of water supply
- cost of obtaining water as measured by energy or cash expenditure
- climate and terrain

Moreover we may not forget the demand in the shape of leakages and wastes in the system.

All these factors have to be analysed on their individual merits in a tot

Because of the limited financial resources rural water systems in most cases serve their consumers through public standposts, predominantly and through houseconnections selectively.

The rate of supply per capita in such cases is to be determined by the minimal needs; subject to a maximum of what each household would care to carry home from the nearest standpost which may be located some 200 meters away.

Generally we can say that when there is a supply in the house or courtyard, the demand may be five or more times greater, then if water has to be withdrawn from a public standpost. Also can be used as general statement that, if water has to be carried a considerable distance - say more than one mile - consumption may fall to as low as 5 liters per capita per day, which approaches the minimum necessary to sustain life. The decision on the character and content of a piped rural water supply depends on social and economic factors. Limiting it to a minimal supply may inhibit desirable expansions but designing on urban or semi-urban scales will be an unrealistic overinvestment. Moreover, piped supplies into rural homes may precipitate problems of waste water disposal sooner than they can be solved.
Water demand for live stock can be an impotant factor in rural water supply, just as water for gardening etc.

We may never forget that water demand estimates have a long range influence on the design. For example, they determine adequacy of the sources, the size of the plant and often they provide the base for financial and economic analyses of the project as pre-investment appraisals.
In the literature several figures for water use could be found but most of them refer to developed countries.In some countries national institutes in charge of rural water supply have published official standards for water use; in other cases consulting engineering companies, involved in the preparation of long term water plans have produced design figures for a particular region or for the whole country. Such figures are generally based on measurements, assessments or experience and make distinction between supply through public standposts and through house connections. A review of some standards of this type extracted from national publications or from available project reports shows figures of about

40 to 60 l.p.c.d. for public standposts, and a greater range of figures from about 50 to 200 l.p.c.d., for houseconnections. Also may be mentioned that while figures, recommended as standard for supply by standposts determine from field experiments, are about 40 to 60 l.p.c.d., those for traditional sources, including wells, springs, etc. are 5 to 30 l.p.c.d. (Idelovitch) The WHO survey (World Health Statistic report) gives the following data for average daily consumption in rural areas.

	liters per capita per day	
	Min.	Max.
Africa	15	35
South East Asia	30	70
Western Pacific	30	75
Eastern Mediteranean	40	85
Europe (Algeria, Marocco, Turkey)	20	65
Latin America and Caribbean	70	190
World average	35	90

Evaluation studies of the price of water show a great influence on the consumption pattern. The story that formerly the water was free is not true think for example on the prices which had to be paid in the dry seasons of arid areas. The last mentioned factor was the reason of the rainwater catchment plant described by M. Ionides in his article "Water on Dry Places".

No payment can make the people indifferent, may be by the idea that there always will be water and that can cause a fairly high or too high consumption.

The risk of a water tariff is that in the rainy season the people go back to the unreliable water sources. The problems and discussions in the field of water prices are well represented in "Drawers of Water" (White e.a.) and described bij G. Tschannerl.

When a new or improved water supply functions, people may have more time, because of the shorter distance to the water tap and due to less diseases. So there is more time for other possibilities.
R. N. Parker described these positive developing possibilities in "The Introduction of a Catchment System for Rural Water Supply: A Benefit Cost Study in a S.E. Ghana Village". The just mentioned article shows the necessity of a total development programme for a region of which the drinking water programme is a part. The importance of such a total development for every region can not be emphasized enough.

Also don't forget the road communication problems. Supply of construction materials, possible renewing of accessories chemicals for coagulation and disinfection quite complicated by this reason. The Chapter C and D, "Technology" and "Management", respectively,
give attention to this problem. The evaluation report of Wignot, "A Report on the Condition of UNICEF-assisted Demonstration Rural Water Supply in Kenya", and R. J. Frankel, "Evaluation of Effectiveness of Community Water Supply in North- East Thailand", give good examples of the lack of success of some programmes.
The problem of energy supply is an important item for Water Supply projects especially in developing countries. For example oil energy asks always for money and can give supply problems by the communication shortage as already mentioned above. A free local available energy source solves both difficulties. Wind, water power (hydraulic ram) and perhaps sun energy in the future can be suitable energy sources.

Conclusion: A planning and design which tries to use as much as possible locally available labour and materials, technical systems and treatment methods with few and easily renewable accessories and possible self-made chemicals must have the preference above other solutions.

143 "A Non-conventional Mass Approach to Rural Village Water Projects" Morfitt, R.P. and associates *)

59 "Urban Water Supply Conditions and Needs in Seventy-five Developing Countries", Dieterich, H.B. and Henderson, J.M.

207 "Water Supply: Proceedings of the Conference on Rural Water Supply In East Africa 5 - 18 April", G. Tschannerl.

230 "Drawers of Water", White, G.F., Bradley, D.J. and White, A.U.

22 "Sahel Drought" Brett-Young, A.

26 "Technology Assessment and Research Priorities for Water Supply and Sanitation in Developing Countries (with special reference to rural population in small communities", Burton, I, Idelovitch, E., and Maystre, J.

3 "Impact and Economic of Community Water Supply", Carruthers, I.D.

4 "Underground Water Resources of the Region to the North of the Wadi Hadhramaat and the Yebel Mahrat and their Development", Report of the F.A.O. to the Government of South Yemen

103 "The Introduction of Rain Water Catchment Tanks and Micro-irrigation to Botswana", Intermediate Technology Development Group Ltd.

20 "Low Cost Distribution Systems", Borjesson, E.K.G.

29 "Conflicting Functions for Water Rates Effects Upon Income Redistribution" Carruthers, I.D.

111 "Rural Water Supply Programme in Madhya Pradesch", Khana, R.A.

25 "Forecasting Urban Water Demands in Developing Countries", Bryant, E.A.

61 "Dorf Entwicklung in Kamerun", Helvetas

180 "l'Eau en milieu rural centre-africain", van Riel, J.

83 "Community Water Supplies", Ghose, H.P.

17 "Regulated Reservoir Operation for Augmenting Community Water Supply", Bhalerao, B.B.

27 "Rural Water Systems, Planning and Engineering Guide", Campbell, M.D., and Lehr, J.H.

66 "Development of Community Water Supply", Etienne, G.

130 "Principles and Standards for Water and Land Resources Planning", Maughan, W.D.

131 "Summary Analyses", Maugham, W.D.

152 "Planning and Development Water Supply Programmes in Developing Countries", Okun, D.A., McJunkin, F.E.

179 "Smaller Capacity Water Purification Installation for the Supply of Water to Rural Communities and Domestic Consumers", Richard, Y.

---

*) The numbers in the text correspond with the alphabetical register

187 "Informacion General Para la Evaluacion de las Programas de Acueductos Acontarillados en America Latina y Zona Del Caribe", Sandoval, R.

189 "Enige aspecten van drinkwatervoorzienings projecten in ontwikkelingslande Satijn, H.C.M.

194 "The Influence of Community Water Supply on Health and Social Progress in Israel", Shuval, H.I.

23 "Modern Wells Produce Quality Water Economically", Briggs, G.F. and Mogg, J.L.

133 "Engineering Measures for Control of Schistosomiasis", McJunkin, F.E.

134 "Surveillance of Drinking Water Quality", McJunkin, F.E.

205 "Groundwatermining, Waterlifting, Wells and Pumps, Windmill Energy, Water Supply, Tool, c/o Agromisa.

213 "Rural Water Supply and Sanitation in the Developing Countries", United National Children's Fund.

175 "Lower Cost Methods of Water and Waste Water Treatment in Less Developed Countries", Reid, G.W.

202 "Techniques rurales en Afrique", Bureau Central d'Estudes pour les Equipement d'Outr Mer.

41 "Survey of Water Treatment Plants", CPHERI

198 "Principles for planning water and land resources", Special Task Force

226 "Water Resources Research Centre", University of Hawai

251 "National Rural Water Supply Programmes", Wood, W.E.

166. "Community water supply and excreta disposal situation in the developing countries", Pineo, C.S. and Subrahmanyam, D.V.

240 "Provision of safe water supplies to rural communities in South East Asia", WHO Regional Committee for South-East Asia

241-249 "Reports on rural water supply of Bangladesh; Burma; India; Indonesia; Maldives; Mongolia; Nepal; Sri Lanka; Thailand", WHO Regional Committee for South-East Asia

236 "Fourth Annual Report", WHO, International Reference Centre

101 "Procedures to be followed special interest", UNDP Water Supply and Water Projects", IBRD

262 "Seminar on Sanitation Problems of Rapid Urbanization", WHO Eastern Mediteranean Region

71 "Domestic Water Use in the New Guinea Highlands: the case of Raiapu Enga", Feachem, R.

176 "Lower cost methods of water and waste treatment in less developed countries", Reid, G.W.

"Design and selection criteria for community water supply", WHO

"Potable water problems and the development of rural community water supply in Thailand", Somnuek Unakul; McQuary, W.A.

"Public water supply in Thailand", Sakoljitt Panomvan

"Alimentation en eau des centres urbains et rureaux du Maroc", Khemmar Ouriagli

"Bangla Desh", Delft University of Technology

"Bilharzia; een nieuwe plaag voor de derde wereld", Bruijning, C.F.A.

"Water Laws in Moslem Countries", Caponera, D.A.

"The control of water-borne epidemics", Wood, W.E.

21 "Water Legislation in Asia and the Far East", No. 31 and 35, United Nations

"Common sense design for rural water systems", Rose, C.W.

"Demotech: Uitvinders voor de Derde Wereld", Esser, J.

"Te elfder ure", Beynon, H.C.

"Hulp moet worden aangepast aan nood der armsten", Beynon, H.C.

"Water supply in rural areas", Linati-Bosh, J.A. and Aparicio, I.

"The WHO/IBRD cooperative programme on water supply and wastes", IBRD

"Lahore Water Supply - Tariff Study", IBRD

"Urban Water Supply and Sewerage pricing policy", IBRD

"Water and waste water engineering", Fair, G.M.; Geijer, J.C. and Okun, D.A.

B. DATA COLLECTION

B.I. THE CAPACITY OF RAW WATER SOURCES

A good design of any water supply starts with the identification of the alternative raw water sources.

Reliability - the ability to deliver sufficient quantities 365 days a year - is the most important factor in the choice of raw water sources to prevent that in periods of water shortage the consumers are driven to other, unsafe sources, thereby counteracting the advantages of their safe supply during the remainder of the year.

For precipitation as a source we need to know for example the quantities, spatial and temporal distribution of rain and snow. When we use surface water in streams, lakes or reservoirs we want to have the data on evaporation and the quantities and distribution of surface runoff and of ground water, that passes through soil and rocks on the earth, the quantities and distribution of soil moisture, location and properties of the different ground layers.

We are interested in data on all phases of the hydrologic cycle, although the typical questions whose answers are the determinants in water resource development and management may differ depending on the level of sophistication (Hacket and Davis).

The success of water source evolution will depend on the availability of data on the quantity and quality of naturally occuring groundwater and surfacewater. The collection of such data could be undertaken most economically through the use of integrated measurement and observation systems (Mostertman). For most of this data we have to rely upon the hydrologists with their instrumentation and methodology. Fotogrammetry and remote sensing techniques are methods, which deliver some data in a quick and easy way.

An organized data collecting programme is of the greatest importance in the national and regional programming for water supply in the developing countries. (WHO, Techniques for the collection and reporting of data on community water supply; WHO, Groundwater resources in Kenya; WHO, Surface water resources in Kenya).

Nevertheless in many cases the sanitary engineer is supposed to built. a water supply plant, although hydrologic and other data may be inadequate or even not available. In those cases he has to acquire these data himself. Therefore he needs equipment for test drilling, water analysis, and measuring difference in ground elevation, distances, streamflows, and also topografic survey, and pumps, for testing the yield of available water sources and finally transportation equipment. (Vita; Wagner and Lanoix).

Many data on, for example, site and seasonal delivery of existing wells o the pattern of the riverflow during the seasons, just as existence of natural springs, ponds and lakes in the neighbourhood of a community etc., are well-known to the local residents. With inquiries etc., we can get this information, but the problem is the reliability of this data. We have to be very careful in their interpretation.

Delays between initial investigations and final design can be utilized to advantage by initiating further data collecting on seasonal quantity and quality variations and related factors likely to be valuable in preparing the final design.

87 "Water Data for Progress" - Hackett, O.M. and Davis, G.H.
111 "Rural Water Supply Programme in Madhya Pradesh" - Khana, R.A.
131 "Summary Analyses" - Maugham, W.D.
130 "Principles and Standards for Water and Land Resources Planning" - Maugham, W.D.
159 "Community Water Supply and Sewage Disposal Programs in Latin-America" - Pan American Health Organization
202 "Techniques rurales en Afrique" - Bureau Central d'Etudes pour les Equipement d'Outre Mer
224 "Village Technology Handbook" - VITA
225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.
226 "Annual Report 1970 - 1971" - Water Resources Research Center
261 "Techniques for the Collection and Reporting of Data on Community Water Supply" - World Health Organization
254 "General Community Water Supply Problems" - World Health Organization

3 "Techniek" (Technique) - Agromisa

199 "Het meten van neerslag en eventuele andere weerkundige waarnemingen ten behoeve van de landbouw op het eigen project" - Stigter, C.J.

184 "Effective Re-use of Contaminated Water" - Robinson, T.B.

B.II THE QUALITY OF WATER

The fundamental principle for potable water is: "It has to be hygienic reliable".
This principle can have been the start of the development of drinking water standards. A problem of the developing countries can be that the international WHO drinking water standards are not feasible.
No money for any treatment is the simple reason for this problem and the question of standards is a luxury question. The most important issue in such a case is human health. With this in mind, you have to take each chance of inventigation of the raw water sources, which is necessary to decide which treatment you have to apply. So, the designer, who starts a drinking water project must aim at the most feasible interpretation of the international water standards with human health as the most important issue.

From the principle of hygienic reliability you start with the investigation of the biological character of the water. The indicating method of the coli-form is well-known and well-used. This method is described by Prof. G.W. Reid (May 31st, 1974). The possible temperature problem in tropical circumstances is described by J. Kreysler in the workshop of Dar es Salaam, (17-19 Dec. 1969).

The chemical character has in many cases not such direct influences as the biological character. For chemical investigation the test kit, described by Prof. G.W. Reid in his already mentioned annual report, can be used. With the travel and distance problems of many developing countries in mind; this test kit has the advantages to be simple, moveable and light.

The physical character is directly noticed by the consumers and is in this way of greater importance than the two already mentioned characters. The smell, taste and colour can be the factor to change their water source, even when the new source is worse in comparison with the old one. It will be hard to teach the consumers that the physical character of water has not always something to do with possible chemical and biological impurities. The problem of the consumers is that the two last mentioned impurities can not always be recognized by them. So, giving

1. The importance and influence of the quality in community water supply.

230 "Drawers of Water" - White, G.F.; Bradley, D.J.; White, A.U.

26 "Technology Assesment and Research Priorities for Water Supply and Sanitation in Developing Countries" - Burton, I.; Idelovitch, E.; Maystre, J.

47 "Safe Drinking Water" - Committee on Interstate and Foreign Commerce House of Representatives

134 "Surveillance of Drinking Water Quality" -McJunkin, F.E.

139 "Importance of Bacteriological Standards in Water Supply" - Mishra, R.P Lonsane, B.K.; Rao, N.U.

172 "Endemic Fluorosis in Aadhra Pradesh" - Rama Mohano Rao, N.V.; Sub Subba Rao, K.U.

181 "La Desinfeccion del Aqua en Areas Tropocales" - Rivas Mijares, G.

202 "Techniques Rurales en Afrique" - Bureau Central d'Etudes pour les Equipement d'Outre Mer

225 "Water Supply for Rural Areas and Small Communities", Wagner, E.G.; Lanoix, J.N.

254 "General Community Water Supply Problems" - World Health Organization

255 "Ground Water Resources in Kenya" - World Health Organization

261 "Techniques for the Collection and Reporting of Data on Community Water Supply" - World Health Organization

257 "Health Hazards of the Human Environment" - World Health Organization

237 "Health aspects relating to the use of uPVC pipes for community water supply" - WHO, International Reference Centre

256 "Health hazards of coagulant aids"- WHO

171 "Guide to simple sanitary measures for the control of enteric diseases" - Rajagopalan, S. and Shiffman, M.A.

184 "Effective re-use of contaminated water" - Robinson, T.B.

2. Drinking water standards.

258	"The International Drinking Water Standards" - World Health Organization
64	"Water Quality Criteria" - The Environmental Protection Agency
47	"Safe Drinking Water" - Committee on Interstate and Foreign Commerce House of Representatives
50	"Operation and Control of Water Treatment Processes" - Cox, C.R.
136	"Maximum permissible concentrations of harmful substances in the water of watersources used for hygienic and domestic purposes" - Ministry of Health of the U.S.S.R.
48	"Water Quality Standards" - Common Wealth of Virginia - Virginia State Water Control Board

3. Investigation and/or indication of the impurities of water.

39	"Membrane Filter" - Central Public Health Engineering Research Institute
177	"Water Test Kit Users Manual" - Reid, G.W.
37	"Icing of Water Samples" - Central Public Health Engineering Research Institute
55	"Water Supply & Waste Disposal for Greater Bombay" - CPHERI
50	"Operation and control of Water Treatment Processes" - Cox, C.R.
102	"The Technological Frontier" - Idelovitsch, E.
137	"Standards Methods for the Water Quality Examination for the Member Countries of the Council for Mutual Economic Assistance" - Ministry of forestry and water management in cooperation with the hydraulic research institute
175-176	"Lower cost Methods of Water and Waste Treatment in Less Developed Countries" - Reid, G.W.
114	"Total Coli Counts: A method to determine biological contamination of rural water supplies, the Ismani example" - Kreysler, J.

C. TECHNOLOGY

I. SOURCES

The choice of the raw water source is obviously one of the first and most important decisions to be made for any water supply project. Groundwater (deep or shallow) or surface water (stream, river or lake) may be used, or springs which combine some aspects of each.

Where alternatives exist, choice is likely to depend upon reliability safety and economy, in that order:

- Water, which requires no treatment to meet bacteriological, physical and chemical requirements and which can be delivered to the consumer by a gravity system should be given first considerat
- Water, which requires no treatment to meet their requirements, but which must be pumped to the consumer, would be the second choice.
- Water, which requires simple treatment but which can be delivered. to the consumer through a gravity system should be given third priority consideration.
- Water, which requires both simple treatment and which must be delivered to the consumers by pumping, would be the next choice. (Wagner and Lanoix)

a. Groundwater

Wells for the extraction of ground water may be divided, depending on the depth of the layer from which the extraction takes place, in "shallow" and "deep" wells. We can almost ever rely on the bacteriological safety of the water from deep wells, and also the water from comparatively shallow wells can be expected safe, as long as any short circuiting is prevented. The principles of well construction techniques, like digging,boring, jetting,driving with all their variants are well described in handbooks. (Wagner and Lanoix; Gibson and Singer; etc.)

This number of different construction techniques together with the variety of (outside) firms which compete to supply their own equipment, constitute a great problem in developing countries. Before initiating a drilling programme or making major extensions to existing activities, it is worthwhile to obtain expert and impartial advice on these factors to ensure that the maximum and most efficient use is made of the expensive equipment involved. In cases of breakdown, exchange of equipment accesories from different firms is mostly not possible and seldom a firm delivers enough units to make supply of accesories profitable.

The casings of tube-wells are now often made of PVC which decreases the problem of corrosion. In some countries, however, there are difficulties to cut the very fine slots for the screens or strainers in the PVC. Sometimes the use of PVC is also too expensive for some communities. For their sake the research in locally available material suited for this purpose, is going on. An example of this is the bamboo tube well first engineered by a village farmer in Bangladesh. ("The Bangladesh Observer", July 12; 1974).

With the increase of tubewells, the hand dug well wrongly has become less popular. Luckily the interest in dug wells is reviving. Modern materials, tools and equipment, often locally produced, may transform crude holes in the ground, host for parasitic and bacterial diseases, into more safe, soundly engineered, hygienic and reliable sources of water. Dug wells are inexpensive and easy to construct and to maintain by fairly unskilled labour. Moreover dug wells will always be the best solution for shallow low yielding aquifers because the storage within the body of the well itself allows the water collected during the night, to be available for use during the hours of peak draw off next day, and also for inaccessible regions where transporting drilling equipment is difficult.

Dug wells, however, do have distinct limitations:

- They cannot be used to reach groundwater deeper than 20-30 m.
- The capacity is usually low
- Well digging technology is understood and used in most countries, but the art of lining wells has regressed, and there is an important need for improved linings. The liner protects against caving and collapse and prevents polluted surface water from entering the well. The main problem is lining the walls below the level of the water table.
- Another need is for safer, more rapid, more efficient digging techniques.

One of the first steps in the improvement of the water supply is often the improvement of existing wells. Mostly by well protection (surface drainage around the well and covering of the wells) and adding a pump. It happens sometimes, especially in rural areas, that when the pump is fallen in disrepair, the people use force to open the cover for drawing their water with buckets, and thus expose their supply again to contamination. The reason for this can be that the community cannot raise enough money for a new one or simple that it would take several days to get a new pump or accesories in the nearest town and such a long time the people cannot stay without their water supply.

Horizontal wells

In the development of water supplies, small springs are often neglected. Yet in many remote and arid mountain regions, springs are the safest and most dependable sources of water for domestic use. The horizontal well system, an improved spring-development process, has many possibilities for providing and conserving reliable water in geologically appropriate areas.

A horizontal well is a "cased" spring. A horizontal boring rig is used to drill a hole and install a steelpipe casing into a mountain or hillside to tap a trapped water supply.

Tapping water from springs is an ancient art. Conventionally, when a seep or spring is located, it is opened by digging or dynamiting to expose t water-bearing rock. Results are erratic and always carry a risk of damaging the natural barrier that dams the underground reservoir. The flow, once established this way, is almost impossible to control and may result in rapid depletion of the aquifer.

Horizontal wells virtually, eliminate these hazards. They are drilled at promising sites where springs, seeps, or traces of water are found. Occurrence of phreatophytes, dried up springs and favorable geology are all indicators used to select the drilling site. A horizontal well are tap the aquifer with precision and safety. Furthermore, it protects against contamination by animals, dust, erosion, etc. No pumps are needed. Maintenance, costs and other problems are insignificant in comparison to thos of other systems for harnessing springs.

If the flow is very low, a storage tank can be added to accumulate water during the night or off-season. With adequate storage, spring sites that flow only during a few weeks in the year may be useful.

Successful yields varied from 1-230 l/minute; most were in the 10-40 l/minute range. Drilling time averaged 32,3 hours per producing well.

Horizontal drilling equipment is currently manufactured; it is simple, portable, and dependable. The drilling process involves a rotary, wet boring horizontal drill stem rig, a carbide-tipped or diamond-core drill bit, a small recirculating water pump, a cement slurry pressure tank, a drill water supply, and a few standard plumbing tools and supplies.

Horizontal-well drilling is quite a different technology from vertical drilling. Skill, patience, and field experience are required to master it.

(More water for arid land)

Qanats

An interesting water supply system, the qanat is used for more than 3000 years in some countries in the Eastern Mediterranean area and North Africa. A qanat is essentially a wel dug horizontally instead of vertically. A site is chosen where the elevation of the groundwater table is known to be higher than the area to be irrigated or the community to be served. At the consumption or lower end if the topography is steep, an oval shape tunnel is started and driven into the aerth towards the water source. If the topography is flat, the tunnel section may be proceeded by some distance as an open channel. The qanat excavation is given just sufficient slope to reach the groundwater source, location of which has been predetermined. The water thus intercepted is discharged by gravity through the tunnel to the point of use. The usual size of the qanat excavation is just enough for a man to work in a crouching position. Unstable sections of the qanat are supported by pottery ovals about four feet high and two feet wide. About every 30 or 40 meters along the route of the qanat shafts are sunk for ventilation and for the removal of excavated material. There are qanats in Iran reported to have the astonish. length of 48 kilometers and to have taken several generations to complete.

The discharge of an average qanat is said to be about 70 liter per second. This figure appears much too high in relation to the total annual ground water recharge and probably refers to a maximum discharge rather than an average yearly discharge. In fact, some recent estimates would indicate that average qanat flows will vary from about 7 to 30 liters per second.

The advantages of the qanats, particularly for a time preceeding the mechanical age, are obvious. The principal construction ingredient was human labour, and the water flowed by gravity to the areas of use. A relatively small amount of annual maintenance assured the continuity of their flow. There was no dependence on machinery, fuel or imported materials. The only manufactured article that entered the construction was the pottery liner for soft ground, and the Persians were well versed in the arts of burnt clay manufacture.

The disadvantages of the qanats are equally obvious. They usually flow continiously and year round, so unused water is wasted. Qanats may dry up alltogether in drought years. The water can be polluted through the open shafts. Qanats are expensive and dangerous to build by the primitive handtunneling methods of the past, and in recent years construction costs have increased along with rising standards of living and labour costs. Though new qanats are seldom build today, many old ones are still used, especially in Afghanistan and in Iran, where there are some 40000 qanats comprising more than 270.000 km of underground channels that supply 35 precent of the country's water. However if modern engineering, geology, hydrology, and remote sensing are applied, the qanat principle could play a role in future water production in arid lands.

A recent innovation now used in Iran is a hybrid between a dug well and a qanat: a dug well is excavated to below the water table and then horizontal galleries are driven out using the excavating methods of the qanat builders. In the dug well shaft a centrifugal pump is then installed to pump to the surface the water collected by the horizontal galleries. (More water for arid lands (National Acedemie of Sciences) and Iran Water Supply and Sewage Sector report).

This seems to be an appropriate solution for the more sophisticated radial wells which are used in shallow ground water layers in some developed countries.

225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.
84 "Small Wells Manual" - Gibson, U.P. and Singer, R.D.
146 "More Water for Arid Lands" - National Academy of Sciences
102 "The Technological Frontier in Rural Water Supply for Developing Countries" - Idelovitch, E.

7 "Bamboo Tube Well" - Assaduzaman, M. and Khan, O.K.
26 "Technology Assesment and Research Priorities for Water Supply and Sanitation in Developing Countries" - Burton, I., Idelovitch, E. and Maystre, J.
27 "Rural Water Systems, Planning and Engineering Guide" - Campbell, M.D. and Lehr, J.H.
74 "Underground Water Resources of the Region to the North of the Wadi Hadhramaat and the Yebel Mahrat and their Development" - Food and Agruiculture Organization
23 "Modern Wells Produce Quality Water Economically" - Briggs, G.F. and Mogg, J.L.
134 "Surveillance of Drinking Water Quality" - McJunkin, F.E.
140 "The Use and Design of Sand Screens and Filter Packs for Abstraction Wells" - Monkhouse, R.A.
170 "Water Supply to Small Communities from Tube Wells in the Calcutta Metropolitan District" - Rajagopalan, S.; Basu, A.K.; Dhaneshwar, R.S. Rao, C.S.G.
173 "Screen Wells improve the Yield of Community Water Supplies" - Ramaswamy, J.
174 "Community Water Supply in Drug District" - Ranade, V.K. and Tiwari, A.R.
202 "Techniques Rurales en Afrique" - Bureau Central d'Etudes pour les Equipement d'Outre Mer.
213 "Rural Water Supply and Sanitation inthe Developing Countries" - United Nations Children's Fund
224 "Village Technology Handbook" - VITA
265 "The Qanats of Iran" - Wulff, H.E.
268 "Rural Water Supply in Taiwan" - Yung, D.F.

b. Rainwater

For many tens of centuries people have used rainwater as a source for their water supply. Half a century ago it was still an important source in Western Europe. (Cohen et al.), and even in our day rainwater is used by people who need soft water. Harvesting rainwater could be one of the best ways to provide water for areas where other sources are too far away or too costly. Especially on a small scale, such as for individual households and small villages, rainwater harvesting is particularly suited. Rainwater harvesting is as much a case of catchment as of storage. The size of the catchment area, just as the content of the storage tank depends on the intensity and the distribution of the natural rainfall on the one hand and , of course, the water consumption on the other hand. Theoretically 25 mm (1 inch) of rainfall over 9.3 m^2 (100 sq feet) of horizontal surface will yield 236 litres (62 US gallon) of water. Allowing for losses due to evaporation, it may be safety estimated that 190 litres (50 US gallon) will reach the storage tank. For individual households roof-chatchment will be the first solution to consider, although the poor roofing in many developing countries calls for some improvements before they can be used for this method. This can be done by the inhabitants themselves, but attention has to be given to the fact that the quality of this kind of water supply is affected by the nature, the degree of maintenance of the catchment surfaces and the collection troughs.
Rough surfaces are likely to retain wind-blow-dust which is later collected by the rainwater. Galvanized iron roofing provides excellent and smooth surfaces for the collection of rainwater. The storage tank consists in its simplest form of an oil drumand in its most complex form of a reinforced concrete cistern . To strain out suspended matter, sand filters may be built at the entrance of the storage tank, however, one can never rely on the safety of so such water, so that disinfection will always be necessary.

In arid areas it would always be a good policy to supply public buildings, like schools and other community centres with roof catchment and greater storage capacity so that the community has some water in storage for emergency use.

Roofcatchment is an old technique in which very little is changed but for ground catchment we cannot say the same. New developments has given ground catchment great opportunities for rain water harvesting. The purpose of these developments is to increase the percentage of the rainfall as runoff and/or to reduce the seepage.

A method, though not new, is the alteration. This means simply clearing the slopes of a hill of rocks and vegetations, sometimes compacting the soil surface and making ditches or rock walls along hillside contours. When the erosion is not too excessive, this can be a very economical solution.

Another method is soil treatment. This can be the adaptation of chemicals which fill the pores or make the soil hydrofobic, but it can also be ground stabilisation with lime. This is an old technique, now scientifically approached, whereby lime is added to the soil, after which treatment the soil is compacted.
A third method is soil covering. The soil is covered with waterproof membranes or asfalt layers. Sometimes the membranes have, on their turn, to be covered by gravel, to protect them against damage bij radiation, wind or cattle.
There are much different synthetic sheet materials which are very well suited for catchment purposes, but we must not forget that most of these materials are oil derivates and although we can consider them at the moment as relatively cheap, this can change in the direct or near future, because the oil prices are getting higher and higher.

D. Maddocks discusses in his "Methods of creating low cost waterproof membranes for use in the construction od rainwater catchment and storage" the merits and limitations of all methods and materials known at the moment.
An exemple of a drinking water supply by means of rainwater catchment in the Sudan is described by M. Ionides.

120 "Methods of Creating Low Cost Waterproof Membranes for Use in the Construction of Rainwater Catchment and Storage" - Maddocks, D.
146 "More Water for Arid Lands" - National Academy of Sciences
105 "Water in Dry Places" - Ionides, M.

46 "Drinkwatervoorziening te Plattelanden", Cohen, Ch.H.A. et al
86 "Harvesting Precipitation for Community Water Supplies" - Grover, B.
103 "The Introduction of Rain Water Catchment Tanks and Micro-irrigation to Botswana" - Intermediate Technology Development Group Ltd.
161 "Butyl Rubber Sheeting in Water Conservation and Storage" - Parker, P.W.
162 "The Introduction of Catchment Systems for Rural Water Supplies" - Parker, R.N.
169 "Rainwater Catchment Project, Jamaica" - Inter-Technology Service Ltd.
144 "Water Supply on Gibraltar" - Martimer Sheppard, J.
91 "A Technical and economic review of water harvesting methods" - Hollick, M.

Evaporation - Normally the captured water is stored in relatively small reservoirs, while in one of the ways described for soil catchment seepage losses are reduced or even stopped. Another cause of great losses. forms the evaporation. Sometimes evaporation losses even exceed the amount of water used productively. Much research is done to reduce this evaporat The adaptation of monolayers of aliphatic alcohols and other liquid chemicals is one of the possibilities. It seems to be very difficult to keep the alcohol barier in tact against wind and water action. Furthermo the film do not reduce the amount of solar energy which the water absorbs, and they decrease the amount of heat normally lost from the water because inhibiting evaporation also inhibits the cooling effect of evaporation. Although evaporation decreases where the alcohol layer is in tact, the higher water temperature increases evaporation at any part of the water surface the barier does not cover. A better solution seems to be wax, that softens by sunlight, flows over the water surface and forms a flexible, continuous film. The film can crack during cold weather, but the sun heat will reform it again. Blocks of floating and if possible light coloured reflecting materials are also adapted in several reservoirs with reasonable success. In the Sudan rainwater catchment supplies, another method is adapted, namely evaporation suppression by means of sand filled reservoirs. The disadvantage of this system is that the required tankvolume will increase considerably. Anoth method is simply to cover the tank; but mostly it may be cheaper to buil additional catchments to make up for the quantity of water lost by evapo than to provide a cover.

We can conclude with a comment of the Irrigation and Water Supply Commis Brisbane, Australia, that they know of no technique for evaporation com on small reservoirs of a given volume which is more economical than bui deeper reservoir with a smaller surface area.

However, there could be several additional reasons for covering, like preventing pollution, suppressing algae-growth or preventing that the reservoir becomes a breeding place for mosquitos.

146 "More Water for Arid Lands" - National Academy of Sciences

9 "Field Study of Evaporation" - Australian Water Resources Council (no. 1)

10 "Field Study of Evaporation" - Australian Water Resources Council (no. 2)

8 "Evaporation from Water Storages" - Australian Water Resources Council

13 "The Influence of Solar Radiation Reflectance on Water Evaporation" - Beard, J.T., Hollen, D.K.

17 "Regulated Reservoir Operation for Augmenting Community Water Supply" Bhalerao, B.B.

18 "Een Apparaat voor het Registreren van de Verdamping van een vrij Wateroppervlak" - Bloemen, G.W.

41a "Water Conservation by Evaporation Control" - Central Public Health Engineering Research Institute, Nagpur, India

81 "Water Evaporation Suppression" - Gainer, J.L., B ard, J.T., Thomas, R.R.

107 "Studies on Solar Still for Production of Water for Small Communities" - Jain, J.S., Shaikj, S.G. and Dhabadgaonkar, S.M.

183 "Lake Evaporation in Illinois" - Roberts, W.J. and Stall, J.B.

49 "Evaporation Reduction with Reflective Covers" - Cooley, K.R.; Asce, A.M. Meyers, E.L. and Asce, F.

79 "Stable Alkanol dispersion to reduce evaporation" - Frasier, G.W.; Myers, L.E. and Asce, F.

c. Surface water

Surface water sources must always be regarded as suspect in respect to hygienic reliability and the amount of surface water, especially in the dry season, is unreliable. This means that hydrological investigations must always be carried out (see Chapter B) and that surface water always needs some treatment to make it safe. An uniform raw water benefits the simplicity and by that also the economy of the treatment process. For this reason the following points can be of importance:

- Water from natural ponds and lakes would be more uniform in quality than water from flowing streams.
- Self-purification is usually less complete in smaller lakes than in large ones.
- Deep lakes may throw up heavy microsopic organisms during seasonal overturns.
- Impounding reservoirs may pose algae problems near the surface, while water near the bottom may be high in turbidity, carbon dioxide, ir manganese and on occasion hydrogen sulfide.
- In arid lands, because of the high evaporation, the salinity of waters in lakes and reservoirs rise considerably during the times.
- Irrigation water contains sometimes pesticides, fungiciden etc. for agricultural purposes and we don't know if these additions are removed by regular treatment processes.

The place and the type of intake is very important. Generally you could say that the intake can save you a lot of treatment, nevertheless there is relatively little literature about intakes. It is up to the ingenuity of the engineer to find the best solution in a given situation. Infiltration galleries or sand-screened intakes below river-bed level improve raw water quality. Impoundment of a stream or simple raw water storage basins may be effective in removing turbidity and in reduction of bacterial content of the water.

The WHO/CWS paper; "The village tank as a source of drinking water" gives a good example, how a very dirty source can be improved to a simple but reliable community water supply.

232 "The Village Tank as a Source of Drinking Water" WHO/CWS/RD/691

225 "Water Supply for Rural Areas and Small Communities", Wagner and Lanoix

d. Salt and brackish water

" At least 60 of the underdeveloped countries and territories associated with the U.N., face forms of water shortage which in time can be met only from non-traditional sources; that is from brackish and salt water sources.", reported P. Hoffman managing Director of the United National Special Fund several years ago. Desalination is increasing in importance. There are nearly 1,000 desalination plants in operation in various areas of the world with capacities in the 100 m^3/d to 30,000 m^3/d range. Despite the large research activities in the last 15 years to improve the technology, the costs of the water from the various desalting processes remains high. The theoretical energy required to remove salts from a solution is a fundamental factor (the laws of thermodynamics) so that for reducing costs, we had to look for lower energy consumption by reducing energy losses and by improved efficiencies like economics of scale, multipurpose application, particularly when linked to power generation next to somewhat extended plant life and lower maintenance requirements. Even for the solar stills, which use solar energy the costs are high at present mainly due to the need for large amounts of capital and a large land area to produce even small amounts of fresh water. Maybe solar stills get more interesting, since due to the oil crisis, the energy cost for the other desalination techniques are much higher.

Cost range from 5 to 10 times higher than those experienced from conventional alternatives. Generally desalination should only be considere as an alternative to fresh water transported by pipelines, when pipelines longer than 200 km. are required.

There are many desalination processes, for example those which use evaporation(distillation), membranes (reverse osmosis, electrodialysis), freezing or chemical means for the separation of salt from water. In rural areas of developing countries reverse osmosis and the solar still are the most appropriate technologies. The solar still is described by the Brace Research Institute.

Membranes processes have even some advantages over distillation.

- large metallic components such as heat exchange pipes are not required.
- High capital investment equipment such as tube rolling and milling machines are not needed.
- Capital and operating costs for the small membrane plants are about 50% of those for distillation plants.
- Membranes process equipment can be manufactured with local materials and manpower (less dependency on foreign import).
- Membrane plants are simple to construct and operate.
- There are no corrosion or scale problems.

Between the membrane process, the Reverse Osmosis deserves preference because of;

- its lower energy consumption
- the complete removal of bacteria and viruses
- the little sensitivity of the process to the salinity changes in brackish water
- the low maintenance requirement (except for the high pressure pumps) and
- highly skilled operators are not required for plant operation.

Generally we could say that attention must be given to consider not only the cost of a drinking water supply but also the reliability of the source of supply as well in quantity as in quality. We should keep in mind that desalting plants produce high quality water, which, while it may cost more, may be worth more.

Or as O'Meara says, "Desalting plants give man the opportunity to produce the quantity of water he requires, when he requires it and at a location of his own choosing.".

"Water Desalination", International Bank for Reconstruction and Developme
(Prepared by H. R. Shipman)
"How to make a Solar Still (plastic covered)", Brace Research Institute
"Reverse Osmosis as a Village Water Supply System", K. Channa basappe
"An Analysis of Cost and Production Factors in Operating Solar Stills",
Lawand T.A. and R. Alward

153	"Feasibility of Desalination for Water Supply", J. W. O'Meara
215	"Water Desalination in Developing Countries", United Nations
212	"Solar Distillation, as a means of meeting small-scale water demands" U.N. Department of Economic and Social Affairs
97	"Water desalination" - I.B.R.D.

II TREATMENT

Each transformation of raw water into potable water can be called water treatment. Depending on the raw water source, you apply one or a combination of the processes described below. Before starting a further description of the different processes, a survey of the headlines of different developments in water treatment will be given.

One development is the placing of a complete, mostly sophisticated installation in a village or town. By the gap of technical and managing knowledge of the local people, operational problems will start soon. So this development does not seem to be the right one. An example of such a packaged solution is described by Hintz, D.M.

Another sort of development is the investigation to find adaptations of the traditional treatment methods, so that they can be a solution for the shortages and problems of the treatment plants in developing countries. To find these adaptations, research and investigations of the water treatment systems are necessary. An impression of this sort of development is given by Burton, I., Idelovitch, E. and Maystre, J. in their draft report of 22nd November, 1973.

A third sort of development wishes a fundamental change, whereby appropriate technology is seen as the only way to find a solution for the water treatment problems of the rural areas of the developing countries. The books "Water Treatment and Sanitation", written by Mann, H.T. and Williamsen, D., and "Village Technology Handbook" give an impression of this development.

These are the three main developments in community water supply treatment in developing countries. A few publications follow, which cannot really be placed under the headings of the different processes.

1) A fundamental study book of almost every drinking water treatment:
    (50) "Operation and Control of Water Treatment Processes", Cox, C.R.
2) An evaluation example which gives an impression of the management and maintenance problems of the treatments: (76) "Evaluation of Effectiveness of Community Water Supply in North-East Thailand" - Frankel, R.J.

3) A Treatment Plant which can be a solution in emergency circumstances:
   (58) "A Potable Unit for the Supply of Drinking Water in Emergencies" - Diamant, B.Z.
   (151) "Planta Movil Experimantal de Tratamiento de Aqua" - Nyerges, N.V. and Genrales, E.R.

4) Complete ready made treatment installation: (90) "Packaged Water Treatment Plants for Small Communities, Industries, Institutions and Camp", Hintz, D.M., Proc. of a seminar, ed. Pescod and Okun

5) State of the art reviews and practical handbooks for drinking water treatments:

26 "Technology Assesment and Research Priorities for Water Supply and Sanitation in Developing Countries" - Burton, I., Idelovitch, E. and Maystre, J.

225 "Water Supply for Rural Areas and Small Communities", Wagner, E.G. and Lanoix, J.N.

60 "A Practical Handbook of Water Supply", Second Edition, London, 1950, Dixey, F.

121 "Water Treatment and Sanitation" - Mann, H.T. and Williamson, D.

224 "Village Technology Handbook" - VITA

102 "The Technological Frontrier" - Idelovitch, E.

213 "Rural Water Supply and Sanitation in the Developing Countries" - United Nations Children's Fund.

For a survey of the processes the following division is made:

a) disinfection
b) sedimentation, flocculation and coagulation
c) filtration
d) demineralization
e) aeration

a. Disinfection

The lack of money and knowledge of techniques is a great problem in the rural areas of developing countries. In many cases this problem is the reason of disinfection being the only feasible drinking water treatment. Disinfection means chlorination in most cases. The dosing of the chlorine depends on the raw water quality. To guarantee the hygienic reliability, you need a reasonable reliable dosing device. How to find a clear simple low cost method for rural situations is the great problem. This has been the reason of much research and many experiments of disinfection methods. Now you see two main developments of dosing methods for chlorination, pots and dripfeeders.

Examples of simple low-cost solution feeders are described by Marais and McJunckin and another feeder is used in the Sudan which is described by Reid in his annual report of 1974.

More appropriate dosing methods are the "pot or cartridge" systems. The start of these developments took place in three different countries. namely: Bulgaria, India and Malaysia. The method is just a pot or a coconut filled with bleaching powder or another disinfectional substance and is to be hanged in the water. The only operation is to renew the disinfectional substance from time to time. The experiments and experiences with these pot methods are described clearly by the Indian Institute CPHERI, Mr. Zdravkov from Bulgaria and Mr. Talib from Malaysia.

Chemicals for disinfection can get overaged, so the activity of the substance will decrease from time to time. A solution for the communication problem of the developing countries as mentioned before can be greater storage, but this will cause the disadvantage as described above. A clear survey, describing the decrease of activity by storage is published in the article "Disinfection techniques for small community water supplies", edited by CPHERI, India.

Another difficulty for the developing countries can be the import of foreign chemicals. Often this takes such a long time, that sometimes the chemicals are overaged, when they arrive at the place concerned.

To solve these problems, the developing countries can try to establish factories themselves which will produce the chemicals needed.
In cases of large countries with an inferior network of roads, small units spread over the country will be a better solution than one big factory serving the needs of the population of the whole country.
So, when the distances are short the supply of chemicals will be frequent and storage is not necessary anymore.

An operator, who has a good insight in the dosing of chemicals for disinfection is not easy to find but nevertheless necessary even in rural situations. Because of the objectionable taste or even the danger for health with a too high level of disinfectants in the drinking water, this operation is a responsible job. Especially for simple village wells, using iodine or chlorine, this is very important and shows the necessity of a good training course in this field. Another necessity is to have one responsible man who takes care off a water supply unit, so that the responsibility is always clear.

1) Disinfection methods for individual use or on small domestic scale:

239 "The Purification of Water on a Small Scale", (no.3) - WHO,International Reference Centre for Community Water Supply.

271 "The Suitability of Iodine and Iodine Compounds as Disinfectants for Small Water Supplies" (no. 2) Zoeteman, B.J.C. - WHO, International Reference Centre for Community Water Supply

44 "Sterilization of Water under Field Conditions" - Chatterjee, A.K. and Srivastava, G.C.

2) Different types of solution feeders:

175 "Lower Cost Methods of Water and Waste Treatments in Less Developed Countries", First Annual report, May 31, 1974 - Reid, G.W.

126 "Floating Platform Hypochlorite Solution Feeder" (no. 7) - Marais, G.V.R. and McJunkin, F.E.

129 "Individual Household Desinfection and Filter Unit for Turbid Waters" - Marais, G.V.R. and McJunkin, F.E.

128 "Bottle Hypochlorite Solution Feeder" - Marais, G.V.R. and McJunkin, F.E.

124 "Float Valve Hypochlorite Solution Feeder" - Marais, G.V.R. and McJunkin, F.

125 "A Proportional Chemical Feeder for Small Water Purification Plants" - Marais, G.V.R. and McJunkin, F.E.

3) Basic information on the application of different disinfection methods.

50 "Operation and Control of Water Treatment Processes" - Cox, C.R.

35 "Disinfection Techniques for Small Community Water Supplies" - Central Public Health Engineering Research Institute

263 "Suggested Protocol for the Laboratory and Field Testing of the Watersure Hypochlorinator" - World Water Resources

163 "Disinfection of Water in the Field" - Patil, M.D., Joshi, S.R., Rao, N.U.

"Manual Para la Desinfecion de Aguas Mediante la Chloration" - Lopez, O.C.

60 "A Practical Handbook of Water Supply" - Dixey, F.

119 "Water Supply Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.

145 "Water Quality" - Mostertman, L.J.

4) Backgrounds and manuals on disinfection systems:

270 "New Method of Chlorinating Drinking Water" - Zdravkov, M.

36 "Disinfection for Small Community Water Supplies" - Central Public Health Engineering Research Institute

200 "The Pahang Continuous Chlorinator" - Talib, Et Al

154 "Basic Gas Chlorination Workshop Manual" - Ontario Water Resources Commission, Training and Licensing Branch.

204 "Potable Water for Villages" - Thakkar, M.R.

174 "Community Water Supply in Drug District" - Ranade, V.K. and Tiwar, A.R.

b. Sedimentation, flocculation and coagulation

The most simple method of sedimentation on both small and large scale is the use of intermittent basins.

For individual use and for small scale installation every available small basin, for example a carefully cleaned oil drum is of good use. You can fix the settle time by experiments.

For large scale installation a lot of ponds and lakes already function as a se mentation basin. To construct a basin which will have the same function, a simple shape can be used. In this way it seems possible to use local available materials for intermittent sedimentation basins on a large scale.

To design a sedimentation basin in for example a more extensive treatment plant, a fundamental hydraulic knowledge is necessary. Otherwise the shapes of the construction are mostly uncomplicated. Investigations to find local available materials which can be used, can promote low cost constructions.

In his article, "high rate settlers", Mr. Yao gives a survey of the development of high rate settlers in comparison with the traditional settlers. Perhaps there is some future for tube settlers made of locally produced plastic pipes.

A new trend in the coagulation process is described by Singly, J.E. in his article "Experiences with the magnesium carbonate process in North America". It is a complicated process but it has advantages as recycling of coagulant, elimination or reduction of sludge disposal, additional disinfection due to the high pH, removal of iron and manganese, production of a water with adequate hardness and alkalinity to allow corrosion control by stabilization of the water, potential saving in treatment costs.

A study report on native methods to purify water describes a new development in Sudan. Rauwag, a clay soil and some different plants are used and seem to give good flocculation results. Regarding native methods one should give preference to clarifier material which can be easily identified and used in quantitive terms, is one of the conclusions of the report, "Sudanese native methods for the purification of Nile water during the flood season with clay soil", written by Jahn, S.A.A.

1) Theoretical handling and manuals on settlers, flocculation and coagulation processes.

50 "Operation and Control of Water Treatment Processes" - Cox, C.R.

195 "Experiences with the Magnesium Carbonate Coagulation Process in North America" - Singley, J.E.

267 "High Rate Settlers" - Yao, K.M.

196 "State of the Art of Coagulation" - Singley, J.E.

135 "Solid Contact Reactors" - Miller, D.G.

118 "Some Practical Problems with Water Treatment in Technical Age" - Lloyd, R.D.C.

225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.

224 "Village Technology Handbook" - VITA

121 "Water Treatment and Sanitation" - Mann, H.T. and Williamsen, D.

60 "A Practical Handbook of Water Supply" - Dixey, F.

256 "Health hazards of coagulant aids" - W.H.O.

93 "Sedimentation and flotation; Mechanical filtration" - Huisman, L.

2) Native methods for flocculation

106 "Sudanese Native Methods for the Purification of Nile Water during the Flood Season with Clay Soil" - Jahn, S.A.A.

3. Filtration

In situations of individual supply or on small village scale, simple filter systems give good results. The advantages of these systems are that you can mostly use local available materials and the operation is uncomplicated. The so-called drum filter is a good example. Other clear examples are described in "The Purification of Water on a Small Scale", edited by WHO/International Reference for Community Water Supply, technical paper no. 3 and in "Individual household disinfection and filter unit for turbid waters", written by Marais and McJùnkin. In their book "Water treatment and sanitation" Mann and Williamson describe an example of what they call a horizontal slow sand filter, which can be a good and very simple solution for low turbid water at least when there is sand available in the region.

Slow sand filtration is the kind of filtration which was the beginning of the filter history. The advantages: uncomplicated in management and maintenance, unskilled labour and production of clear hygienic reliable water make that this technique deserves great attention in the developing countries. A practical example of slow sand filtration is published in: "Filtres à sable lents à aeration intermittante à Bujumbura in Burundi" (slow sand filter with intermittent aeration in Bujumbura in Burundi). This gives an impression of the construction and management of a slow sand filtration plant. The biological purification of a slow sand filtration is better under circumstances of higher temperature, so this seems to be an advantage in tropical areas. A fundamental book about slow sand filtration was written by Huisman, L.

In several cases the raw water supply is limited. In such cases intermittent water supply is used as a solution. For filtration plants such a solution will give problems, because the bacteriological actions only can function in an optimal way with a continuous filter operation. With standstill or even standing dry of the filter unit, the bacteria have no food and will become less in number or die. So the bacteriological purification is worse or lost. A reason to apply an intermittent slow sand filtration can be to repress the growth of algae (West-Germany), but generally a continuous filter operation has the preference above an intermittend filter operation.

For more turbid waters pretreatment like sedimentation or so will be necessary, or the use of rapid filtration followed by disinfection. A more sophisticated development in the use of slow sand filters is described by Agarwal, I.C. and Agrawal, G.D. They start an investigation on operating slow sand filters with alunn-coagulated water. The problems and probable advantages of this new development are discussed in their article: "Operation slow sand filters with alunn coagulated water".

A problem of filter plants is the controlled operating, so declining the rate of filtration may be an advantage. A development in this way is described in the article of Mr. Cleasby, "New ideas in filter control systems".

Using local filter media is another development. Because there is almost everywhere sand on the world, the necessity of other local filter media is not always clear. The selection of sand grains and the cleaning of sand gives problems, but often also the local filter media for example rice husk have to be treated (Burning). Nevertheless this development is a good one for areas with sand selecting problems or almost complete lack of sand in comparison with other local available and good functioning filter media. An example of this development is given by Frankel, R.J. in his article: "Evaluation of low cost water filters in rural communities of the Lower Makong Basin".

The problem of the grading of sand can find a solution by the upflow filtrati By the vertical up-flow during back-washing a natural selection takes place. This filter system, developed in the Netherlands, got a new move by experiments in India and Latin America. An example is: "Some performance observations on an upflow filter", written by Paramasivan and others.

The multi media filter is another solution for the attempts to get more water out of a filter run. The grading now takes place by the different weight of the different media. Experiments of multi media filter processes are discussed in the article of Mr. Robeck, G.G.; "Modern concepts in water filtration".

The "Pressure filter plant" and the "Low rate filters" are new developments in the field of the more sophisticated rapid sand filters. The Indian institute CPHERI describes these new trials in comparison with the

1) Solar stills

116 "An Analysis of cost and Production Factors in Operating Solar Stills" - Lawand, T.A. and Alwand, R.

107 "Studies on Solar Still for Production of Water for Small Communities" - Jain, J.S., Shaikj, S.G. and Dhabadgaonkar, S.M.

82 "Use of Solar Energy for Production and Supply of Water from Salt Water" - Garg, S.K., Gomkale, S.D. and Datta, R.L.

109 "Overzicht Waterdestillatie door middel van Zon met zogenaamde Solar Stills (Survey of Water destillation by solar energy) - Jansen, L.

113 "Zuiver Water, Zelf Maken" (Make your own fresh water) - De kleine aarde

60 "A Practical Handbook of Water Supply" - Dixey, F.

3 "Techniek" (Technique) - Agromisa

212 "Solar Distillation, as a means of meeting small-scale water demands" - U.N. Department of Economic and Social Affairs

97 "Water desalination" - I.B.R.D.

2) Defluoridation

150 "Defluoridation of Water by Nalgonda Technique" - NawLakhe, W.G., Kulkarni, D.N., Pathak, B.N. and Bulusu, K.R.

50 "Operation and Control of Water Treatment Processes". - Cox, C.R.

148 "Defluoridation of Water by Nalgonda Technique" - National Environmental Engineering Research Institute

32 "Defluoridation" - Central Public Health Engineering Research Institute

34 "Defluoridation" - Central Public Health Engineering Research Institute, no.4

40 "Limitation of Magnesia in Fluoride Removal" - Central Public Health Engneering Research Institute, no. 41

33 "Defluoridation" - Central Public Health Engineering Research Institute no. 1.

16 "Defluoridation of Community Waters: A Problem" - Bhakuni, T.S.

191 "Fluoride Menace in Certain Community Water Supplies of Andhra Pradesh" - Seethapathi, Rao, D. and Sriniuasan, K.

3) Iron and Manganese Removal

50 "Operation and Control of Water Treatment Processes" - Cox, C.R.

38 "Iron and Manganese Removal in Rural Water Supplies" - Central Public Health Engineering Research Institute, no.9

1) Filter treatments for individual supply or on small village scale.
239 "The Purification of Water on a Small Scale" - WHO/International Reference Centre for Community Water Supply (Technical Paper no.3)
129 "Individual Household Disinfection and Filter Unit for Turbidwaters" - Marais, G.V.R. and McJunkin, F.E.
176 "Lower Cost Methods of Water and Waste Treatments in Less Developed Countries"- Reid, G.W.
224 "Village Technology Handbook" - VITA
121 "Water Treatment and Sanitation" - Mann, H.T. and Williamson, D.
206 "Hoe water te zuiveren op het platteland" (How to treat water in rural situations) - Tool

2) Studies and manuals of slow sand filtration.
96 "Slow Sand Filtration" - Huisman, L. ; Wood, W.E.

50 "Operations and Control of Water Treatment Processes" - Cox, C.R.
2 "Operating Slow Sand Filters with Alum Coagulated Water" - Agarwal, I.C. and Agrawal, G.D.
73 "Filtres à Sable lents à Aeration Intermittante à Bujumbura" -
192 "Slow Sand Filtration for Small Communities and Rural Areas" - Semra Siber
60 "A Practical Handbook of Water Supply" - Dixey, F.
225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.
253 "Biological or Slow Sand Filters" - W.H.O.
92 "Artificial groundwater recharge" - Huisman, L.
94 "Slow sand filtration" - Huisman, L.
232 "The village tank as a source of Drinking Water" - W.H.O.
88 "A museum of 50 years treatment design" - Hengsuvany, K.

3) Filter control systems.
45 "New Ideas in Filter Control Systems" - Cleasby, J.C.

4) Local available filter media.
75 "Evaluation of Low Cost Water Filters in Rural Communities of the Lower Makong Basin" - Frankel, R.J.
77 "Series Filtration Using Local Filter Medias" - Frankel, R.J.
108 "Development of A Series Filtration Water Treatment Method for Small

w and multi media filters.
160 rformance Observations on an Upflow Filter" - Paramasivam, R.
dkari, S.K., Deshpande, A.K., and Joshi, N.S.
138 Filtration" - Mirchandani, N.W.
182 Concepts in Water Filtration" - Robeck, G.G.
4 on of Cucuta, Colombia water treatment plant using dual media
ltration" - Arboleda, J.

Sand filtration.
95 iltration" - Huisman,
132 or Saigon" - McPhee, W.T. and Nguyen Huu Tuan.

sophisticated filter systems.

57 on the Pressure Filter Plant for Small Communities" - Dave,J.M.
kari, S.K., Khana pur kar, P.Y. and Tuli, J.M.
164 Water Filters" - Patwardhan, S.V.

55 pply & Waste Disposal for Greater Bombay" - CPHERI
134 lance of Drinking Water Quality" - McJunkin, F.E.
167 ngs of the Syposium on Water Filtration - The State of the Art"
ponsored by the bureau of sanitary engineering, California
te Departement of Public Health.
157 ary Investigations on the Use of Coal for Removing Viruses from
er" - Oza, P.P., Srizamulu, N. and Chandhury, M.

d. Demineralization

Until now most demineralization processes have been costly. Nevertheless demineralization especially for desalting can be the only solution to get drinking water in some areas. Desalting the water takes place by distillatio and by membrane systems but in the case of rural conditions it is most of the time too costly and too complicated. There is a new development which may become of good use for rural sunny areas. It is a kind of distillation and it is suited for all kinds of water, like salt, brackish, disturbed water etc. The plant, the so called "solar still", uses solar energy. Trough a transparant cover water is warmed up, by sun heath. This causes evaporation and condensation against the cover. This condensate is collected. For individual and for community use, many experiences in the field of solar stills have been made. Some examples of big plants were described by, Lawand, T.A. and Alward, R. in their article, "An analysis of cost and production factors in operating solar stills" and by Brace Research Institute in their article "How to make a solar still (plastic covered)".

Defluoridation is a great problem in some areas. The high level of fluoride is rather unhealthy for the consumer in these areas but sometimes it is the water there is. This indicates the necessity to find a payable, uncomplica defluoridation treatment. Especially the Indian Institute CPHERI pays much attention to this problem. The process described in the article: "Defluoridation of water by Nalgonda Technique" is described as to be simple and adaptable even by illiterate persons, so this can be a good process to apply in rural areas. The Nalgonda technique comprises addition in sequence of sodium aluminate or lime, bleaching powder and filter alumm to the water followed by flocculation, sedimentation and filtration. Experiments in buckets, drums (intermittent) and pilot plants (contineous) are taken.

Too much iron and manganese in the water causes trouble for the laundry and plumbing fixtures and are objectionable for the taste and colour of drinking water. We cannot mention a special development in developing countries for iron and manganese removal. A short, clear description of an aeration filter-bed system is given in "Technical Digest", No.9, Sept.1970, edited by CPHERI, India. A good survey of the treatment possibilities is given by Cox, C.R. in chapter 12 of his book "Operation and control of water treatment processes.

e. Aeration

Aeration is a good treatment for the purification of raw water deficient in oxygen. Especially in tropical areas it seems important. Often there is a more abundant growth of waterplants, which in many cases cause a higher biological oxygen demand. The micro organisme, which are supposed to do the labour in the case of biological purification, need oxygen to purify the wat This shows the importance of aeration.

In general aeration has a positive influence on objectionable taste and odour properties of drinking water.

Sometimes H_2S or iron and manganese are found in groundwater. Also for the removal of these substances, aeration can be the right treatment.

Waterfall and cascade aerators are a simple kind of aeration, which can be applied especially in hilly areas. Spray- and diffused-air aerators are somewhat more complicated techniques is described in "Operation and control of water treatment processes" by C.R. Cox.
by C.R. Cox.

1) Theoretical descriptions of aeration

50 "Operation and Control of Water Treatment Processes" - Cox, C.R.

60 "A Practical Handbook of Water Supply" - Dixey, F.

225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.

2) Manuals of aerators

38 "Iron and Manganese Removal in Rural Water Supplies" - Central Public Health Engineering Research Institute, no.9

46 "Drinkwatervoorziening te plattelande". - Cohen, Ch.H.A. and Guldestein, E.

229 "Hydrogen Sulfide Problems of Small Water Systems". - Wells, S.W.

III. WATERLIFTING AND PUMPS

Many types of pumps find their origin in Europe and North America, in consequence, people from other cultures have problems to manage these pumps, because in general they have not the real feeling for western techniques. A practical advice is: use as uncomplicated as possible waterlifting devices in every water supply project. Experiences of this problem from the field are described by Wignot, R.E. in his report "The Condition of Unicef-assisted Demonstration Rural Water Supplies in Kenya". This report shows that almost all handpumps were out of use, in the case of motor pumps the transmission between engine and pump was in many cases bad, while the hydraulic ram functioned most of the time well, just like the rainwater catchments and the gravity supplies. The three last mentioned supply systems require hardly any maintenance. This is considered to be the reason of their good functioning.

This report emphasizes the importance of evalution. In order to get more insight, further investigation into the exact shortages of waterlifting systems in operation has to be stimulated.

In the field of the possible energy shortage we can think of reviving the already long known and long used possibilities such as windmills and animals and in the future may be solar energy. Investigations in this field for adoption in several local situations should be promoted.

A simple turning rope or chain with nuts or other thickenings can be a waterlifting system. This kind of very simple waterlifting systems is described in the "Village technology handbook" edited by VITA. The disadvantage of these systems is the great risk of contamination, because the water source can never be completely covered when such a system is used so the consumers have to behave hygienic and to use it carefully.

Because of the contamination risk and in a case of higher consumption, a simple handpump can be a better solution. How to repair and to manage them seems to be the shortcomings of handpumps, as known from experiences in the field. So the research and the investigations to find a strong long life handpump have to be stimulated as much as possible. A good impression of the investigations and research in this field is given by the final reports of Frink, D.W. and Fannon Jr. R.D.

A longer transportline or a more wider spread distribution system can cause the necessity of pumps with the possibility to vary in head and/or in quantity. One other development is the already mentioned hydraulic ram. The presence of different ground levels and enough water is necessary for its operation; so in cases where this is no problem the hydrualic ram can be of good use. The publication of Watt, S.B., "A Manual of the Hydraulic Ram for Pumping Water", is a clear explication of the technique, construction and management of this hydrams. Other important simple pump engines are the "Humphrey pump" and the pump describe water bulletin no. 1, edited by The National Institute of Agricultural Engineering of England. The Humphrey pump has the advantage that different kinds of energy can be used, so the pump can be adopted to several circumstances.

1) Simple Waterlifting systems and handpumps

60 "A Practical Handbook of Water Supply" - Dixey, F.
224 "Village Technology Handbook" - VITA
214 "The Persson Pump" - United Nations Children's Fund

225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G. and Lanoix, J.N.
67 "A Pictorial History of the Handpump" - Eubanks, B.M.
121 "Water Treatment and Sanitation" - Mann, H.T., and D. Williamson
202 "Techniques Rurales en Afrique" - Bureau Central d'Etudes pour les Equipement d'Outre Mer
197 "Eenvoudige hulpmiddelen voor waterwinning" (Simple resources for obtaining water) - Smit, J.W.

2) Research, and evaluation of handpumps

250 "The Condition of UNICEF-assisted Demonstration Rural Water Supplies in Kenya" - Wignot, R.E. , dec. 1974
69 "Development of a Hand Operated Water Pump for Developing Countries" - Fannon, R.D.

80 "The Development of a Water Pump for Underdeveloped Countries" - Frink, D.W. and Fannon Jr., R.D.
70 "The Continued Development and Field Evaluation of the Aid Hand-

3) Manuals on hydrams and motor pumps

228 "A Manual on the Hydraulic Ram for Pumping Water" - Watt, S.B.

63 "The Humphrey Pump" - Dunn, P.D.

3 "Techniek" (Technique) - Agromisa

149 "Simple Water Pump" - National Institute of Agricultural Engineering

127 "Characteristics of the Unknown Pump" - Marais, G.V.R. and McJunkin, F.E.

12 "Localized Corrosion-Erosion in Pump". - Baumgarten

266 "De waterram" (The Hydram) - van Wulfften Palthe, B.R.

4) Systematic surveys of types of pumps

62 "Energievoorziening, Pompen en Motoren" (energy supply, pumps and engines) Duin, J.F.

26 "Technology Assesment and Research Priorities for Water Supply and Sanitation in Developing Countries" - Burton, I., Idelovitch, E. and Maystre, J.

27 "Rural Water Systems Planning and Engineering Guide" - Campbell, M.D. and Lehr, J.H.

IV DISTRIBUTION

a. Storage

There are two different types of storage, namely raw water storage and clean water storage.

Raw water storage with plain sedimentation can provide a simple effective and self-contained treatment under favourable conditions. Large impoundingreservoirs, natural lakes and ponds serve such purposes in many cases. They carry multi-benefits: equalisation of fluctuating flow, sedimentation of silt and suspended matter; oxidation of unstable organic impurities; reduction of colour and turbidity; dying out of pathogenic organisms and evening out of quality fluctuations. Sometimes sedimentation basins are providedas the only treatment before disinfection. In those cases at least from one to several days settling have to be provided before the water is drawn out for use. Long storage however, particularly with alkaline water, can give algae problems. Where the storage cannot be limited to an optimum of two to three weeks, measures must be taken, for example, coppersulphate dosing.

The open rain water catchment reservoirs as dealth with in chapter C. I. form an example of an artifical storage.

Can raw water storage be considered as a form of treatment, clear water storage on the other hand must be considered as a part of the distribution system. The clear water or service storage fulfills several purpose.

- As a storage for fluctuating demand, it permits pumps and filter plants to operate at constant rates and ensures economy in their size and capacity.
- In the case of an elevated reservoir, more uniform pumping heads are possible which facilitates the selection of pumping sets operating at a high efficiency.
- It ensures the necessary presure in the whole or part of the distribution system.
- In emergency cases adequate storage within the system will assure uninterrupted supply against power failure or plant breakdown. Just as in the cases of normal maintenance periods and fire-fighting.

- Also it permits pumping to take place during parts of the day only.

The storage capacity depends on the demand pattern like peak demand and average daily demand, etc. Therefore the local customs have to be studied very intensively because of the divergence of this demand in the different cultures. It also depends on the technology adopted. When rainwater catchment is adopted it depends on the size of the catchment area and the intensity and spreading of the rain. In the case of man or animal power, pumping takes place during parts of the day only.

Storage tanks, both ground level and elevated, lend themselves readily to type designing and to the adoption of locally available skills and materials. The avoidance of complicated pipe work, the use of thin block or masonry skin walls filled in between with mass concrete in stead of traditional reinforced concrete design, the restriction of the number of types and sizes to a minimum (even if this involves overcapacity in some instances) are possible ways of economising on imported materials and on design and construction staff. Steel tanks have advantages in speed of contruction but need regular painting and do not last as long as concrete; these and similar economic conditions must be balanced. (Other techniques are described in the chapter on rain water and in the annexes).

If topography is suitable, elevated reservoirs are constructed on elevated grounds, in other cases it is a reservoir supported on a tower. In traditional Islamitic countries there is, besides the minaret, no other tower allowed so there an other solution (pumping) has to be chosen.

Mostly elevated reservoirs are not designed to "float on the system". All water is pumped the full height to the top of the reservoir and then flows to the village by gravity. This is a wasteful use of power particularly in view of the high cost of both electricity and fuel. The custom of pumping all water into the reservoir is so ingrained that it is difficult to obtain acceptance by the engineers of the concept of direct pumping to the distribution system with only excess over demand going to the reservoir.

Reservoir structures are frequently given considerable architectural embellishment in villages which otherwise have no architectural distinction. The excuse of this is that it makes only a small difference in the total cost. With the limited budget for rural water supplies there appears to be no valid reason for unnecessary expenditures of any kind. The function of community water supply programmes is not landscaping improvement, but rural health improvement. If the cost of the reservoir embellishment will provide only a few more cubic metres storage or 100 meters of much needed distribution pipes, then that is where the money and effort should go. The enclosed space created under reservoirs is seldom put to any use.

The problem of evaporation is treated in the chapter on rain water.

225 "Water Supply for Rural Areas and Small Communities" - Wagner and Lanoix.

60 "A Practical Handbook of Water Supply" - Dixey

102 "The Technical Frontier in Rural Water Supply for Developing Countries" - Idelovitch

b. Pipes

In urban supplies, more than half and usually two thirds to three fourth o the total investment on the community water supply goes into the distributi system. In rural areas the supply is in many cases operating without any piped distribution system or with a simple system supplying water to severa public standpipes only. A distribution system generally consist of: pipes, accesories such as valves and meters; and servical connections. The pressure and the amounts of water which have to be delivered are the important parameters to design size and material of pipes.

The use of bamboo has drawn much attention since, in Indonesia, this materi is used for gravity systems in rural areas. Bamboo systems are easy to construct by unskilled labour and bamboo is cheap in those countries where it is available. But there are many problems which have to be solved before bamboo systems can compete with the traditional systems. One of the problems is, that bamboo is not suited for pressure systems, for the maximum possible pressure is about two atmospheres. Duration of lif of bamboo is relatively low, about 3 to 5 years. Great research efforts in this field are going on, to find suited conservation methods for the bamboo. Another disadvantage is the bad taste and odour which presents itselfs in the system during the first weeks that water is passing through the bamboo pipes. Concluding we can say that the mechanical properties of natural bamboo cannot compete with the properties of, for example, plast

Perhaps that after intensive and expensive research these properties can be improved, but then it is the question is bamboo still a low cost material?

However plastic pipes cannot be considered a new technology any more, it deserves special attention because of its properties which makes its very suited for adoption in developing countries. The main advantages of plastic pipes are:

- the relatively low cost. Although after the oil crises we do not know whether the prices of plastics (which are oil derivates) will stay low any longer.
- the suitability for local manufacturing, due to the availability of raw materials on international markets and the low cost of equipment requirec for manufacturing.

For the mechanical properties of the plastic pipes itselves we can mentio
as advantages:

- Excellent resistance to corrosive water and corrosive soils
- Bacteriological inertness
- Low thermal conductivity
- Extreme lightness
- Flexibility
- Smooth internal surface
- Very low water absorption
- Availability in greater lenghts
- Good workability

While as main drawbacks have to be mentioned:

- Temperature sensitivity, e.g. the mechanical strength diminishes with the increase of the temperature.
- Relatively high thermal expansion
- Sensitivity to light (ultraviolet light) and weather (weatherability)
- Sensitivity to notches, particularly PVC-pipes
- Impact strength of PVC diminishes by decrease of temperature
- Diffusion of odorants and other very volatile gasses through the wall of PE-pipes
- Sensitivity to organic solvents as ketones, ethers and chlorinated hydrocarbons.
- Detrimental effect of the plastics to the water
- A special problem with these plastics in drinking water supply is the requirement of a quality control programme to accompany the manufactur and use in order to avoid intrusion of toxic substances in the water. In many developing countries this will not be easy. Polyvinyl chloride and polythylene by themselves are not detrimental to health, but additives necessary for the manufacturing like stabilizers and lubric for PVC and anti-oxidizers for PE can be toxic.

Generally the choice lies between steel, cast iron, spuncast iron, prestre concrete, asbestos cement, and plastic for medium and large diameters, and between asbestos cement, galvanised iron or steel and plastic for smaller diameter; copper and lead piping have but a limited use and for specific purposes only in home plumbing. These materials, which are used for long times are properly discussed in the handbook of Vaillant and Loussouarn.

Pipe appurtenances, like specials,joints and clamps and valves and fittings form a sizeable portion of the network system. Their quantity should be minimized by carefull design

A very important factor in water systems design, especially in the long range developing programmes, is the standardisation of materials and equipment. The first design may set the pace for others. Easy availability and interchange ability of pipe materials over a regional or country wide area is an asset in efficient maintenance.

223 "La choix des Materiaux pour les Conduites d'adduction et de Distributio
d'Eau" - Vaillant, G.R. and Loussouaru, J.L.

133a "Role of Plastic pipe in Community Water Supplies in Developing Countrics
- McJunkin, F.E. and Pineo

123 "Water Supply using Bamboo Pipes" - Marais, G.V.R. and McJunkin, F.E. (e.

238 "Plastic Pipe in Drinking Water Distribution Practice" - WHO/IRC Technica
Paper no.1

53- 54 "Plastic Pipe in Water Supply and Drainage" - CPHERI

89 "Feasibility Study on the Use of Bamboo in Pressureized Water Systems"
- Herrera, E.D.

147 "Thermoplastic Piping for Potable Water Distribution Systems" - National
Academy of Sciences - National Research Council

115 "Plastics Pressure Pipe: Design Criteria and Performance Assesments" -
Lanu, J.M.

168 "Cement Joint for Cast-Iron Water Pipe" - Raghu, V.

208 "Laying Small Diameter PVC Pipes" - Turpie, R.M.

237 "Health Aspects relating to the Use of uPVC Pipes for Community Water
Supply" - W.H.O., International Reference Centre

c. Service connections.

The WHO knows three stadia of development in water supply systems:

I A distribution with maximum 10% house connections and the other 90% are supplied with standpipes

II About 50% house connections and 50% standpipe delivering

III The advanced stage, we can say the target of most programmes, whereby most houses are connected.

For design purposes we can divide the houseconnections in single-tap and multi-tap houseconnections. In the first development stage the discussion is often about how many people have to be served by one standpipe and what should be the medium distance from standpipe to dwellings. The result will mostly depend on the financial ressources on the one hand and on the other hand on the eagerness of the people to step over from their own sources to the reliable community water supply. Though the change from standpipe to houseconnection seems to be a progress because of the increased convenience which results in time and effort savings due to the elimination of carrying and storing water, it is not always felt so with the local people. Of course there are countries where the saving in time and efforts may have an important economic value but there are even countries where there is no economic (or social) replacement for them while in many areas the gathering at the public fountain is regarded as a special social activity that provides the best use of women's and children's leisure time. Nevertheless the public standpipe has some great disadvantages:

- The collection of water charges is difficult because of the large number of people supplied from the same point with different levels of service
- The maintenance of a public standpipe is difficult, because of careless useng by many people, none of whom considers it his property.

We often see return in the literature remarks about the great wastes in the water supplies of many developing countries, both with standpipe and with houseconnections. For an enlarging community in many cases the necessity to build a new plant to deliver enough water, should be considered against the possibilities to reduce wastes to gain the same objective. There are a lot of supplies which have only a part of the day pressure on their distribution system. In those villages you can see that in the beginning of

There is a large queue for the standpipe and in the houses the storage tanks are getting filled. An hour later there is no one at the still flowin standpipe and even the reservoirs in the houses are running over without someone doing something about it. It will not be necessary to tell the consequences of pressure fall for the hygienic reliability.
Ofcourse there are also great leakages, due to the improvised way of pipelaying and connecting.
Solutions. for these wastes can be for example the adoption of special devices like the fordilla faucet, a springloaded mechanism which closes automatically after a few seconds and can discharge a fixed amount of water every time when it has been pressed. However it seems that the reception in South America was good (the reason could be the unknowness of other possibilities), this is not necessary for other areas.

The disadvantages of this press button system are the difficulties to repa them and their need for substantial pressure to function adequately.

Another solution could be the adoption of constant flow valves, for which is proved that they can reduce the water use by 25 to 30 percent (Zambia).

A further solution could be metering, whereby everyone pays for his actual consumption. Meters are comparatively short living and require testing and servicing facilities including a trained staff for reading, billing and collecting. The cost of the meter and all these recurrent charges fall any on the consumer.
The most simple and economic solution is naturally the use of smaller diameters for the pipes.

230 "Drawers of Water" - White, G.F., Bradley and White
20 "Low Cost Distribution Systems" - Borjesson, E.K.G.
122 "Reduction of Water by the Use of Constant Flow Valves" - Marais and McJunkin, F.E. (ed)

5 "Municipal Water Supplies in East Pakistan" - Arbuthnot, J.
26 "Technology Assesment and Research Priorities for Water Supply and Sanitation in Developing Countries" - Burton, I.;. Idelovitch, E. and Maystre, J.
85 "Design Parameters for Rural Water Distribution Systems" - Ginn, H.W.; Corey, M.W. and Riddlebrooks, E.J.
156 "Manual de Referencia, Medicores de Aqua Domiciliar" - Organizacion

158	"Demand for Potable Water in Small Communities of Thailand" - Paichayon Shonvanavirakul
201	"Hygienic and Technical Guidelines for Water Supply and Waste Water Systems in Buildings" - Taylor, F.B.
227	"World Health Orgaization - Assisted CPHERI Course on Preventive Maintenanc of Water Distribution Systems"- The Water Research Association
19	"New concept in water service for developing countries" - Borjesson, E.K.G and Bobeda, C.M.
6	"Low cost distribution systems in Guatemala" - Aris, D.

D. MANAGEMENT

The start and the delivery of a water supply project is difficult, that is for sure. But it has to be concluded from practical experience that in general the management of a water supply plant is more difficult. In many cases governmental or foreign ministries or institutes give advice in planning, designing and construction of a water supply project. Then the water supply starts and the advisors leave, leaving a group of local people not trained enough. So when a part of the water supply plant breakes down, the problems start right away. It seems that many of the breaks can be prevented by a better maintenance. So a good technical training regarding how to operate, to maintain and to repair the plant has to be stimulated.

Another item in maintenance is: use as less as possible foreign accessories for a project. In most cases the renewing of accessories from foreign countries takes too much time or does not happen at all due to bad communication possibilities or to shortage of money.

Besides these more technical aspects, the financial problems draw attention. A good impression of this has been given by the evaluation project report of North.
East Thailand by Mr. F.J. Frankel. The salaries for the serving staff and the money for the operation of the plant were some of the main problems mentioned in this report. It proves the importance of good communication and well arranged agreements between all parties concerned in financing a community water supply. There has to be agreement between the level that decides who gets water, and the level that will have to pay for the water. The costs of the salaries of the serving staff, and also a good estimate of the operational costs of the plant in the future have to made up in advance.

Directly in connection with all other mentioned aspects stands administrat
For a good operation of a water supply you need some kind of an administr.
Administration does not mean some notes on a sheet of paper but it has to surveye all parts of the drinking water supply.

The fore-going pleads for training programmes in maintenance, repair, administration and finance for the local people. The training programmes

76 "Evaluation of Effectiveness of Community Water Supply in North-East
Thailand" - FRankel, R.J.

143 "A Non-Conventional Mass Approach to Rural Village Water Projects'
Morfitt, R.P.
254 "General Community Water Supply Problems" - World Health Organization
261 "Techniques for the Collection and Reporting of Data on Community Water
Supply." - World Health ORganization
264 "Community Water Supply" - World Health Organization,
5 "Municipal Water Supplies in East Pakistan" - Arbuthnot, J.
42 "Water Supply and Sewerage Programs in Latin America and Carribbean
Countries" - CEPIS
56 "Domestic Rural Water Supplies, An Expost Evaluation of Eight Selected
Schemes" - Cronin, A.J.
110 "New Ideas for Evaluating Public Water Supplies" - Kabler, P.W.
141 "Project Evaluation in Developing Countries" - Morell, D.L. and Frankel,
209 "Thailands Rural Community Water Supply Program" - Unakul, S.
201 "Hygienic and Technical Guidelines for Water Supply and Waste Water
269 Systems in Buildings" - Taylor, F.B.
269 "Guide for the Development of Local Water Projects" - Zimmerman, S. and
Cobb, E.L.
260 "Recommendations on Administration and Organizational Structure for
Water Supply Development" - World Health Organization
159 "Community Water Supply and Sewage Disposal Programs in Latin America an
Caribbean Countries" - Pan American Health Organization
190 "Village Water Supply and Sanitation in Less Developed Countries" -
Saunders, R.J. and Warford, J.J.
142 "America Latine: La Planification Hidralica Y Los Planificadores" -
Morera, A.L.
225 "Water Supply for Rural Areas and Small Communities" - Wagner, E.G.
and Lanoix, J.N.
41 "Survey of Water Treatment Plants" - C.P.H.E.R.I.
75 "Evaluation of Low cost Water Filters in rural Communities of the
Lower Makong Basin" - Frankel, R.J.,
155 "Manual de Operacion y Mantenimiento de Instalaciones y Equipos en
Un Acueducto" - Org. Panamer. de la Salud
251 "National Rural Water Supply Programmes" - Wood. W.E.
240 "Provision of Safe Water Supplies to Rural Communities in South East
Asia" - W.H.O. Regional Committee for South-East Asia

241-249 "Reports on rural water supply of Bangladesh; Burma; India; Indonesia; Maldives; Mongolia; Nepal; Sri Lanka; Thailand" - W.H.O. Regional Committe for South-East Asia

78 "A system approach to assessment of rural water supply program effectiven - Frankel, R.J.

72 "Water supply for low-income communities in developing countries" - Feachem, R.G.

98 "Urban water supply and sewerage procing policy" - I.B.R.D.

99 "Lahore Water Supply - Tariff Study" - I.B.R.D.

100 "The WHO/IBRD Cooperative program on water supply and wastes" - I.B.R.D.

250 "A report on the condition of UNICEF - assisted demonstration rural water supplies in Kenya" - Wignot, R.E.

235 "Fifth Annual Report" - W.H.O. International Reference Centre

259 "International conference on Research and Development in Community Water Supply" - W.H.O.

68 "Water and waste water engineering" - Fair, G.M.; Geijer, J.C. and Okun,

1 "Thailand rural water supplies" - Adams, W.E.

E. CONCLUSIONS

We started a survey on data regarding community water supplies in developing countries, especially concentrated on treatment processes. The intention was to find out which processes have been accepted in those countries, and what the experiences are in applying these processes in different areas and whether it is possible to make some general conclusion out of these data. Unfortunately we have to admit that we did not reach these targets very closely.

The first reason is, the relatively small number of treatment processes used in developing countries. When people care about a community water supply they consider treatment as a second stage in development.
They first try to find a reliable water source. In some development programmes for drinking water supplies this policy had to be followed, for economic reasons. Of course we do not mean water supplies in big cities. In big cities the plants are mostly very complicated just as in western countries. But we must realize that these plants, supply a very small part of the population in the developing countries with drinking water.

The second reason is the shortage of proper evaluations of existing plants. Of course there are many assesment reports on countries, regions, etc. but these reports are mainly limitted to general remarks on percentages of people supplied with reliable water, percentages of standpipes or house-connections, number of drilled tubewells, department responsible for developing programmes, financial restrictions etc.

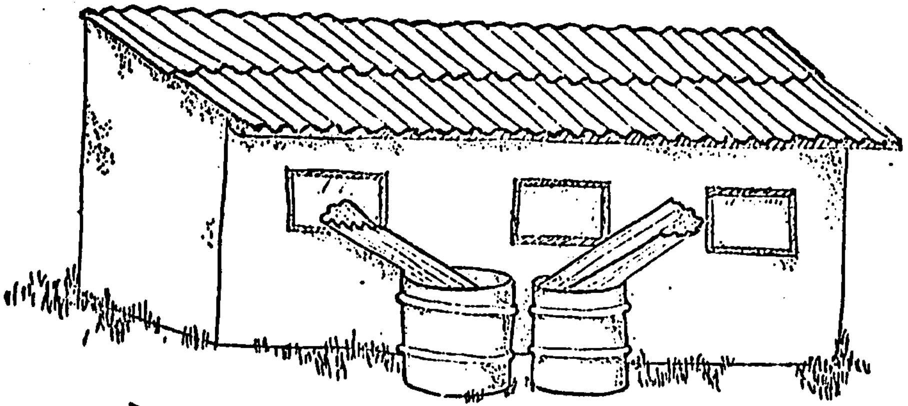
Seldom we found reports giving a technical evaluation of existing plants or current programmes, or giving information on the technical performance of plants, or parts of it, causes and duration of breakdowns, relation between final and former breakdowns, possibilities of repair etc.
There are indeed some of these reports but these do not consider the situation and position of the designer neither the situation under, and the materials with which the plant must be built. This kind of data seems necessary to us for a more fundamental approach of the drinking water problem of the developing countries. At the moment for most of the designs of community water supplies in developing countries, we must rely on the individual judgement of a few insiders, like staffmembers, and consultants of the WHO and the World Bank, on the enthusiam of the

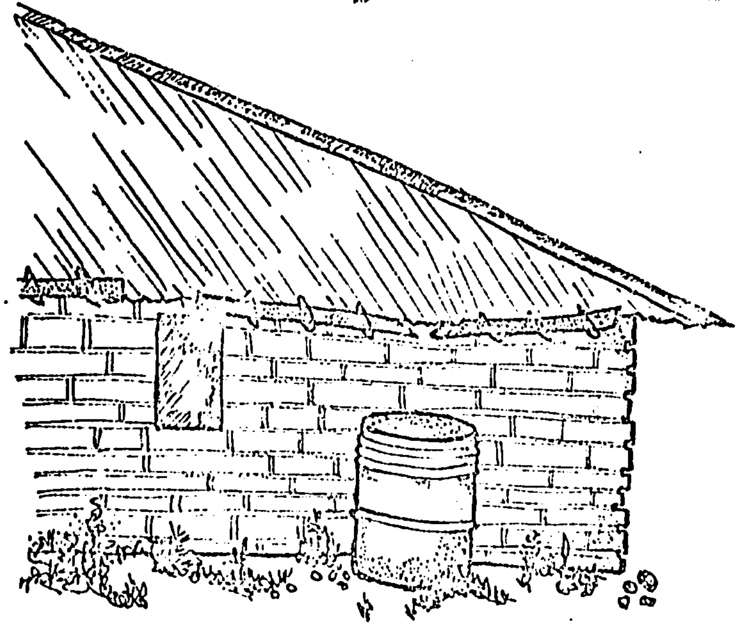
army of volunteer workers or on the conscience of commercial undertakings. For many of these developing projects it is common practice that the planning and construction takes place under supervision of the WHO. After the project has finished further responsibility is being carried over to the local authorities and that is where the intervention of outside project managers etc. ends. It seldom happens that these people obtain some information on their former projects later on. So they are not able to learn from their own and other people's mistakes, but nevertheless these people have to work on and put their stamp on future projects. Although these people bring in each great experience, they have all the same limitations and that is their more or less western education and in consequence their western approach of these problems. Wedo realize that this problem cannot be solved easily; that is a reason to plead for more proper evaluation. The problem however, is the financing of these evaluations. It is hard enough to get first priority for the building of a water supply project. Later on it even will be impossible to get first priority for the same project, because evaluation projects seem to have only scientific value do not contribute directly to, in this case, more water. Nevertheless we have to realize that there was and still is being spent on drinking water supplies many millions of dollars, but we hardly can say that there is any progress in the percentage of the World population provided with hygienic reliable water. Will we succeed in providing nearly everyone with reliable water then the greatest possible useful effect of all our efforts is necessary.

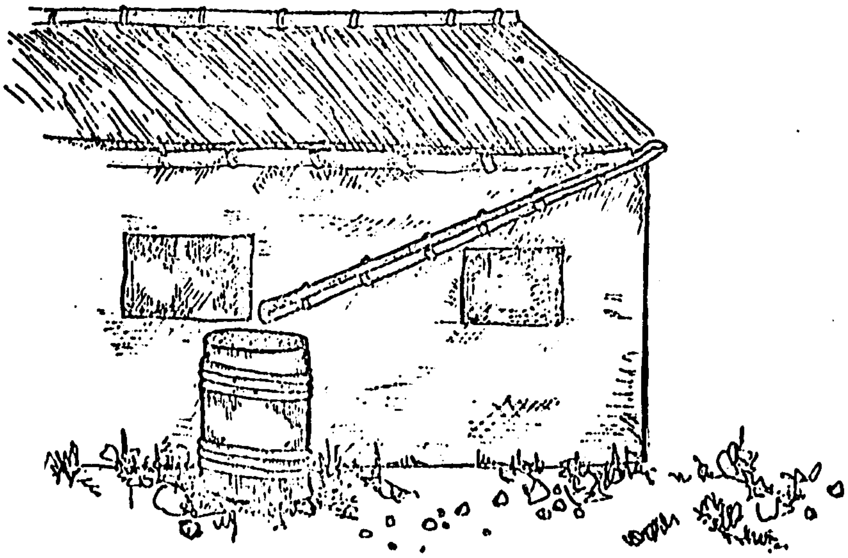
F. ANNEXES

ANNEX 1

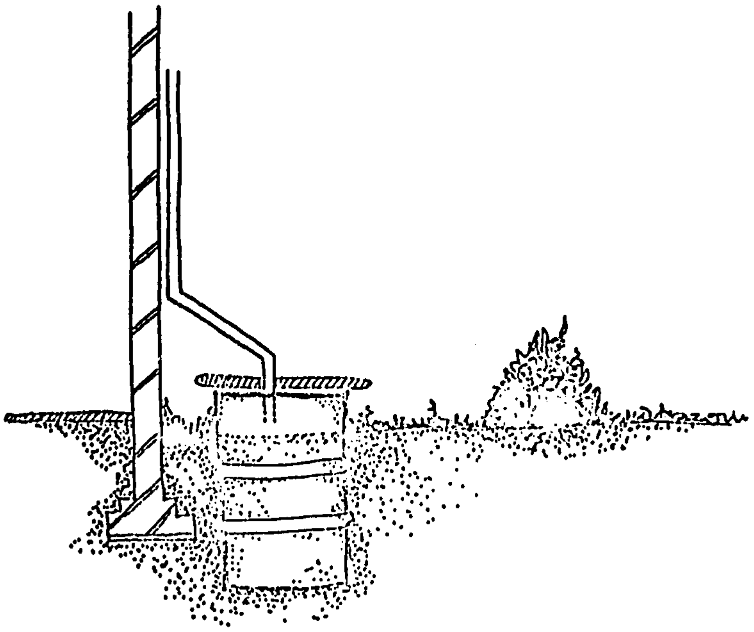
Roof Catchment
Some practical solutions of different complexity

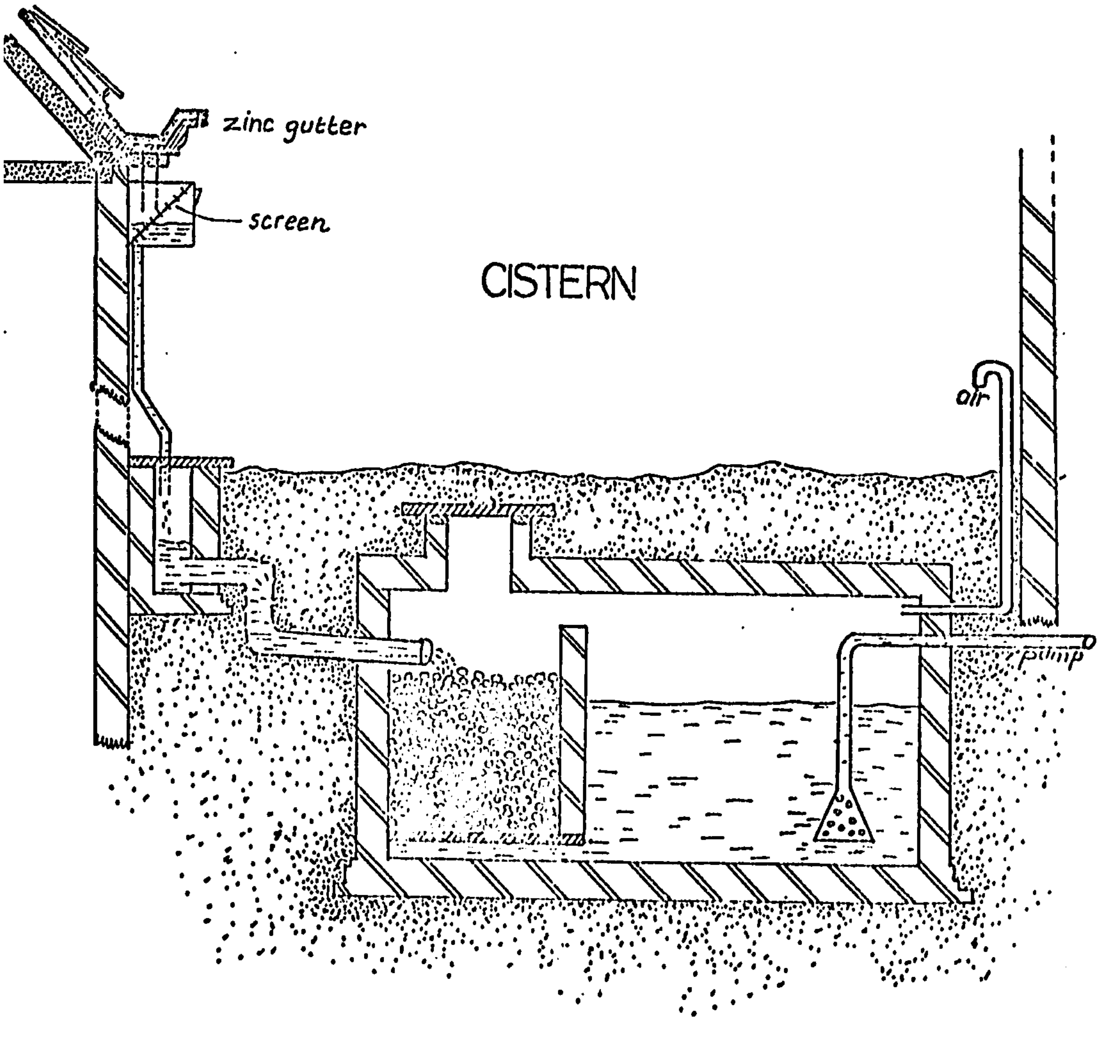






ANNEX 1 (cont.)





ANNEX 2

Ground catchment

When the roofcatchment gives too little water to tide over long dry periods, then ground catchment would be the most appropriate way of acquiring rainwater.

Ground catchment can be improved by increasing the percentage of the rainfall as runoff and/or reducing the seepage.

- a method, though not new, is the land alteration. This means simply clearing the slopes of a hill, of rocks and vegetation, sometimes compacting the soil surface and making ditches or rock walls along hillside contours. When the erosion is not too excessive, this can be a very economical solution
- Another method is soil treatment. This can be the use of chemicals which fill the pores or make the soil hydrofobic, but it can also be ground stabilization with lime. This is an old technic now scientifically approached, whereby lime is added to the soil, after which treatment the soil is compacted.
- a third method is soil covering. The soil is covered with waterproof membranes or asfalt layers. Sometimes the membranes must, in their turn, be covered by gravel, to protect them against damage by radiati wind or cattle.

Often the storage tanks are covered or filled with rock or sands to reduce evaporation.

In the region El Obeid in the Sudan subsurface water storage tanks are developed. In this region only two local construction materials are available, namely sand and wood. For that reason the cap-mix sausage, ma of 0.015 mm polythene sheeting filled up with local sand mixed with a small quantity of cement, is developed and used in the constructions (a and b). In Jamaica stones are used for approximately the same constructions of water storage tanks.

Figure a.

The smallest design of sub-surface water storage, constructed in El Obe Sudan, the "bottle" tank. It can supply a family with drinking water for the eight dry months.

Figure b.

is a multiple interconnected beehive tank consisting of a series of domes surmounted by a sand filter through which incoming water has to percolate. There is a small exit filter around the well-shaft. This construction is applied in Manchester Jamaica and in El Obeid Sudan.

Information:

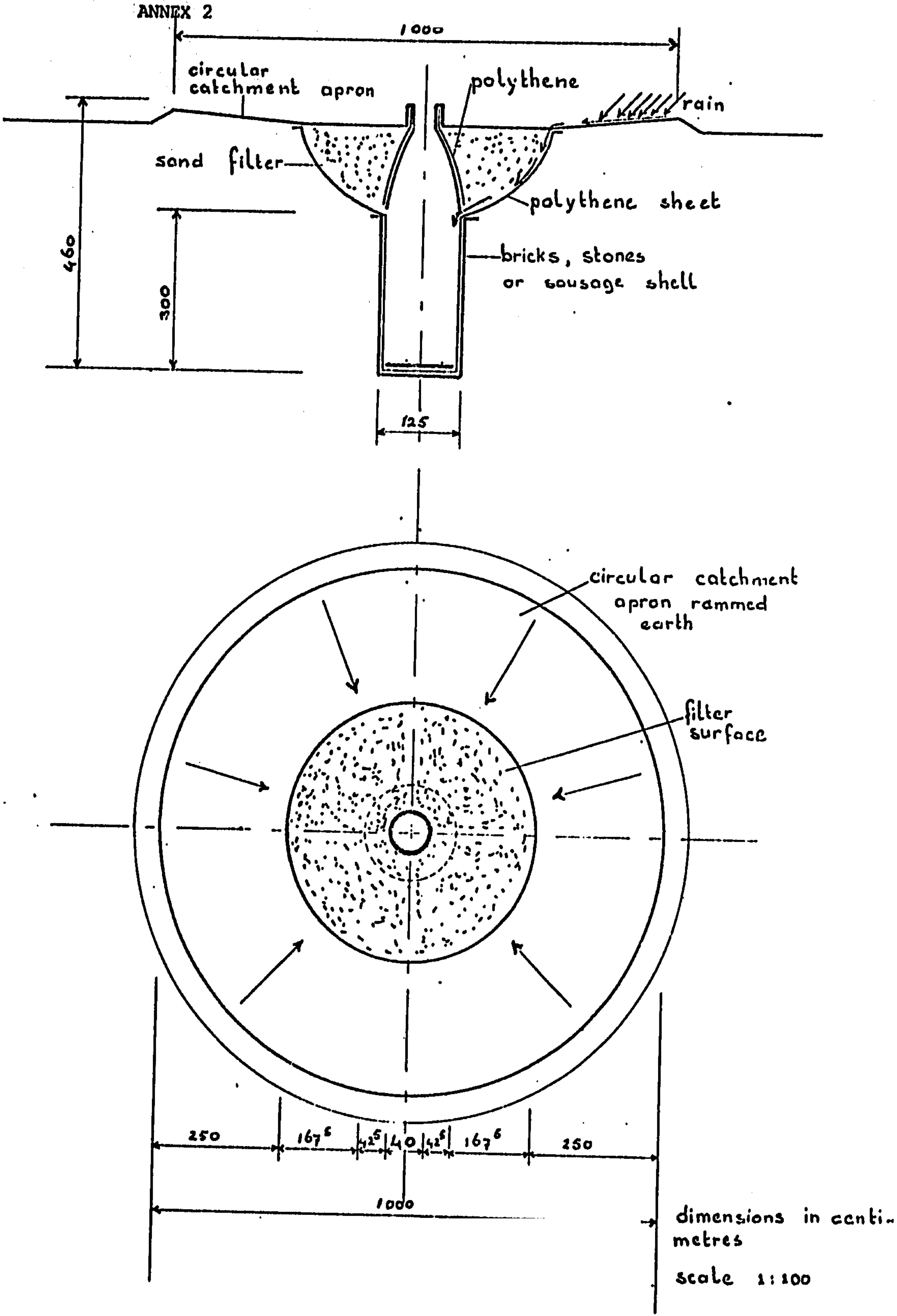
1. A clear discription of the circumstances and the constructions of El Obeid is given by Ionides in Engineering 27 Oct. 1967, page 662-666
2. Report on Rain water catchment Jamaica, Nov. 1972, edited by Overseas Development Administration, Foreign and Commonwealth office.

Figure c.

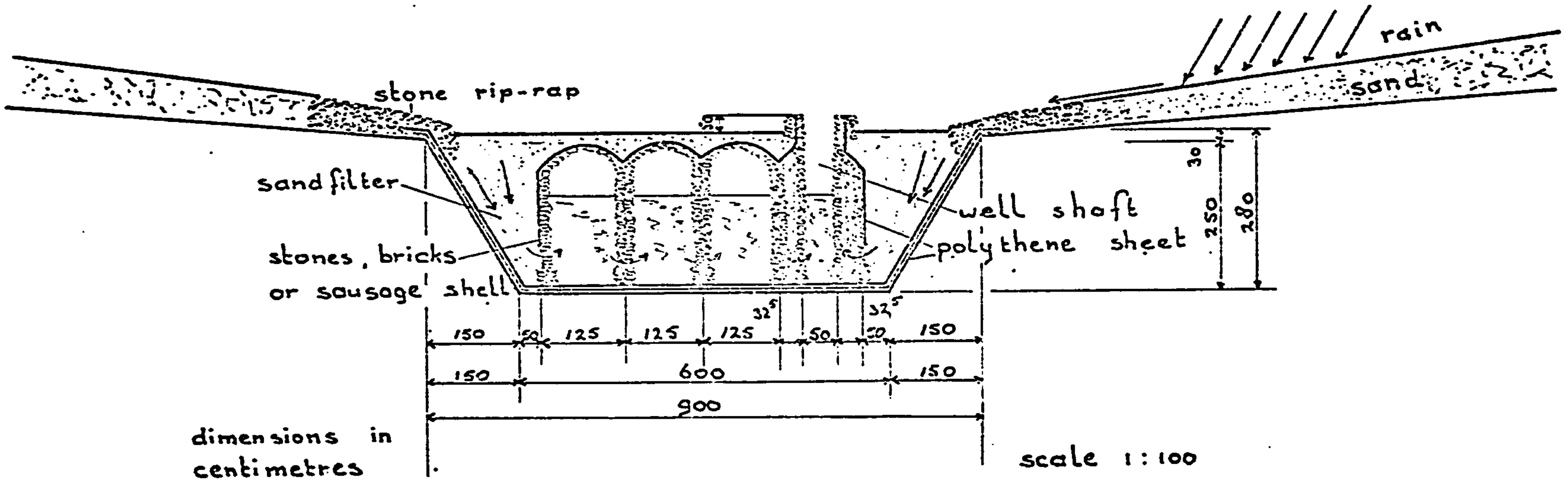
Western Australia rain water harvesting system. Catchments are graded and rolled and shed water with a minimum rainfall of 7.6 mm. They cost $30.-/$40.- per acre (1968). They are designed in such a manner that with only 5 cm of runoff, 1.6 ha of catchment will provide 800 cubic m. of water. Catchments are cambered so that rainfall runoff quickly goes to the side of the "road", where a ditch conveys it to the main-collector drain and there through a silt trap to the storage tank.

If too much water is lost through evaporation, one should consider constructing a cover for the storage tank. (Taken from Department of Agriculture of western Australia).

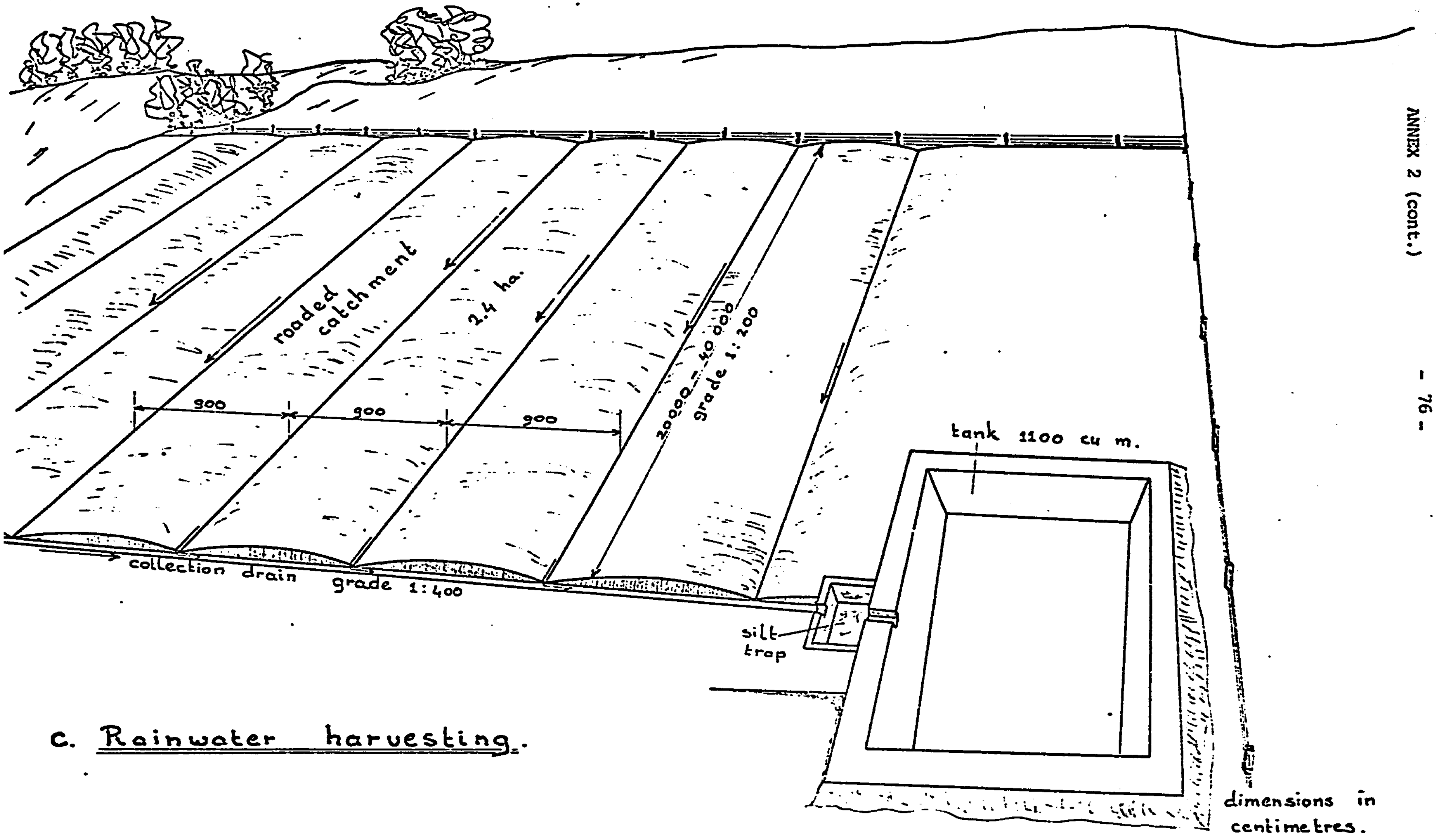
ANNEX 2



a. Individual system of sub-surface water storage, the "Bottle tank".



b. Storage tank for communities.



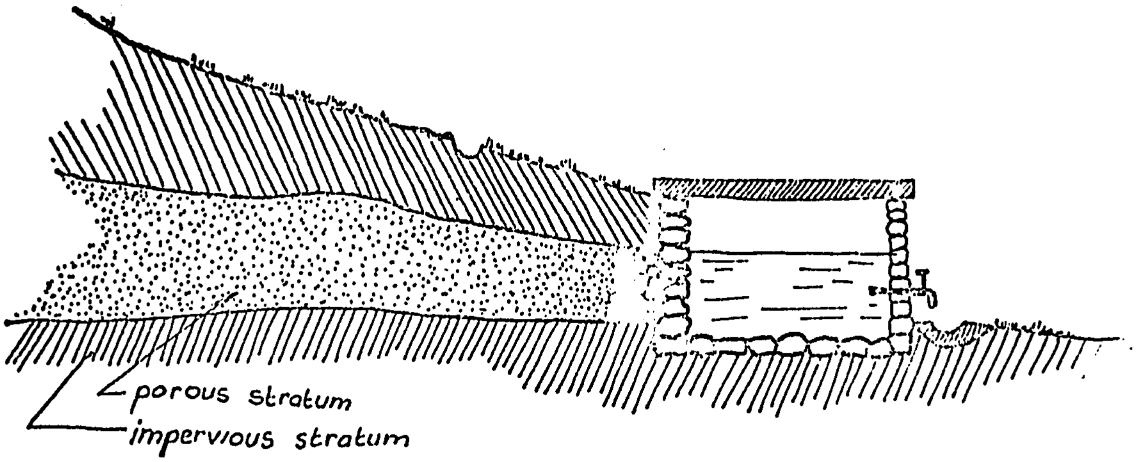
c. Rainwater harvesting.

ANNEX 3.

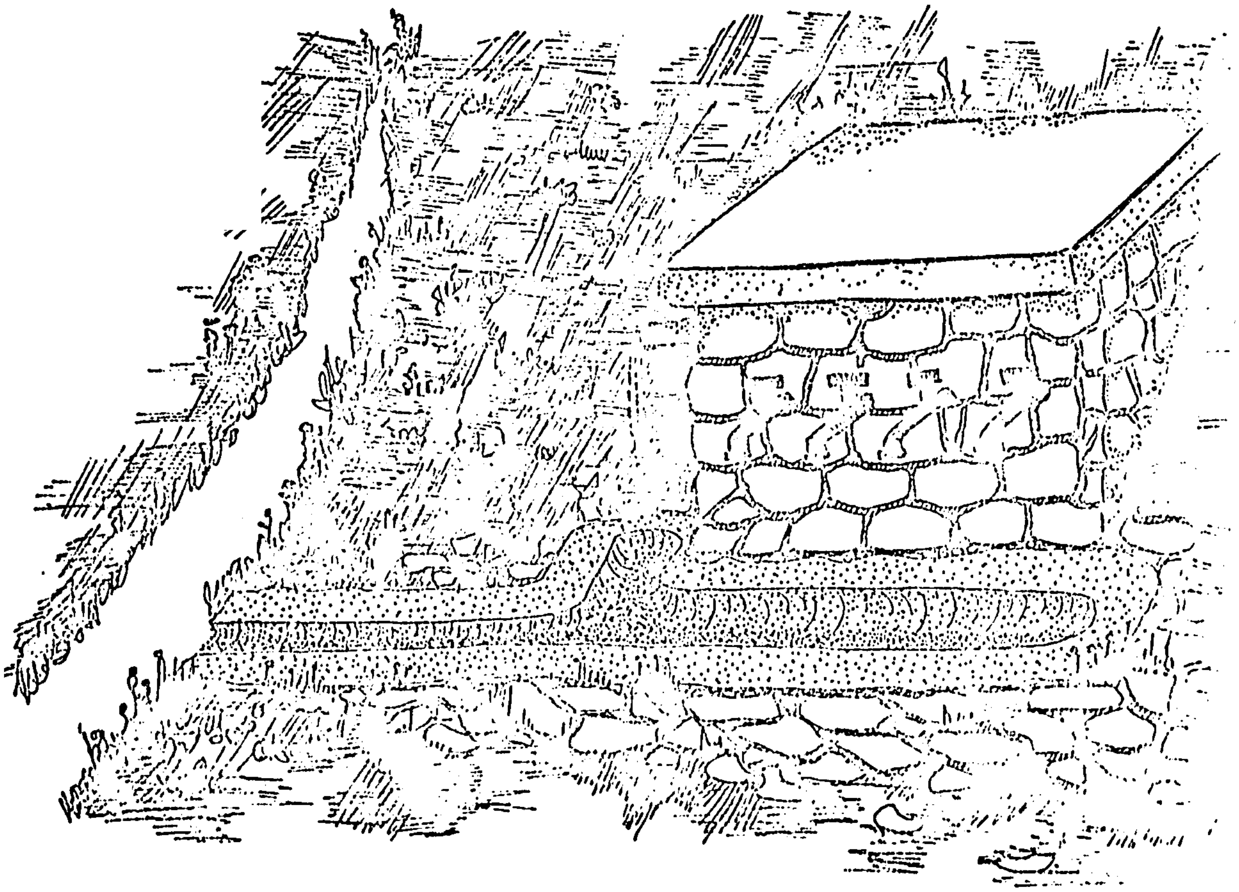
Recovery of Springwater

The access to springs is often difficult and, as a rule, they do not provide easy means for large numbers of people to fill buckets, etc. in a short time. Consequently "Spring improvements often have to be carried out, in order to make the water more easy to obtain.
This is done by enclosing the spring with a concrete or masonry structure to protect the water from pollution, mud, etc. From this the water is sometimes piped to a balancing tank having a capacity of some 20.000 to 45.000 liters, located at the side of a road or at another convenient point.
Connected to this tank is a range of four or five taps from which buckets and other receptacles can be quickly filled.
A concrete platform and adequate drains are provided to keep the filling area dry and free from mud. By this means, more water than the spring actually discharges can be drawn off during the mornings and evenings, owing to the storage capacity of the tank. Sometimes concrete cubicles were attached to the tank to provide separate washing places for men and women.

ANNEX 3. (cont.)

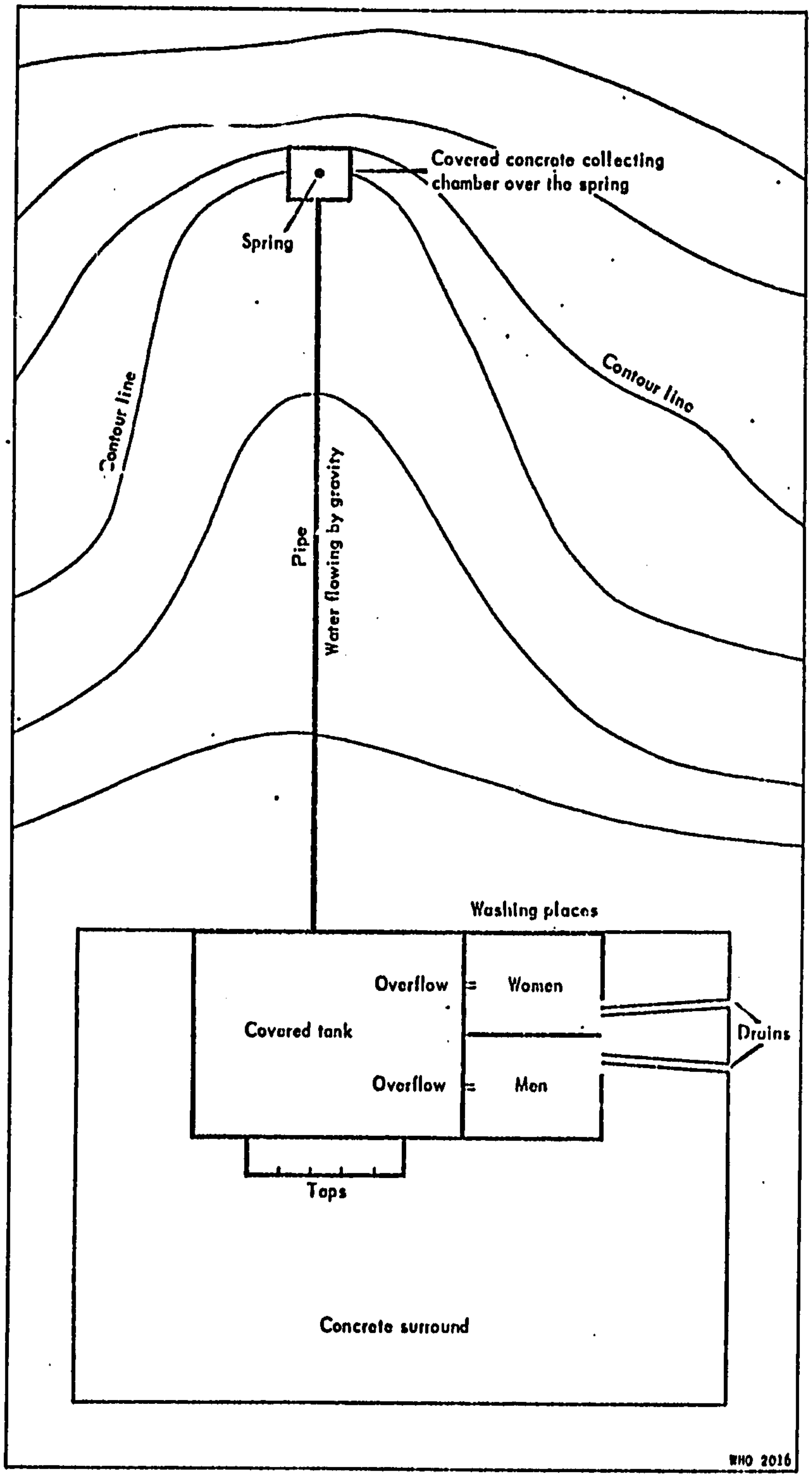


Balancing tank



ANNEX 3. (cont.)

DIAGRAM OF A SIMPLE SPRING IMPROVEMENT

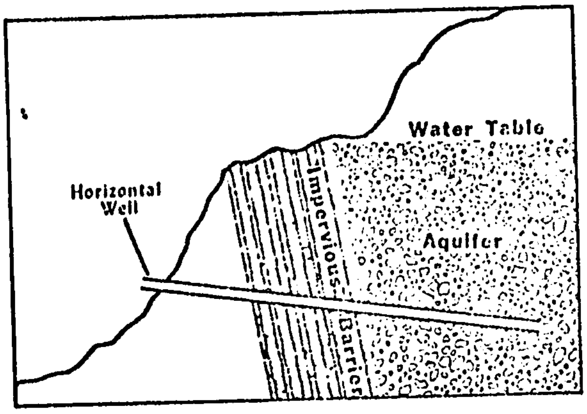


ANNEX 3. (cont.)

Horizontal wells

A horizontal well is a "cased" spring. A horizontal boring is used to drill a hole and install a steel pipe casing into a mountain or hill side so as to tap a trapped water supply.

Good sites for horizontal wells are dike formations, impervious geologically tilted clay, or rock walls that form a natural dam. (W. T. Welchert)



Horizontal Wells

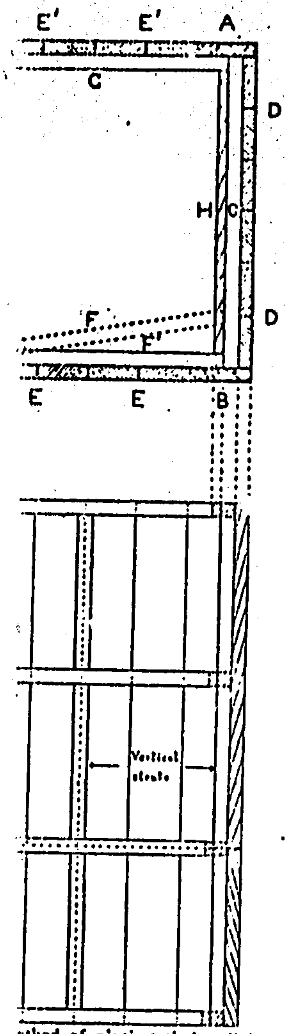
ANNEX 4.

Construction of dug wells

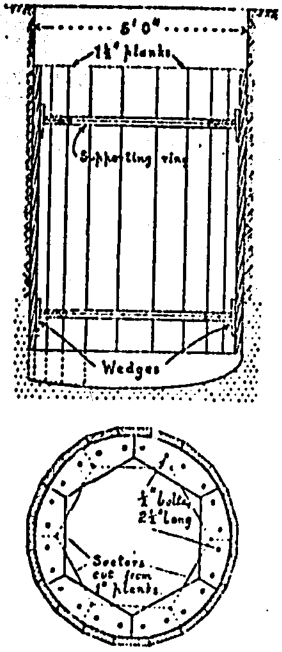
The digging of wells can mostly be done with locally available equipment and a minimum of supervision.

Due to the space necessary for a man to work in, the well must have a minimum diameter of about 1 m. 1,3m is a convenient standard size, leaving room for two men, which has proven to be more efficient. Most wells constructed now are circular in plan because of the strength. There are many materials suitable for linings; masonry, brick work, steel and timber all being used in various parts of the world, according to circumstances; but for wide spread use, there are very great advantages in utilizing plain or reinforced concrete.

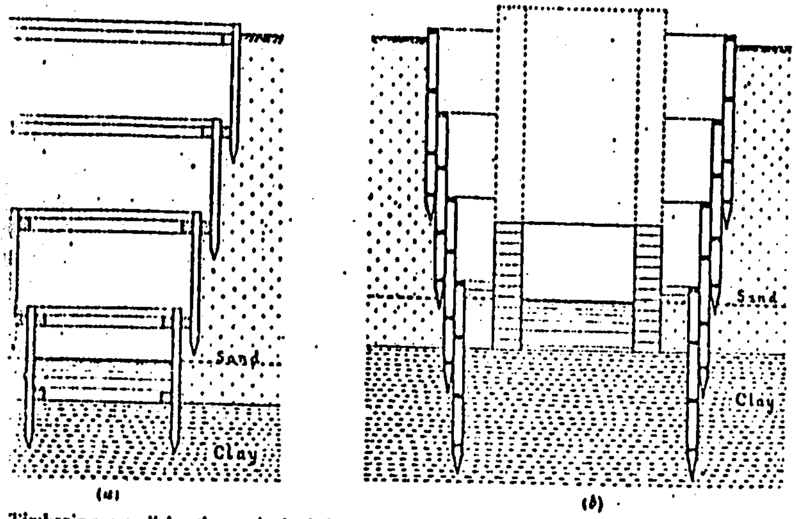
Timber lining rots and requires frequent renewal, particularly above the water line. It can be rendered more resistant to decay by means of a waterproof coating or another suitable preservative.



ethod of placing timber lining in a well.



—A method of timbering shallow wells in loose ground. (R. Whiteley.)



(a)

(b)

Timbering a well by the method of sheet piling. Where necessary brick sides can be built up within the timber lining.

ANNEX 5.

Surface water intakes

Figure a. A very simple form of raw water intake. It can only be used when there is no chance of clogging.

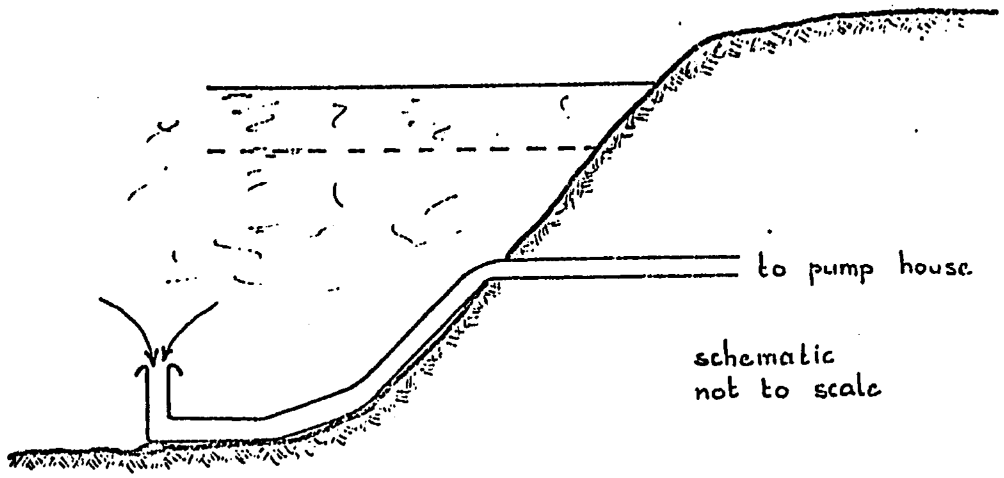
Figure b. Protected river intake, a vertically bent pipe within a stone caisson close to the shore. The caisson protects the intake against flowing water, floating wood, shipping, etc. The stone caisson should be above the highest water level. With such a design it is easy to reach the intake grid for control and cleaning.

Figure c. A pond or lake intake. This floating system has the advantage that it avoids intake of floating dirt and mud off the bottom. The flexible joint of rubber or plastic can be a difficulty and has to be renewed from time to time.

Figure d. The intake acts as a roughing filter by the sand bed.

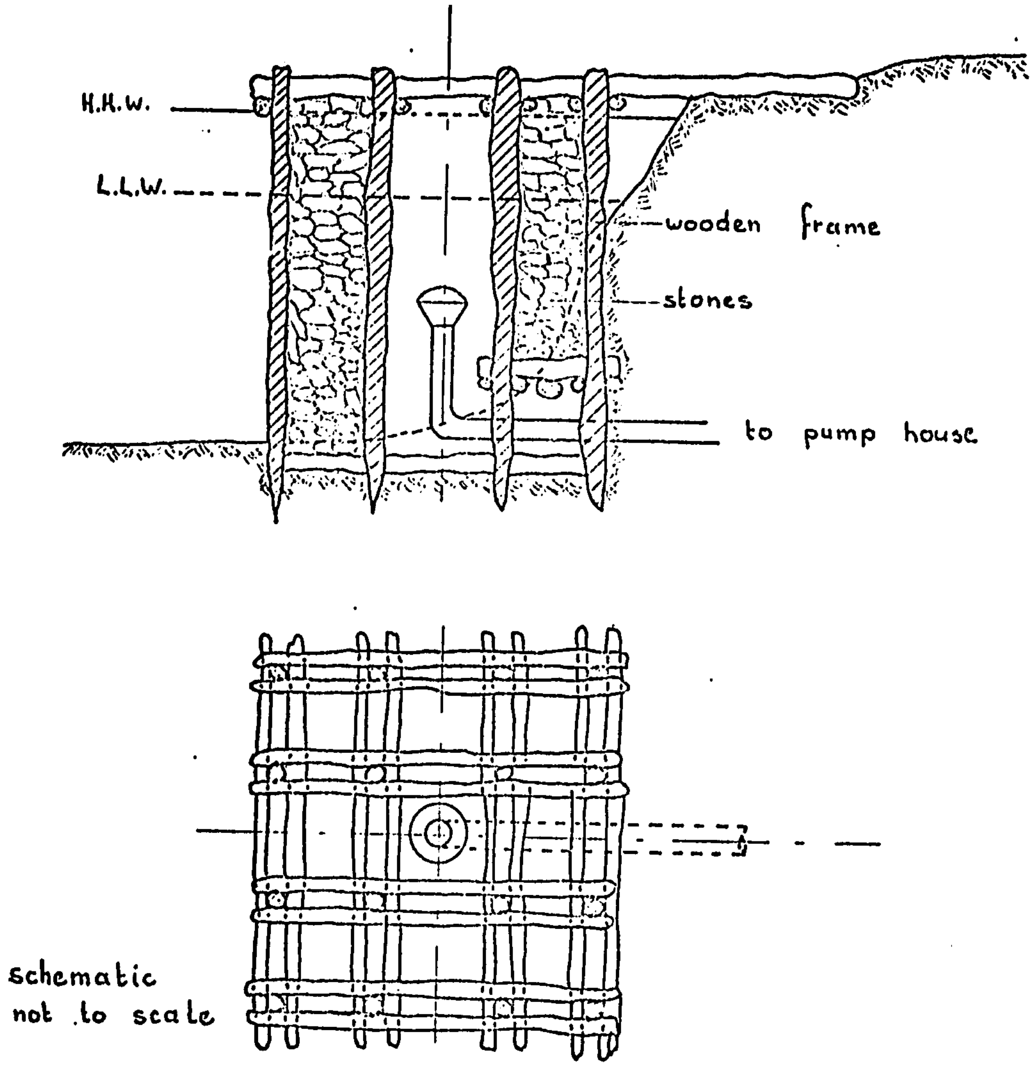
Information: "The village tank as source of drinking water"
WHO/CWS/RD/69.1

ANNEX 5. (cont.)

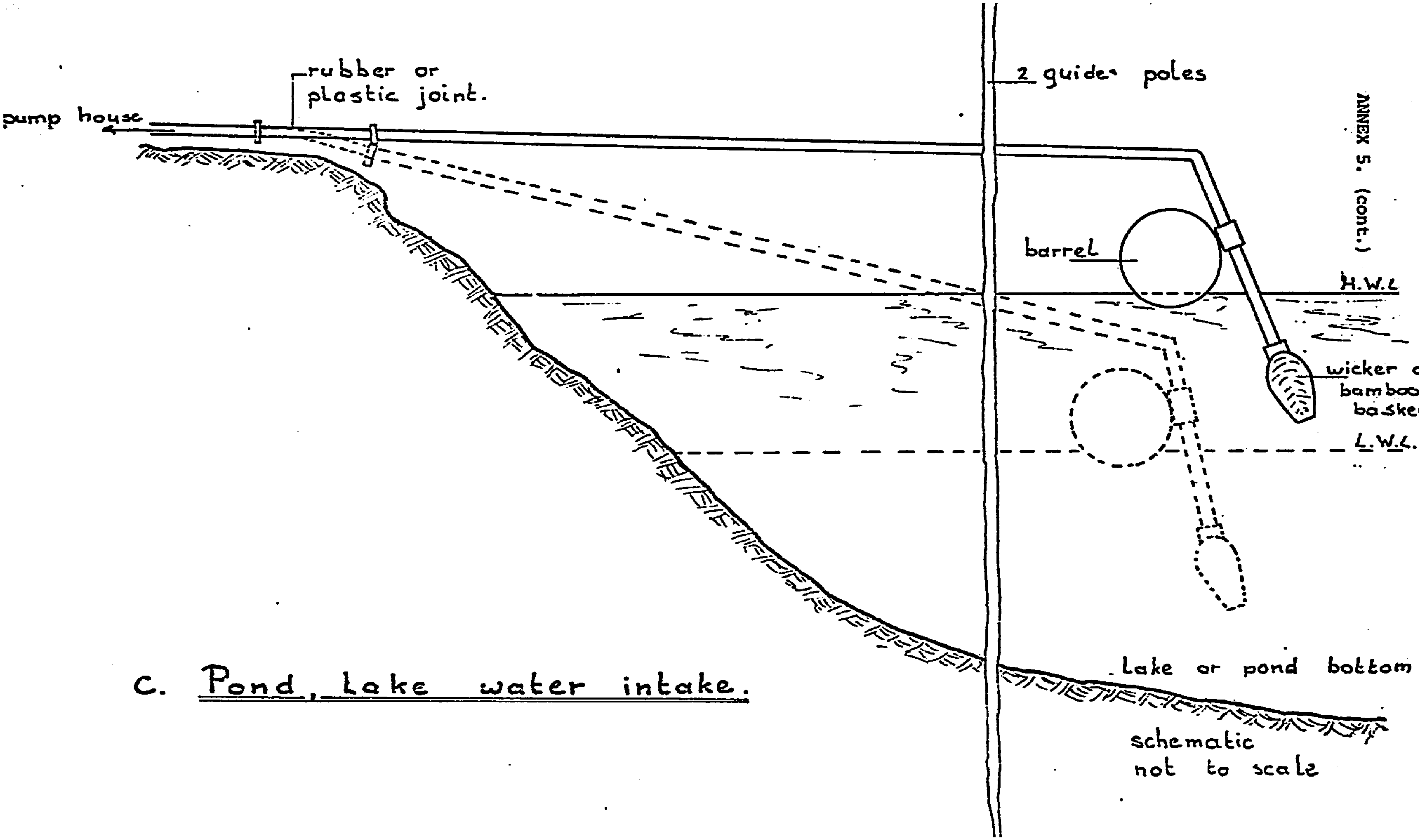


a. Simple intake

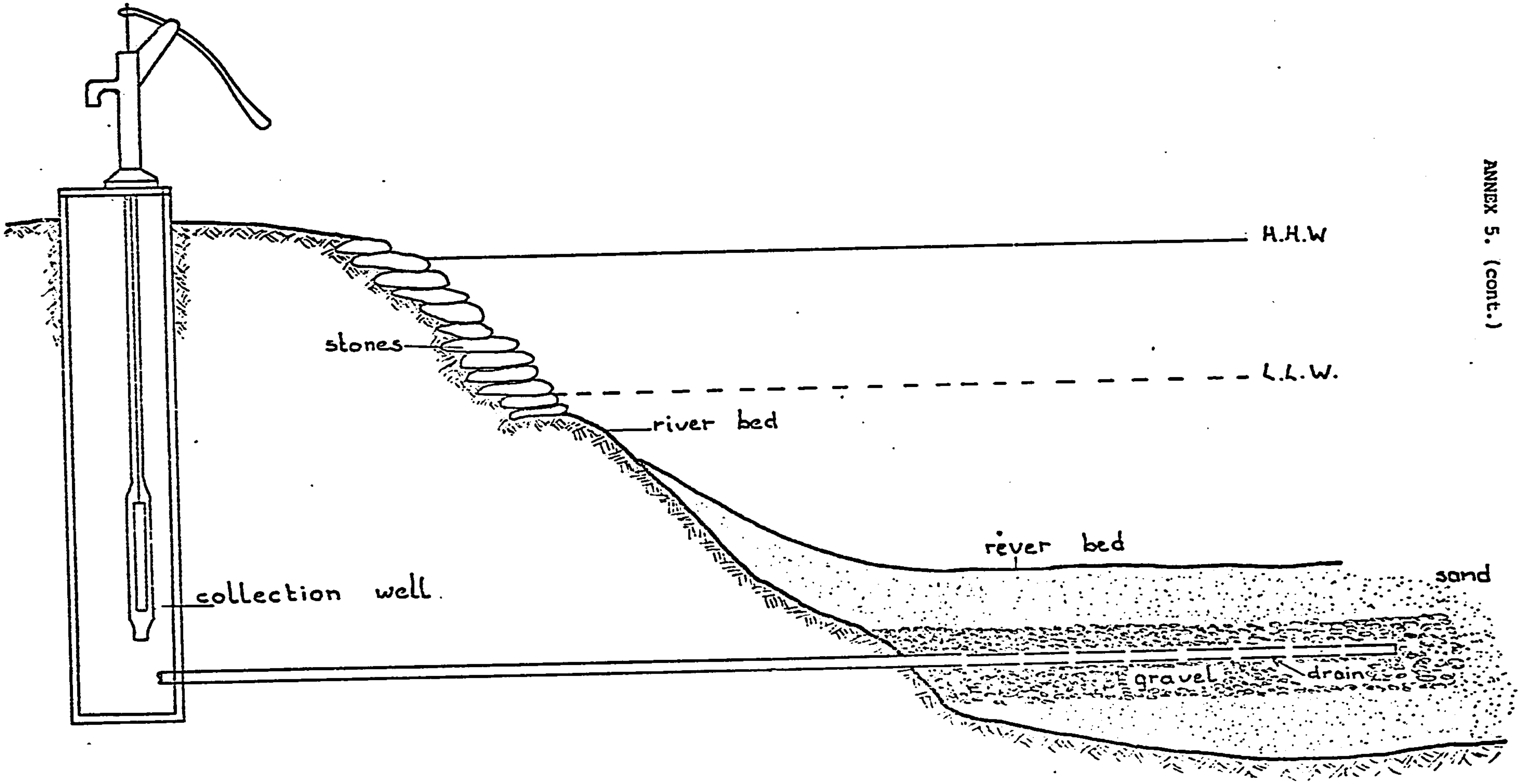
ANNEX 5. (cont.)



b. Protected intake



C. Pond, Lake water intake.



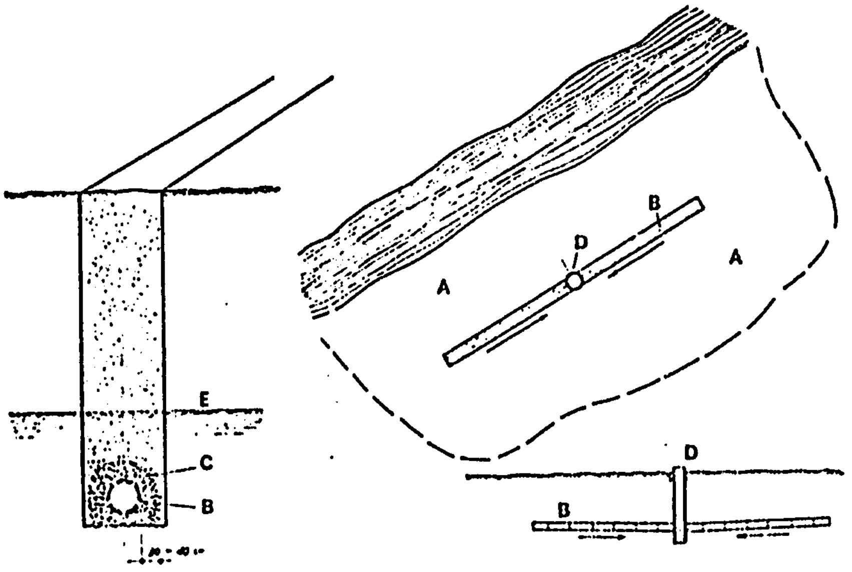
schematic
not to scale

d. Surface water intake

ANNEX 6.

Induced recharge

INFILTRATION GALLERY BESIDE STREAM



A = Sand banks beside streams offer excellent opportunities for infiltration galleries or shallow dug wells.
B = Perforated pipe should be laid on a prepared filter bed and more filter bed should be constructed over it.
C = Round, 12- to 25- mm (1/2- to 1- in.) stones should be laid around the pipe, and the filter should be built out away from the pipe with graded sand and gravel. Filter should be 30-40 cm (12-16 in.) in thickness from pipe to extreme edge.
D = Well in middle of gallery for mounting pump and collecting water
E = Water table

Wagner and Lanoix.

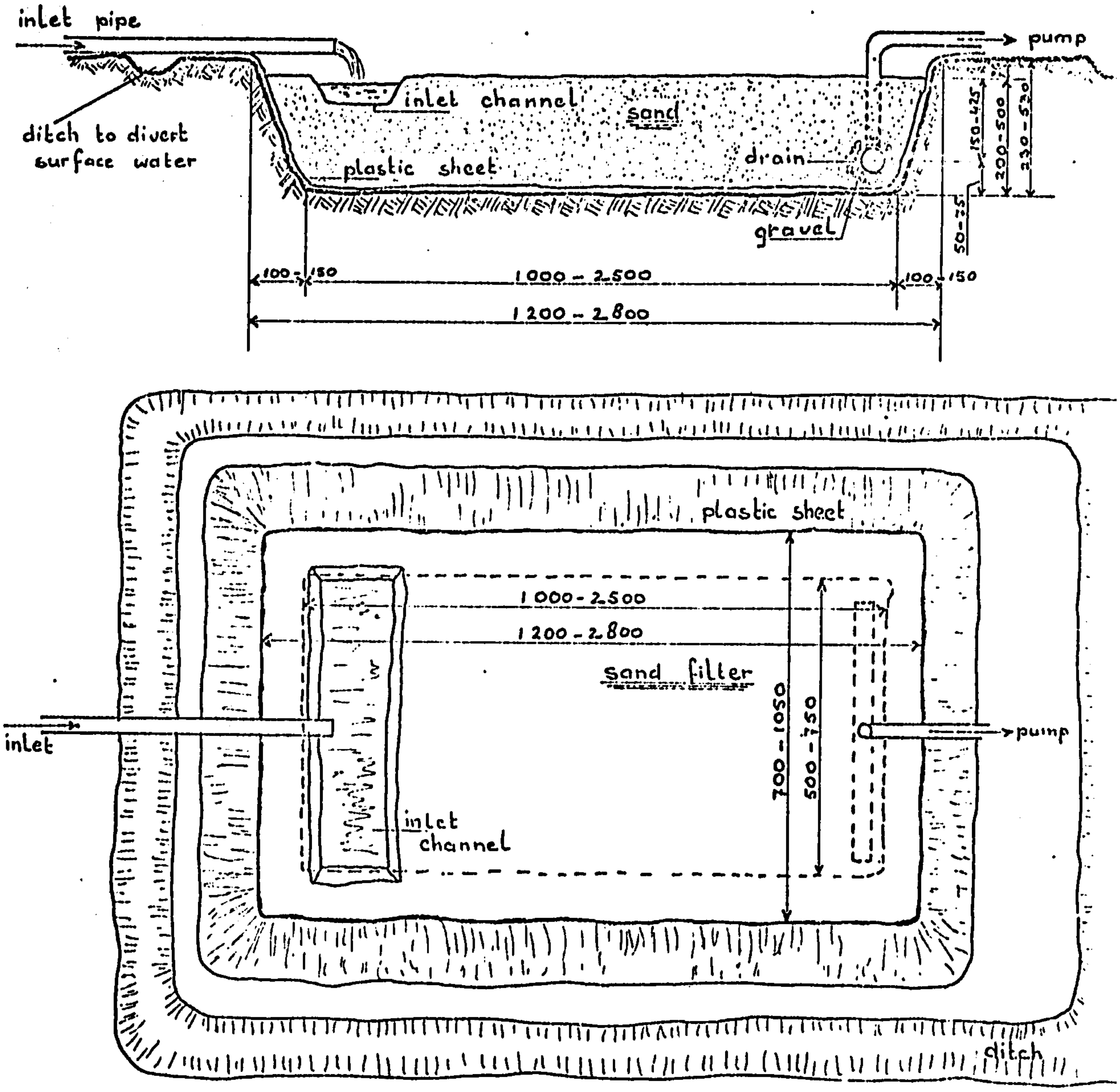
ANNEX 7.

Artificial Recharge

In the cases where induced recharge is impossible due to the clogging of the river bed or the absense of sandy ground near the river, artificial recharge can be a good solution. This method of recharge uses the natural filtering properties of sand.The biological activity is very important in this process and requires time. For that reason the retention period of the water has to be at least a few days, so do not construct the unit too small. The example designed in the following figure is a bed cut into the ground,lined with polythene sheet to provide a water seal and filled with suitable clean sand (1,85 to 0,25 mm) The polythene sheet is not a necessity when, for example, there is a good, almost water tight earth clay then you can use that, see also annex 2.

Information: Water treatment and Sanitation, simple methods for rural areas. By H.T. Mann, D. Williamson

ANNEX 7. (cont.)



dimensions in centimetres.

Artificial recharge.

ANNEX 8.

Coagulating and flocculating chemicals

Alum sulfate.

Even in those countries where no bauxite is available, it is possible to produce alum sulfate locally by simple methods. To obtain suitable alum, you must use simple clay or (kaolin). as raw material.

Dosing of the alum sulfate happens by means of a wooden tower about 4 m. high, filled with alum stones, with a water shower on top.

Rauwag

In Sudan, a clay soil named rauwag has proven to give good results for the flocculation of water heavily loaded with solid matters.

A study on the use of different plant material for the same purpose is being made there. (Jahn S.A.A. University of Kathtoum, Sudan)

Red Sorrela

Seeds of red sorrela: a natural coagulant.

K.R. Bulusu and B.N. Pathak report in the Indian Journal of Environmenta Health, 1974, 16, pg. 63-67 on the excellent coagulating properties of the seeds of the Red Sorrela plant (Hibiscus Sabdariffa) when applied to turbid water. The plant is widely cultivated in India and the green seed pod is thrown away or used as cattle food. The dried seeds when pulverised and mixed with sodium carbonate (9:1) can be stored without deterioration Dispersed in water and heated, it gives a milky suspensi which can be used as a coagulant.

Experiments at high and low turbidities (7600, 3500, 315 and 86 units measured with the Hack turbidimeter) showed good removal of turbidity with lower dosages than those required for alum. Coagulation finally was not affected by the presence of phosphates.

(Newsletter)

Natural coagulant aids

Some natural organic products like starch, gelatin and alginates can be used as coagulant aids.

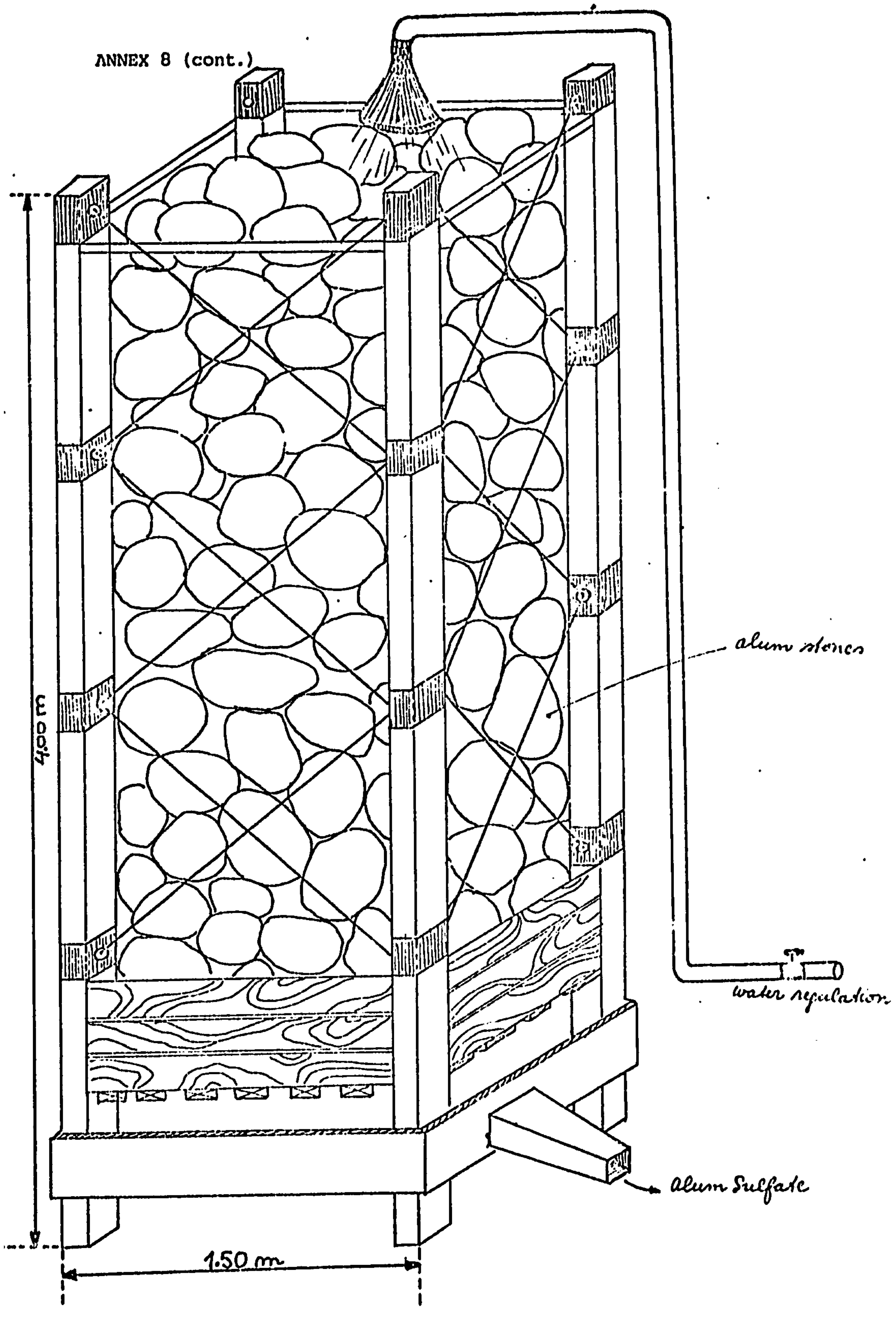
In Western Europe, for example, an extract of potato flour is used for this purpose.

In Peru CEPIS has initiated a study of natural coagulant alginate

1. Name: Device for dosing alum sulfate for water plant of any size.
2. Country: Used already for many years in Chile
3. Description: Wood's tower of about 4m height, with a water shower on top
4. Way for use: We fill the tower with alum's stones, we open the shower, after a few minutes we obtain a saturated solution of alum sulfate on the bottom. We calibrate the dose by simply regulating the amount of water of the shower.
5. Place to be used: In countries where we can obtain local products of alum sulfate manufactured by rudimentary and simple methods. This is possible in most countries if we take in account that suitable alum can be obtained using as raw material, simple clay or kaolin instead of bauxite.
6. Advantages:
   a. This tower can be filled with any size or qualities of stones of alum sulfate
   b. Simple wooden construction without mechanical devices
   c. Avoids importation of alum or even bauxite by the use of local clays
   d. No operational problems

contributed by B. Rosenfeld

ANNEX 8 (cont.)



ALUM DOSING TOWER

ANNEX 9

Dosing Chemicals

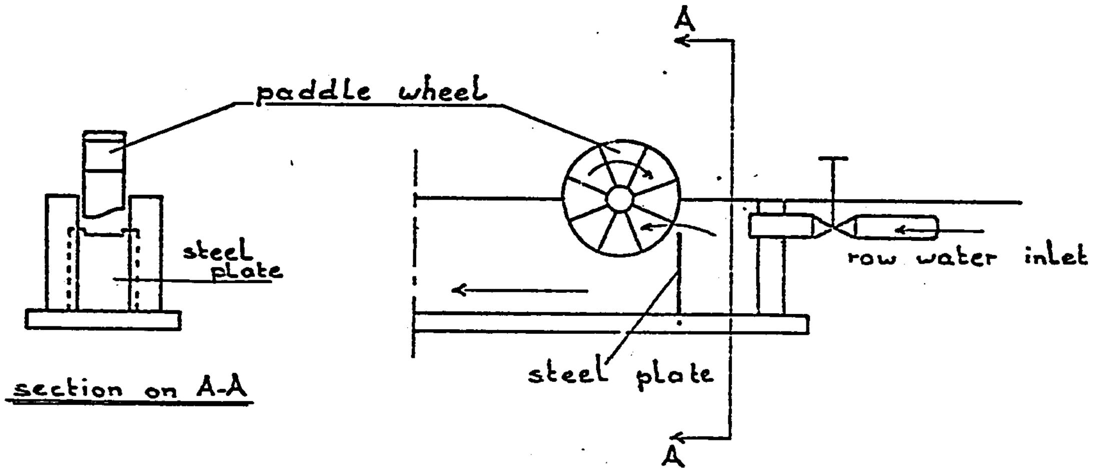
Small water purification plants, where the raw water flow rate varies, nearly always present problems of feeding the chemicals proportionally to the rate of flow.

Figure a. shows schematically an ingenious device, developed in Swaziland. The flow in the influent channel drives a paddle wheel at a speed proportional to the flow rate. On each side of the raw-water influent channel there is a solution tank holding chemical solutions. Upstream of the paddle wheel, a water level higher than the downstream flow level is maintained by damming the channel with a steel weir plate. The flow over the weir falls on the paddles and drives the wheel. The paddle wheel drives a horizontal shaft above the wheel by means of an endless chain belt. This shaft is supported by two bearings outside the tank walls and passes through holes in the walls to the inside of each tank. Bolted to each end of the shaft is an arm with a chemical dosing cup welded to the free end. As the shaft rotates, the cup sweeps through the chemical solution in the tank and empties a fixed volume of the solution to a funnel appropriately located above the shaft. The bottom of the funnel is connected to a plastic hose which discharges the dose to the channel.

Information: "Water supply and sanitation in Developing Countries"
by G.R. Marais and F.E. McJunckin, Aid/Unc/IPSED, Series
item no. 5, University of North Carolina.

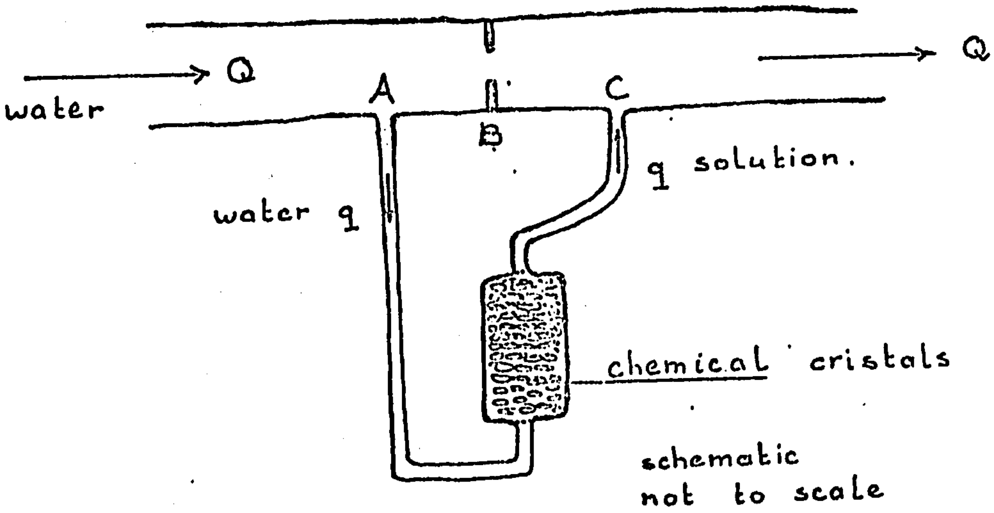
Figure b.

Declining the cross-secting of the pipe causes a difference of head in the pipe left and right of point B. The difference of head is proportional to the rate of flow and so to the quantity Q. This head loss over B. causes a stream, quantity q, from A to C. Passing the chemical cristals, a saturated solution comes into existence, this quantity q is proportional to Q. So this system gives a dose of chemicals proportional to the water quantity Q.



Schematic
not to scale

a. Proportional chemical feeder.

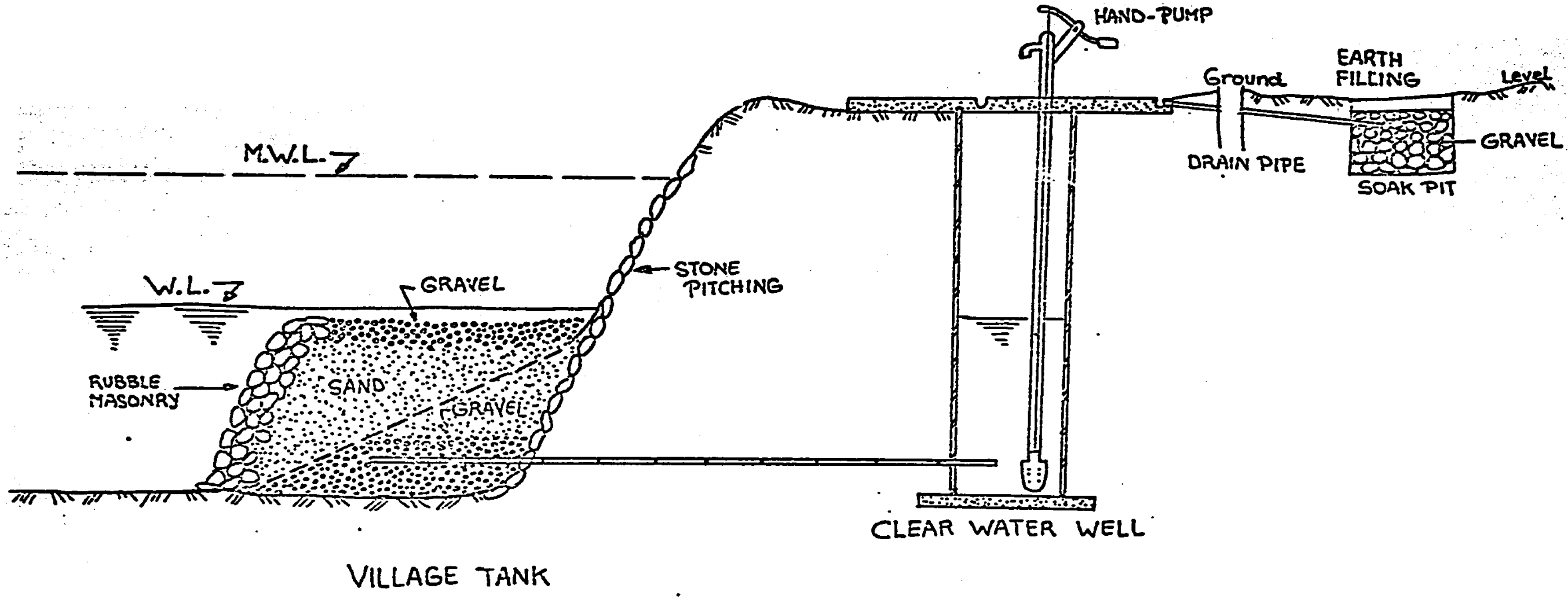


b. Proportional chemical feeder.

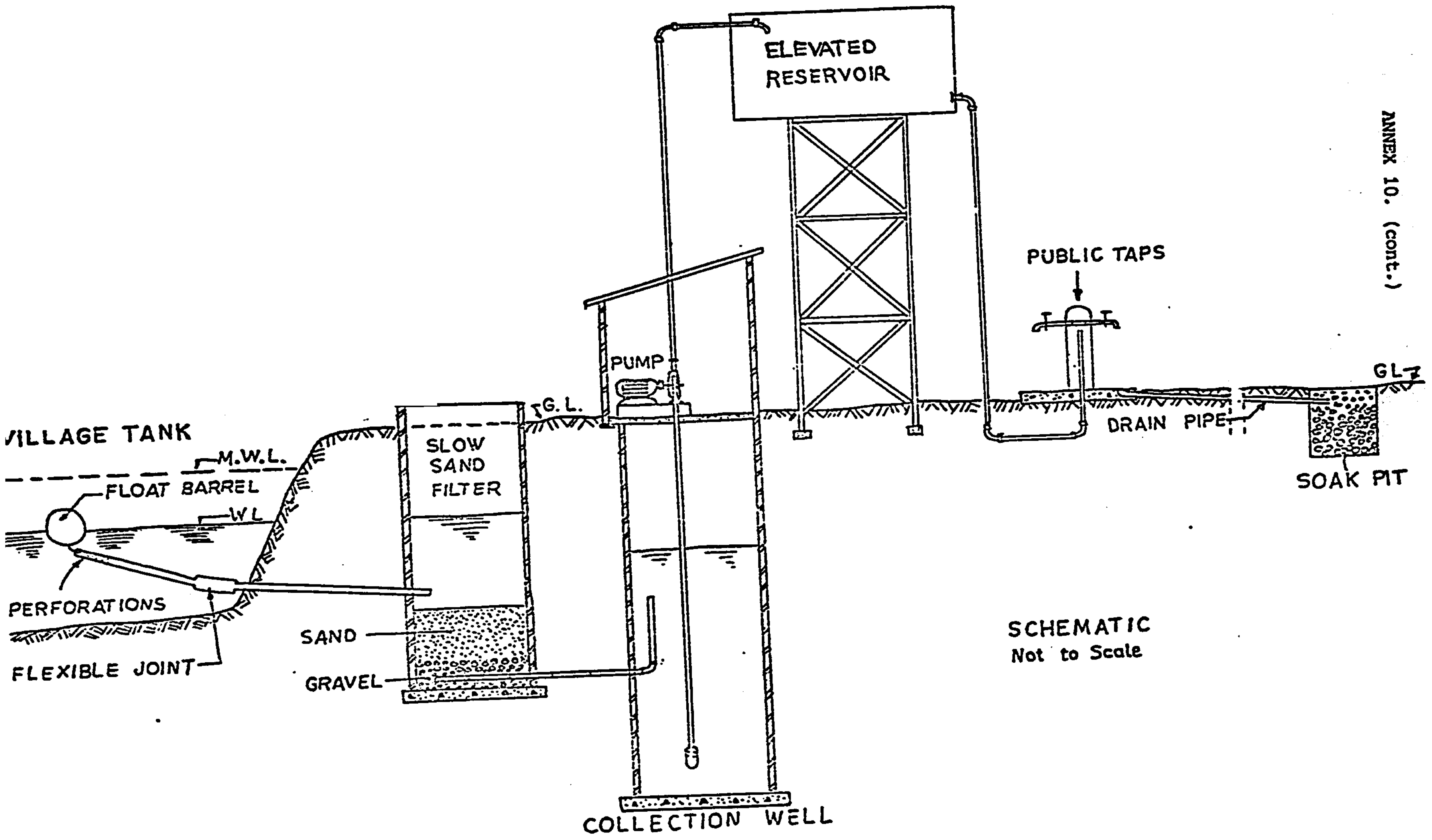
ANNEX 10.

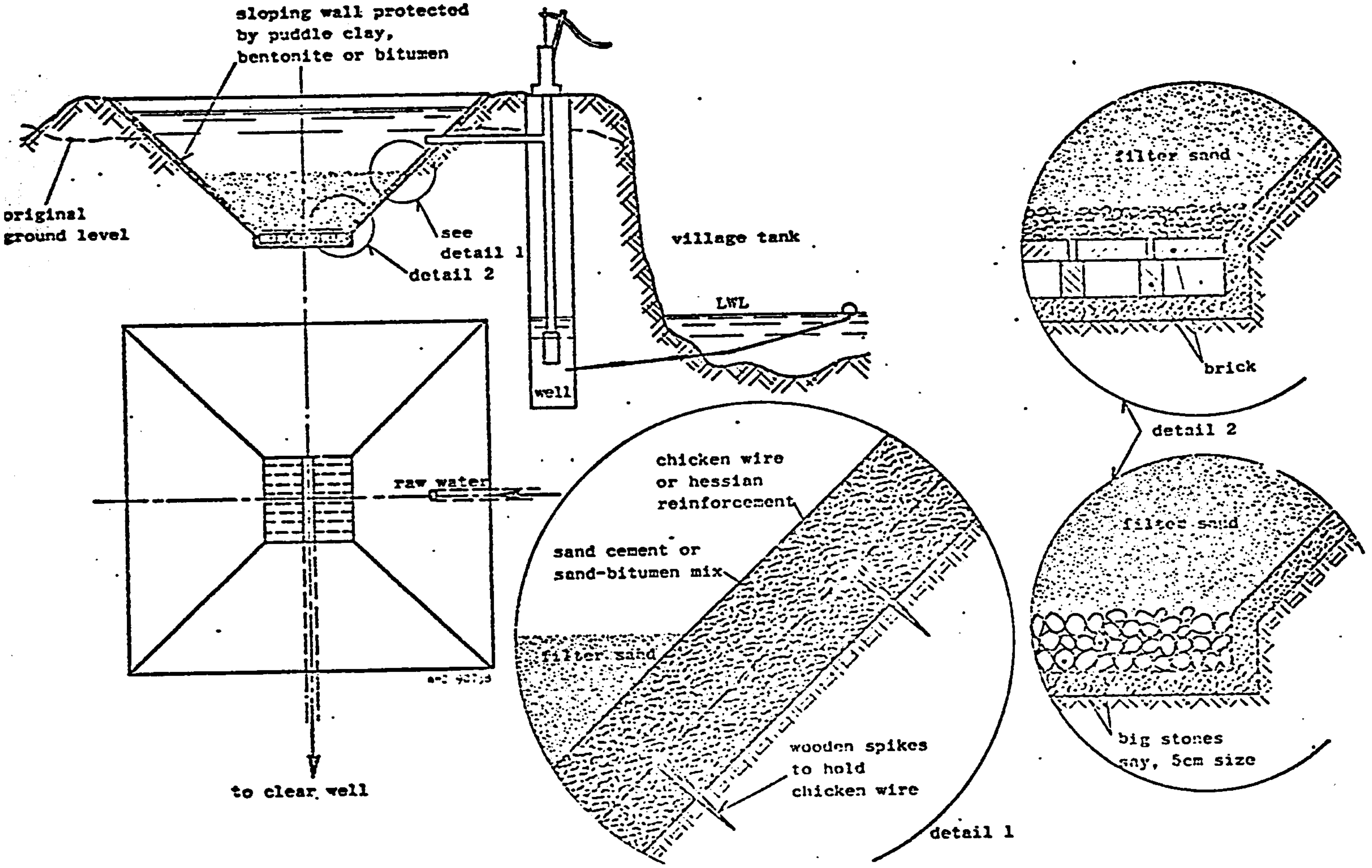
Slow Sand Filters

The most simple filter consists of drains, on the bottom of a river, or covered with a sand bed.
Another simple construction is to excavate the filter box, and protect the sloping walls by puddled clay, or make them otherwise watertight.
Many solutions have been found for the construction of the underdrainagesyste
Bricks, stones and even bamboo have been suggested for this purpose.
However, bamboo requires frequent renewal because of its putrifying tendency.



SCHEMATIC
NOT TO SCALE


ELEVATED RESERVOIR
PUBLIC TAPS
PUMP
G.L.
GL
VILLAGE TANK
M.W.L.
SLOW SAND FILTER
FLOAT BARREL
WL
DRAIN PIPE
SOAK PIT
PERFORATIONS
SAND
FLEXIBLE JOINT
GRAVEL
COLLECTION WELL
SCHEMATIC
Not to Scale



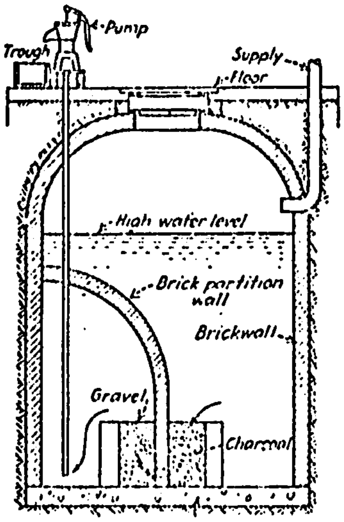
FILTER IN OPEN EXCAVATION
WITH ALTERNATIVE LININGS

Schematic.
Not to scale

ANNEX 11.

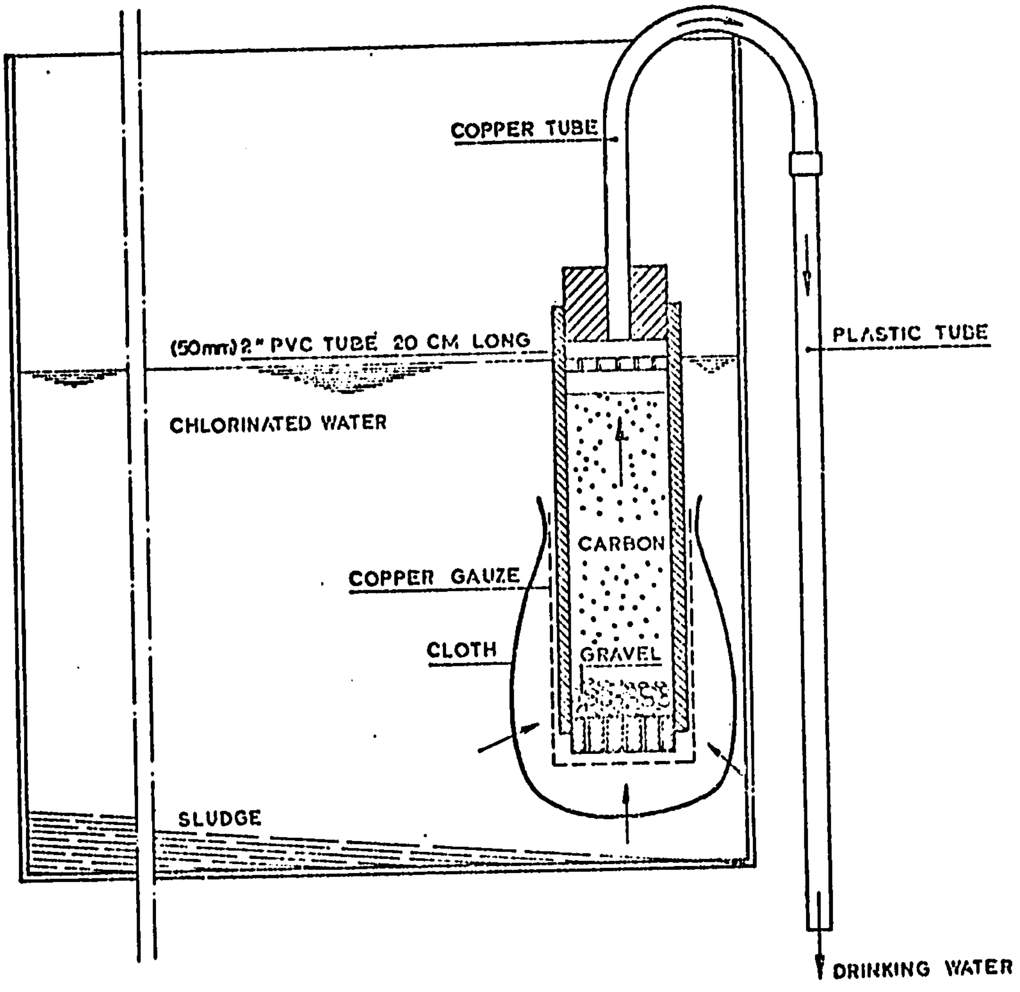
Activated carbon

For more than two centuries, different types of coal have been used for the removal of bad taste and odour in water. Particularly charcoal and bone char. However, for treatment on a larger scale the absorptive capacity of charcoals was insufficient. Through special treatment some carbon acquired a much greater absorptive capacity.
Very little is known about the possibilities of manufacturing activated carbon in developing countries. However, it is known, for example, that coconut charcoal would absorb considerable volumes of certain gases but this means little in water treatment.



—Filtering cistern in use about 1880.

ANNEX 11. (cont.)



CARBON FILTER
FOR REMOVING EXCESS CHLORINE
(SOURCE: MIN. OF HEALTH, INDONESIA)

ANNEX 12.

Disinfection

The dosing of disinfectants, mostly chlorine, must be constrained to certain limits. Below this level, chlorination is ineffective; and above this level the water becomes so unacceptable to the consumer, that he returns to the polluted source rather than drink the highty chlorinated water.

Disinfection methods for village supplies normally fall into one or two categories; pots or drip feeders.

Figure a. shows schematically the working of pot chlorination in a village well.

Figure b. the coconut type chlorinator developed in Malaysia. The plastic bag is filled with a mixture of chlorine of lime and coarse sand (1:1). The coconut shell which is readily available in rural regions of Malaysia, functions as a container and is lowered into the well. Information: "the pahang continuous chlorinator" by Talib and coworkers.

Figure c. Developed in India. Two earthen pots locally available are used. The inner pot is filled with bleaching powder and holes are made in the outer pot. The inner pot is covered and rests inside the outer pot. The whole arrangement is suspended under water, to be disinfected. Information" Environmental Health" Vag. 9. 203 - 209 , 1967, CPHERI, Nagpur, India

Figure d. Used in Bulgaria. Pots are made of infusorial earth or potters clay, and range in size from 28 to 195 mm in dia. and 500 mm in height, to contain from 200 to 10.000 gms wetted bleaching powder. Wall thickness varies from 10 to 25 mm. The Pot is submerged in water.
Information: "New method of chlorination drinking water" by M. Zalravkov, WHO/Env. San./124, 1959

Figure e. Developed in Iran. Locally available 1 gallon (4,5 litre) earthenware jars, with a wall thickness of 5 mm approx. are used. 2% chlorine solution in jar is preferred to dry powder. Information: H. Sondarzi, Director, E.H. Division, Ministry of Health, Teheran.

ANNEX 12. (cont.)

Figure f. Plastic pipe 15 cm. in dia, capped on top and with a streched membrane at the bottom, is filled with bleaching powder. Water enters the pipe by osmosis through the membrane and resulting pressure causes an outflow of concentrated bleach solution into the well through holes in the pipe near the top. It can also be used with iodine

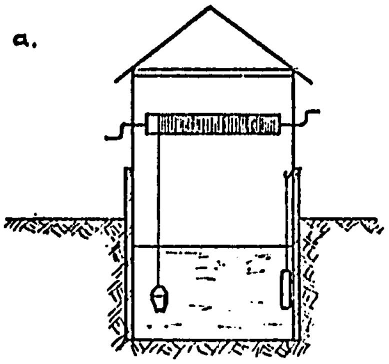
Figure g. From the Netherlands. Inner plastic pipe has a slot with an opening that can be increased or decreased by screwing in or out the outer pipe, which is filled with iodine crystals. Iodine diffussion from inside the pipe can thus be controlled. Information: Dr. H.J. Boersma, the Hague, the Netherlands

Figure h. "The drip feed chlorinator". The chlorine solution tank is placed at a height of 1 metre. The variation of 10 cm between max.- and min. level in the tank will produce a variation in discharge of only 2,5%. This is quite acceptable. This tank has a capacity of 18.000 (30 x 30 x 20) cubic centimetres, which is sufficient to hold one week's supply of chlorine to disinfect 10 m^3 of water per day. So 500 people can have a daily intake of 20 litres.

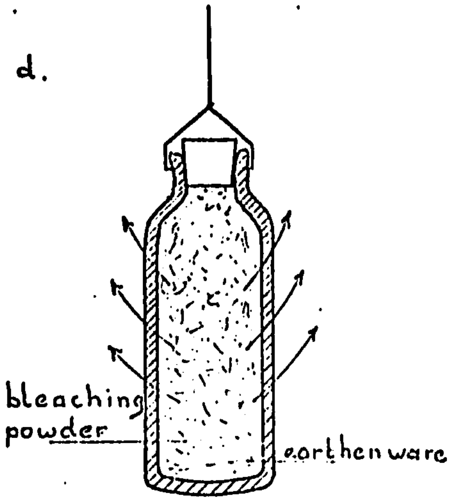
Figure i. This figure shows the construction of a small (20 litres) portable chlorinator, used in rural water supplies in the Sudan. In the base of the plastic jerrycan a hole has been cut. A sieve and a loose-fitting, non-airtight cover are removable for filling and access. The float system gives the constant feed device.
In the Sudan, chloride of lime has been used as a disinfecting agent. This is mixed at the rate of 100 grams to 5 litres of water in a bucket and is then allowed to stand for some hours before pouring into the chlorinator, taking care that the inactive sediment is thrown away.

ANNEX 12 (cont.)

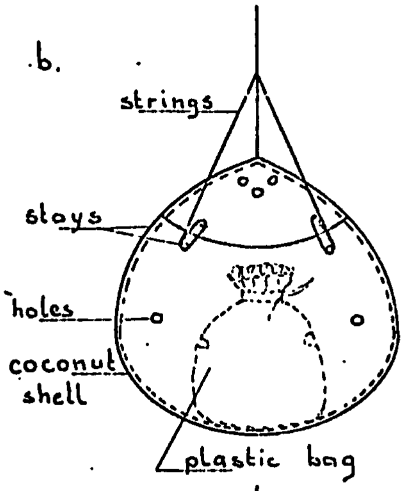
a.



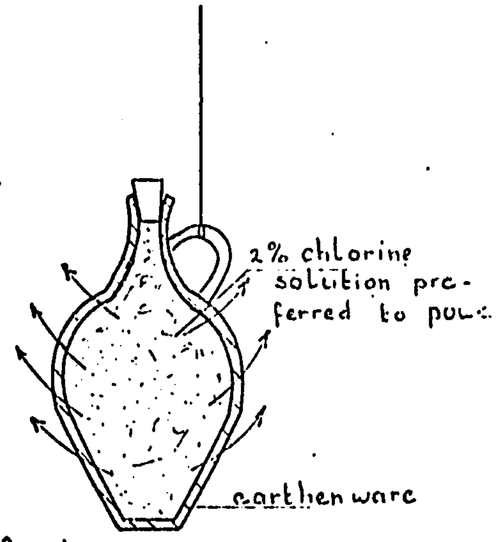
d.



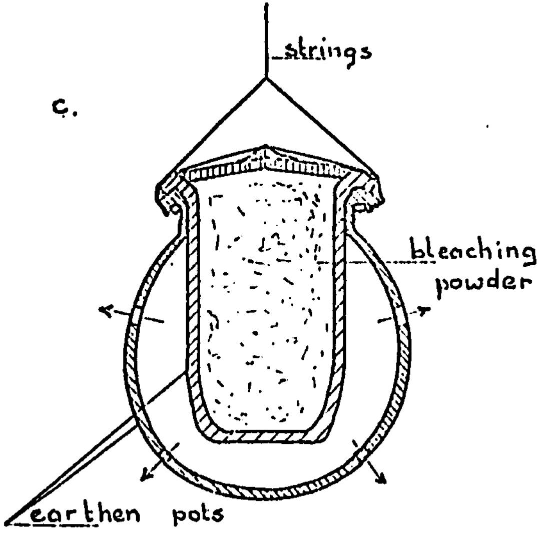
b.



e.

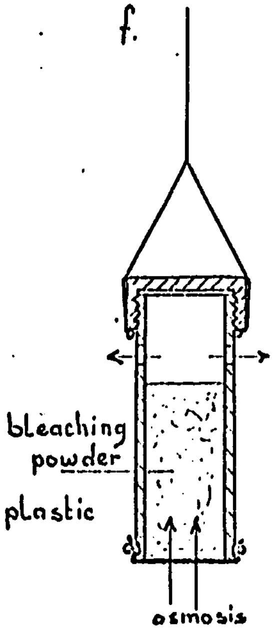


c.

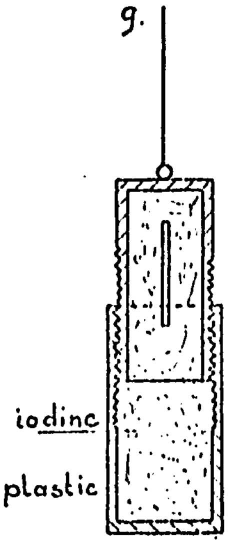


schematic
not to scale

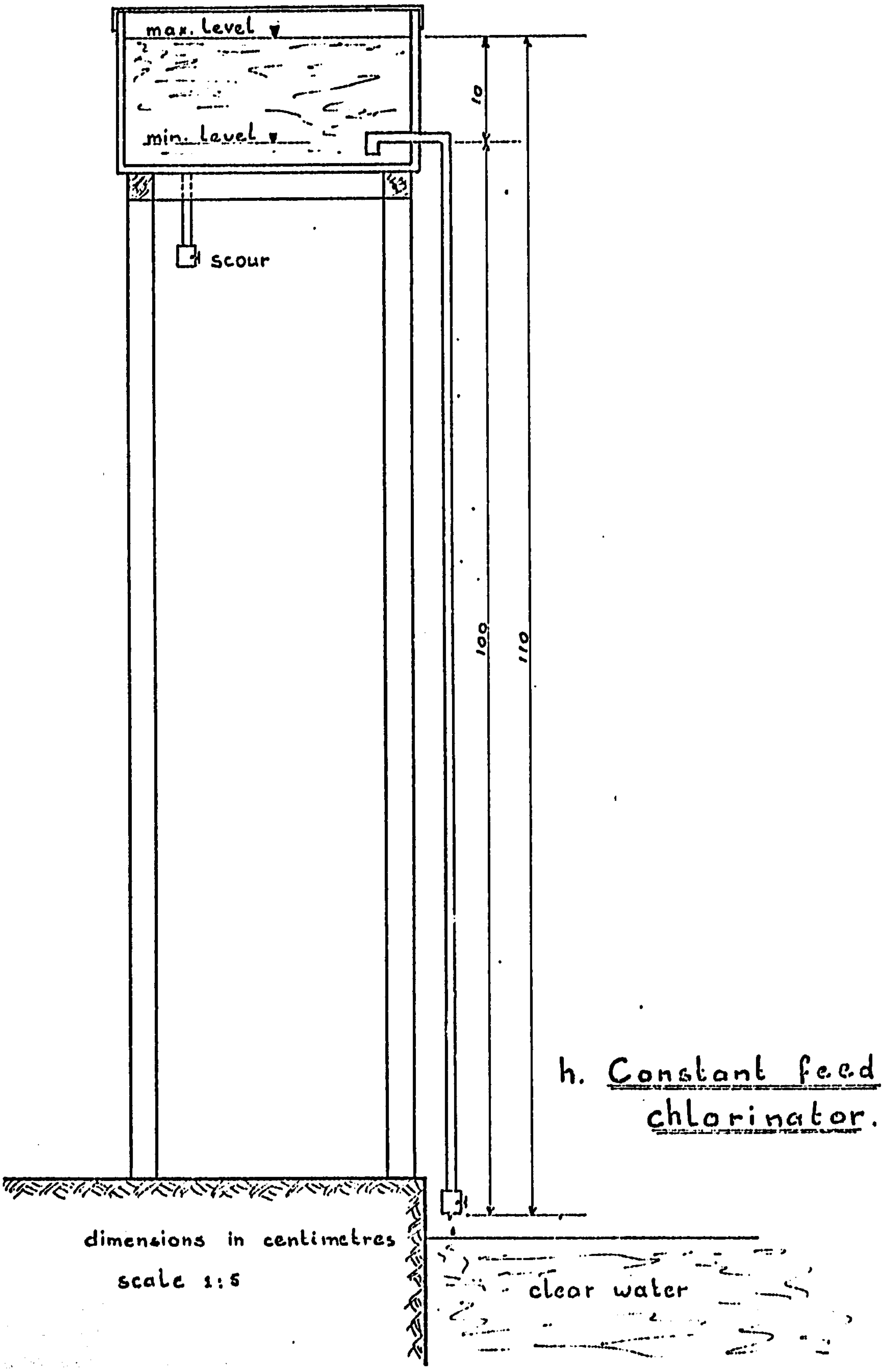
f.



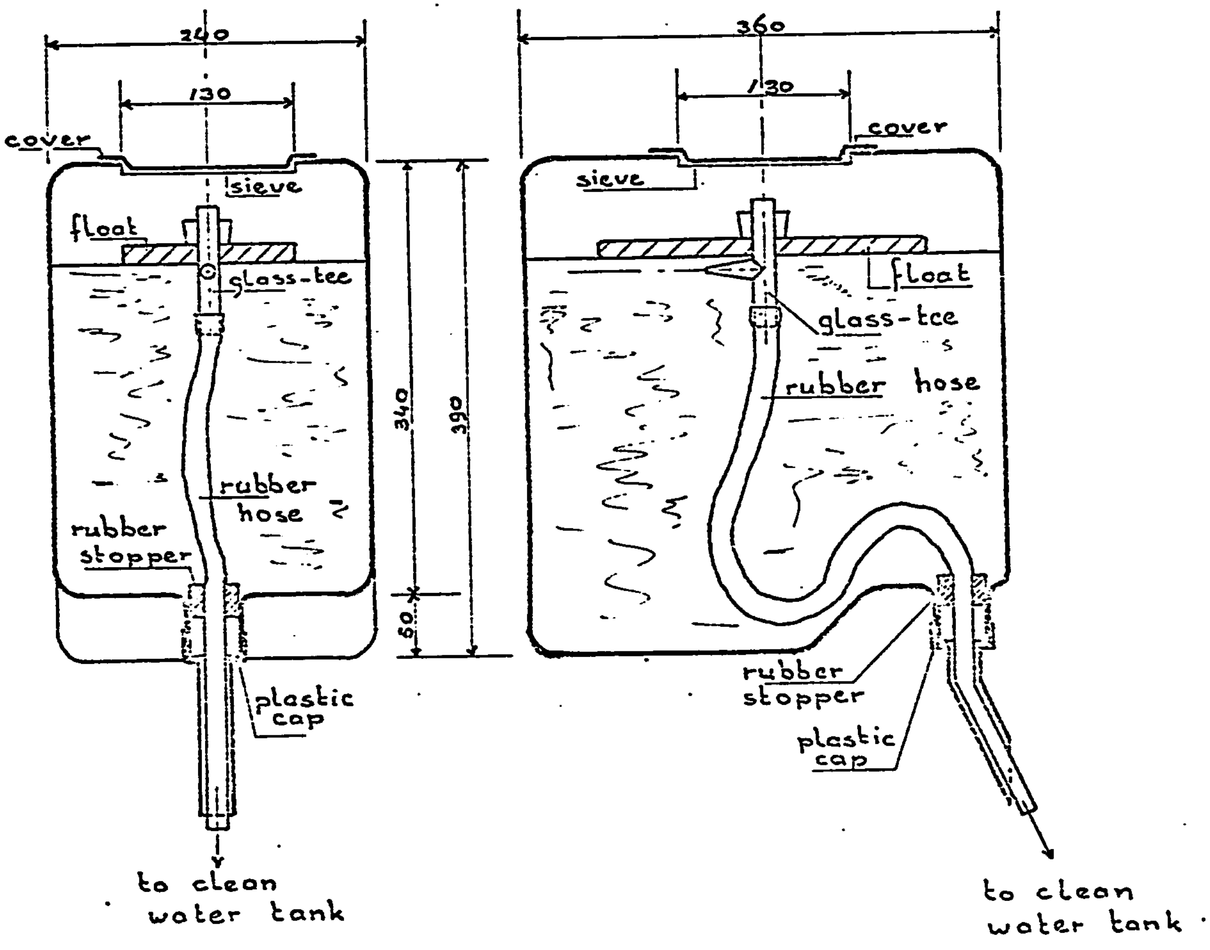
g.



schematic
not to scale



h. Constant feed chlorinator.



dimensions in millimetres
scale 1:5

i. Constant feed chlorinator.

Annex 13

WATER SUPPLY AND SANITATION
IN DEVELOPING COU

UNIVERSITY
GENCY FOR INTERNATIONAL DEVELOPMENT

GERRIT V. R. MARAIS AND FREDERICK E. McJUNKIN, EDITORS

AID-UNC/IPSED Series
October 1966

WATER SUPPLY USING BAMBOO PIPE

ABSTRACT

Bamboo pipe is extrensively used for small water supply systems in Indonesia. This report briefly desc the salient features of design and construction of elements of the system.

(Key words: Water supply, water pipe lines)

Source of Information: Department of Health
10 Tosari
Djakarta
Indonesia

Introduction

In Indonesia bamboo pipe to convey water to villages is extensively used. Where bamboo is readil available its use as a substitute for metal pipe appears to have considerable merit. It is simple to construct using unskilled labor and local materials.

Design and Construction

Bamboo pipe is made of lengths of bamboo of the desired diameter by boring out the dividing membrane at the joints. A circular chisel for this purpose is shown in Figure 3.1. One end of a short lenc of steel pipe is belled out to increase the diameter and the edge sharpened. A length of bamboo pipe sufficiently small diameter to slide into the pipe is used as a boring bar and secured to the pipe by dril a small hole through the assembly and driving a nail through the hole.* Three or more chisels ranging from smallest to the maximum desired diameter are required. At each joint the membrane is removed b first boring a hole with the smallest diameter chisel, then, progressively enlarging the hole with the l diameter chisels.

---

*Such a nail is also known as a cotter pin or linchpin.

This publication series is prepared by the International Program in Sanitary Engineering Design (IPS under the sponsorship of the Community Water Supply Branch, Agency for International Development (AI United States Department of State. IPSED is a program of the Department of Environmental Sciences School of Public Health, University of North Carolina at Chapel Hill. Correspondence

Bamboo pipe lengths are joined in a number of ways, as shown in Figure 3.2. Joints are made watertight by caulking with cotton wool mixed with tar, then tightly binding with rope soaked in hot tar.

Bamboo pipe is preserved by laying the pipe below ground level and ensuring a continuous flow in the pipe. Where the pipe is laid above ground level, it is protected by wrapping it with layers of palm fiber with soil between the layers. This treatment will give a life expectancy of about 3 to 4 years to the pipe; some bamboo will last up to 5-6 years. Deterioration and failure usually occur at the natural joints, which are the weakest parts.

Bamboo piping can hold pressure up to two atmospheres (± 30 psi* or 2.1 kg/cm^2**), hence, it cannot be used as pressure piping. It is most suitable in areas where the source of supply is higher than the area to be served and the flow is under gravity. Where the depth of the pipe below the hydraulic gradient is such that the maximum pressure will be exceeded, pressure relief chambers must be installed. A typical chamber is shown in Figure 3.3. These chambers are also installed as feederboxes for branch supply lines to villages en route.

A diagrammatic sketch of a bamboo pipe water supply system for a number of villages is shown in Figure 3.4. Size requirements for bamboo pipe may be determined using the pipe capacity nomograph provided as Figure 3.5. A design for a public fountain made from bamboo is shown in Figure 3.6.

Health Aspects

After a bamboo pipe is put into operation it gives an undesirable odor to the water. This, however, disappears after about three weeks. If chlorination is done before discharge to the pipe, a reservoir giving sufficient contact time for effective disinfection is required since bamboo pipe removes chlorine compounds and no residual chlorine will be maintained in the pipe. To avoid possible contamination by ground water, an ever present danger, it is desirable to maintain the internal pressure within the pipe at a higher level than any external water pressure outside the pipe. Any leakage will then be from the pipe, thus, contaminated water cannot enter the pipe.

Use in Other Countries

In many rural areas of Taiwan, bamboo is commonly used in place of galvanized iron (G.I.) for deep wells up to a maximum depth of 150 meters (492 feet). Bamboos of 50 mm (2 inches) diameter are selected, straightened by means of heat, and the inside nodes knocked out. The screen is made by punching holes in the bamboo and wrapping that section with a fibrous mat-like material from a palm tree, *Chamaerops humilis*. In fact, such fibrous screens are also used in many G.I. tube wells.***

Use of bamboo pipe is also being investigated in Thailand. Results of this work, however, are presently unavailable to the Editors.

---

*Pounds per square inch

**Kilograms per square centimeter

***D. F. Yung, "Rural Water Supply in Taiwan," Taiwan Institute of Environmental Sanitation, Fuchow Street, Taipei, Taiwan, Republic of China.

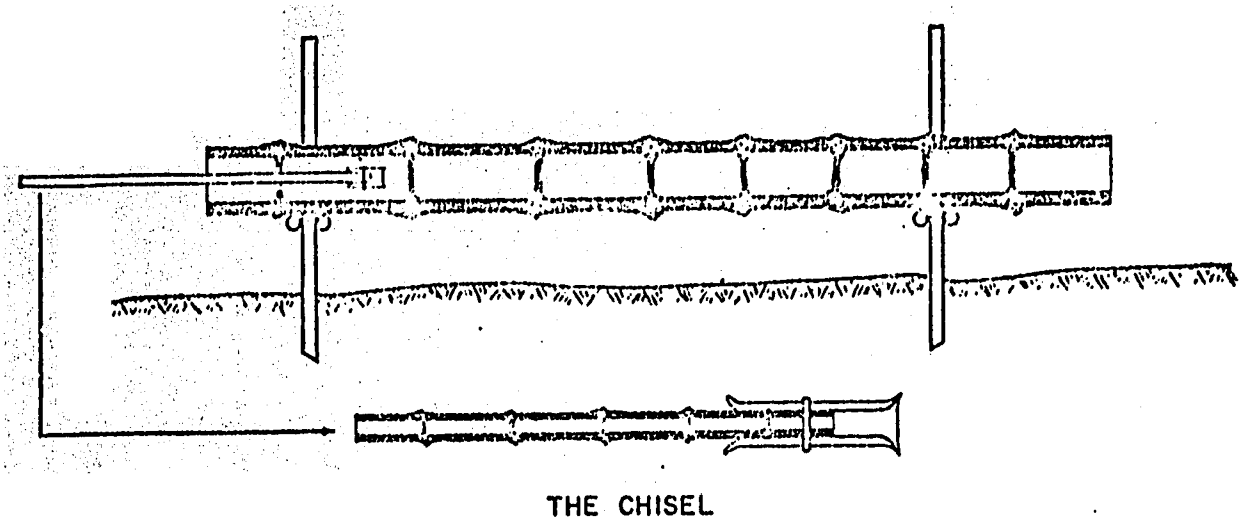


FIGURE 3·1 REMOVAL OF DIVIDING WALLS

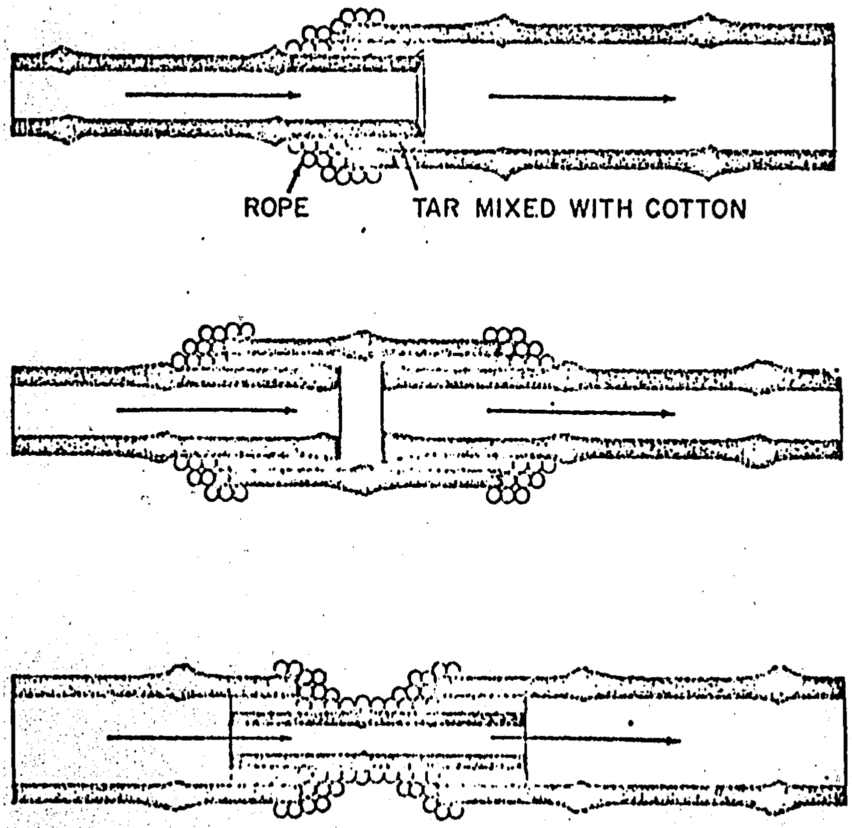
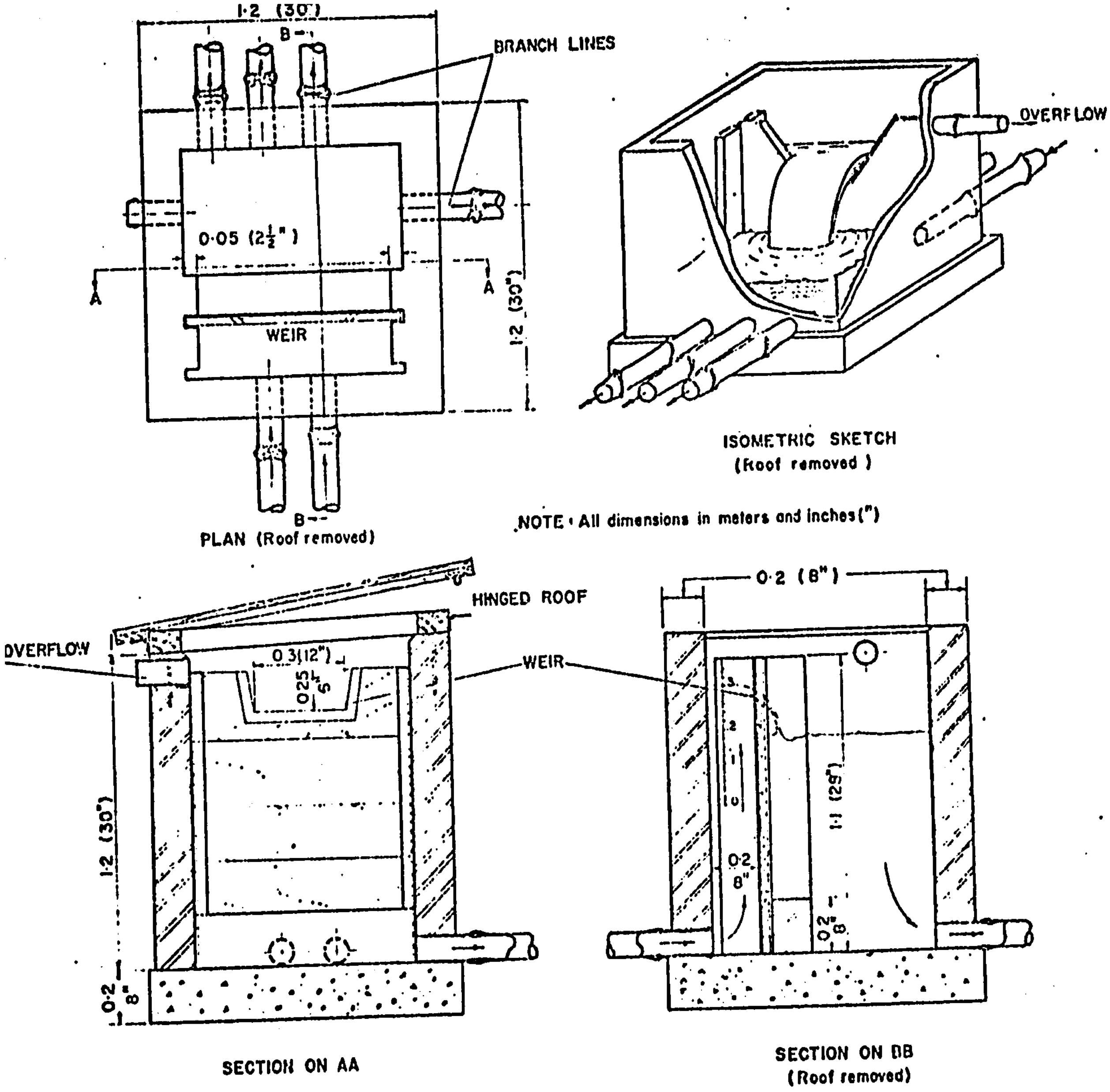


FIGURE 3·2 CONSTRUCTION OF JOINTS



PLAN (Roof removed)

ISOMETRIC SKETCH (Roof removed)

NOTE : All dimensions in meters and inches(")

SECTION ON AA

SECTION ON BB (Roof removed)

FIGURE 3·3 CHAMBER FOR DISTRIBUTION & PRESSURE RELIEF

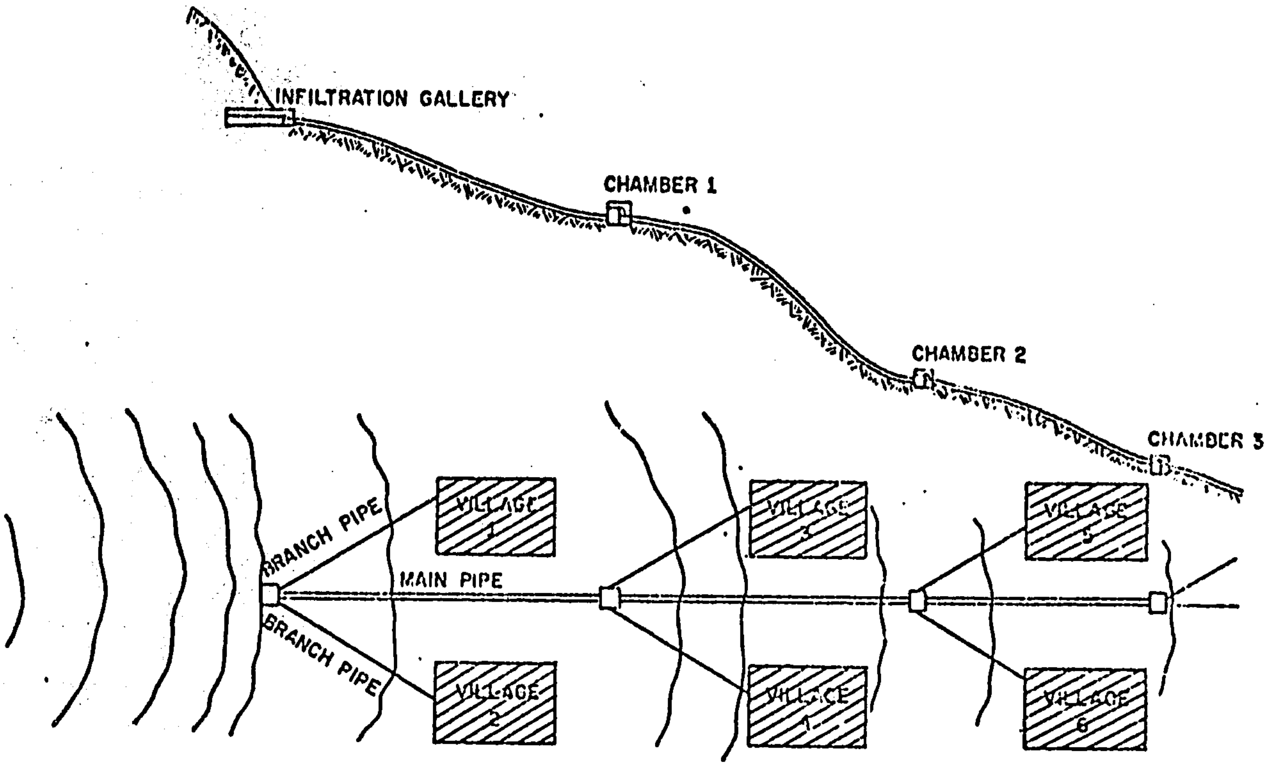
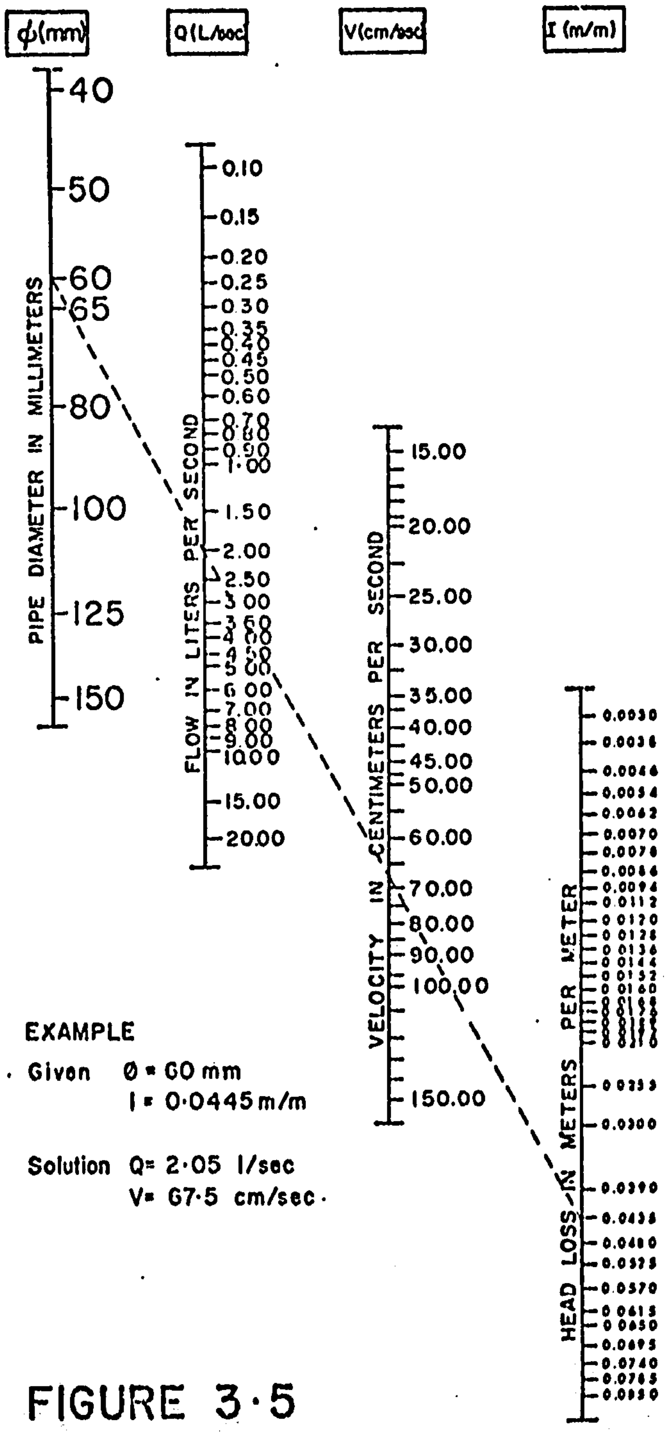


FIGURE 3·4 LAYOUT OF BAMBOO WATER SUPPLY SYSTEM

NOMOGRAPH FOR FLOW IN BAMBOO PIPE



EXAMPLE

Given Ø = 60 mm
I = 0·0445 m/m

Solution Q = 2·05 l/sec
V = 67·5 cm/sec

FIGURE 3·5

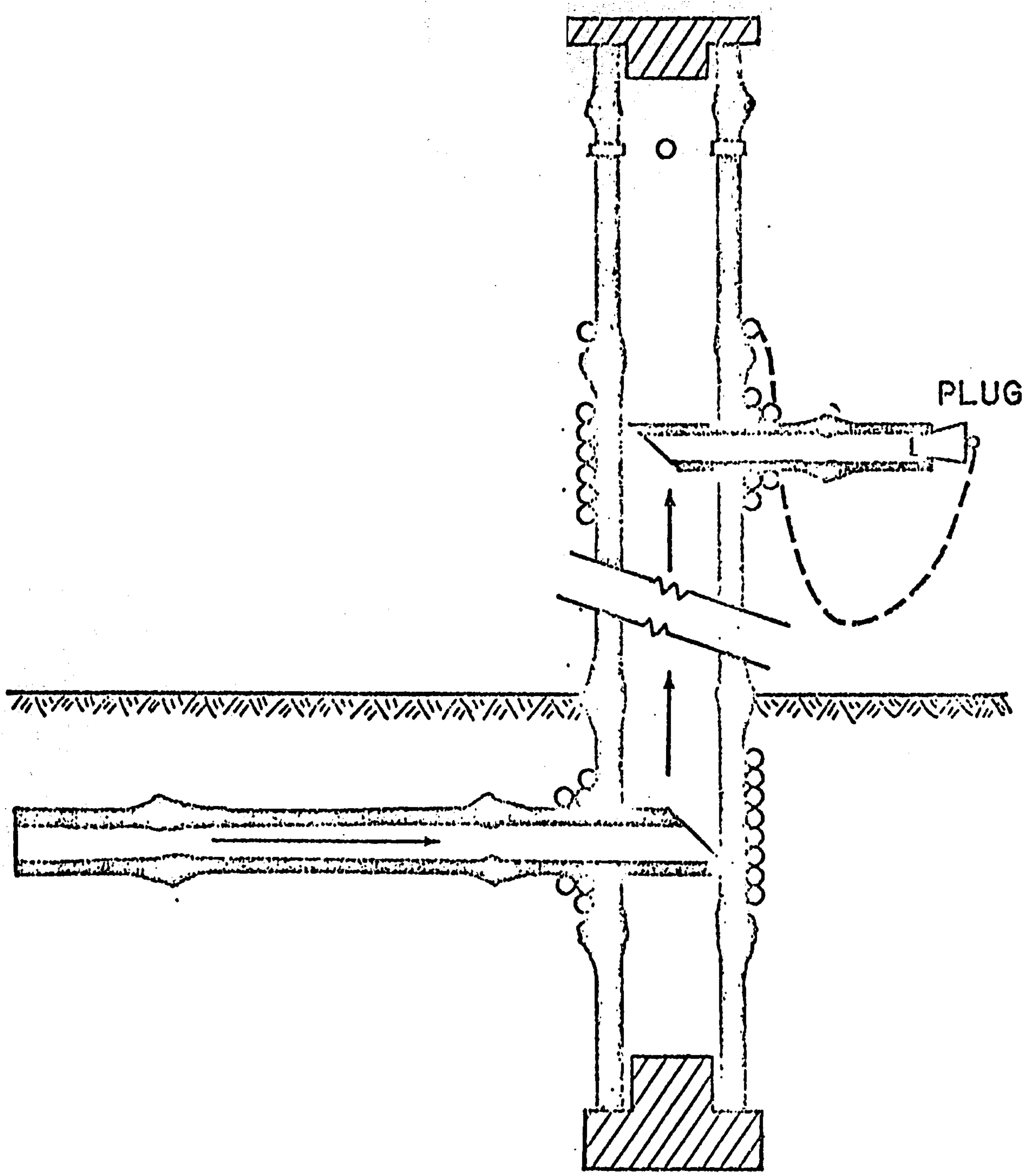


FIGURE 3·6 PUBLIC FOUNTAIN

AID-UNC/IPSED Series Item No. 3

WATER AND MAN'S HEALTH

Water is a physiological necessity to man; it is also essential to agricultural and industrial development and growth. From time immemorial, man has accepted water wherever he found it and used it to maintain life and for other advantageous purposes. Many people in the world today still pursue this course, either by choice or through necessity. But all men were not forever satisfied with mere acceptance of available water; some conceived the idea that certain waters could be controlled and made more responsive to their needs. In ancient times, control actions took two forms: one, to protect and enhance quality, and another, to improve accessibility and availability.

The beneficial alteration of the quality of water may antedate 2000 B.C. However, in that year "Ousruta Sanghita" - a collection of medical lore in Sanskirt - included a statement that "It is good to keep water in copper vessels, to expose it to sunlight, and filter through charcoal." Other ancient records, including the Bible, refer to water storing, clarifying, filtering, and distilling to make it more palatable and less objectionable for hygienic use. From these days until the present time, man has continued his efforts to improve the palatability and potability of water.

As man increased in numbers, migrated to other land areas and clustered together for greater physical safety, he contributed more and more to the degradation of the water available to him. Diseases and bodily afflictions were not then so well identified and catalogued but people were just as vulnerable to them as they are today. With the improvement of the medical and biological sciences, recognition of the part played by water in the initiation and transmission of diseases and other bodily disturbances became more and more obvious until today there is a frightening array of agents which can exist in water and affect the susceptible person if and when the opportunity is presented.

Many living contaminants of water - the parasitic organisms which take up their abode on or within other living organisms to obtain food - are ready to attack man if they can get to him. Some of these use water as their habitat while others require it to complete their life cycle or as a vehicle to a point of entry to man. Some attack man directly; others need water-living intermediate hosts to produce their attack posture. Water consumed by man may also contain a large number of non-living or chemical contaminants and a variety of them can be present in water both prior to and after its purification. Man, as well as other living matter, is always exposed to background ionizing radiation coming from outer space and from traces of naturally radioactive isotopes. Now he must also worry about artifically-produced radiation.

In a less complicated manner, water is important to man's health. The need to keep the body clean, to remove substances and organisms which can thoughtlessly or unknowingly be caught up in entrances to the body, is of great importance. The small child who rubs his itchy eye with a dirty finger has no realization that he may be pushing the trachoma virus into his eye. Given an opportunity and encouragement to wash his hands, this might never happen. Cleanliness is inimical to external parasites such as lice and mites, and to the fungi responsible for skin diseases. The use and reuse of common utensils in homes and public institutions and places, without adequate cleansing and disinfection, is another cause of disease transmission even among people living in relatively highly advanced countries. Without adequate, safe water, conveniently available, many communicable diseases will just continue to run their disabling course. Dispelling filth, on the person and in the surroundings, requires clean water sufficient to maintain hygienic conditions.

The need for a clear and complete account of the relationship between water and health was recognized by the Community Water Supply Branch of the United States Agency for International Development (AID) and they asked Mr. Arthur P. Miller, formerly a sanitary engineer of the U. S. Public Health Service, to prepare such a document. The result was a 100 page booklet entitled, "Water and Man's Health." This booklet has been printed in English, Spanish, and French and may be obtained, without charge, from the representative of the U. S. Agency for International Development in the capital of your country or from the Community Water Supply Branch, Health Service, Office of Human Resources and Social Development, Agency for International Development, Washington, D. C. 20523, U.S.A.

G. BIBLIOGRAPHY (see Volume II of this report)

The bibliography consists of three parts:

Part I : Titles and authors arranged according to subjects.

Part II : Abstracts on water supply, alphabetical arranged according to authors

Part III : Abstracts on sewage and excreta disposal composed by Hugo van der Berg.