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II

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File Title	Barcode No.
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Document Date	Document Type
Dec 26, 1974	Memorandum

Correspondents / Participants

To : Messrs. Shipman and Warford

From : Ms. Phyllis Peter

Subject / Title

Cost Estimates for the Health Panel

Exception No(s).

☑ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 A-C ☐ 10 D ☐ Prerogative to Restrict

Reason for Removal

Personal Information

Additional Comments

The item(s) identified above has/have been removed in accordance with The World Bank Policy on Access to Information. This Policy can be found on the World Bank Access to Information website.

Withdrawn by	Date
Chandra Kumar	Nov 25, 2013

Mr. Shipman

WATER SUPPLY & SEWERAGE

December 23, 1974

Mr. Curtis Farrar
Assistant Administrator
Technical Assistance Bureau
Agency for International Development
Department of State
Washington, D. C. 20523

Dear Mr. Farrar:

I would like to express my division's continued interest in your Office of Nutrition's proposed research project in Brazil, "Health and Nutrition Benefits of New or Improved Water Supplies", managed by Dr. J. P. Keeve. As you may know, the original impetus for this study arose from discussions between Alan Berg of the Bank's Population and Nutrition Projects Department and Martin Forman of AID's Office of Nutrition. Staff from this division have participated in early discussions with Dr. Keeve about the project and have contributed to the collaborative literature review and recommendations for research which will be used to define the study. The Bank's Central Projects Staff engaged David Bradley as a consultant to write a paper which, among other things, comments on the proposed Minas Gerais study. This division has discussed the study with our borrower in Minas Gerais, COMAG, the statewide water company, and has communicated to Dr. Keeve its intention to cooperate with the study in all possible ways. We certainly intend to continue coordinating the relations between the study's staff and COMAG to the extent required.

I understand the next step in the progress of the study is a formulation of the experimental research design. Staff from this division stand ready to review and advise on this formulation to the limits of our expertise in economic and sanitary matters. If indicated, we can refer any questions outside these limits to others in the Bank on an informal basis.

Our fundamental interest in the study will remain what it has been in the past: a desire for more information on the relations between water, health and nutrition so we can better justify, select, and design water supply projects to meet the needs of individuals in developing countries. We have reason to hope this research project will significantly contribute to this purpose.

Very truly yours,

John M. Kalbermatten
Chief, Water Supply and Sewerage Division
Latin America and the Caribbean Regional Office

Cleared with and cc: Mr. P. Geli (PBPDR)
cc: Messrs. Martin Forman, Office of Nutrition, T.A.B., AID
Jack Keeve, Shipman, Warford, Berg, Keare, Reutlinger, Jeurling

Mr. Shipman
WATER SUPPLY & SEWERAGE

December 23, 1974

Mr. Jack P. Keeve, M. D.
Office of Nutrition
Technical Assistance Bureau
Agency for International Development
Department of State
Washington, D. C. 20523

Dear Dr. Keeve:

With this letter I am sending a draft of David Bradley's paper, "Measuring the Health Benefits of Investments in Water Supply", for your personal use. Appendix B has not been received so far. I'll send you a copy as soon as one is available.

This is an unrevised first draft that has not been subjected to the World Bank's internal review. Its contents, conclusions, and recommendations do not necessarily reflect World Bank policy and should not be taken as such. The paper has not been released for general use as it has yet to appear before a review panel sometime after the first of next year. I am sending it to you because, of course, it comments on your office's proposed research project in Minas Gerais and may be of some value to you in this regard.

I would like to take this opportunity to assure you of this division's continued keen interest in this study and willingness to aid in this effort to the extent possible.

Very truly yours,

John M. Kalbermatten
Chief, Water Supply and Sewerage Division
Latin America and the Caribbean Regional Office

Enclosure

Cleared with and cc: Mr. Shipman (PBP)

cc: Mr. Martin Forman, TAB/AID

cc: Messrs. P. Geli (PBPDR), Warford (PBP), Berg (PNP), Keare (ECD), Reutlinger (ECD), Jeurling (LCPWS)

Mr. Warren C. Baum

December 20, 1974

John A. King

Water Resources in the Bank

1. In part because of Mr. Kuiper's impending departure, there have been several meetings on the question of how water resource issues should be handled in the Bank. Those who have taken part include Messrs. Lee, Kirpich, Kuiper, Shipman and Weiss.

2. Gaps in the handling of water resource issues are believed to occur in both economic work and project work. Although water resources may be the critical limiting factor in many countries, we have the impression that economic reports do not systematically look into water resource issues and alternative uses, though in some cases they do so very effectively (e.g. it was an economic report that led to the major Mexican water resource study). In project work, we believe that the impact on other sectors of the use of water resources for a project in a particular sector is not systematically considered and the relative costs and benefits weighed, except when the project is a multi-sector project. Furthermore, there is a feeling that during the preparation phase of projects involving water resources, pressure for appraisal may tend to foreclose the consideration of alternative approaches, different patterns of allocation and different technologies that might provide a better utilization of water resources as a whole than those proposed for the particular sectoral use.

3. From an organizational point of view, it would seem that there are several needs:

a) A need for knowledge about what the Bank is doing operationally in the field of water resources and water use, and for an exchange of experiences relating to that work.

b) A need for the identification of issues and the development of policy guidance in this area as well as for a review, coordinating and quality control activity for individual projects.

4. Our conclusion was that these needs could best be met by the creation of two committees -

a) An Operational Committee consisting of one projects staff member from each Region, chaired by Mr. Kirpich to meet essentially the needs described in 3(a) above. Latin America, in Mr. Kirpich and his unit, is already in a position to look at water resource management in the Region as a whole; he is already concerned with several water resource studies in two other countries (on a much smaller scale than the Mexican study). No other Region, as far as I know, is now set up in this way, though work on water resources and water resource management is going on in them and though we believe that in varying degrees individuals such as Heinz Vergin are informed about Regional activities in this field.

b) A Policy Committee consisting mostly of CPS staff concerned (e.g. Messrs. Lee, Shipman, Friedman, Bruce (Drewes), Carmichael (Churchill?), the new Irrigation Adviser, Weiss) and Mr. Kirpich. Its major tasks would be in the areas described in paragraph 3(b) above, primarily to identify policy issues in the water resource field and to guide the preparation guidelines in this field. These guidelines would apply both to economic work and to sector and project work and would assure effective incorporation of the principles of water resource management in the generation, design, appraisal and implementation of projects in the fields of irrigation, hydropower; water supply and sanitation, flood control, navigation, forestry and fisheries. Mr. Kuiper would be available to prepare these guidelines under the guidance of the Committee. He estimates that it would require about 12 mandays of his time over, say, a four-month period. This Committee would also be in a position to evaluate the lessons learned from particular projects and studies like the Mexican study and to make these available to operational staff.

5. Before going any further in preparing a more detailed proposal, both organizationally and with respect to terms of reference for the preparation of the proposed guidelines, for presentation to you, the Regional Vice Presidents and Mr. Knapp, I would like to get your reaction. As you can see, this is an attempt to tackle the water resource problem without using a post for a Water Resources Adviser. On the whole, the group believed that this solution was less satisfactory than the appointment of a Water Resources Adviser in PAS, but accepted it as a "second-best".

cc: Messrs. van der Tak, Weiss

JAKing:jlg

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

OFFICE MEMORANDUM

Yellow File

TO: Mr. J.M. Kalbermatten, Latin America & Caribbean Projects

DATE: December 16, 1974

FROM: S.S. Basta

SUBJECT: Literature Review, Water Supply and Nutrition

1. I have received the second draft of the above paper and I have corrected some portions which I discussed in detail with Mr. John Wall. With the exception of the points mentioned below, it represents a significant improvement over the first draft.

2. The first of these points is that the authors should clearly differentiate between infective and non-infective diarrheas in children (point c, summary and conclusions, as well as pages 3, 10, 11, 20) including the definition of weanling diarrhea, and mention of the diarrheas resulting from introduction of new foods in infants due to subsequent enzymatic or biochemical deficiencies or adaptations in the intestines.

3. The second, and most important, is that rapid reference should be made to the many experimental studies which have established conclusively the relationship between infection and nutrition, instead of relying solely on the two inconclusive epidimiological studies mentioned.

4. Thirdly, page 12 needs to be completely re-written, and page 11 modified slightly, because the statements that are made are not in keeping with modern scientific or clinical theory. By this I am alluding to the statement (p. 11) (my italics) that "cause of death (from diarrhea) in some children may be due to changes outside the intestines such as dehydration and electrolyte imbalance", and to the section on page 12 which attributes a certain fixed percentage of water exchange and body water in children without specifying their age or weight, as well as the statement that the complex organic compounds supplied by food function in the active transport of water.

5. On page 14, attention should be drawn to the fact that it is not the comparatively rare phenomena of physical occlusion of the gut with parasites that represents most of the problems of parasitic disease in human beings, but rather the bleeding, malabsorbtion, and loss of nutrients associated with infestation by tiny hookworm, microscopic protozoa, or the larger roundworms.

6. Finally, on page 21, the 18th line should be amended so as to remove the impression that Professors Gordon et al were only studying nutrition in the Guatemalan studies. They were in fact attempting to establish the importance of a number of factors in the etiology of infection.

7. With these relatively minor modifications, I think the paper will read much better. Mr Wall is to be congratulated for his effort and patience in the pursuit of this difficult literature review.

cc: Mr. Weiss (VP,DPS), Reutlinger (DED), Berg (PNPD), Wall (LAC)

SBasta/gw

WSP P.U. Water + Sewerage

December 10, 1974

Dr. Cvjetanovic
World Health Organization
1211 Geneva 27
Switzerland

Dear Dr. Cvjetanovic:

As Mr. Dieterich has indicated to you, the World Bank is becoming increasingly involved in rural water supply projects, and is facing a number of difficulties which have long been familiar to sanitary engineers and epidemiologists, including in particular the question of predicting the impact of such projects on public health.

To help us frame an approach for dealing with this issue, we have recently commissioned a paper entitled "Measuring the Health Benefits of Investments in Water Supply." This paper has now been completed and we intend to send it to a high level panel of experts (about six in number) for evaluation. Mr. Dieterich has indicated to us that you might be interested in serving on that panel and we are taking this opportunity of formally inviting you to do so.

Panel members would be asked to spend two or three days evaluating the paper in light of the terms of reference given to the author and to prepare a set of comments on the paper, raising questions or adding further considerations deemed important by the panel member in reaching conclusions on feasibility and methodology. It is planned that the panel members' comments would be received by the Bank by the end of January 1975 at which time we would forward each member's comments to the others for information. Sometime during the second half of March, a two day meeting of the panelists would be convened in the Bank. Professor Abel Wolman will serve as chairman of that meeting and a report would be prepared reflecting the views of the panel. The Bank would use this report as a guide in deciding possible action for dealing with the health-water supply issue.

If your reply to this invitation is affirmative, we will make arrangements with WHO on the terms of your assignment. We would be happy to at least pay your travel and per diem costs, and, as noted in our previous letter to Mr. Dieterich, are quite flexible should other arrangements be necessary.

I look forward to your early reply on this matter.

Sincerely yours,

Yves Rovani
Director
Public Utilities Department

cc: Prof. Wolman
J.J. Wolfard BJR

WATER SUPPLY + SEWERAGE

December 10, 1974

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World Health Organization
1211 Geneva 27
Switzerland

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I look forward to your early reply on this matter.

Sincerely yours,

Yves Rovani
Director
Public Utilities Department

cc: Prof. Wolman
cc: Messrs. Shipman, Jeurling, Saunders, Warford

OP PUBLIC UTILITIES - WATER SUPPLY & SEWERAGE

December 9, 1974

Dr. Ronald F. Layton
Water & Wastewater Technical School
NEOSHO
Missouri

Dear Dr. Layton:

The World Bank has been investing in water supply and wastewater disposal facilities in a large number of the developing countries of the world. The objective of this investment has not been only to provide funds for the construction of the facilities, but also to help our member Governments improve the institutional arrangements and the operation and maintenance of their systems. I need not tell you that availability of competent staff in the countries is the major obstacle that stands in the way of rapid improvements in all of these aspects, and while we have given a considerable amount of attention in the past to training and education, we are rather convinced that much greater attention must be given to these matters in the future. It is in this connection that I am writing you.

I would appreciate knowing what the resources of your facility may be, both with respect to personnel who might serve in the role of consultants on certain assignments, and on training manuals and visual aids which might be adapted for developing country use.

Concerning the first of these, I visualize the approach which we may take to be one of going into countries and evaluating training needs and determining those actions which are appropriate for the particular country to establish a training program compatible with the needs and the economy. Experience in working with developing countries and competence in languages in addition to English are highly desirable qualifications for personnel who might be selected for such work. Any comments which you could make with respect both to personnel in your own facility, and within the United States who you feel could undertake short term consultantships, would be appreciated.

With respect to actual training operations, it is our experience that such training is best done within countries and therefore the use of existing short courses and operator-training seminars which are carried out in various countries are not particularly attractive for use with the types of personnel which we normally have in mind. We feel that it is necessary

to restrict out-of-country training to the maximum and where employed, to confine it only to those who may be actually engaged in training or for the highest level professional staff.

We would be interested in knowing whether the courses carried out by your school are confined to the technical sides of water supply operations, or whether you do go into such matters as accounting, and middle management training. Our interests extend from the top management down to the lowest levels and incorporate all of the personnel normally associated with water supply operations, and, therefore, whatever information you could give us on your operations would be appreciated.

Thank you for your comments on the foregoing.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

HRShipman:cfa

WATER SUPPLY + SEWERAGE

December 5, 1974

Professor David Bradley
London School of Hygiene and
Tropical Medicine
Ross Institute of Tropical Hygiene
Keppel Street (Gower Street)
London, W.C.1.E 7HT
England

Dear David:

We are making progress on the arrangements for the panel discussion of your paper; the list of participants will be sent to you as soon as agreement with all members has been reached.

In the meantime, I would like to have your response to our letter of November 1 about the suitability of some date in March for your visit here. In case you did not receive that letter, a copy of it is attached.

I hope you are enjoying your new job and that commuting is not too big a burden for you.

Sincerely yours,

J. J. Warford
Economic Adviser
Public Utilities Department

Attachment

cc: Mr. Saunders
Mr. Shipman
Mr. Jeurling

JJWarford:pjk

Mr Hanford

WATER SUPPLY & SEWERAGE

HARVARD MEDICAL SCHOOL

DEPARTMENT OF PREVENTIVE AND SOCIAL MEDICINE

25 Shattuck Street
Boston, Massachusetts 02115
Tel. (617) 734-3300

December 5, 1974

Mr. Yves Rovani
Director
Public Utilities Department
International Bank for Reconstruction
and Development
1818 H Street, N.W.
Washington, D.C. 20433

Dear Mr. Rovani:

I appreciate very much, indeed, your letter of November 26th in which you invite me to serve on a panel of experts for the evaluation of the paper, "Measuring the Health Benefits of Investments in Water Supply". I am, indeed, honored to be considered and will be happy to serve to the best of my ability.

The only problem that arises is a rather well committed overseas trip from the first of February until the 31st of March. I plan to travel with my wife to Kathmandu, Nepal, where we have been invited to attend the Coronation of the new King of that country. Also, I have a long standing commitment at the World Health Organization about the 20th of March for one week. It would be exceedingly difficult to change either of these two commitments.

At present, however, I do plan to be in Boston steadily until the first of February and if you send me the report reasonably soon I should be able to read it with care and submit my comments before my departure.

I can well understand, however, that the actual meeting of the panel and the discussion and interchange among them will be an essential feature of the evaluation of the report and if you must meet before the first of April you may well wish to invite another person in my place.

Sincerely yours,

Alexander D. Langmuir

Alexander D. Langmuir, M.D.
Visiting Professor of Epidemiology

ADL:emd
cc: Prof. A. Wolman

P.S.: For purposes of the record, please note that I am a Visiting Professor in the Department of Preventive and Social Medicine of the Harvard Medical School. I do not hold a formal appointment at the School of Public Health, although I do some teaching there.

OP-PUBLIC UTILITIES-WATER/SEWERAGE

December 4, 1974

Mr. R.R. Doddridge
Manager, Training, Certification & Safety
Technical Services Branch
Ministry of Environment
135 St. Clair Avenue West, Suite 100
TORONTO
Ontario, M4V 1P5
Canada

Dear Mr. Doddridge:

Mr. Brian Grover has been kind enough to pass to me your letter of November 18 and the documents which you have forwarded relating to the training programs carried out by your Ministry in the field of water and wastes. Since the Bank is particularly interested in assisting its borrowers in the developing countries to establish and carry out training programs on a continuing basis for their water and wastes personnel, we have reviewed the information which you have provided with considerable interest. Several questions have been raised by this review and I would like to trouble you further for some additional information.

We note that most of the course work as it is reflected in your documents is directed at the operator level, and presumably concerned with municipal water utilities, as contrasted for example with the rural. Also, it appears that the activities are primarily for technical personnel rather than for training at all levels, including those in the commercial and management end. We would welcome information on this point and any plans you might have for expanding this training if our understanding is correct.

In countries which do not have institutions of higher learning for training engineers, accountants and financial analysts, the training will usually have to be done outside the country. The point is rapidly reached, however, in moving down the organization ladder where it is non-productive to send the personnel outside. Then the means has to be determined by which training of lower level staff can be accomplished within the country. It is in this connection that we are currently exploring external resources that may be brought into countries for more rapid development of their training programs.

One of the steps in establishing training programs is the study, nationally, of the existing facilities, if any, and of manpower requirements. Training needs and the means by which such training can be most economically and effectively carried out can then be defined. In those instances where rather clearly defined approaches are found which the country is willing to accept, funds could usually be provided in our loans to finance at least some of the preliminary stages of the program.

The foregoing is given in order to lead up to some of the questions on which I would like your views.

1. Has your Ministry done any overseas work in connection with training of water and wastes personnel?

2. Has it had opportunity to look at a broad program approach to training in a given agency or region, analyzing the problems and approaches, and coming out with specific recommendations on the means by which the training activity can most effectively be carried out on a continuing basis?

3. Has it been involved in the training of personnel other than operators, for example, book-keepers, assistant accountants and lower level management personnel?

4. Would it have the staff that could be made available on occasion to assist us on the study of training programs, and later for assisting agencies in developing countries in the implementation of recommended programs?

There is a considerable interest at the present time among a number of the international agencies for focusing greater attention on rural water supplies and sanitation. To whatever extent this interest is reflected in increasing actions within the developing countries, it will certainly mean that a sizable training effort will be required. I am sure that you are well acquainted with David Hopper who is the President of the Canadian International Research and Development Center in Ottawa. His address is Box 8500, Ottawa. He is well acquainted with the efforts now being made in connection with rural water supply and it might be useful for you to get in touch with him, should you feel that the rural water and sanitation training activities in the international field is an area of interest to you.

On the assumption that your staff might have experience in the international field, or should you decide that this is an area in which you would like to become active, it would be entirely possible from our side to include members of your staff, from time to time, on missions where training may be one of the problems needing attention. The means by which this could be done would have to be explored further, should you have an interest.

Would it be possible for us to receive one more set of the training documents which you sent Mr. Grover? Thank you for this favor and for the additional comments you may have in connection with the foregoing questions.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

HRShipman:cfa

cc: Mr. Brian Grover (IBRD) and Mr. Van Wagenen (IBRD)
Mr. David Hopper, Box 8500, Ottawa, Ontario, Canada

WORLD HEALTH ORGANIZATION

1211 GENEVA 27 - SWITZERLAND
Telegr.: UNISANTE-Geneva

ORGANISATION MONDIALE DE LA SANTÉ

WATER SUPPLY & SEWERAGE

1211 GENÈVE 27 - SUISSE
Télégr.: UNISANTÉ-Genève

Tél. 34 60 61 Télex. 27821

In reply please refer to: W2/86/1
Prière de rappeler la référence:

21 November 1974

Dear Ship,

I refer to your letter of 1 November 1974 concerning economic justification of the health benefits from investments in water supply. I wonder if the epidemiologist to whom Dr Wolman referred is Dr Cvjetanovic (Yugoslavia)? He is the Chief of Bacterial Diseases, Division of Communicable Diseases here at Headquarters, and has an interest in this subject area. He has authored or co-authored some papers in this area and I am attaching copies of two of them for your information.

Unfortunately, Dr Cvjetanovic is away from Geneva just now so I am unable to determine whether his schedule for March would permit him to participate in your meeting. Presumably the meeting will be in Washington.

The best thing is for you to contact Dr Cvjetanovic directly with your proposal. I am sending him a copy of your letter and of this for his advance information.

Insofar as the participation in the meeting by the Division of Environmental Health is concerned, I consider this possible but cannot give a definite answer at this time. Perhaps I can be more definite in this regard after your plans have been firmed up and a definite date has been set. We will, of course, be glad to cooperate in any way possible.

With best regards, I am,

Yours sincerely,

Dr B.H. Dieterich
Director
Division of Environmental Health

Mr Harold R. Shipman
Water Supply Advisor
Public Utilities Department
International Bank for
Reconstruction and Development
1818 H Street, N.W.
Washington D.C. 20433
United States of America

Encl: Epidemiological Model of Typhoid Fever and its Use in the Planning and Evaluation of Antityphoid Immunization and Sanitation Programmes

Cost effectiveness and cost-benefit aspects of preventive measures against communicable diseases

WORLD HEALTH ORGANIZATION
1211 GENEVA 27 - SWITZERLAND
Telegr.: UNISANTE-Geneva

ORGANISATION MONDIALE DE LA SANTÉ
1211 GENÈVE 27 - SUISSE
Télégr.: UNISANTÉ-Genève

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WATER SUPPLY & SEWERAGE

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21 November 1974

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With best regards, I am,

Yours sincerely,

Dr B.H. Dieterich
Director
Division of Environmental Health

Mr Harold R. Shipman
Water Supply Advisor
Public Utilities Department
International Bank for
Reconstruction and Development
1818 H Street, N.W.
Washington D.C. 20433
United States of America

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... Encl: Epidemiological Model of Typhoid Fever and its Use in the Planning and Evaluation of Antityphoid Immunization and Sanitation Programmes

Cost effectiveness and cost-benefit aspects of preventive measures against communicable diseases

Bull. Org. mond. Santé
Bull. Wld Hlth Org. } 1971, **45**, 53-75

Epidemiological Model of Typhoid Fever and its Use in the Planning and Evaluation of Antityphoid Immunization and Sanitation Programmes*

B. CVJETANOVIĆ,[1] B. GRAB [2] & K. UEMURA [2]

An epidemiological model has been constructed for typhoid fever in a stable population in order to study the transmission of infection at different levels of endemicity. It involves a number of parameters representing the proportions of epidemiological subgroups in the population—such as the susceptible, the infected, and the immune—and rates of transition between the groups. Numerical values based on available evidence were assigned to the parameters, to provide a realistic simulation of stable endemicity.

Changes were then introduced in the values of some of the parameters in order to study the consequences of mass vaccination and improvements in general health conditions and sanitation, in particular on the incidence of disease.

The model shows that a single mass vaccination reduces the incidence of disease considerably, but the gain is largely lost after a few years. Repeated vaccinations at 5-year intervals will produce further decreases in incidence, though the additional gain becomes smaller at each consecutive vaccination.

The model was also used to estimate the possible effect of improvements in sanitation. The incidence decreases to a new level of stability when the transmission of the infection is reduced because of improved sanitation. The effect of sanitation is long-lasting and in this respect gives better results than vaccination.

The simultaneous application of mass vaccination and sanitation gives a cumulative effect, which in some cases tends to be close to the effect of sanitation alone.

The model was used to forecast the probable effect of preventive measures against typhoid fever, such as mass immunization and sanitation programmes, on a selected population in terms of prevention of disease, as well as in terms of relative costs and benefits. It provides a useful guide for the rational use of funds and the facilities to be set aside for typhoid fever control purposes.

Other possible uses of the model are briefly discussed.

The need to adjust the model in relation to specific conditions in the community is stressed, as is the need to readjust it to take into account changes in the pattern of life and the natural history of typhoid fever.

Typhoid fever is a public health problem primarily in endemic areas; accordingly, we have studied mathematical models for this disease in relation to endemic conditions.

The model has been constructed with a view to its possible use for forecasting trends of the natural course of infection and the effect of preventive measures—vaccination and sanitation—on such trends. For the sake of simplicity, stable endemic situations were taken as a basis for the model.

* Part of this paper was presented at the Eighth International Congresses on Tropical Medicine and Malaria, Teheran, September 1968. Manuscript received for publication 27 November 1970.

[1] Division of Communicable Diseases, World Health Organization, Geneva, Switzerland.

[2] Division of Health Statistics, World Health Organization, Geneva, Switzerland.

The effectiveness of antityphoid vaccines has been evaluated (Cvjetanović & Uemura, 1965) in controlled field trials in endemic areas. The degree of protection conferred by various vaccines, and methods of production and testing, have been established (WHO Expert Committee on Biological Standardization, 1967), as well as immunization schemes and dosages (Yugoslav Typhoid Commission, 1964; Typhoid Panel, United Kingdom Department of Technical Co-operation, 1964; Hejfec et al., 1966; Cvjetanović & Tapa, unpublished data).

The effect of sanitation has been demonstrated (WHO Expert Committee on Enteric Infections, 1964), although the available information does not give a clear idea of the exact quantitative effectiveness of each particular component of environmental sanitation.

We therefore believe that the essential information is available for the construction of the model, in spite of certain inadequacies that make it difficult to determine exactly each specific factor and parameter in the model. For example, the effect of mass immunization cannot be expressed in simple equations that take into account only the protective effect of the vaccine and the numbers of people immunized and not immunized. There are other factors that influence the outcome of vaccination programmes—e.g., the sources of infection and routes of transmission, the size of the challenge dose, and the degree of exposure of the population. Furthermore, transmission from the known sources of infection, sick persons or carriers, to other people depends on various characteristics of the population such as state of immunity, food habits, occupation, customs, and personal hygiene.

Environmental sanitation, like immunization, has a considerable effect on the control of typhoid fever. However, many factors, such as level of education and economic status, play a role, and make the effect of specific sanitation measures much more difficult to determine than that of immunization programmes. All these factors should be taken into consideration in constructing and, in particular, in applying mathematical models to specific population groups.

It is hoped that the mathematical model will be used for determining the probable results and relative benefits and costs of mass immunization and sanitation programmes. An attempt has therefore been made to construct a simple model that will enable health workers to plan and apply an effective typhoid fever control programme within the limits of their financial means and available facilities and resources.

BASIC EPIDEMIOLOGICAL FACTORS

For the construction of any mathematical model, it is necessary to establish some basic epidemiological factors and parameters as a point of departure.

Natural history of typhoid fever

The natural history of typhoid fever is known and will not be described here except in so far as it concerns the construction of the model. Data on the natural history of the disease used in the construction of the model—i.e., incubation period, duration of illness, and relapse, morbidity, fatality, carrier, and other rates—were compiled from numerous studies in different countries. It was realized that the data obtained in one study frequently differ from the results of other studies. This is sometimes the result of differences in methods of investigation, laboratory techniques, and procedures of data collection and analysis, as well as of different environmental and other conditions. For the construction of the model, it was necessary to take some definite parameters as a starting-point.

Some of the prevailing opinions concerning these parameters (American Public Health Association, 1965) were critically appraised. Many of the parameters varied considerably, and it was necessary to come to some arbitrary compromises in order to arrive at definite numerical values to be used for the construction of the model.

Some of the basic values that were used are presented below:

Incubation period: range, 7–21 days; mean, 14 days
Duration of sickness: range, 14–35 days; mean, 28 days
Duration of relapse: range, 7–28 days; mean, 18 days
Frequency of relapses: 5% of cases
Proportion of cases: symptomatic (typical, febrile), 20%; asymptomatic (and mild), 80%
Case fatality rate: 1–10%; average, 3%
Carrier rate: chronic—range, 2–5%; average, 3%: temporary (mean duration, 90 days)—range, 7–20%; average, 10%
Incidence in endemic areas: 10–150 per 10 000 population

Infection was considered in the light of the complex host–parasite–environment relationships, and, as far as possible, from the quantitative point of view.

The host factor—number and immune status—was taken into account in constructing the model as this factor largely determines actual morbidity rates and levels of endemicity.

In some studies, a relationship has been demonstrated between age, sex, and socio-economic status and the typhoid morbidity rate; young age groups, females, and poor people being the most affected, while women, in particular, tended to be carriers for a longer period and were more difficult to cure. These and possibly other factors might be important in specific population groups but we have, for the sake of simplicity, omitted them in the construction of this model.

The parasite factor was also considered from the quantitative point of view and therefore the simple presence or absence of *Salmonella typhi* was not the only criterion for determining the risk of infection. The techniques used in some studies showed that carriers excrete regularly, rather than intermittently, a large and fairly constant number of organisms (Merselis et al., 1964). It seems that persons living under poor hygienic conditions in the vicinity of carriers are at high risk and frequently contract the disease.

Studies carried out on healthy volunteers (Hornick & Woodward, 1967) have shown that the ID_{50} is about 10^6–10^7 organisms, and that the ID_{25} is about 10^4 organisms. However, people in natural conditions are usually infected with a lower dose (Cvjetanović, 1957; Hornick & Woodward, 1967). In most of the communities with endemic typhoid, the micro-organisms are spread widely by carriers and by convalescent and sick persons. Accordingly, infection may under favourable conditions be easily transmitted through contaminated food and water or on the hands. Infected persons and carriers are often found accidentally and *Salmonella* may be detected in the blood stream of apparently healthy persons (Watson, 1967). We have therefore considered that the parasite is more widely present than might be assumed from the incidence of clinical illness.

The morbidity rates in communities with different levels of endemicity of typhoid fever were determined from the available national statistical returns, but these data were critically appraised in the light of the many studies that have revealed much more infection than was indicated in health statistics reports.

For example, among 40 students in an army school stricken by a typhoid epidemic, 15 had *Salmonella typhi* in their faeces and/or blood, but only 2 had a febrile illness: 2 more had been subfebrile and in routine clinical and public health practice would never have been diagnosed as typhoid cases (*Vojna Epidemiologija*, 1966). The typical clinical illness, we believe, occurs in only a small proportion (perhaps 20%) of those infected.

While many studies have revealed that the rate of temporary and chronic carriers after an illness varies, it is usually about 10% for the former and about 3% for the latter (Ames & Robbins, 1943; Vogelsang & Bøe, 1948). However, in the older age groups the chronic carrier rate has been as high as 10% (Ames & Robbins, 1943), or even higher among those having typhoid concurrently with other conditions such as schistosomiasis (Saad El-Din Hathout et al., 1966) and cholelithiasis (Tynes & Utz, 1962).

There are other factors that must be taken into account when constructing mathematical models. For instance, superimposed infections may change greatly the susceptibility and resistance of the host, and thus alter the natural history of the disease. Studies in Egypt (Saad El-Din Hathout et al., 1966) have shown that the carrier rate or the rate of urinary excretors of *S. typhi* among people infected with schistosomiasis is much higher, and the carrier state lasts longer, than among otherwise healthy people. Moreover, the presence of urinary carriers in rural areas with much stagnant water and poor sanitation leads to extensive environmental contamination and to a high risk of infection. This fact has to be taken into account when our model is adapted for use in areas where schistosomiasis is a common disease.

The environment undoubtedly plays a role in the natural history of typhoid fever and it should not be neglected, since the risk of transmission of infection depends greatly on environmental conditions.

There may be a greater risk of infection in certain specific population groups—e.g., nurses and school-children—owing to the environmental conditions to which they are exposed.

The transmission of typhoid fever varies under different climatic, socio-economic, and cultural conditions and determines, to a great extent, the level of endemicity and morbidity rates. The rapid decline of typhoid fever in the USA during the last few decades is primarily the result of rapid changes in environmental conditions and standards of personal hygiene (National Communicable Disease Center, 1967). We have taken these environmental factors into account in the construction of our model, and have considered them to be the most important

and decisive factors determining the actual level of endemicity in a community.

Effectiveness of vaccines and mass immunization

The effectiveness of vaccines was calculated from the data obtained in various controlled field trials (Cvjetanović & Uemura, 1965). The degree of effective protection conferred by the vaccine was taken as being equal to that conferred by the most effective vaccines in the controlled trials. These were the acetone-dried and heat–phenol vaccines given in two doses; however, in endemic areas, similar results could be expected with only one dose (Typhoid Panel, United Kingdom Department of Technical Co-operation, 1964; Cvjetanović & Tapa, unpublished data).

In view of the field experience, it was considered that booster doses of an effective vaccine should be given about every 5 years, and this was applied in the model. For reasons of simplicity, these factors were applied to a homogeneous population.

In constructing the model, we did not make adjustments for differences in the risk of infection and consequently in the expected morbidity rates between various population groups, including differences between those who did and those who did not volunteer to be immunized. It has been observed that, for various reasons, volunteers contract disease less readily and less often than those who do not volunteer for vaccination. In one controlled field trial, the typhoid morbidity rate among volunteers belonging to the control group and receiving placebo was 13 per 1 000, while in non-volunteers in the same community it was 26 per 1 000 (Yugoslav Typhoid Commission, 1964). The ratio was thus 1 : 2. In the same study, the difference in morbidity rates between volunteers and non-volunteers was especially great among populations exposed to a heavy challenge dose in a water-borne outbreak, the morbidity rates being in the ratio of 1 : 11. This important fact should not be neglected as the immunization of a volunteering population tends to give results far below those that would be expected from the application of simple arithmetic.

For the above reasons, the " theoretical " effectiveness of typhoid vaccine, as determined in controlled field trials, differs from the " use " effectiveness in mass immunization campaigns. We have taken this into account and have made adjustments on the grounds of field experience (Yugoslav Typhoid Commission, 1964; Cvjetanović, 1957) to compensate for the differences in vaccine effectiveness in the volunteers and the non-volunteers.

There are other possible reasons why the impact of immunization on the natural course of infection in the community may not in fact follow the straightforward calculations based on effectiveness determined in controlled field trials and expressed as a percentage reduction of the incidence rates. The possibility that vaccine is less effective for the prevention of inapparent infection and its spread than for the prevention of clinical illness has not been fully evaluated in any field trial and we still lack reliable information. We did not try to speculate or to make adjustments in our model to take this into account but this may become necessary if further research brings forth more clear-cut information.

Effectiveness of sanitation

Environmental sanitation—primarily the disposal of excreta, but also water chlorination, food control, etc.—when introduced and practised regularly considerably lowers the level of transmission of infection. The transmission rate or force of infectic could easily be reduced to half its former level by the construction of privies and the provision of sufficient safe water (Schliessman et al., 1958; Wolff & van Zijl, 1969). Environmental sanitation appears to be the determining factor in the transmission of infection.

For the purpose of the model, the introduction of a specific sanitation programme could be considered simply as changing the force of infection. The construction of latrines would result in a diminished rate of transmission of infection from carriers—e.g., to 50% of its original value—which is supported by field observations.

Sanitation campaigns that are not followed by sustained efforts to maintain adequate sanitary practices may produce only temporary results. However, when sanitation is introduced together with health education and improvement of living standards, the effects tend to be cumulative, resulting in steady reduction of typhoid morbidity rates owing to the decline in the force of transmission of infection.

CONSTRUCTION OF THE MODEL FOR TYPHOID FEVER ENDEMICITY

Structure of the model

The general population was divided into subgroups identifiable in the natural course of typhoid fever. The natural history and epidemiological evolution of the infection in the population depends essentially

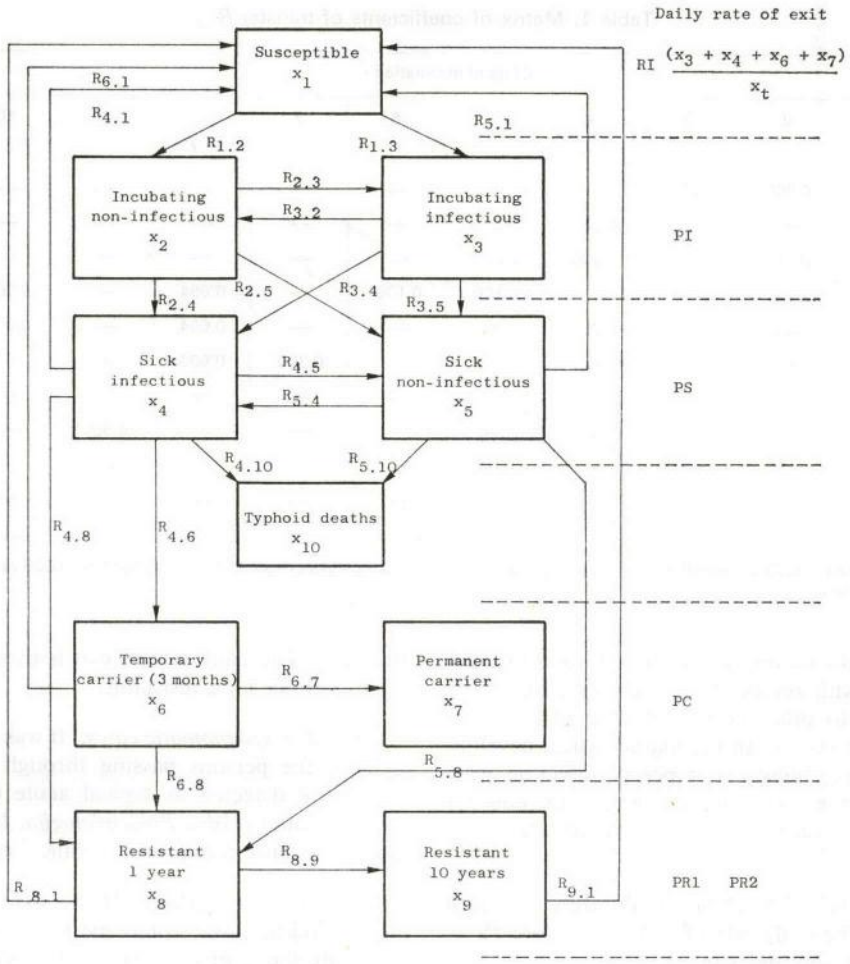

Fig. 1. Flow chart for epidemiological model of the natural course of typhoid fever.

on changes in the various classes of individuals over a period of time. The structure and the class symbols adopted to simulate the dynamics of typhoid fever in the population [1] are illustrated in the flow chart (Fig. 1).

It is not easy to estimate the numerous rates of transition directly from available quantitative evidence. It was found more convenient to consider the rate of transition as the product of the rate of change from one stage of the disease to the other stages (or rate of exit) by a coefficient of transfer, which would represent the relative size of the class moving to any other subgroup.

Epidemiological parameters and daily rates of change

The epidemiological parameters involved in the present model are specified below. The numerical values of the corresponding daily rates of change are also indicated. They should, however, be considered as possible values only. Other simulations of typhoid fever dynamics could easily be worked out with different levels for these quantities.

An infected person may or may not become sick. In the present model it was assumed that the same

[1] The movement of births and deaths due to causes other than typhoid fever is not shown in the flow chart but was taken into consideration in the mathematical expression of the model.

Table 1. Matrix of coefficients of transfer $R_{i,j}$

Class of origin i	Class of destination j										Total
	1	2	3	4	5	6	7	8	9	10	
1	—	0.990	0.010	—	—	—	—	—	—	—	1.000
2	—	—	0.040	0.950	0.010	—	—	—	—	—	1.000
3	—	0.010	—	0.900	0.090	—	—	—	—	—	1.000
4	0.100	—	—	—	0.100	0.100	—	0.694	—	0.006[a]	1.000
5	0.100	—	—	0.200	—	—	—	0.694	—	0.006[a]	1.000
6	0.100	—	—	—	—	—	0.300	0.600	—	—	1.000
7	—	—	—	—	—	—	—	—	—	—	0.000
8	0.100	—	—	—	—	—	—	—	0.900	—	1.000
9	1.000	—	—	—	—	—	—	—	—	—	1.000
10	—	—	—	—	—	—	—	—	—	—	0.000

[a] Fatality rate is 0.03 of clinical cases. Assuming that 0.20 of classes x_4 and x_5 develop clinical symptoms, 0.006 of these classes are ransferred to class x_{10}.

dynamics of disease apply equally well to both types of infection with respect to the ability to transmit the infection to other persons and to maintain or lose resistance status. In the mathematical development, therefore, these two types of infection were treated, as far as possible, as one group, and for convenience the term " sickness " is used below also for asymptomatic infections.

Period of incubation. The mean duration was fixed at 14 days. The daily rate of exit is therefore $PI = 0.07143$ per person under incubation.

Period of sickness. The mean duration was fixed at 28 days for both symptomatic and asymptomatic cases. In addition, it was assumed that 5% of affected persons would relapse for a mean period of 18 days. Hence the mean duration of the sickness period is $0.95 \times 28 + 0.05\ (28 + 18) = 28.9$ days per case. The daily rate of exit is therefore $PS = 0.03460$ per case.

Temporary carriers. The mean duration was fixed at 90 days. The daily rate of exit is therefore $PC = 0.01111$ per temporary carrier. The permanent carrier can exit only by death.

Resistants. The mean duration of short resistance was fixed at one year (365 days). The daily rate of exit is therefore $PR_1 = 0.002740$ per short resistant. The mean duration of long resistance was fixed at 10 years. The daily rate of exit is therefore $PR_2 = 0.0002740$ per long resistant.

Clinical or symptomatic cases. It was assumed that 20% of the persons passing through the sickness period are detected as typical acute clinical cases (symptomatic) (*Vojna Epidemiologija*, 1966). In this study, incidence rate refers to clinical cases only.

Mortality from typhoid. It was assumed that 3% of the clinical cases would die from typhoid fever. Therefore 0.6% of the daily exit of persons in the sickness period was allocated to typhoid deaths.

Natality and general mortality. For simplicity, a stable population was used in the model.[1] The annual birth rate and crude death rate (all causes) were both fixed at the same level of 20 per thousand. The daily rates are therefore $PB = PD = 0.0000548$ per person in the community.

Force of infection. The risk of transfer of infection to a susceptible individual is proportional to the proportion of infectious persons in the population and to a factor (RI) that is an expression of the force of infection. This factor is the resultant of the mean values of several parameters: frequency of contact,

[1] An actual example of a growing population is treated in the section entitled " Use of the model for the planning of preventive measures ".

effective challenge dose, degree of susceptibility, etc.

In the present study, the factor *RI* will be considered as the main variable determining the pattern of the epidemiological characteristics of the population. Four different values of *RI* were successively entered in the model: 0.0018, 0.0020, 0.0025, and 0.0040 per susceptible and per infectious person per day.

Infectiousness. The infectious persons are: a small fraction of the persons incubating the disease, the majority of the sick, and all the carriers. The relative importance of each class was fixed as indicated in the matrix of coefficients of transfer (Table 1). The intensity of infectiousness was supposed to be constant for all persons in these classes.

Coefficients of transfer

All transfers from one epidemiological subgroup to another are represented in the flow chart (Fig. 1) by a set of coefficients $R_{i,j}$, which express at each stage of the disease the fraction of individuals transferred from class i to class j, out of all the individuals leaving class i.

The numerical values of the coefficients of transfer $R_{i,j}$ were derived from available epidemiological evidence (see Table 1).

It is recognized that many of these coefficients can vary over a wide range and that for some of them the range of variation is not even known. It would not, however, be difficult to simulate typhoid fever dynamics with other values for the coefficients of transfer.

Mathematical model

The mathematical relationship between the 10 classes of individuals defined in Fig. 1 is expressed in the following system of 10 equations, where the differentials dx_i are in fact finite daily increments, as all the rates were calculated on a daily basis:

$$dx_1 = -(x_3 + x_4 + x_6 + x_7)(x_1/x_t)RI + (x_4R_{4.1} + x_5R_{5.1})PS + x_6R_{6.1}PC + x_8R_{8.1}PR_1 + x_9R_{9.1}PR_2 + x_tPB - x_1(PD - dx_{10}/x_t)$$

$$dx_2 = R_{1.2}(x_3 + x_4 + x_6 + x_7)(x_1/x_t)RI + x_3R_{3.2}PI - x_2(PI + PD - dx_{10}/x_t)$$

$$dx_3 = R_{1.3}(x_3 + x_4 + x_6 + x_7)(x_1/x_t)RI + x_2R_{2.3}PI - x_3(PI + PD - dx_{10}/x_t)$$

$$dx_4 = (x_2R_{2.4} + x_3R_{3.4})PI + x_5R_{5.4}PS - x_4(PS + PD - dx_{10}/x_t)$$

$$dx_5 = (x_2R_{2.5} + x_3R_{3.5})PI + x_4R_{4.5}PS - x_5(PS + PD - dx_{10}/x_t)$$

$$dx_6 = x_4R_{4.6}PS - x_6(PC + PD - dx_{10}/x_t)$$

$$dx_7 = x_6R_{6.7}PC - x_7(PD - dx_{10}/x_t)$$

$$dx_8 = (x_4R_{4.8} + x_5R_{5.8})PS + x_6R_{6.8}PC - x_8(PR_1 + PD - dx_{10}/x_t)$$

$$dx_9 = x_8R_{8.9}PR_1 - x_9(PR_2 + PD - dx_{10}/x_t)$$

$$dx_{10} = (x_4R_{4.10} + x_5R_{5.10})PS$$

where $x_t = \sum_{1}^{9} x_i$

The annual number of cases is given by the formula:

$$\Sigma(x_2(R_{2.4} + R_{2.5}) + x_3(R_{3.4} + R_{3.5}))0.2\ PI$$

where the summation Σ is done over 365 days.

The annual number of typhoid fever deaths is simply given by the sum of dx_{10} over 365 days.

The above set of equations would constitute a system of differential equations if the daily rates were replaced by instantaneous rates of change. However, it was suspected that such a system could not be solved analytically with all mathematical rigour. On the other hand, the daily changes of the classes x_i are extremely small and can be calculated at high speed on the electronic computer. It was therefore decided to apply this technique in the simulation of typhoid fever dynamics.

In order to facilitate their interpretation, the numerical results of computer simulations actually produced will be presented here mainly in graphical form.

Table 2. Stable percentage distribution in population classes for different levels of force of infection (*RI*). Birth rate and crude death rate are both equal to 20 per thousand population

Population class	Daily force of infection (*RI*)			
	0.0018	0.0020	0.0025	0.0040
susceptible	94.5	84.9	67.3	41.7
incubating non-infectious	0.0244	0.0661	0.143	0.254
incubating infectious	0.00122	0.00331	0.00716	0.0127
sick infectious	0.0511	0.139	0.300	0.534
sick non-infectious	0.00583	0.0158	0.0342	0.0609
temporary carriers	0.0158	0.0430	0.0930	0.166
permanent carriers	0.966	2.62	5.73	10.3
short resistant	0.527	1.43	3.09	5.51
long resistant	3.96	10.7	23.3	41.5
total	100	100	100	100
annual typhoid incidence rate [a]	12.8	34.8	75.2	133.9
annual typhoid death rate [b]	4.3	11.7	25.3	45.1

[a] Per 10 000 population.
[b] Per 100 000 population.

APPLICATION OF THE MODEL TO EVALUATION OF THE EFFECT OF PREVENTIVE MEASURES

Stable endemicity

The first objective was to find the set of x_i values that would correspond to a stable endemic situation for a given value of the force of infection *RI*; it was then possible to study clearly the effect of specific preventive measures imposed upon the stable endemicity.

Several preliminary trials showed that situations corresponding to existing levels of endemicity were obtained with the following four values of the parameter *RI*: 0.0018, 0.0020, 0.0025, and 0.0040. The percentage distribution of the population in the various epidemiological classes, when the stable situation is reached,[1] are shown in Table 2 for the selected values of the force of infection.

It was found that the size of the epidemiological classes was almost linearly related to the reciprocal of the force of infection *RI*. This fact facilitated the derivation of a stable situation from another already known stable situation. It is thought that a stable level of endemicity can establish itself only if the rate *RI* remains above a certain critical value and that this value is a function of the birth and death rates. Further study in this direction might be fruitful.

Immunization

The mathematical model was then used to simulate the dynamic changes that would occur in the various epidemiological categories of the population under conditions of stable endemicity if mass immunization were carried out.

It was assumed that, by vaccination, a certain proportion of the susceptible persons was directly transferred to the short-resistant class. This proportion is measured by the efficacy of the immunization, which is itself the product of the immunization coverage and the effectiveness of the vaccine used. Ranges covering the more common values for these factors, as used for the computation of the resulting efficacy of the mass vaccination, are shown in Table 3.

The effects of different typical levels of efficacy of mass vaccination are analysed in the present study.

[1] The mathematical problem consists of finding the set of values of x_i that simultaneously render null all the dx_i. Asymptotic solutions were obtained with the computer by successive trials covering long periods.

Table 3. Efficacy of vaccination against typhoid fever for various combinations of population coverage vaccine effectiveness

Population coverage	Effectiveness of vaccine		
	0.60	0.75	0.90
0.60	0.36	0.45	0.54
0.80	0.48	0.60	0.72
1.00	0.60	0.75	0.90

Single mass immunization. The effects of a single mass immunization on the annual incidence rate of typhoid fever as well as on the various epidemiological categories are shown in Fig. 2 for the two extreme levels of vaccination efficacy (36% and 90%). Separate graphs were drawn for each of the four levels of endemicity stability (see Table 2).

It is clearly seen that the sudden transfer of a certain proportion of susceptible persons to the resistant class has an immediate effect on the incidence rate (per 10 000 population), the importance of the decrease being, of course, directly related to the efficacy of the mass immunization. It is, however, observed that after this spectacular drop the incidence rapidly rises and that, depending on the initial level of endemicity, between 50% and 90% of the gain is lost 10 years later. The speed of the loss is then considerably reduced and the curve tends slowly to the initial stability level. This fact is believed to be a consequence of the delayed repercussion of the mass vaccination on the carriers (see Fig. 2).

Periodic mass immunization. The results of seven successive mass immunizations carried out at intervals of 5 years are illustrated in Fig. 3 for the situation characterized by a low endemicity level ($RI = 0.0018$) and a medium level of vaccination efficacy (60%).[1]

Repeated vaccinations largely compensate for the rapid loss in the benefit observed on the incidence curve after each immunization, but it is noted that the additional gain decreases at each subsequent inoculation. Nevertheless, the long-term level, which is established when the vaccination programme is interrupted, is considerably affected by the number of successive vaccinations carried out. In the example illustrated in Fig. 3, the long-term gain on the incidence curve is, after seven inoculations, at least four times as large as after only one immunization.

It is also interesting to observe the effect of periodic vaccinations on the carriers. Slight decreases occur after successive vaccinations, but the movement is less and less accentuated, and after the last immunization the curve sometimes shows a definite tendency to the re-establishment of the original level.

Improvements in sanitation

Any improvement in sanitation—mainly the disposal of excreta, but possibly also the provision of safe water, the adoption of hygienic habits, etc.—would result in a decrease in the risk of infection, as measured in this model by the force of infection RI (Fig. 4).

The shift in time of the size of each epidemiological subgroup x_i from one stability level to another was simulated with the model.

The thick lines of Fig. 4 show the pattern of change of the annual incidence rate (per 10 000 population), and of the percentages of carriers and of susceptible and resistant persons, on the assumption that a high force of infection ($RI = 0.0040$) is suddenly reduced, at the fifth year, to a lower level ($RI = 0.0020$) as a consequence of the reduction in the risk of transmission.

As seen in Fig. 4, the size of the various epidemiological classes will ultimately pass from the initial stability level to the new, more favourable, level of endemicity.

The 50% reduction in the force of infection causes an immediate decrease in the annual incidence rate to about 50% of its original level, followed by a temporary increase, most probably as a result of the slower decrease in the reservoir of infection (see the trend of the percentage of carriers in Fig. 4). A long-term decrease is then observed, bringing the incidence rate asymptotically to its new stability level.

Combined effect of immunization and sanitation

Fig. 4 also shows the additional gain on the incidence of the disease that can be expected from combined mass immunization and sanitation programmes with either single immunization or periodic vaccinations at 5-year intervals. For the present illustration, the degree of immunization efficacy was fixed at the medium value of 60% and the degree of efficacy of sanitation at a value of force of infection

[1] Computer runs were also produced for other levels of these parameters but are not reported here.

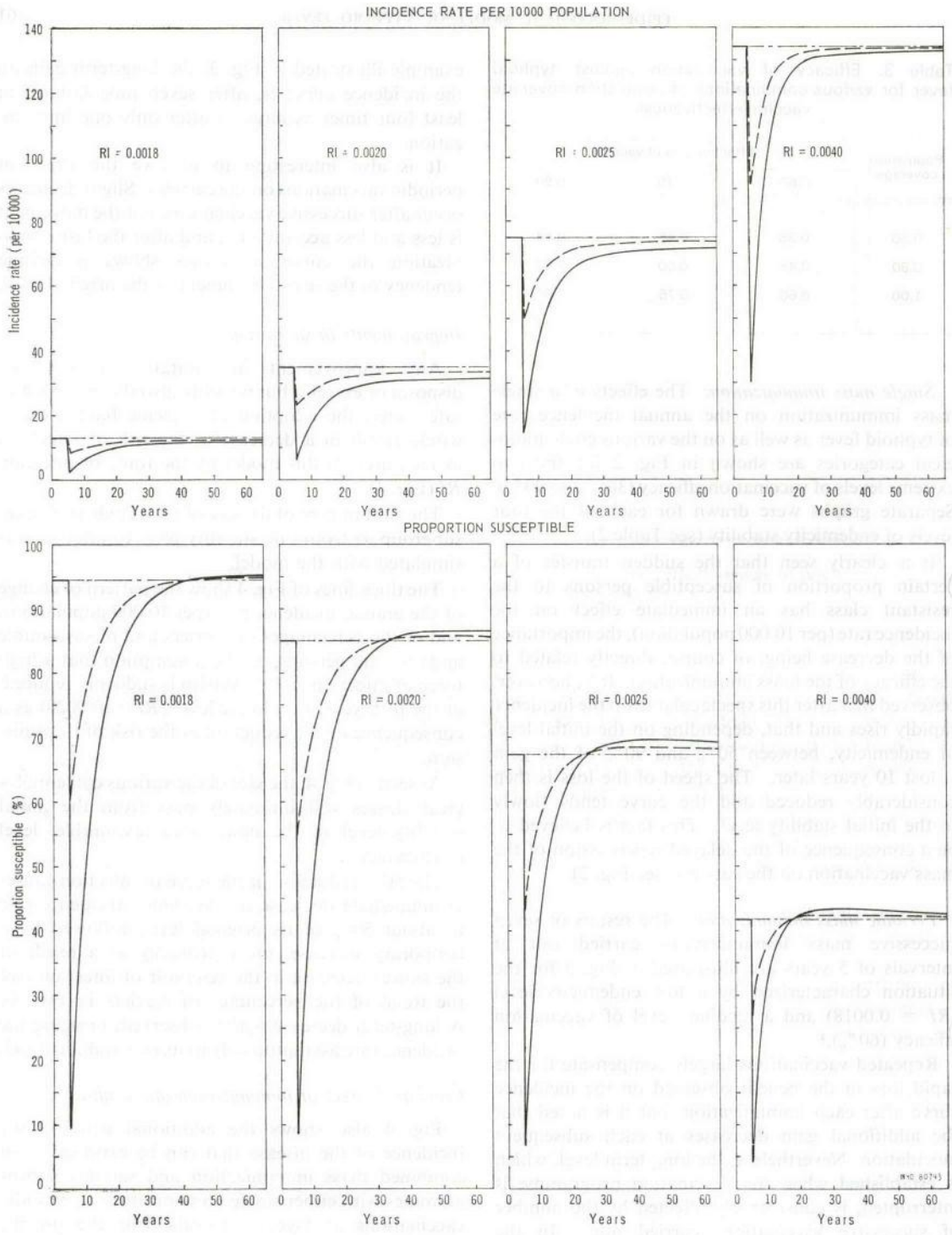

Fig. 2. Effect of a single mass vaccination on the dynamics of typhoid fever at different levels of endemicity and efficacy of vaccination: horizontal broken line—stability level; solid curve—efficacy of vaccination 90 %; dashed curve—efficacy of vaccination 36 %.

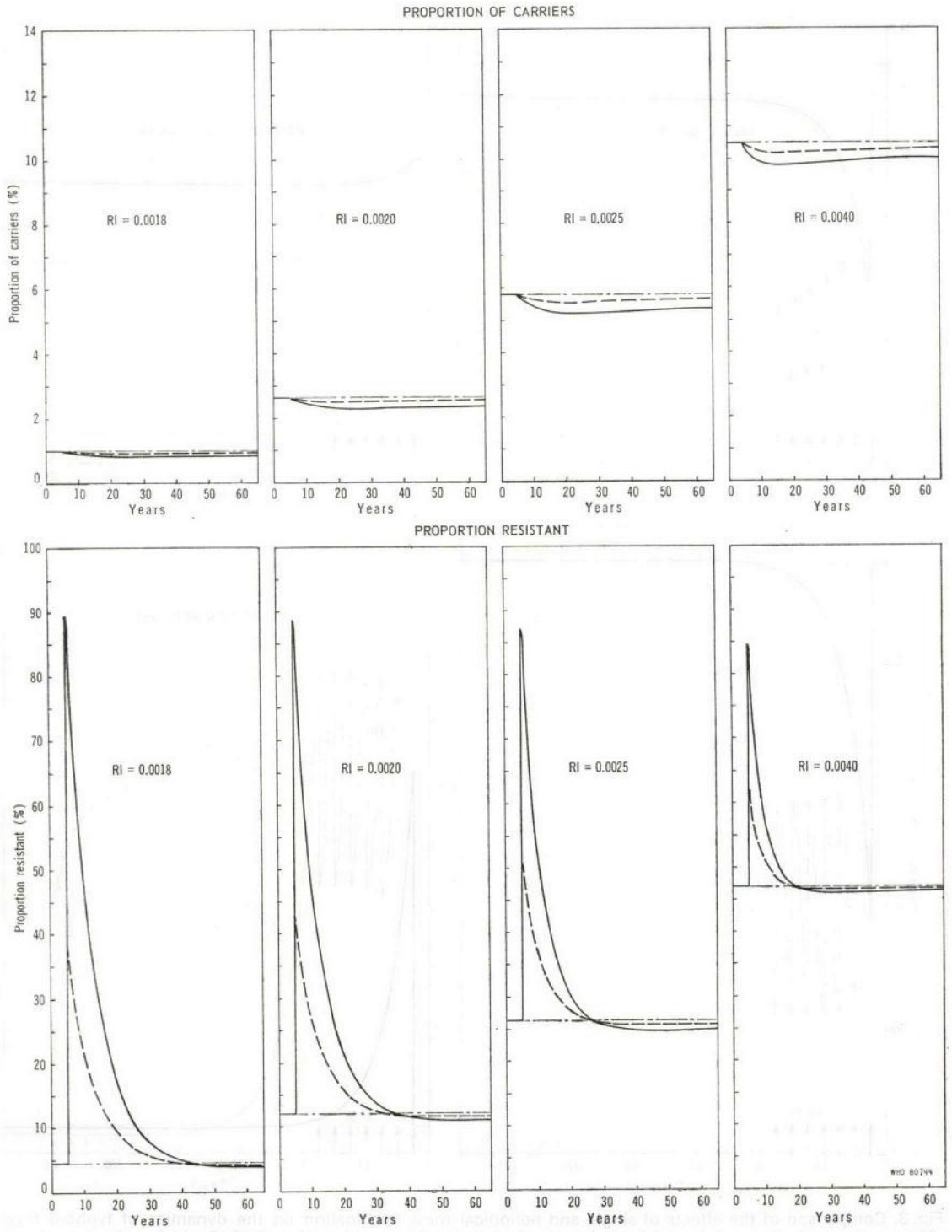

Fig. 2 (*concluded*)

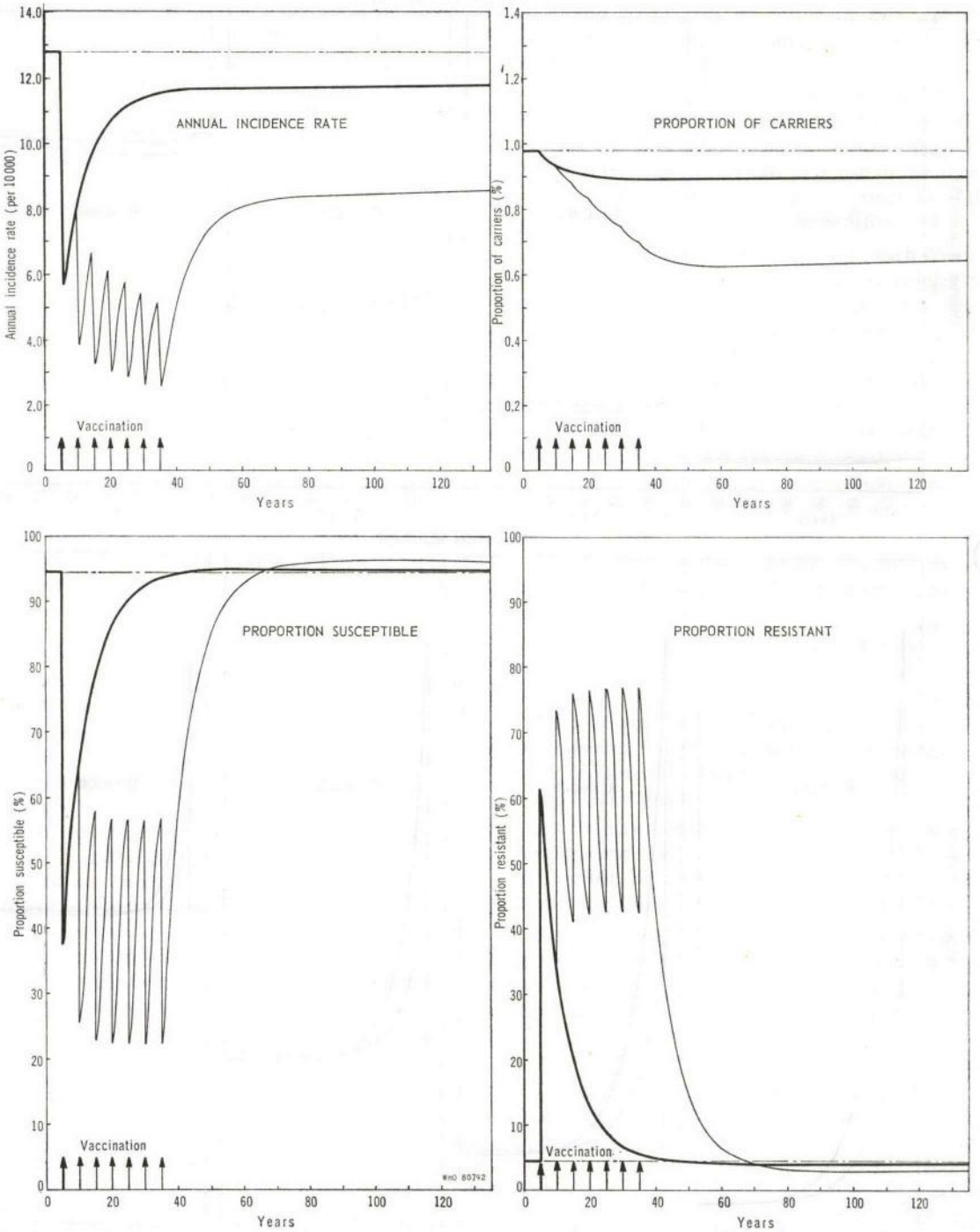

Fig. 3. Comparison of the effects of single and periodical mass vaccination on the dynamics of typhoid fever; efficacy of vaccination, 60 %: horizontal broken line—stability level for RI = 0.0018; thick solid line—1 vaccination; thin solid line—7 periodic vaccinations.

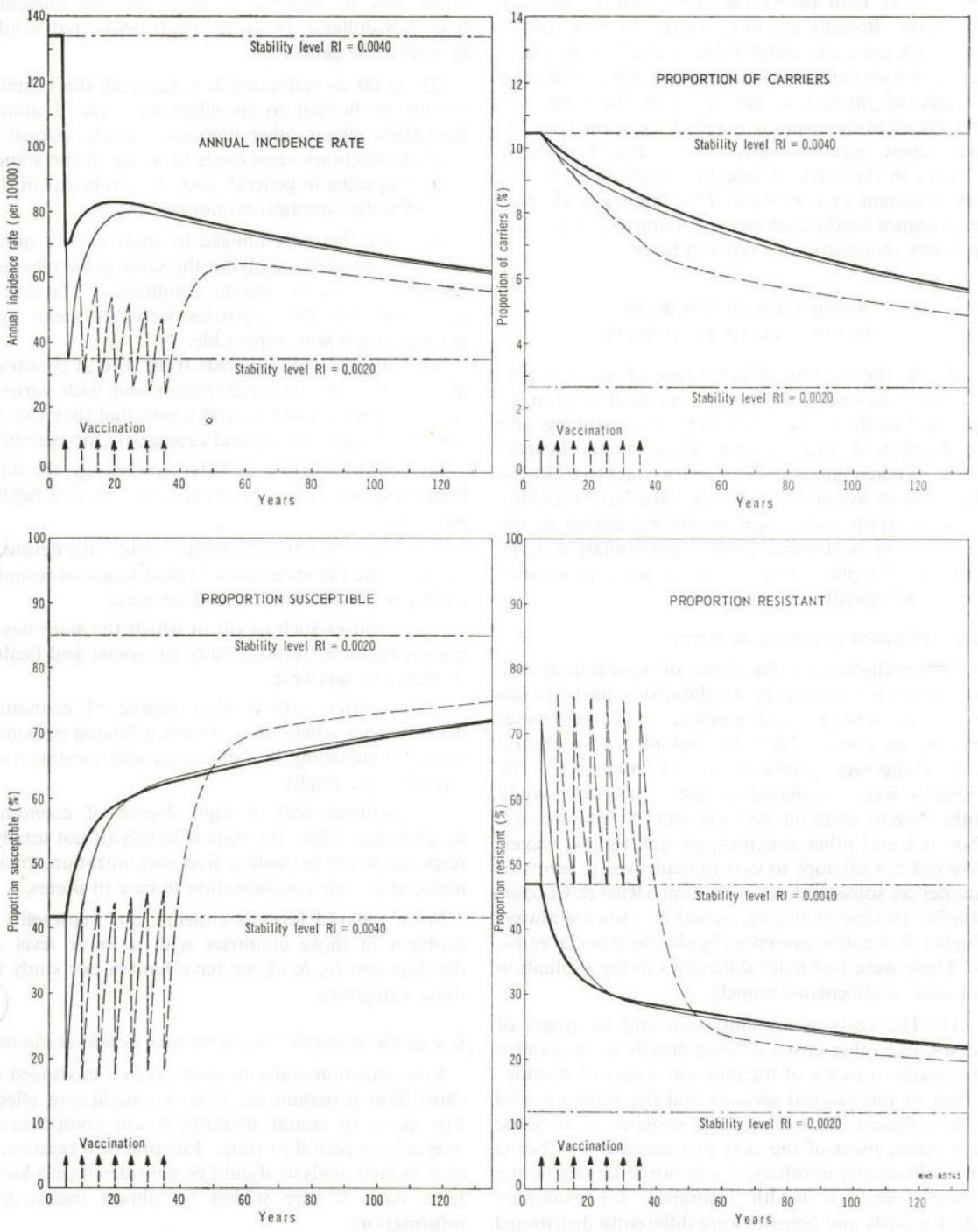

Fig. 4. Effect of a change in the force of infection on the dynamics of typhoid fever with or without mass vaccination: thick solid line—no vaccination; thin solid line—1 vaccination; broken line—7 periodic vaccinations.

50% lower than before the application of sanitary measures. Broadly speaking, the results of combined measures are quite comparable in the long run with those of improvements in sanitation alone. The main feature of interest is perhaps that the long-term benefit of immunization is largely governed by the permanent gain resulting from the favourable change in the force of infection resulting from the improvement of sanitation. This finding is of great importance for the long-term planning of control and, possibly, eradication of typhoid fever.

APPLICATION OF THE MODEL IN COST–BENEFIT EVALUATION

While the relative effectiveness of various preventive measures is of great practical interest to public health workers for both the planning and application of such measures, the costs and benefits must be taken into consideration in order to make the best use of available resources. We have therefore tried to apply our model to the evaluation of the relative merits of immunization and sanitation in the control of typhoid fever from the point of view of costs and benefits.

Determination of costs and benefits

Determination of the costs of vaccination and sanitation is not difficult. To the cost of the materials (vaccines, syringes, and needles; or latrines, water mains, etc.) was added the cost of transportation and manpower (professional and auxiliary). The benefits were calculated as the funds that would otherwise be spent on the treatment of typhoid cases, hospital and other expenses, as well as lost wages. We did not attempt to cost human lives in terms of money as some authors have done (Rice & Cooper, 1967). In view of this the actual benefits are always higher than can be presented by simple financial gains.

There were two main difficulties in the evaluation of costs and benefits, namely:

(1) The costs of immunization and treatment of cases, like other costs, differed greatly from country to country in view of the different stages of development of the medical services and the economy and the different socio-economic systems. In some countries, most of the cost of treatment was borne by individuals; in others, it was borne largely by the state (social or health insurance, for example). As the costs and benefits were differently distributed between individuals and state services, it was impossible to find a common international denominator and to express, in terms of one currency (e.g., US dollars) the costs and benefits that would be applicable generally.

(2) So far as sanitation is concerned, the benefits cannot be limited to its effect on typhoid alone. Sanitation affects other illnesses—enteric, parasitic, or skin infections—and leads to a rise in the standards of hygiene in general, and also brings (as in the case of water supplies) economic benefits.

We were therefore obliged to study each country or area separately, applying the same principles but taking into account specific conditions. The differences between the countries were so great that generalization was impossible.

We collected data on costs from several countries at various levels of development and with various socio-economic systems, and found that they can be roughly divided into several categories; for example:

(*a*) countries with a subsistence economy, the state being responsible for the provision of modest health services;

(*b*) countries with intermediate economic develo, ment, where the state has a limited financial responsibility for health matters and services;

(*c*) countries such as (*b*) in which the state has a greater financial responsibility for social and health matters and services;

(*d*) countries with a high degree of economic development, where the state has a limited responsibility for financing immunization and treatment of typhoid; and finally

(*e*) countries with a high degree of economic development where the state is largely (if not totally) responsible for providing free immunization, treatment, and wage compensation in case of illness.

Since typhoid fever is endemic and represents a problem in those countries with a lower level of development (*a*, *b*, *c*), we have limited our study to those categories.

Use of the model for long-term cost–benefit evaluation

Immunization and sanitation, even if envisaged as short-term programmes, have a long-lasting effect. The costs of initial investment are compensated over a long period of time. For practical reasons, a cost–benefit analysis should be considered on a long-term basis if one wishes to obtain meaningful information.

In view of the fact that conditions change with time, the cost–benefit analysis must be re-examined

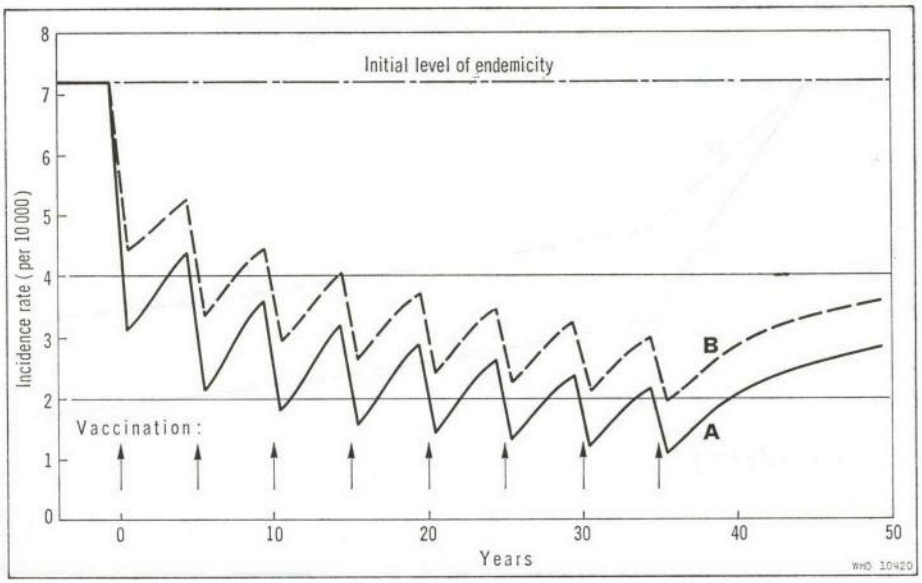

Fig. 5. Effect of eight successive mass vaccinations at five-year intervals on the annual incidence of typhoid fever. (A) = vaccination coverage, 75%; vaccine effectiveness, 80%; (B) = vaccination coverage, 50%; vaccine effectiveness, 80%.

from time to time in the light of these changes and should become a continuous process in the planning and evaluation of public health programmes.

Use of the model for the planning of preventive measures

The model can be used for the planning of preventive measures in various countries and areas only if the necessary parameters, as described above, are known and if the relevant information is collected. Some of the parameters and information may be available from existing statistical returns and others may have to be collected in special surveys or studies designed for this purpose.

Once the data are available, they can be fed into the model and into the computer to predict the trend of typhoid for years to come, assuming that no special preventive measures are taken in the meantime. The model can also be used to simulate the possible effect of the application of various immunization and/or sanitation programmes. On the grounds of costs and benefits, the merits of relevant preventive measures can be compared and those most suited to the goals envisaged and the resources available can be selected.

In order to illustrate these uses of the model with an example, we shall take actual data on the epidemiological situation in a small, typical Pacific island with an initial population of about 150 000. The annual birth rate was taken as 35 per 1 000 inhabitants, and the annual death rate as 8 per 1 000 population. The annual natural incidence of typhoid fever cases was taken at the level of 7.2 per 10 000 inhabitants. These data correspond closely to the actual situation in Western Samoa and resemble that in some other islands.

The effect of one type of vaccine in two different immunization campaigns with vaccination repeated at 5-year intervals (A = 75% coverage, B = 50% coverage) on the population of this island is presented in Fig. 5. This shows how the incidence of typhoid would decline after immunization and indicates that higher coverage of the population with the same type of vaccine would give better results. The data thus obtained could be used for cost–benefit analysis. The cost of immunization could be compared with the benefit derived from savings in the cost of treating the typhoid cases that would be prevented by immunization.

The effect of constructing privies is anticipated to produce a 50% drop in transmission owing to prevention of the spread of disease. Even if the effect of privy construction were smaller (e.g., 30%) it would still be considerable, as shown in Fig. 6, which

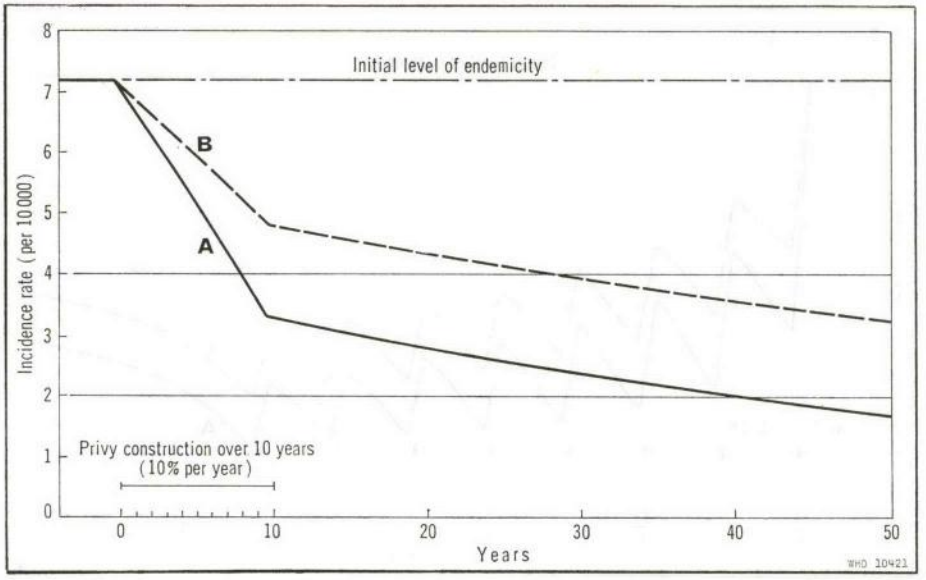

Fig. 6. Effect of privy construction on the annual incidence of typhoid fever. Effectiveness of privy construction (A) = 50 % on transmission by carriers; (B) = 30 % on transmission by carriers.

presents the effect of a sanitation programme comprising construction of privies for the whole population over a 10-year period. The effect is long-lasting and produces a continuous decline in the incidence of typhoid owing to the gradual elimination of carrier-transmitted infection.

Fig. 7 shows the effect of sanitation—namely, privy construction—on the incidence of typhoid when construction is accomplished over a period of 5 years and covers the whole population (case A). This is compared with privy construction over a 10-year period (case B). It is obvious that only a small additional long-term gain is achieved by early construction of all privies. This simulation (Fig. 7) shows, as does Fig. 6, that the endemicity level of typhoid in this community would, as a result of sanitation, begin to decline steadily and continuously. The same data can also be used for cost–benefit analysis.

Fig. 8 compares the effect of privy construction alone with the cumulative effect of vaccination and privy construction combined, taking into account possible different levels of effectiveness of vaccination and sanitation. The effect of sanitation and vaccination is obviously greater, but a tendency to return to an earlier level of endemicity is obvious after immunization, whereas sanitation produces a definite and continuous downward trend in the endemicity level. It is therefore clear that sanitation would give a more permanent effect than immunization, although vaccination alone, or combined with sanitation, might, in the short run, be more effective for the control of typhoid fever.

In the present study, the numerical application of the cost–benefit calculation will be limited to three examples of single or combined activities drawn from the situations described above.

The cost factors have been determined from actual records available for the community and fixed as follows:

The estimated average cost of immunizing one person was taken as US$ 0.20, while the treatment of a typhoid fever case, including the cost of medical and paramedical personnel (but not lost wages), was estimated at US$ 100.00.

The average cost to the government of constructing a new, satisfactory privy or making sanitary an existing privy serving an average of six persons was estimated to be US$ 3.15. This represents the cost of the services of skilled manpower to aid and supervise construction or reconstruction of the privy. Other expenses of construction (unskilled labour and material) are readily borne by the population. The total cost of construction of a new, sanitary privy

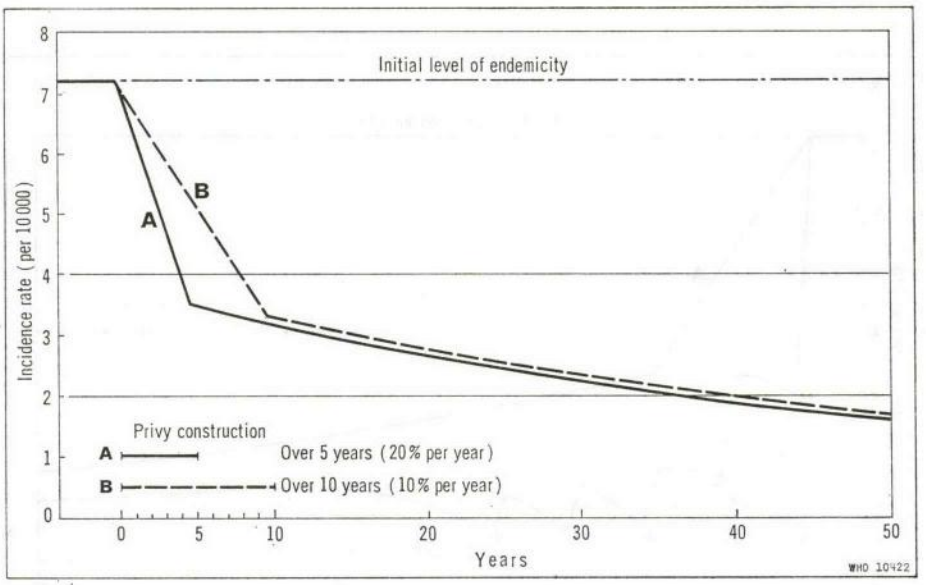

Fig. 7. Effect of rate of privy construction on the annual incidence of typhoid fever. Effectiveness of privy construction: 50 % on transmission by carriers.

excluding unskilled manpower and superstructure was estimated to be US$ 5.00. Thus the government's contribution represents over one half of the total cost of a new privy. The *per caput* cost of privy construction for the government is about $0.50 as compared with $0.20 for a single vaccination.

The costs and benefits are presented from the government's point of view, the government being fully responsible for the cost of immunization and treatment of cases, while contributing only partly to the cost of privies; the population would provide, free of charge, the necessary material and manpower for construction of the privies.

The actual computer runs are presented graphically (Fig. 9), and only final values for a 30-year period are given in Table 4.

Example of costs and benefits of vaccination campaigns. In the first graph of Fig. 9 (left), the cost of vaccination and the saving on case treatment are cumulated over time for an immunization programme corresponding to the situation illustrated in Fig. 5 (line A).[1] The cost of the first mass immunizations of 75% of the population would already be offset by savings on treatment in a 5-year period. After the third vaccination, owing to the decrease in case incidence, the difference between the cost of vaccination and the benefit on treatment is definitely positive and the balance is progressively augmented by the subsequent mass immunizations. One should not forget, however, that the incidence will slowly return to its initial level if vaccination activities are stopped.

Example of costs and benefits of privy construction. This example shows the cost of a programme for sanitation through the construction or improvement of privies. The parametric values and epidemiological effects of this programme were taken as described in Fig. 6 (line A). Furthermore, it was assumed that there was a necessity to rebuild or to make sanitary all the privies required by the population, the cost of material and manpower being borne by the population and the services of a sanitary inspector being provided by the government. The programme would cover a 10-year period and would then continue at a reduced rate to satisfy the needs of the annual population increase.

Fig. 9 (centre) shows that the savings resulting from the reduction in the number of typhoid fever

[1] That is, vaccination at five-year intervals with an 80% effective vaccine of 75% of a community affected by a typhoid endemicity level of 7.2 per 10 000, the initial size of the population being about 150 000 and the natural annual growth 2.7%.

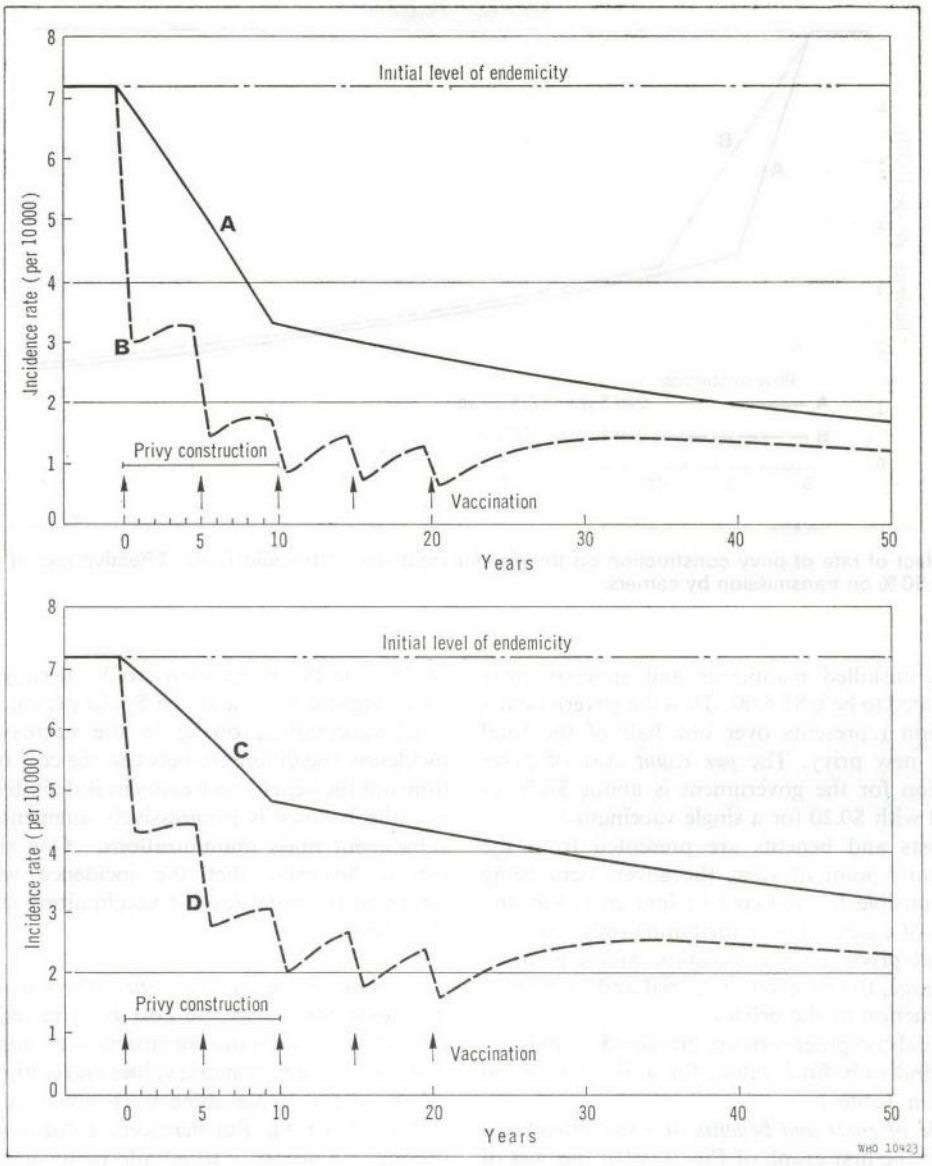

Fig. 8. Effect of privy construction and mass vaccination at different levels of effectiveness on the annual incidence of typhoid fever. (A) = privy construction only—effectiveness, 50 % on transmission by carriers; (B) = privy construction and vaccination—vaccination coverage, 75 %; effectiveness, 80 %; (C) = privy construction only—effectiveness, 30 % on transmission by carriers; and (D) = privy construction and vaccination—vaccination coverage, 50 %; effectiveness, 80 %.

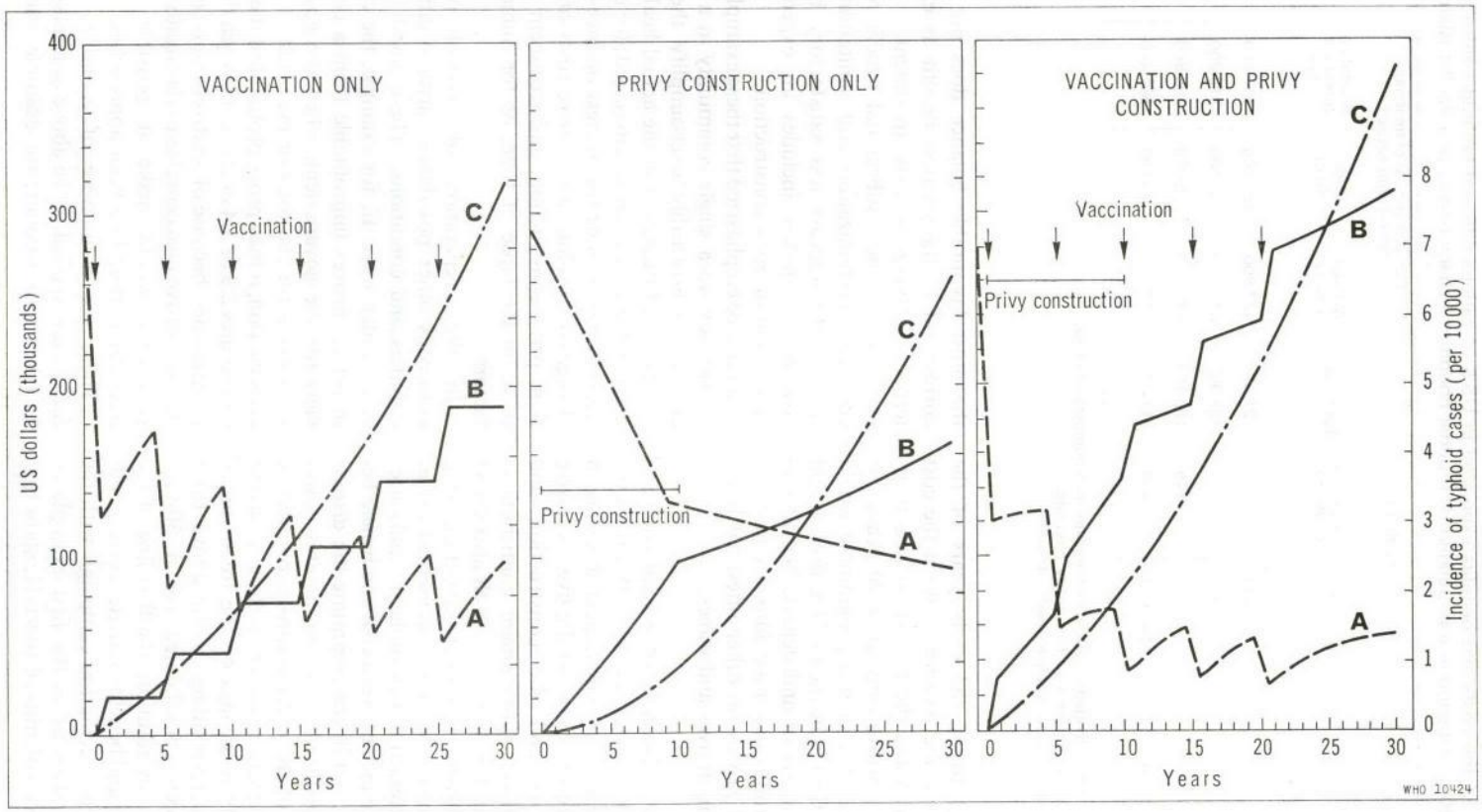

Fig. 9. Impact of different typhoid control programmes on the incidence of the disease and on the cumulative costs and benefits. (A) = incidence of typhoid cases (per 10 000 population); (B) = cumulative costs; (C) = cumulative benefits.

Table 4. Summary of the costs and benefits expressed in US $ of various different typhoid control programmes over a 30-year period in a population and under conditions characteristic of a Pacific island

Activity	Cumulative cost			Cumulative cost of treatment of typhoid cases [a]			Balance between cost and benefit
	Vaccination	Construction of privies	Total cost	Without activity	With activity	Benefit on treatment cost	
vaccination, single	21 924	—	21 924	477 900	367 300	110 600	+ 88 676
vaccination, repeated [b]	188 305	—	188 305	477 900	161 100	316 800	+ 128 495
privy construction	—	166 149	166 149	477 900	219 000	258 900	+ 92 751
vaccination [c] and privy construction	145 632	166 149	311 781	477 900	93 500	384 400	+ 72 619

[a] The values shown when divided by 100 give the respective numbers of cases.
[b] Six successive mass campaigns at five-yearly intervals.
[c] Five successive mass campaigns at five-yearly intervals.

cases grow slowly during the early years of the programme, and that the balance between the cost of privy construction and the benefit on case treatment starts to be positive only after 20 years. It should be observed that such a programme would ultimately lead to the eradication of the disease and thus provide an important and definite benefit (see Fig. 6). One should also take into account the beneficial effect of privies on other intestinal infections and the saving in lives and wages.

Example of costs and benefits of immunization and sanitation combined. The last example illustrates the impact of the combined strategy indicated for line B in Fig. 8. The cumulative cost of the five successive mass immunizations and the construction and improvement of privies (government contributions only) is presented in Fig. 9 (right), which also shows the corresponding benefits on case treatment expected from this programme. With the numerical values given to the parameters in this example, it is only after 25 years that the balance between cost and benefit begins to be positive, but in the meantime the disease would have been reduced to a considerably lower level than by any of the other control programmes.

The costs of vaccination and/or sanitation and the benefits obtained from savings on the treatment of prevented cases corresponding to the above three examples have been consolidated for a 30-year period in Table 4. In addition, the first line of the table shows the cost and benefit estimates corresponding to a single mass vaccination campaign with the same parametric values as in the first example of Fig. 9. The last two columns of this table show that the most favourable balance does not necessarily correspond to the greatest benefit as expressed in terms of saving on case treatment. In fact, as expected, the most substantial benefit results from combined immunization and sanitation, although the balance appears less satisfactory because the cost of this policy includes an expensive initial investment in privy construction.

It must be emphasized that these examples—limited by necessity to a single community in a developing country—considerably over-simplify the economic and financial treatment of the actual health problem and the strategy of control envisaged; for example, no allowance was made for interest on investments, for changes in absolute and relative costs of immunization, privy construction, and treatment that would occur in the lapse of time, or for numerous other factors.

In the preparation of control programmes numerous other possibilities arise in different communities and conditions. These could be analysed in a similar way. If, for example, the construction of privies proves unprofitable from a cost point of view for the government, when the government is responsible for the total or even half of the cost of construction, it may prove profitable if the population contributes 2/3 or 3/4 of the cost. When the proposed programmes, because of relatively high costs and low benefits, prove unacceptable to the health authorities, simulation would make it possible to explore alternative more beneficial approaches.

There are a number of economic and other factors not applied in the above examples that could be taken into account; for example, the secondary

effects of control measures against typhoid fever, such as the effect of sanitation on the control of other enteric infections and intestinal parasites, or the effect of this control on the development of tourism.

The above examples of cost–effect and cost–benefit analysis showed that in a community resembling the population of Western Samoa, immunization and sanitation would give essentially the same results for about the same cost and that in selecting the most suitable control programme both would have to be considered in the light of local conditions.

A close inspection of local conditions in Western Samoa revealed, however, that the various districts of that country differ greatly in respect of incidence of typhoid fever and availability of water (necessary for the functioning of water-sealed latrines—the only satisfactory type of privy for these islands). Moreover, it was found that the cost of vaccination against typhoid fever could be significantly reduced if this antigen were combined with other vaccines (DPT) given to children. Such combined vaccination would cover only the younger age groups, as these are the only ones to receive DPT; however, it is precisely the very young age groups that are at highest risk of typhoid fever. Furthermore, in view of the serious financial limitations, the priorities in the control programme were determined, but the final analysis and plan of action demonstrated that the programme could be carried out all over the country without any appreciable increase of the Government's budget (but with continuing international assistance at the existing level).

In some districts with a water system, sanitation alone was shown to be the best long-term proposition for controlling typhoid fever, while in other areas, where incidence was very high and running water not available, vaccination was obviously of considerable benefit for a certain period of time until a water supply system and sanitary privies could be built.

It could be argued that such planning was possible earlier even without the help of a model. While there is probably some truth in this, there is no doubt that the model made it easier to prepare a sound programme. The above plan for typhoid control at present forms a part of the national health programme.

OTHER USES OF THE MODEL

So far, the examples have shown how the model can be used to simulate the effects of preventive measures and to analyse their costs and benefits, and how it can assist in the planning and evaluation of typhoid fever control programmes.

The model has other uses, such as the prediction of future trends of typhoid fever and the requirements in material and manpower for specific control projects.

We used the model in this way by applying recent typhoid fever morbidity data from certain countries and simulating present trends. Comparing data obtained through the model with actual incidence in the countries studied, we observed a regularity and parallelism in the declining trend. However, in Great Britain, the natural decline was recently much slower than the model had predicted. On checking this discrepancy it was found that the majority of the recent cases of typhoid fever in Great Britain were imported or occurred among immigrants. The trend towards eradication of the disease shown by the model was therefore not borne out by fact. However, eradication would still be possible if cases and carriers were no longer imported into the country.

This theoretical exercise demonstrates how the model could be used to explore the possibilities of eradicating typhoid fever in a country and to determine the factors to be taken into account should eradication be the aim of the health authorities.

DISCUSSION

The typhoid fever model that has been developed represents a simplified natural epidemiological process. Nevertheless, it could be used in its present form for drawing up long-term public health programmes concerning, in particular, the use of both vaccines and sanitation for control. Whenever this model is applied to an actual population, it is necessary to keep in mind the factors (mentioned in the introductory paragraphs of this article and in the section on epidemiological factors) that have not been included in the model. These factors differ from population to population. They should first be evaluated and then, if necessary, introduced according to their relative merits and importance.

Knowledge of the number of carriers in a population is helpful in determining the dynamics of typhoid fever and will differ by age groups according to the past incidence in these population groups. When most carriers are aged it should be expected, if other factors do not change, that they will be eliminated by death, and that a somewhat more favourable level of endemicity will be established. However, it should be mentioned that many elderly carriers represent a particular risk for the population since their standard of personal hygiene tends to deteriorate and they thus become a dangerous source of infection.

An increase of population under favourable environmental conditions should also lead to an improvement, particularly if the new generation is immunized. Where unfavourable conditions exist, an increase of population may lead to a deterioration, owing to overcrowding and general lowering of standards of living, sanitation, and personal hygiene. The growth of population should therefore be considered in the light of other pertinent epidemiological factors.

There are numerous other factors that may also have an important impact on the incidence of typhoid fever—e.g., natural calamities, superimposed infections such as schistosomiasis, and changes in food habits and standards of hygiene. It is the task of epidemiologists and public health workers to evaluate these factors critically and to use the mathematical model creatively in practice.

A few other factors should also be kept in mind, such as timing of the immunization campaign and selective protection of groups at high risk. The effect of mass immunization, as shown by the model, is of only a temporary nature. However, if it is repeated at the proper intervals and on sufficiently large portions of the population, immunization will lead to a definite decline in the endemic level of the disease. It must be realized, however, that while a more potent vaccine and a greater number of immunized persons signify a lower incidence of disease, they also mean an increased number of susceptible and a decreased number of resistant persons in the population. In practice, this means that once an immunization campaign has started it is important that it should continue if the gains made are not to be lost, since the carriers not eliminated by immunization represent a constant danger of further spread of infection. The effect of mass immunization campaigns should not be over-estimated as is often the case. Immunization campaigns have only temporary effects and, in addition, have other limitations as mentioned above.

The effect of sanitation is more spectacular and permanent. However, it is difficult to determine with certainty the degree of effectiveness in practice of any one of numerous sanitary measures or of their combinations: the effectiveness may be affected by additional health education and by changes in the standard of living.

A combined immunization and sanitation programme, while not much more effective than sanitation alone, is indicated, in particular, in cases of disaster when disruption of the normal sanitary installations and measures occurs and maximum protection is required.

We have limited ourselves, in this instance, primarily to evaluation of the effect of immunization and/or sanitation programmes on the natural course of typhoid in an endemic community, but other preventive measures could also be evaluated by use of the same model.

The model could also be used to evaluate the relative costs and benefits of immunization and/or other measures such as sanitation, treatment and isolation of cases, and treatment of carriers in various economic and epidemiological circumstances and at different levels of endemicity.

The effect of employing vaccines with increased potency or the effect of immunization of increased numbers of people in the campaigns can also be investigated. Finally, the model could be used for operational research in the evaluation of various public health programmes in terms of their costs and benefits, thus ensuring that the programmes set up give the best results possible with the financial means available.

No attempt has been made at this stage to determine the optimum use of funds for typhoid control in a wider public health programme, since it is difficult to evaluate all the economic and other consequences of an effective typhoid control or eradication programme. This would involve a complex study of balanced economic and health development and detailed cost–benefit analysis of numerous interrelated activities in the field of health and other spheres.

RÉSUMÉ

MODÈLE ÉPIDÉMIOLOGIQUE DE LA FIÈVRE TYPHOÏDE: SON EMPLOI DANS LA CONCEPTION ET L'ÉVALUATION DES PROGRAMMES DE VACCINATION ANTITYPHOÏDIQUE ET D'ASSAINISSEMENT

On a construit un modèle épidémiologique de la fièvre typhoïde en vue d'étudier les modalités de la transmission de l'infection à différents niveaux d'endémicité. Le modèle met en jeu un certain nombre de paramètres représentant les proportions des divers sous-groupes épidémiologiques de la population (par exemple: sujets réceptifs, sujets infectés et sujets immuns) et les taux de transfert d'un sous-groupe à un autre. Afin de simuler

avec le maximum de réalité une situation endémique stable, on a attribué aux paramètres une valeur numérique basée sur les données actuellement connues. On a ensuite modifié les valeurs de certains paramètres de façon à étudier les conséquences de la vaccination de masse et de l'amélioration des conditions d'hygiène générale et de l'assainissement, en particulier sur l'incidence de la maladie.

Le modèle montre qu'une vaccination de masse unique entraîne une baisse très notable de l'incidence, mais que le bénéfice de l'opération est en grande partie dissipé après quelques années. La répétition des vaccinations à 5 ans d'intervalle a pour effet de réduire encore l'incidence, mais le gain additionnel obtenu par chacune d'elles s'amenuise de plus en plus.

Le modèle a été utilisé pour évaluer les conséquences éventuelles des mesures d'assainissement. L'amélioration des conditions d'hygiène, en contrecarrant la transmission de l'infection, amène l'incidence à un niveau stable plus bas. Cette action est durable et, à cet égard, l'assainissement donne de meilleurs résultats que la vaccination.

Le recours simultané à la vaccination de masse et aux mesures d'hygiène a un effet cumulatif qui, dans certains cas, se rapproche de celui qu'on obtient par l'assainissement seul.

On a aussi tiré parti du modèle pour prévoir les résultats probables des programmes de lutte antityphoïdique dans une population donnée, non seulement en termes de prévention de la maladie, mais aussi en termes de coût et de bénéfice relatifs. La méthode s'avère utile lorsqu'on désire utiliser de manière rationnelle les crédits et les moyens de lutte.

D'autres possibilités d'emploi du modèle épidémiologique sont brièvement évoquées.

REFERENCES

American Public Health Association (1965) *Control of Communicable Diseases in Man*, 10th ed., New York

Ames, W. R. & Robbins, M. (1943) *Amer. J. publ. Hlth*, **33**, 221

Cvjetanović, B. (1957) *Vrijednost Cijepiva Protiv Trbušnog Tifusa*, Zagreb, pp. 25-26

Cvjetanović, B. & Uemura, K. (1965) *Bull. Wld Hlth Org.*, **32**, 29-36

Hejfec, L. et al. (1966) *Bull. Wld Hlth Org.*, **34**, 321-339

Hornick, R. & Woodward, T. E. (1966) *Trans. Amer. clin. climat. Ass.*, **78**, 70-78

Merselis, J. G. et al. (1964) *Amer. J. trop. Med.*, **13**, 425-429

National Communicable Disease Center (1967) *Salmonella Surveillance*, issue dated 9 October 1967 (US Department of Health, Education, and Welfare)

Rice, D. P. & Cooper, B. S. (1967) *Amer. J. publ. Hlth*, **57**, 1954-1966

Saad El-Din Hathout et al. (1966) *Amer. J. trop. Med.*, **15**, 156-161

Schliessman, D. J. et al. (1958) *Publ. Hlth Monogr.*, No. 54

Tynes, B. S. & Utz, J. P. (1962) *Ann. intern. Med.*, **57**, 871

Typhoid Panel, United Kingdom Department of Technical Co-operation (1964) *Bull. Wld Hlth Org.*, **30**, 631-634

Vogelsang, Th. M. & Bøe, M. D. (1948) *J. Hyg.*, **46**, 252

Vojna Epidemiologija (1966) Beograd, p. 176

Watson, K. C. (1967) *Lancet*, **2**, 332-334

Wolff, H. L. & van Zijl, W. J. (1969) *Bull. Wld Hlth Org.*, **41**, 952-959

World Health Organization Expert Committee on Biological Standardization (1967) *Wld Hlth Org. techn. Rep. Ser.*, No. 361, p. 61

World Health Organization Expert Committee on Enteric Infections (1964) *Wld Hlth Org. techn. Rep. Ser.*, No. 288

Yugoslav Typhoid Commission (1964) *Bull. Wld Hlth Org.*, **30**, 623-630

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Cost-effectiveness and cost-benefit aspects of preventive measures against communicable diseases

B. CVJETANOVIĆ

Man has the right to expect that the resources he has created will be put to the most effective use for his benefit and well-being, including his health. For this purpose, the discipline of health economics has been developed, and methods such as cost–effectiveness and cost–benefit analysis, devised by economists for other purposes, have come to be applied in the field of health.

The available financial and other resources of any community are insufficient to meet the many health, educational and other requirements for improving the standard of living. Thus there is a need for the use of cost–effectiveness analysis in the planning and delivery of health services in order to achieve the highest attainable level of health with the available resources. Cost–effectiveness analysis may also be applied to achieve the most efficient allocation of resources for the control of communicable diseases.

One preventive measure may not only prove to be more effective per unit cost than another (in the sense of protecting more people at risk per unit of resource) but may also bring more economic benefits if that protection results in greater productivity. Cost–benefit analysis can theoretically be used, therefore, to show whether implementation of a given preventive measure has brought, besides benefits in health, an increase in production which may in turn be used for further improvement in health and/or a rise in the general standard of living. Clearly health is one aspect of welfare and the problem of any government or planning authority is to determine the most efficient allocation of resources for the improvement of welfare. It is thus important to establish the *indirect* effect of health expenditures as well as the direct or immediate effects. This is always exceedingly difficult, conceptually as well as practically.

Without a detailed account of the costs and benefits of an investment in health *and a similar account for any alternative investment*, a scientific decision

on the use of resources for the health services is impossible. Furthermore, those responsible for such a decision have to take into consideration basic philosophical issues and political concepts, the aims of the community, and the responsibilities and rights of individuals, including the right to health—and none of these variables are readily quantifiable. As concepts and socioeconomic structures vary greatly from one community to another, there is no single approach to the problem of determining the relative importance of health and the ways and means of achieving the desired level of health in given conditions.

There is, however, one basic element common to all systems and concepts: once the priorities and aims in health have been decided upon, the allotted budget must be used in the most efficient way, in order to minimize cost per unit of 'health care' achieved. The purpose of this chapter, accordingly, is to discuss ways and means of making the best use of resources available for the promotion of health. I shall ignore the unquantifiable aspects of different socioeconomic systems, and their respective merits and disadvantages for health. These are indeed of great importance, but at present we lack a methodological framework to do them justice.

PREVENTION OF COMMUNICABLE DISEASES

Before cost–effectiveness analysis can be applied to preventive measures against communicable diseases, the aims and role of control of these diseases in the promotion of health must be specified. It is customary to assess morbidity by measuring the frequency of diseases in the community, and that of infectious diseases in particular. The disadvantages and fallacies of this method are obvious. The effect of infections on health could not be measured by the incidence of infections and frequency of illness and death alone, even if exact data were available. Morbidity and mortality figures are inadequate for the measurement of the numerous deleterious effects of infections on the functions of various organs and of irreversible damage leading to the impairment of the normal physical and psychic adaptability of individuals to environmental stress. Various disabilities caused by infectious diseases (less obvious than, for example, paralysis resulting from poliomyelitis) reduce the level of health and well-being, creativity and productivity to the detriment of the social and economic progress of the community. Since our knowledge of the biology and pathology of infections is still too incomplete to allow a full assessment of their effect on health, it is difficult to estimate the *benefits* derived from the prevention of communicable diseases. These important limitations must be kept in mind in further considerations of the problem. If an enteric infection results in

malnutrition, or *vice versa*, the ill-effect of such a combination may be much more serious and longer lasting than that of the infection alone.

It can be asked whether preventive measures against infectious diseases can be considered as capital investment in the same sense as, for instance, a road or a hydroelectricity scheme. Can cost–effectiveness and cost–benefit analysis serve as a guide in deciding the best way to invest efforts and resources so as to obtain a lasting improvement in health and an overall improvement in general welfare?

Cost–effectiveness analysis requires exact data on the costs of preventive and curative measures and on the impact of these measures on mortality and morbidity. While costs can be relatively easily determined, the assessment of the effectiveness of preventive measures is a considerable problem, for, by definition, exact data on the effects on health and the economic effects of the prevention of disease cannot be obtained.

The data demands for cost–benefit analysis are even greater. For how can we determine the full *economic* benefits resulting from a given change in morbidity and mortality patterns? The usual, but very crude, approach, developed originally in quite different contexts, is to sum the earnings-streams that have been made possible by the improvement in health and then discount these to derive an aggregate net present value. There are many objections to this technique, the details of which need not detain us here. It is enough to note five main difficulties:

(i) We do not know with any precision the earning-streams to be discounted.

(ii) The discount rate is important but arbitrary.

(iii) The benefits (and costs) included are only the direct ones; the benefits do not include the multiplied effects of the earning (and expenditure) streams. The costs do not include those associated with a higher rate of growth of population.

(iv) No economic benefit is attached to social variables, such as the saving of a mother's life.

(v) This technique assumes that a given health programme is an investment, to be judged by the same criteria as other investments. But a preventive (or curative) programme has a large (perhaps predominant) element of present consumption. This can theoretically be fitted into a cost–benefit model but we then need to know the *value* of that *present* consumption. This poses immensely difficult problems which an earnings-streams approach misses.

For these reasons it is more sensible, if less satisfying, to put prime emphasis on cost–effectiveness and regard cost–benefit analysis more as an invitation to review health expenditures in a broader perspective than as a call to analytical rigour—a call to which, at the moment, we cannot adequately respond.

EFFECTIVENESS OF PREVENTIVE MEASURES

The effects of preventive measures are best ascertained by controlled field trials,[11] but few of them have actually been evaluated by this method. Most of the vaccines in current use have been subjected to field trials, in which their preventive effect has been assessed by comparing the incidence of illness in an immunized and a control group. However, as the exposure and infectious dose vary under different conditions, one cannot be sure that in other trial populations and circumstances the effect of such measures would not be different. It was found that the incidence of some infections, such as enteric fevers, differs greatly in volunteering and non-volunteering populations, being considerably higher in the latter.[3] The actual effect on the overall incidence of infectious diseases of mass vaccination campaigns based on voluntary participation may therefore not be as good as one might assume from the protective effect of vaccination in controlled field trials where both the control and the vaccinated groups were volunteers. This indicates that, even with such measures as vaccination with a vaccine of known potency that has been well studied, it may be difficult to ascertain the effectiveness of the immunization programme and consequently to make an accurate cost–effectiveness analysis. Much less exact is our knowledge of the effect of measures such as health education, or general education, or cultural background, or socioeconomic status and other factors, which may play an important role. It has been shown that healthy living habits (regular sleep, regular meals, weight control, active sports and/or exercise, no [or moderate] drinking, no smoking [or little, without inhaling]), which are believed to be due to a higher level of education and the specific attitude of some groups of people, result in a higher level of health and longer life expectancy.[2] A preventive measure may be more effective among such people than in less health-conscious groups of the population. Since health is more fully attained by health-conscious individuals, health education makes preventive measures more effective, and in fact should be an integral part of disease control programmes.

Because the effectiveness of preventive measures is related to educational standards, measures that require the active participation of the population, such as sanitation and personal hygiene, may be less effective in developing countries with low levels of education than in developed countries. In developing countries such measures are not only less effective but also, as a consequence, relatively more expensive per unit of 'output'. An underprivileged, illiterate and poor population is likely to benefit relatively less from a given set of preventive measures than would a better-off and better-educated group.

However, in developing countries where there is a high incidence of infectious

diseases, preventive measures will greatly reduce their frequency. That this will bring economic benefits is certain, even if those benefits are not scientifically quantifiable. As the incidence decreases, so the efforts and resources needed to reduce it still further will increase. Finally, at a certain point, it will be very expensive to maintain a low level of incidence of infectious diseases that cannot be eradicated. For eradicable diseases, the need is to establish the cheapest and speediest way to achieve eradication. Again, economic benefits will flow from eradication, perhaps particularly in the longer run.

COST–EFFECTIVENESS AND COST–BENEFIT ANALYSIS

The common theme of cost–effectiveness and cost–benefit analysis is that each tries to establish an optimizing pattern of expenditure. In the former, the intention is to minimize cost per unit of health output (however that may be defined); in the latter, it is to minimize cost per unit of economic benefit. Both therefore require detailed data on costs and both require that we know the physical results—short-term and long-term, positive and negative—of a given programme.

As an extension of cost–effectiveness methods towards cost–benefit analysis, we have developed a simple method, using nomograms,[10] which indicates whether expenditure on prevention would be compensated by savings on the treatment of cases. For this purpose, it is necessary to have data on the costs of preventive measures and treatment, as well as on incidence.

This method is based on a comparison of the cost of treatment and the cost of prevention of one case. Accordingly, it is possible to ascertain whether at a certain level of incidence it is cheaper to treat or to prevent infection. The consumption effect of prevention should also be taken into account, as we may assume that any community will be ready to spend some of its resources purely for health and well-being. However, in the search for a more effective and economical use of resources for preventive measures, we leave the consumption element aside and consider only the direct relationship between costs of treatment and costs of prevention.

As an example, a nomogram of the cost–benefit balance of immunization against typhoid in developing countries is illustrated in Fig. 1. This presents graphically on log-log paper the relationship between incidence (abscissa), cost of treatment (ordinate), and cost of immunization (45° slope line). These relationships have been developed from mathematical formulae[10] which show that a point of equilibrium or indifference (i.e. when costs of treatment are the same as costs of prevention) can be defined as

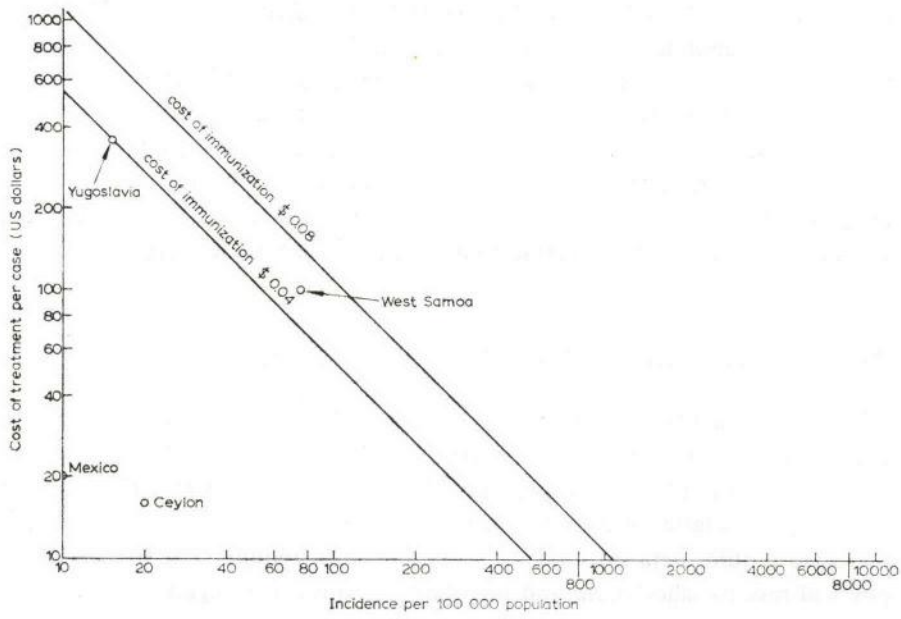

FIG. 1. Nomogram for determining the cost-benefit balance of immunization against typhoid, using an 80% effective vaccine giving immunity lasting for five years, and assuming costs of immunization of US $0.2 and $0.4 per head ($0.04 and $0.08 per head per year).

$$C_t = \frac{C_v}{E_v} \times \frac{1}{i}$$

where C_t = cost of treating one case
C_v = cost of vaccinating one individual
E_v = vaccination effectiveness
i = incidence of cases.

By solving this equation for given values of C_v and plotting the values of i and C_t, we can demonstrate 'profits' and 'losses' for various values of C_t and i. The area below and to the left of the given 45° indifference slope line represents loss, while the area above and to the right of the line represents benefit. Accordingly, the data (collected from several countries[4]) show that, at a cost per head of vaccination of US $0.04 per year (calculated on the basis of costs of vaccine, manpower, supplies and transport, and a duration of immunity of five years) and with 80% effective vaccine, there will be neither an economic loss nor a gain from immunization in Yugoslavia at an incidence of 15 cases of typhoid

per 100 000 population and a cost of treatment of US $360 per sick person. In Western Samoa (at a cost of treatment of US $100 and an incidence of 75 per 100 000 population) there will be a benefit if the cost of immunization per head is US $0.04 and a loss if it is US $0.08. In Mexico and Ceylon vaccination seems to bring no economic benefit because of the extremely low cost of treatment and low incidence. However, the low cost of treatment also means a low level of health services and a high fatality rate. There is probably also much under-reporting of typhoid in these countries. One should not draw the conclusion that immunization in these developing countries is not beneficial because treatment facilities are poor and the reporting system inadequate.

Many other aspects have to be taken into account in the evaluation of immunization programmes.[4] Immunization procedures may be rendered less expensive by technical improvements such as *(a)* adjuvant vaccines; *(b)* combined vaccines; *(c)* larger vaccine containers; *(d)* smaller doses; *(e)* speedier immunization by jet injectors; *(f)* better use of transport and manpower; and *(g)* selective immunization of high-risk groups.

There are other even simpler, but still valuable, ways of calculating the costs and benefits of immunization programmes[13] than the nomogram method.

The simple nomogram method for determining the cost–benefit balance is limited by the fact that it permits only short-term analysis, namely of the situation at a given moment, and does not take into account its possible evolution. For this purpose, epidemiological models should be used, such as those we have developed for typhoid[5] and tetanus,[6] and similarly for cholera and cerebrospinal meningitis. These epidemiological models of acute bacterial diseases permit projection and simulation of the natural evolution of the infection as well as the results of long-term control programmes. Thus, when the incidence and costs of treatment and prevention are known, the relative effectiveness of various preventive measures can be ascertained and the most effective and least expensive measures selected for implementation.

As an example, the results and cost–benefit balance of three different control programmes for typhoid have been simulated and are presented in Fig. 2, which is based on actual data from Western Samoa. The figure displays the cost and effects of a long-term programme of *(i)* immunization (consisting of 75% coverage with an 80% effective vaccine, every five years); *(ii)* sanitation (construction of privies for the whole population during a 10-year period); and *(iii)* immunization and sanitation combined *(i + ii)*. The results of *(i)* and *(ii)* are similar, but the simulation shows that sanitation, because of its cumulative effect on the amount of infection and the relatively low cost of maintenance in comparison with the high maintenance cost of immunization, should be both more effective and less costly in the long run.

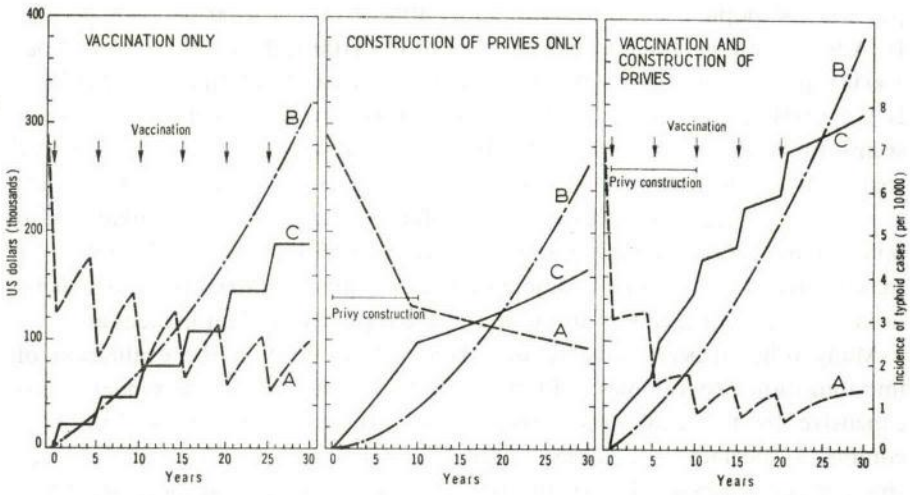

FIG. 2. The impact of three different control programmes on the incidence of typhoid and on the cumulative costs *(C)* and benefits *(B)*. *A* is the incidence of cases of typhoid per 10 000 population. The cumulative costs are calculated from the costs of vaccine, equipment, manpower and transport required for the immunization programme, and from the costs of constructing privies for the sanitation programme. The cumulative benefits are calculated as the difference between the savings on the treatment of cases, as a result of prevention, and the cost of the control programme in each case.

Similar models have been developed for chronic diseases such as tuberculosis.[16]

The methods described here are now coming into frequent use. They enable public health administrators to determine which control measure will be most effective. In this way, the budget of the department of health can be put to better use and the national health programme can be better constructed.[1] These techniques, for example, were used in planning a typhoid control programme in Western Samoa.[5] As it had been found there (see Fig. 2) that the immunization programme and the sanitation programme did not differ greatly in effectiveness, an attempt was made to make vaccination less expensive. It was found that if combined vaccines could be used, vaccination would be made cheaper than sanitation per unit reduction in morbidity. Research on combined vaccines was set up and DPTTy (diphtheria, pertussis, tetanus, typhoid) quadruple vaccine was developed,[7] which allowed a programme to be designed consisting of a combination of immunization and sanitation in selected areas and among high-risk groups that made immunization much cheaper but still very effective. Nevertheless, in view of the fact that sanitation represents a lasting investment with cumulative effect, priority was given to sanitation in

plans for the future. Other models have been used for similar purposes, for example, for allocating resources for the control of tuberculosis.[9,12]

DISCUSSION

Techniques of cost–effectiveness and, in the limited sense intended in this paper, of cost–benefit analysis have reached a fairly advanced stage of development and can be used in the planning of disease control programmes. Although certain methods are simple and only approximate, they nevertheless have considerable practical value because they do not require much mathematical knowledge or expensive computing equipment. Other modelling techniques that require electronic computers are evidently more sophisticated, particularly in their ability to handle long-term variables, but may not be accessible to all health workers and health services.

The accuracy of all these approaches depends on the accuracy of the basic data on costs and on the effectiveness of preventive measures. We must constantly bear in mind the frailty of our conclusions; much careful and critical study is needed to ascertain the real values of such approaches.

In spite of the advantages that are being derived from cost–benefit and cost–effectiveness analysis and other similar procedures used in health economics it should not be forgotten that although economics now play an important role in life, human health should not be unconditionally subjected to the verdict of economic and financial analyses. Humanitarian principles demand that man be treated as a human being and not as an economic unit or monetary value. Some attempts to assess the value of human lives[14] for the purpose of cost–benefit analysis, if pushed to the extreme, could lead to the dehumanization of medical services and society. Ultimately, an individual who happens to be unable to provide financially for the preservation or restoration of his health, and for whom the community (on the basis of cost–benefit arguments) is unwilling to do so, may be deprived of his fundamental right to health. There are limits to what can be achieved in health, as in other fields, but let us set these limits in accordance with humanitarian rather than economic principles.

CONCLUSIONS

Cost–effectiveness and cost–benefit analyses facilitate the proper use of available resources in health programmes. They permit selection of the most effective and least expensive control measures so that human rights in health are more quickly and more efficiently attained, and therefore should have a prominent place in health planning.

Discussion

Potts: I do not follow the logic of Dr Cvjetanović's concluding remarks. As a doctor I feel that one of my responsibilities is to use available resources to the greatest effectiveness. I do not look upon cost–effectiveness analysis as something which economists force upon the medical profession but as something which we are obliged to use in order to help the greatest number of people, with the available resources. I can press for greater resources, but I have to be a realist, and I accept that I won't be given all the resources I want. I do not see the conflict with human rights which has been implied. I often find, when I visit developing countries, a terrifying misuse of available resources to the detriment of the community, and I feel that if we had more analysis we might not make so many mistakes.

Cvjetanović: There is a 'conflict' between different areas and branches *within* the total system of health services, which are competing for the same funds. One wants to know which area can use the funds most effectively and to the best advantage of the health of the community. Certainly we find in every community that the actual needs and the rights which people want to attain are far beyond the available resources. So within the field of health there is a dilemma: for example, should we let a man die of cancer in order to save a hundred children from diphtheria?

Potts: The answer to this would be an unequivocal *yes*.

Cvjetanović: The second dilemma is that economists tell us that health will continue to receive a certain small percentage of national income. Yet large sums are being spent in providing television, say, or armaments. This is another area of conflict.

We know that we must make the best possible use of the funds allocated for health, but it is difficult for the doctors to say what this allocation should be. This decision should be left for the community itself to decide—because if we propose any ceiling we have accepted the limitation that will prevent somebody from achieving health aims that he may consider very important. Therefore the population itself should decide on the priority that it wants to give to health.

C. Elliott: In Fig. 1 (p. 192), Dr Cvjetanović illustrated his technique by which he can tell whether or not a programme is worth mounting, from the cost of vaccination and the cost of treatment. I would have thought that one also needed data on the incidence of treatment before one could draw any conclusion from the data presented, because one cannot assume, as this technique does, that everyone who contracts the disease is treated. Almost certainly a small proportion only of those who contract the disease are treated. So I would doubt whether those three bits of data are adequate.

Secondly, and more fundamentally, the argument was made that if one can show a saving to be expected as a result of a particular programme, then the programme would be beneficial to the country. That is correct. But it does not follow, as Dr Cvjetanović seemed to imply, that the programme should be carried out. An economist would need to be convinced that this was the most beneficial use that the money could be put to. There may be many other programmes in health, in environmental engineering, in sanitation or water supply, which would have a higher return than this particular programme. So this rather limited approach would not convince economists that a programme should be implemented. One would need to look at a series of other possibilities before that choice could be made. Economics is a science of making rational choices and, therefore, one needs in theory (one seldom has it and that is why economists are using these techniques less now than in the past) a list of possible projects among which to choose what seems to be the most beneficial one. I am delighted that the medical profession is asking the question that Dr Potts is putting, of what is the best use we can make of the available resources, because this is a question that would be very easy to avoid, and has in the past sometimes been avoided; but I would argue for a very careful application of economics in the approaches that are developed.

Cvjetanović: Our nomograms have of course only limited use, namely to provide information about the most beneficial use of funds allocated for health services, and therefore they cannot give an answer to the complex problem of the best economic uses of the total national resources.

White: Cost–benefit analysis in the public sector was first and most extensively used in the management of water resources, and from that experience, which is now a somewhat jaundiced experience, there are lessons that can be pointed out.

Cost–benefit analysis in a way is like a blunt scalpel: in the hands of a poor surgeon at a provincial hospital it can perform monstrosities; in the hands of a very skilful person in the most auspicious circumstances it may serve the public good. One way in which cost–benefit is susceptible to misuse is in its failure to specify the assumptions that are ploughed into it. An assumption just noted is that all viable alternatives have been examined. Usually this is not so; there is some arbitrary selection of alternatives and the others have been ignored. Another assumption is that certain kinds of action will necessarily follow, for example the auxiliary activities related to an irrigation project. It is assumed that these will be put into effect. Often they are not, and the anticipated flow of impact doesn't materialize. Again, it is often assumed that people's attitudes are equivalent to their behaviour, but if there is anything we know from behavioural sciences it is that you cannot equate attitudes with

behaviour. And one is finally concerned with behaviour—what is done—rather than with articulated aspirations or preferences.

The second thing we can learn from the application of this technique is that there is a mystique of quantification; by and large, modes or attributes that can be quantified are given a different kind of weight from those that cannot be quantified. This shows itself in several ways. If some ingenious person comes up with an estimate of the value of the human life, for instance, there is a tendency to fasten on to that figure and use it. Then if someone can't put a value on human misery, it is given a value of zero. When we come to the matter of quantifying anticipated impacts, we run into extreme difficulties of multivariate analysis, as exemplified by the report[17] on the impact of schistosomiasis among certain groups in St Lucia, where after considerable investment of money and time it was concluded that there was almost no perceptible or quantifiable impact of schistosomiasis on income in the population studied.

The third lesson that we can learn, especially from water management, is that finally the decision is a political one. It is a decision of the responsible political agency as to what are the values that this group honours and wants to advance. In this regard we have to be very careful that the benefit–cost and cost–effectiveness analysis illuminate and help to clarify that basically political decision rather than constrain it and force it into an arbitrary mould. Bearing all this in mind, can we think of cases where there has been an exemplary application of benefit–cost or cost–effectiveness analysis in the public health sector, with a thorough progression from scientific observations to economic analysis to its application to a real public decision?

Llewelyn-Davies: An example (not in the field of health) which is probably the most heroic, conscientious and thorough example of cost–benefit analysis ever made was the attempt to select the site for a third London airport. This analysis cost a million pounds, took two years, and included the quantification of items such as pulling down a Norman church and losing a wild-goose breeding station. The report eventually came out and recommended a particular site; the choice was then reversed by the government, who chose a different site. The moral is that when one looks at methods of quantification or distrain of benefits and costs it is useful to step back from one's technique and ask oneself whether, if this was presented to a political debate at an appropriate forum in parliament or to a community, it would carry conviction. If the answer is negative, it is probably not a good technique!

Bradley: I would like to pursue this one stage further back, to where we formulate a problem, and the picture we present to ourselves of it, if we are on the medical side. I am concerned by the way in which mathematical techniques are used. Dr Cvjetanović gave two examples: the first was the nomogram,

and I think this has the rather wider implication of treating variables as constants. In other words, if one presents to an economist a choice between the present cost of treating tetanus and of the vaccination programme, one is implying that there are only two possibilities whereas, as Gilbert White has just said, one needs to look at other possible situations. Thus if in fact all the babies with tetanus who receive treatment are nevertheless dying, then at least one other choice is not to spend money on treating people who are going to die: look after them, but not at that expense.

When we come on to more complicated mathematical models within the health field, such as the effect of providing privies on the amount of disease in the second example, it is important that we treat these models as hypotheses. In medicine I can't think of any major mathematical model of any complexity which has proved really useful as yet; this is not because the approach is unsound but because the techniques haven't been developed far enough. At the moment a mathematical model is a hypothesis, not a self-evident statement of what must follow.

Cvjetanović: Mathematical models of epidemics have been developed primarily to study the natural course and the effect of interventions such as preventive measures, and to simulate the effect of various control programmes. They have been used for cost–benefit and cost–effectiveness analysis subsequently in order to assist in studies of health economics, but since they have not primarily been designed for this purpose they of course often fall short in giving answers which would satisfy hard-boiled economists! Yet in the practice of health planning, these models are being used every day more frequently.

Wiener: We have been talking about a number of different mathematical approaches, with some danger of confusion. Three basic approaches have been mentioned: the cost–benefit approach, the cost–effectiveness approach, and mathematical models. They all have their place, but we should keep them apart. The cost–benefit approach comes in in cases where simple benefits can be satisfactorily expressed in monetary terms. This approach may be a satisfactory way of choosing the best of two alternative means of reaching such simple objectives; however, it does not result in an optimal solution of how to use an allocation of funds in order to achieve broad and complex health objectives. The difficulty with the cost–benefit approach is that the most important things, in life and in projects, are usually the unquantifiable ones, and since we cannot introduce them into our cost–benefit calculations, either the method breaks down or we have to quantify unquantifiable variables in a very subjective way.

When we move to cost–effectiveness we operate within a much more general framework, comparing various ways of reaching broad goals (like improving

health) that we cannot express in terms of economic benefits but can quantify by using non-monetary units of benefits, such as lives saved. This approach can, for instance, be used for optimizing the use of funds allocated to a health department.

Mathematical models are another kind of technique based on selective mapping of the interrelationships between the several variables of a system. They can be used to evaluate the outcomes of alternative strategies. I do not think we have the data yet for this much more sophisticated approach in the context of health measures.

Finally, a comment not directly connected with evaluation procedures. I think the political process is a much maligned process; in my experience, many bad decisions attributed to the political decision-making process were due to bad professional advice. If badly advised, the political process makes bad decisions.

Burton: It seems to me that making political decisions, or the choices of the kind we are discussing, is often a very embarrassing exercise, because the choices are unpleasant and they often imply negative things in one direction as much as they do positive things in another. It is, therefore, tempting to go through these kinds of quantitative analysis because they provide a useful peg on which to hang the unpopular aspects of a political decision. They can form an excuse, because the person who is put in the unfortunate and uncomfortable hot seat of making that choice has a rationale that he can present. If it happens to coincide with what we might otherwise decide as being good judgement, that is very well, and perhaps it is helpful and constructive; but if it constrains and acts as an impediment to good judgement, instead of as a support to it, it can be dangerous.

The title of Dr White's paper (pp. 35–51) included the phrase 'good or right', and this made me wonder what the boundary is between a 'good' and a 'right' and when we should think of something in one category rather than the other. I took his remarks, at least in relation to water supply problems, to say that here was a point at which we should take something that we have been accustomed to think about in one category and put it into another, and perhaps it is a question of the appropriate time at which to do this. After all, if we had done a benefit–cost or a cost–effectiveness analysis of the institution of slavery a hundred or 150 years ago, we would probably have been able to convince ourselves that slavery was a good allocation of resources and that abolition was a foolish thing to do. Perhaps we have arrived at the critical moment for some of the provisions of health care and environmental engineering investments at which we can consider these no longer entirely as questions of the *good*, but as matters of *right*. If we do that, we would gain the advantage of

mobilizing a certain spirit—the way in which we go about things—which would have beneficial results in terms of the energy and enthusiasm that can be brought to bear on these problems. If we remain at the stage of agonizing about the allocation of resources, and saying 'it is a good, but how good is it?', we shall be involved in a great deal of concern and analysis but make very little progress.

Evang: Professor Burton's point is highly relevant. We know that the use of certain economic techniques in the field of medicine is declining, because it is the process *before* the Ministry of Health gets its money that is the important one. Economics may be the science which enables us to make a rational choice, but Dr Burton is reminding us that *before* the allocation is made to health, you should try to force your way into the decision-making process. You need the enthusiasm to fight for the largest allocation, and you do not do that through economic techniques but because of your firm belief in the right of the human being to be healthy.

Bradley: It is important to stress that though some economic techniques are being applied less to medicine now, the use of mathematical models, which are ways of handling the technical complexity of, for example, a particular disease or group of diseases, is increasing. Such models allow one to tackle processes of great complexity, though too little has been done for them to be of much practical use yet.

Llewelyn-Davies: There is in fact an increasing sophistication in the development of quantifiable ways of displaying some of the choices which come before society; some of these are developing in other fields than health, such as the 'robustness' theory in decision-making,[15] but might well be applied in this area. Very often when one is dealing with social systems one cannot define the goals, as one can for situations such as putting a man on the moon or defeating a nation in war. With social systems the goals are often contradictory and there is a trade-off: the more you have of one goal, which is a good one (perhaps even a right), the system may be such that you have less of another. There are quantifiable ways of showing the trade-off between the goals.[8]

Wiener: There are now techniques available by which to optimize programmes with two or more objectives. One can list various solutions that are characterized by specific levels of achievement of objectives and then select from this list the most appropriate solution according to one's judgement; every selection represents, of course, a set of trade-offs between objectives. This approach relies in the final analysis on subjective judgement, but it forces the planner to scan all eligible alternatives and to compare trade-offs before making that final choice.

Llewelyn-Davies: However, that kind of formulation polarizes the situation into a part of a problem which is quantifiable and another part which is removed from quantifiable consideration. This does not take account of the dynamics by which the thought is developing in these areas.

C. Elliott: There are indeed a whole series of new techniques which might be useful; but having said that, one also has to say that all these techniques depend on the quality of the data, and in the past we have suffered from not having an adequate data base with which to do anything at all sophisticated. What depresses me, visiting Third World countries, is how little effort is being devoted to getting data that could improve the decision-making process, whether those decisions are made by doctors, economists or politicians.

D. B. Jelliffe: Any final judgement will inevitably be made on the combination of quantity, which is measurable, and quality, which may not be so. I have always felt this myself and am encouraged to hear the same thing from more numerate people. For instance, in doing a survey in the field, one certainly has to measure the prevalence of the condition, say malnutrition, but one has at the same time the qualitative input of what one *sees* in a village, without which one cannot apply any of one's results adequately. Another example is on the microscale of the paediatrician in a developing country who is faced with problems of children coming into the ward. He can work out the cost–effectiveness, if you like, of the use of the beds, and he *must do so;* but ultimately he has to come to a decision which balances cost–effectiveness and his value judgement as a physician in relation to other factors; and it always is a balance between these two.

References

1. Ahumada, J., Arreaza Guzman, A., Durán, H., Pizzi, M., Sarué, E. & Testa, M. (1965) *Health Planning: problems of concepts and method*, Scientific Publication no. 111, Pan American Health Organization, Washington, D.C.
2. Belloc, N. B. & Breslow, L. (1972) Relationship of physical health status and health practices. *Preventive Medicine 1*, 409-421
3. Cvjetanović, B. (1961) Controlled field trials of prophylactics (with special reference to typhoid vaccines). *Journal of Hygiene, Epidemiology, Microbiology and Immunology (Prague) 5*, 7-21
4. Cvjetanović, B. (1971) Cost–benefit analysis of vaccination programs in the developing countries. In *Proceedings of International Conference on the Application of Vaccines against Viral, Rickettsial, and Bacterial Diseases of Man*, Scientific Publication no. 226, Pan American Health Organization, Washington, D.C.
5. Cvjetanović, B., Grab, B. & Uemura, K. (1971) Epidemiological model of typhoid fever and its use in the planning and evaluation of antityphoid immunization and sanitation programmes. *Bulletin of the World Health Organization 45*, 53-75

6. CVJETANOVIĆ, B., GRAB, B., UEMURA, K. & BYTCHENKO, B. (1972) Epidemiological model of tetanus and its use in the planning of immunization programmes. *International Journal of Epidemiology 1*, 125-137
7. CVJETANOVIĆ, B., IKIĆ, D., LANE, W. R., MANHALTER, T. & TAPA, S. (1972) Studies of combined quadruple vaccines against diphtheria, pertussis, tetanus, and typhoid fever: reactogenicity and antigenicity. *Bulletin of the World Health Organization 46*, 47-52
8. FELDSTEIN, M. S. (1964) Particular cost calculations in cost-benefit analysis. *Public Finance 19*, no. 2
9. FELDSTEIN, M. S., PIOT, M. A. & SUNDARESAN, T. K. (1973) Resource allocation model for public health planning. *Bulletin of the World Health Organization 48* (supplement)
10. GRAB, B. & CVJETANOVIĆ, B. (1971) Simple method for rough determination of the cost–benefit balance point of immunization programmes. *Bulletin of the World Health Organization 45*, 536-541
11. POLLOCK, T. M. (1966) *Trials of Prophylactic Agents for the Control of Communicable Diseases: a guide to their organization and evaluation, World Health Organization Monograph Series* no. 52, Geneva
12. REVELLE, C. S., LYNN, W. R. & FELDMANN, F. (1967) Mathematical models for the economic allocation of tuberculosis control activities in developing nations. *American Review of Respiratory Disease 96*, 893-909
13. REY, M., DIOP MAR, I. & SOW, A. (1972) Sur la rentabilité de deux vaccinations de masse en Afrique: les vaccinations antirougéoleuse et antitétanique. *Centre International de l'Enfance Courrier*, 22, 246-250
14. RICE, D. P. & COOPER, B. S. (1967) The economic value of human life. *American Journal of Public Health 57*, 1954-1966
15. ROSENHEAD, J., ELTON, M. & GUPTA, S. (1972) Robustness and optimality as criteria for strategic decisions. *Operational Research Quarterly 23*, no. 4
16. WAALER, H. T. & PIOT, M. A. (1969) The use of an epidemiological model for estimating the effectiveness of tuberculosis control measures: sensitivity of the effectiveness of tuberculosis control measures to the coverage of the population. *Bulletin of the World Health Organization 41*, 75-93
17. WEISBROD, B. A., ANDREANO, R. L., BALDWIN, R. E., EPSTEIN, E. H. & KELLEY, A. C. (1973) *Disease and Economic Development*, The University of Wisconsin Press, Madison

Briefly introduced

LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE

INCORPORATING THE ROSS INSTITUTE

(UNIVERSITY OF LONDON)

WATER SUPPLY + SEWERAGE

David J Bradley

Telephones:
Museum 3041 (4 lines)
Langham 7621 (5 lines)
Telegrams:
Hygower London WC1

ROSS INSTITUTE OF TROPICAL HYGIENE,
KEPPEL STREET,
(GOWER STREET)
~~LONDON, W.C.1.~~ E 7HT

Date Received: Oct 30 1974
Assigned to : M Warford
Action Taken :
By

J. J. Warford,
I.B.R.D.,
1818 H St., N.W.,
Washington, D.C. 20433,
U.S.A.

23 October 1974

Dear Jeremy,

Many thanks for your letter of October 8th. I sent the missing pages of chapter III from Geneva in Charles Weiss's luggage and trust it reached you safely.

Whilst in Geneva I got Abel Wolman to have a look at the paper - it arose out of a discussion on another topic - and he didn't take strong exeption to it. He had a number of comments which I note here:-

p.9. he felt that 'comfort' should be added to 'health' in first line. He was thinking of lice and fleas. I had subsumed these under 'health' but if you think the Bank staff might not, do add the extra word as the concept was in mind.

p.12. under item 14 Abel Wolman was of the view that engineers got taught epidemiology (at Johns Hopkins). I'm sure his students did, but most elsewhere get taught an incomplete and inadequate

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sort of epidemiology and certainly lack the 'sense of a population',,which is more a way of thinking than set of facts.

p.14. line 7. Probably a rhetorical overstatement somewhat, or rather, the 'action' is optimal allocation of scarce funds.

p.31. option II. Wolman queries 'standards of pollution' as a term, and has a fair point, but provided it stays in context the use here seems fairly clear. However, readers of our book tend to ascribe to me wilder ideas than I actually hold and we need to be careful about this.

p.36. some query about onchoceriasis and getting bitten near sources, but this is the case in some endemic areas (as on Mount Elgon), though probably less so in West Africa. Wolman supports bottom line of p. 38 - 'rather unusually', probably with W. Africa in mind, and queries my 20% on p.39.

p.65. line 10. After 'high mortality rate' add 'untreated' as of course with adequate treatment it is low now.

p.86. in the list onchoceriasis should perhaps be in brackets. This got dealt with first in chapter III and therefore most thoroughly and may appear to the reader as more closely related to domestic water than is the case.

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p.95. query over the relative poverty of the rural unsupplied people. I've put it as 'if we assume': no doubt some facts could be acquired in the field one way or the other.

p.112. bottom line but two. There is an "i" missing in "individual".

I'm pleased that Prof. Wolman seemed reasonably content with it overall.

Appendix B is mostly written but the rest of the paper is largely independent of it so please don't hold things up for it.

The Geneva meeting was an interesting experience but less than satisfactory in relation to its aims. It was very nice to meet Charles Weiss and Harold Shipman from the bank: they were such different and interesting people that meeting them was one of the best parts of the meeting. Do give them both my very warmest greetings.

I trust that you flourish. Do come to the Tropical School next time you're passing through London and let me know where you want the report cutting or amplifying. It's important to omit chapter III on first reading!

I enclose the completed form for which many thanks. As I had no secretary in September I've paid out approximately £40 to typing agencies and postage on the report. Do I look after this or is it a separate item?

All good wishes.

Yours sincerely,

David

Enc.

David Bradley

OP.PH - Water + Sewerage

Mr. Alain F. Thys

October 8, 1974

A. Al-Khafaji

RPO G615

Solid Waste Processing and Disposal - Draft Report

I reviewed the draft report prepared for IBRD by Messrs. Julbert Association Incorporation on Solid Waste Processing and Disposal and following are some comments. The report is confined to review of the state of the art analysis and the conclusion section was not included in this draft:

1. The report provides very limited information, particularly cost figures, from developing countries. The Bank and WHO have been in recent years associated with solid waste projects in Singapore, Indonesia, Yugoslavia, Turkey, etc. and it will be desirable to present some of the relevant data from these studies.

2. It is not clear whether the figures on capital and operating costs cited in the report are up-to-date cost estimates or figures quoted in the studies referenced. If the latter is the case then it would be necessary to indicate the dates for such studies to show the relevancy of the data.

3. In discussing sanitary landfill, the possible utilization of the processed solid waste or the completed landfills need to be discussed. High density bails have been used in Japan as building blocks and compacted bails with asphalt coating are being used in few countries for land reclamation.

4. The report does not address itself to the problems of leachate production and emission of methane gas from sanitary landfills. The effects of these by-products need to be discussed and available methods of treatment with cost estimates should be provided.

5. In discussing incineration, the report could elaborate on the achievements, problems and experiences of the European cities who have accumulated a long operating experience in this field. The report could further give indication if there are economies of scale with this process and outline specific parameters that are likely to make this process more economical such as city size, urban character, availability of energy sources, etc.

6. The chapter on resource recovery is quite good and well presented.

7. No economic comparative study of alternative solid waste disposal methods is presented. One can understand the complexity of such study as it has to assess capital and operating costs of waste disposal, transportation and resource recovery. However, the report could detail a guideline for conducting such study which would be very beneficial to IBRD engineers in reviewing or preparing consultants' terms of reference or in the evaluation of studies. The guideline should detail the methodology of a cost/benefit analysis, identify quantifiable parameters and develop comparative indices for such studies.

8. Based on the consultant's experience and overall review of the literature, the report could identify methods that are particularly applicable to developing countries.

cc: Messrs. Haynes
Shipman
Grover
Cosgrove
MacWilliams
Cuellar

cc: EMENA File
Division File
Chron. File

AALKHAFAJI:sm

OP- PUBLIC UTILITIES - WATER & SEWERAGE

September 24, 1974

Mr. Frank Butrico
Director, Division of Environmental Health
Pan American Health Organization
525 23rd Street, N.W.
WASHINGTON D.C.
20037

Dear Frank:

I am enclosing a draft of a paper prepared for us by Gilbert Associates on the State of the Art in Solid Waste Processing and Disposal. We have asked that particular attention be given to the energy recovery aspects and to certain criteria which might be used to alert internal personnel that opportunities exist which may justify studies on feasibility of heat recovery.

One of the areas which is a bit thin in the draft report concerns availability of accurate data from the developing areas. We would appreciate having someone, perhaps Mr. Ribeiro, review the report and give us comments which can be taken into account in preparing the final report. If during this review any data and information is available to you which might be incorporated with that now presented, we would appreciate knowing of it.

Thank you very much for any views you may offer us concerning the draft.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

Enclosure:

HRShipman:cfa

OP-PUBLIC UTILITIES - WATER & SEWERAGE

September 23, 1974

Mr. Richard E. Valiga
Project Engineer
Solid Waste Department
Environmental Division
Gilbert Associates, Inc.
Engineers and Consultants
P.O. Box 1498
READING, PA. 19603

Dear Mr. Valiga:

This will acknowledge your letter of September 18, 1974 and the ten copies of the draft report on Solid Waste Processing and Disposal.

As I indicated to you by telephone on Friday September 20, I am distributing the report to various members of our staff who are knowledgeable in the field, and as soon as I have their comments these will be consolidated and at that time I would believe that a meeting such as you suggest with Mr. Immendorf and yourself would be advantageous. You may therefore expect to hear from me sometime in the not too distant future in connection with the meeting.

Very truly yours,

HRS

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

HRShipman:cfa

September 12, 1974

Mr. C. Weiss, Jr., Science & Technology Advisor
Office - V. P., Development Policy
Richard N. Middleton, Public Utilities Department

Projects Relating to Science and Technology

In response to your memorandum of May 22nd to Mr. Rovani, I have assembled the following information from the public utilities staff:

Telecommunications

Local technical research in India, carried out by the Telecommunications Research Center in the Indian Posts and Telegraph Department, has played an important role in the development of India's telecommunications sector in which the World Bank Group has participated with five lending operations ammounting to US$288 million equivalent. 1/ The work of the center is essentially applied research closely geared to the design and local production of plant and equipment tailored to meet India's specific telecommunications needs and for research in the performance of existing plant in order to make improvements. A number of designs have enabled a wide variety of equipment in large scale use to be manufactured within the country with indigenous knownow. Significant improvements have been made to adapt imported technical knowhow to domestic requirements and manufacturing processes. Special test instruments and other equipment have been designed in the research center to meet special local needs. There is underway an expansion of the technical research activities in order to meet the national objective of self-reliance for design and manufacture of telecommunications equipment by the country and to improve the technical operation of the growing telecommunications network. The IDA credits have contributed to financing of equipment needed for the center.

(Source: C. P. Vasudevan, Division Chief
Central Telecommunications Staff)

Power

Geothermal electricity generation, if not experimental or novel, is at least unusual. The first Bank-financed geothermal project (except for a geothermal plant included in a program-type loan to CFE of Mexico) is the initial 30 MW unit at Ahuachapan, included in El Salvador's sixth power project, Loan 889-ES. A unique feature of the project is disposal of the geothermal effluent, which contains relatively high concentrations of boron and arsenic compounds; CEL, the Salvadoran utility, is building a 60 km covered canal from the plant site to the Pacific Ocean for effluent disposal.

(Source: J. E. Graves, LAC Projects)

1/ Credits 28-IN, 58-IN, 153-IN, 241-IN, 403-IN and Loan 615-IN.

Loan 763-TU - Part of the proceeds are being employed to train Turkish engineers in the use of computer methods for the design of transmission line towers (category 'b' of memo).

(Source: J. N. M. Green, EMENA Projects)

Ecological reconnaissance and selected ecological studies were carried out satisfactorily by the Asian Institute of Technology, Bangkok, for the Quaeyai project (Loan 977-TH).

(Source: E. A. Minnig, Asia Projects)

Water

Almost all Bank water projects meet most of the criteria in your memorandum, since project preparation and execution is usually carried out by the local water authority and some of the objectives of the Bank's involvement are to strengthen their organization, to make full use of local expertise, and to employ technology best suited to local capacity. A typical example is Bombay (Credit 390-IN):

(a) - The Central Public Health Engineering Research Institute was responsible for taking and analyzing water samples and running pilot water treatment plants, and, for the feasibility study, for carrying out some computer analyses of the water distribution network.

(b) - Tata Consulting Engineers, an Indian firm with extensive power expertise but little knowledge of water and sewerage projects, are associated with the main consultants (Binnie & Partners, UK) in order to broaden their field of competence. Tata have particular responsibility for the design of major sewage pumping stations.

- Staff of the Bombay Municipal Corporation (BMC) worked under Binnie's supervision during the preparation of the feasibility reports (1967-73). BMC themselves are now handling the detail design of the water distribution and sewerage networks.

- BMC's contract procedures were cumbersome. Both these procedures and their conditions of contract, technical specifications, design criteria, etc., were reviewed by the Bank and substantially improved as a result.

(c) - The proposed water filtration plant will operate on the "variable declining rate" principal -- in essence the flow through each individual filter is uncontrolled, and the total

incoming flow is shared between filters according to their relative hydraulic capacity, which in turn depends on the time since each individual filter was last cleaned and on the amount of filterable material in the incoming water. This is "novel" in the sense that it has not, to my knowledge, been applied to a plant of this size (500 million US gallons/day) before, and an "intermediate technology" in that the control system of the filters is greatly simplified, in particular by dispensing with sophisticated outflow rate controllers.

(Source: V. Rajagopalan, Division Chief, Asia Projects)

Sewage Treatment

The comments on "Water" above apply equally to sewerage projects.

- Bank-financed projects are likely to include more and more uses of "intermediate technology" treatment by oxidation ponds. A particularly interesting example is Kuala Lumpur, where the oxidation ponds are located in disused opencast tin mines.

(Source: V. Rajagopalan, Division Chief, Asia Projects)

Please let me know (or contact the sources directly) if you require further details. I would appreciate it if a draft of the paper could be given to Mr. Rovani for comments by this department.

cc: Messrs. Rovani, Vasudevan, Graves, Green and Rajagopalan

RNMiddleton:j

OP-PUBLIC UTILITIES - WATER & SEWERAGE

August 22, 1974

Mr. Richard E. Valiga
Solid Waste Department
Environmental Division
Gilbert Associates, Inc.
P.O. Box 1498
READING
PA. 19603

Dear Mr. Valiga:

Thank you for your letter dated August 19, 1974, addressed to Mr. Shipman, concerning the report on the solid wastes project you are undertaking for us. I look forward to receiving the first draft at the end of this month, and would be grateful for ten copies. Your offer to come to the Bank to discuss any comments we may have is much appreciated. However, Mr. Shipman is away on mission until mid-September, and I expect that we would not have such a meeting until about the end of that month. I will contact you in due course to propose a suitable date.

As discussed with Mr. Layland today, I would like Mr. Immendorf and yourself, when you visit, to give a brief presentation on the report to our sanitary engineers. This would not only give you an opportunity to touch on matters which cannot be covered in the report, but should also provide you with a wider range of comments on your report from an operational point of view.

Very truly yours,

Richard N. Middleton
for
Harold R. Shipman
Water Supply Advisor
Public Utilities Department

RNMiddleton:cfa

cc: Messrs. Shipman
(Rajagopalan, Thys and Kalbermatten - preliminary notice; details of proposed seminar will follow, when settled).

OP-PUBLIC UTILITIES - WATER SUPPLY & SEWERAGE

Messrs. Rajagopalan, Morse, Kalbermatten, Ribi and Thys
Richard N. Middleton, for Harold R. Shipman, Water Supply Advisor
August 19, 1974

Summary of Bank Loans and IDA Credits for Water Supply & Sewerage Projects

My attention has been drawn to some errors in the summary circulated recently. A revised version has been prepared, with these errors corrected and with disbursements up to June 30, 1974 added. Two copies of the revision are attached; I would be grateful if you would let me know by September 2 if any further corrections are required before this document is distributed. Meanwhile, please destroy the previous copies forwarded to you July 31.

Attachments:
RNMiddleton:cfa

IBRD Loans and IDA Credits for Water Supply and Sewerage Projects
(US$ Million)

Fiscal Year	Country	IBRD Loan	IDA Credit	City	Type of Project[1]	Total Project Cost[2]	IBRD	IDA	Joint Loans	Total Project Cost (%)	Cancellations or Refunds	Percentage Disbursed (at June 30, 1974)
1962	China		9	Taipei	W	9.7		4.4		45	0.4	100
	Iceland	311		Reykjavik	W	6.2	2.0			32		100
	Jordan		18	Amman	W	2.9		2.0		69	0.5	100
	Total					18.8	2.0	6.4			0.9	
1963	Nicaragua		26	Managua	W	4.8		3.0		63		100
1964	Pakistan:		41	Dacca	WS	50.1		26.0		52	26.0	0
			43	Chittagong	WS	43.0		24.0		56	24.0	0
	Jordan		43	Various Cities	W	5.0		3.5		70	1.0	100
	Total					98.1		53.5			51.0	
1965	Philippines	386		Manila	W	48.2	20.2			42	0.6	100
	Singapore	405		Singapore I	W	13.7	6.8			50		100
	Total					61.9	27.0					
1966	Burundi		85	Bujumbura	W	1.6		1.1		69		100
	Venezuela	444		Caracas	W	54.1	21.3			39	4.2	100
	Total					55.7						
1967	Pakistan		106	Lahore	WS	5.6		1.8	1.7 (Sweden)	63		100
1968	Singapore	503		Singapore II	W	16.0	8.0			50		100
	Colombia	536		Bogota I	W	48.2	14.0		4.6 (US & Germany)	29		97
	Jamaica	598		Kingston	W	9.1	5.0			55		80
	Total					73.3	27.0					
1969	Singapore	547		Singapore III	S	22.4	6.0			27		100
	Malaysia	561		Kuala Lumpur	W	7.7	3.6			47		95
	Tunisia	581		Tunis and Others I	W	32.8	15.0		5.0 (Sweden)	61		66
	Cameroon	604		Yaounde Douala	W	6.7	5.0		1.4 (France)	96		96
	Total					69.6	29.6		6.4			
1970	Ghana		160	Accra-Tema	WS	5.9		3.5		59		95
	Colombia	682		Cali	WS	37.5	18.5			49		35
	Tunisia		209	Tunis and Others II	WS	19.2		10.5	3.5 (Sweden)	73		39
	Total					62.6		14.0				
1971	Botswana:	776		Shashe Multipurpose	W	58.9	32.0		7.8 (USA, UK & Others)	68		92
			233	Gaborone-Lobatse	W	3.3		3.0		91		72
	Brazil:	757		Sao Paulo:	WS	59.8	22.0			37		18
		758			S	81.5	15.0			18	3.0	9
	Colombia:	738		Palmira	WS	3.8	2.0			53		32
		741		Bogota II	W	118.0	88.0			75		15
	Cyprus:	741		Nicosia	WS	6.8	3.5			52	0.8	57
		730		Famagusta	WS	3.2	1.9			56		60
	Kenya	714		Nairobi	W	13.4	8.3			62		60
	Yugoslavia	777		Ibar	Multipurpose	93.3	45.0			48		7
	Total					442.0	217.7				3.8	
1972	Nicaragua	808		Managua	W	10.0	6.9			69		34
	Ethiopia	818		Addis Ababa	WS	13.0	10.8			83		66
	Turkey	844		Istanbul	W	85.1	37.0			44		3
	Tunisia	858	329	Various Cities	Tourism, infra-structure, WS	55.0	14.0	10.0	10.9 (Germany)	62		1
	Total					163.1	68.7					
1973	Morocco	850		Casa-Rabat	W	104.9	48.0			46		33
	Colombia	860		Medium Cities	W	15.9	9.1			59		4
	Israel	869			S	75.0	30.0			40		0
	Bangladesh:		367	Chittagong[3]	W	23.8		7.0		29		59
			368	Dacca[3]	W	41.6		13.2		32		60
	Gabon	895		Libreville	W	19.9	9.5			48		3
	India		390	Bombay	WS	158.2	55.0			35		1
	Jordan		395	Amman	W	11.6		8.7		75		17
	Malaysia	908		Kuala Lumpur	W	26.2	13.5			51		0
	Syria		401	Damascus	W	32.6		15.0		46		0
	Mexico	909		Mexico City	W	194.0	90.0			46		0
	Total					703.7	255.1	43.9				
1974	Thailand	1021		Bangkok	W	214.0	55.0			26		0
	Tunisia	989		Sfax and Others	W	42.6	23.0			54		0
	Ecuador	1030		Guayaquil	W	38.3	23.2			61		0
	Ghana		499	Accra/Tema	W	44.7		10.4	12.3 (Af. DB & CIDA)	51		0
	Brazil	1009		31 Cities	WS	92.0	36.0			40		0
	Nepal		470	Kathmandu	WS	10.4		7.8		75		0
	Singapore	918		Singapore	WS	29.5	12.0			41		3
	Yemen Arab Republic		464	Sana'a	W	6.8		6.3		91		0
	Total					478.3	149.2	24.5				
	Grand Total[4]					2,237.5	816.1	161.2	47.2		60.5	

1/ W = Water Supply; S = Sewerage.
2/ Appraisal Report estimates.
3/ Reappraised from previous Credit Nos. 41 and 42.
4/ In the years 1962-1974, 55 operations in 31 countries with total loans and credits (net of cancellations or refunds) was US$916.8 million.

August, 1974.

OP-PUBLIC UTILITIES-WATER SUPPLY 2
SEABROOK

Mr. Leif Christoffersen
Rural Development Division

August 15, 1974

Richard N. Middleton
for Harold R. Shipman, Water Supply Advisor
Incentive Plan for Rural Water Supply Expansion

I refer to Mr. Pineo's memorandum of July 23 to you on this subject, a copy of which you passed to Mr. Shipman for information and comment. Unfortunately Mr. Shipman was not able to consider the proposal in any depth before leaving on vacation.

My immediate reaction to the proposal is that, while it may be very effective in stimulating the water program of a rural development agency, it may be very difficult to apply in countries where a national water authority has responsibility for both urban and rural supplies. The reason for this is that rural supplies usually consist of a multitude of individual systems, which can frequently be based on standard designs, and so a bonus can easily be attached to the achievements of numerical goals (as described in para 4 of the memo). Urban systems, on the other hand, are larger, far more difficult to sub-divide into targets, and need much more detailed engineering to identify least-cost solutions. Any bonus scheme would need very careful monitoring to ensure that quality did not suffer. It would obviously cause personnel problems if the staff of the rural part of an organization had the opportunity to double their salaries through bonuses while others in the same organization, responsible for urban works, did not. One also runs into the problem that salary levels in national water undertakings are often limited to the general civil service salary structure in the country, so that introduction of a bonus scheme for the undertaking would be blocked by the Civil Service Commission or equivalent body.

Despite these slightly negative initial reactions, I think the proposal is well worth following up, and look forward to discussing it with you further when Mr. Shipman returns in September.

RNMiddleton:cfa

cc: Messrs. Shipman
Rovani

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

OP-AGRICULTURE-IRRIGATION

OFFICE MEMORANDUM

cc: OP-PUBLIC UTILITIES-WATER SEWERAGE
cc: OP-PUBLIC UTILITIES-POWER

TO: Mr. Ed Kuiper

DATE: July 31, 1974

FROM: B. Kanchanalak BK

SUBJECT: Comments on your proposed Water Resources Development Planning
Re: Your draft paper on Water Resources Development Planning

At your request, I have made the following comments:

1. I support your idea of having a national institution set up in the borrowing government as a single body to deal specifically with the projection of future water resources development in the national context.

Relevant Issues

2. In many less/developing countries, the control and utilization of water resources have apparently enjoyed a rapid development. Although the multi-purpose type of development became an accepted idea for decades, some of these undertakings have yet been planned or built to serve a particular single purpose -- domestic water supply, irrigation, power, etc. By the same token, the idea of unified development of a river basin has already been well understood, but little attention has been paid to it. The main reason for these ill-adaptabilities appears to be the lack of unified planning and administration. The work is divided among various governmental agencies with each carrying out a certain component. So long as the control and utilization of water resources have yet to be taken with each kind of work being administered and planned by separate agencies, there will be hardly any opportunity of tackling all aspects of water resources development as a whole. This will lead to a non-optimum exploitation of the resources potential nature has bestowed on the area. If the National Water Development Planning Office (NWDPO) suggested in your paper would carry the task to eliminate this sort of issue, along with the main task -- long-term planning -- then it would be an ideal institution.

3. In a relatively underdeveloped region where little development work has taken place and agencies responsible for various development components are not competent and not well organized, a single authority should provide a good answer. However, in developing countries, where the governmental agencies have long been established with competencies, as a typical approach, they utilize the existing agencies in the fields within the competence of each for preparing the respective development plans. The NWDPO type of body, if they do have, would act as a single coordinating body producing a combination of plans each serving a particular field rather than a comprehensive plan that optimizes every element of development into an organic whole or that lacks the cohesion of an integrated program. Alterations and adjustments, if at all made, would be with the view to reconciling differences of opinion among various governmental agencies concerned. In theory, no adjustment is needed if the plan of each agency is well coordinated, but this can seldom be the case. Then, perhaps,

./...

much more staff than contemplated should be provided to NWDPO, if it has to be vested with the task that enables it to optimize the plan in a more meaningful way. This seems to pose a new issue on those countries for they do not have enough local competent personnel, on the one hand, and are prejudiced against expatriates on the other.

Administration Form

4. The survival of NWDPO depends largely upon the type of arrangement designed for it. It appears that two vital aspects, inter alia, need to be considered carefully -- the commanding power and the mode of cooperation between the agencies concerned -- since it is a matter of one body having authority over other ministerial agencies, and working out to unify their plans. Usually a meaningful authoritative power and the cooperation are hardly obtained by NWDPO, particularly in the less/current developing areas because of their arrangement led by inadequately ranked personnel, though they are technically competent.

5. In some developing countries, they entrust their NWDPO to the Board chaired by the Prime Minister or at least the Deputy Prime Minister, whereby they could obviate the difficulties discussed is paragraph 4. The Board is designed to generate policies and approve plans as well as expediting the necessary cooperation. It reports to the cabinet. Instead of using the Advisory Board, the Executive Secretary who runs the executive show may have a consultant group sort of long-term service experts at a working level (usually expatriates provided by UNDP), if necessary. The secretariat has direct connection channels at a working level to other ministerial agencies concerned in order to help each to contribute to the work to the full extent of their competence and responsibility. However, these channels usually operate on the personal basis rather than on an established accord. An improvement at this point may be made by amplifying the existing operation with an arrangement for other ministerial agencies personnel concerned to work hand in hand with the secretariat staff as counterparts. In this way, the secretariat may have better opportunity for working out a well-coordinated comprehensive plan without employing more staff.

The need for a Multiple-Purpose and Comprehensive River Basin Plan

6. Because of its being the key concern, let me review the finding once again. We all know that the need for such a plan arises from the relationship between the availability of water, which is now scarce, and its possible uses in the various sectors of the basin. We all know that development of the optimum use of the available resources is necessary and that the rate of return is not always the commanding factor -- water has absolute values in the context of life. Of course in the past, when water was plentiful relatively to the demands, river development projects in general had been constructed mainly to meet single purpose requirements at selected individual sites. Decades ago there has been a definite

trend towards the acceptance of the concept of comprehensive basin development, since the remaining water supply is becoming scarce as the demands on the other side of the equation are increasing. Experience has shown that major water control structures, once built, can be altered, if at all possible, only with great difficulty and at substantial expense. Consequently, it is very important that in the future great care be exercised to use promising sites to their best advantage from the standpoint of all the purposes that can be served.

Recommended Bank Actions

7. For an immediate effect, to serve as protection against under-use of the promising sites and basins discussed in paragraph 6, I, therefore, strongly insist that the Bank recognize this issue, and that river development projects cannot, as a rule, be undertaken with the Bank finance if without assurance that this issue has been investigated and the problems, if any, have been reduced to the extent acceptable. A brief discussion on this effect should appear also in their appraisal reports.

BKanchanalak:mam
cc: Messrs. Yudelman
Darnell

V.P. P.H. Water & Sewerage
cc OP Population + Nutrition

Dr. David Bradley July 23, 1974

Yves Rovani

Terms of Reference - Paper on: Measuring the Health Benefits of Investments in Water Supply

1. The Bank is faced with the problem of allocating scarce resources to alternative water supply investments which may have different health benefits. The paper should therefore address the general question "How can the Bank best conduct its decision making when health is one of the important parts of water project justification?"

2. The paper should state why the problem is important and should attempt to identify the health and nutrition benefits that can be expected from improved allocation. It should also identify those conditions where a qualitative or a quantitative analysis can be expected to improve allocations. In particular, it should attempt to isolate those circumstances (if any) where "economic",* and/or "cost-effective"* approaches are likely to be the most successful discriminators between projects, or project designs.

3. In those circumstances where a quantitative analysis is worthwhile, how should it be conducted? What available (and reliable) data should be collected, and what methodology should be used to assess this data. In terms of improved health what physical, institutional, sociological and/or cultural indicators can be used to (i) identify potential projects, (ii) gauge the benefits of successful projects, (iii) indicate the likelihood of project success, and (iv) provide a method of ranking the priority that should be accorded each of the alternatives?

4. Considering the above, what are the most pressing gaps in available knowledge? What research in this area can the Bank most profitably initiate or sponsor? What research has in the past led to a lack of positive results and how can this be avoided in the future? To what extent are the results of successful researches in one area likely to be useful in other conditions? What studies (if any) can be usefully attached to current investments to improve available knowledge? If no such studies appear worthwhile, what alternative courses of action should be pursued, and how might available medical expertise be best utilized?

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* The term "cost-effective" is used to indicate a variety of quantitative approaches which are not fully translated to monetary (economic) terms. For the most part this consists of approaches where benefits are not translated into monetary amounts but where physical improvements are achieved at least cost.

5. Finally, the paper should take particular note of the proposal to monitor health and nutrition benefits in Minas Gerais. Based on the available socio-economic evidence, and on the background material that we will provide, the paper should indicate whether such a proposal is likely to lead to positive and worthwhile results. If so, it should also indicate how the exercise should be organized to ensure the greatest likelihood of success. If not, what alternative actions would be worthwhile?

6. Each of the preceding questions represents a point of interest and concern. The paper should present a review of these and related questions together with your assessment and expert opinion on each topic. The paper should be directed at an audience generally interested in the problems of investment in water supply. It should be noted however that it may be subject to review by a panel of experts and that the panel may include, economists, epidemiologists, public health officials and medical practitioners.

7. On this assignment you should report to Mr. J. J. Warford of the Bank and should forward your report for his receipt before the 30th of September 1974.

MLane:jmt

cc and cleared with Messrs. Rovani, Shipman, Warford, Jeurling

cc: Messrs. Berg
Middleton

O.P. Water + Sewerage

July 9, 1974

Mr. Dov Spector
Chairman, Education Committee
International Congress on Metallic Corrosion
Citrus House, 22 Harakevet Street
P.O. Box 1866
TEL-AVIV
Israel

Dear Mr. Spector:

This will acknowledge your letter of May 15, 1974 in which you again refer to your great interest in the field of corrosion control, and the needs around the world to give more emphasis and attention to this aspect of water operations. The reason for my delay in replying to you has been primarily caused by my interest in exploring what possibilities might exist for us to undertake some more specific actions in the future in this field. At the moment, I have not come up with anything which I would be able to specifically discuss, but because of the importance of the matter I intend to continue to explore possibilities and will be in touch with you as soon as the avenue opens by which I feel we could usefully move ahead.

I believe that you appreciate that most of the activities of the Bank are undertaken through the loans given to our member countries. The consultants employed by the member Governments have a responsibility for looking at the broad aspects of projects and while I recognize that the matter of corrosion control is almost completely ignored, nevertheless it is something that we perhaps will have to push harder through the terms of reference which the consultants follow in the work which they undertake.

Fundamentally, a good deal of the problem of corrosion control on our water systems relates to the treatment methods and control employed and it is here where we become involved in a rather large number of inter-related actions. I would welcome any comments which you might have and which would refer to the approach which you see as feasible as it relates to the specific approaches to be taken within urban areas and urban water agencies. Would you agree with me that the problem essentially boils down to the treatment processes. I am willing to recognize of course that in the cases of pipelines

and storage tanks where electrolysis and cathodic protection may be involved, we have a somewhat different problem. However, in the case of distribution systems where most of our problems are encountered, the solution seems to me to rest largely in the treatment side rather than in other actions. Your views on this however would be appreciated in trying to determine the exact direction we might wish to take.

Your proposal for a feasibility study does not seem to have too much relevance to our normal approach on projects, but I would welcome any expansion of your thoughts in this connection also.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

(R.C. Box 465-13)

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

OFFICE MEMORANDUM

TO: Messrs. Morse, Ribi, Rajagopalan, Thys and Kalbermatten

DATE: June 27, 1974

FROM: Harold R. Shipman

SUBJECT:

OP-C.O.P.-CONSULTANTS
CC-OP-WATER SUPPLY & SEWERAGE
AFF.

The attached copy of a letter was handed to me by Don Cullivan of Camp, Dresser & McKee and I think it contains information which might be of general interest as it relates to consulting engineering costs.

HRShipman:cfa

cc: Messrs. Finne
Engelmann

CAMP DRESSER & McKEE

ENVIRONMENTAL ENGINEERS

ONE CENTER PLAZA BOSTON, MASS. 02108 TEL. 617 742-5151 CABLE: CAMDRES

DONALD C. CULLIVAN
PRESIDENT

24 May 1974

Mr. Fred Kent
Chief, Pre-Investment Planning
Division of Environmental Health
World Health Organization
1211 Geneva 27
Switzerland

Dear Mr. Kent:

Camp Dresser & McKee was one of several firms recently invited to submit a proposal for the provision of engineering services for a master plan for sewerage for Jakarta, Indonesia. The invitation included a Project Description which presented a detailed scope of work and the consultant's fee budgeted for this project.

We stated in our proposal that it would be impossible to complete the scope of work as described for the amount of fee budgeted. Even after making suggested reductions in the scope of work (which would not effect the usefulness of the final master plan) and making maximum use of local consultants and engineers from CDM offices in Asia, the budgeted fee was still considered to be inadequate.

Our estimate of the consultant's component of the manpower needed to properly complete the scope of work given in your terms of reference indicates a requirement in the order of 120 man months. This appears reasonable in light of other master plans prepared by CDM, including about 90 mm of CDM engineers for the Taipei sewerage master plan completed by us for WHO in November 1970. Jakarta is a much larger city and the scope of work for the Jakarta project is much more detailed than that of the Taipei master plan.

On the basis of 120 mm of foreign engineers, the allowable unit cost for Jakarta is about $3,850 per man month ($460,000 ÷ 120). The Taipei contract was negotiated in 1968 and signed in March 1969 and the unit cost was about $3,900

per man month ($350,000 ÷ 90). In the five years since early 1969, the average billing rate for CDM engineers has increased 58 percent (based on the "published" per diem rates CDM uses for charging clients for engineering services for September 1968 and June 1973, our latest list).

If the Taipei fee was fair and reasonable (our total pre-tax profit for that project actually was only 2 percent of the total fee), the equivalent unit cost today would be about $6,150 per man month (1.58 x $3,900).

There is another check on this figure. We have data on the average salary paid to U.S. engineers for projects where at least 75 percent of the services performed overseas and where an average of at least three engineers spent about 15 to 24 months working on the project. These averages vary somewhat depending upon the degree of need for more highly paid specialists. The average paid salary for one of our most recent international projects started in 1974 was $2,020 per man month for U.S. engineers.

Very few U.S. engineers have overheads of less than 100 percent these days and 120 percent or more is not uncommon. Profits before paying taxes (and taxes are about 50 percent for most U.S. firms) may range from 10 to 20 percent of an engineer's gross billings, with 15 percent (7-1/2 percent after taxes) considered as being fair and reasonable. Using these assumptions, a current unit cost for an international project would be in the order of:

Salary		$2,020
Overhead at 110%		2,220
Relocation[1]		1,000
	Subtotal	$5,240
Fee of 15%		790
	Total	$6,030/man month

Unit costs per man month can be misleading unless it is made clear exactly what they cover. The unit costs referred to in this letter include:

1. Salary actually paid to engineers
2. Overhead (including fringe benefits)
3. Profit
4. International air travel for the engineers
5. Freight for the engineers
6. Living allowances for the engineers.

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(1) For a family of four, USA to Asia:

Living allowance	=	$ 400/mo/family
Travel $\frac{4 \text{ @ } \$1,600}{18 \text{ mos}}$	=	350/mo/family
Freight $\frac{\$4,500/\text{family}}{18 \text{ mos}}$	=	250/mo/family
		$1,000/mo/family

Normally these are the principal items of cost which the WHO project fee is expected to cover, with all local support personnel and services to be provided by the local government. There are other miscellaneous direct dollar costs and usually a need for short term specialists These may be balanced by the fact that about 10 percent of the consultant's engineers will work out of the home office, with no need for cost items 4, 5 and 6.

As indicated earlier, it appears that the WHO budget for Jakarta was based on a unit cost of the consultant's staff of from $3,500 to $4,000 per man month. This appears to confirm recent comments by WHO to a CDM officer that WHO is currently budgeting on the basis of up to $4,000 per man month. If so, it is clear that this unit cost budget estimate is low by more than 50 percent for U.S. and Western European firms.

Through negotiations for joint ventures and periodic discussions with many U.S. engineers active in international work we are convinced that, for the six items listed above, realistic costs for highly qualified U.S. consulting engineers are currently in the order of $5,500 to $7,000 per man month. In addition, salary costs are currently increasing at a rate of nearly 10 percent per year, mostly to cover inflation. Further, overhead percentages continue to rise as the clients' demand increases for sophisticated proposals and other non-reimbursable services, and as employees' fringe benefits keep increasing.

WHO has recently published a Report on the WHO/FIDIC Seminar of 24 and 25 October 1973, which the writer attended. On page 8 of this report, in describing WHO procedures for the selection of consultants, the following statement is made. "However, WHO budget estimates are based on American and European cost levels." The facts would appear to contradict this statement, unless the budgets were fixed so long ago as to render them invalid for current use.

Perhaps we consultants should be doing more to keep WHO informed as to what <u>are</u> reasonable current estimates of our costs. This may be possible, through FIDIC, for example. We recognize that frequently there are long delays between the time UNDP budgets are fixed and the project is awarded. Surely, in these days of unusually high inflation, WHO and UNDP should be able to adopt a system to provide the necessary flexibility to meet realistic conditions.

We realize that it is not the intent of WHO to restrict participation in UNDP/WHO projects by U.S. and Western European firms but, clearly, adoption of a $4,000 per man month cost limit has that effect. As much as any international agency, WHO in the past has made an effort to select good quality engineering consultants. Cutting costs during the master planning stage of a project is very false economy indeed. We know that WHO engineers are well aware of this, but there may be a need to bring this to the attention of some of the UNDP administrators. The example in the following paragraph is illustrative.

On the basis of data from the Bangkok sewerage master plan (completed by CDM in 1968), complete wastewater collection, treatment and disposal facilities for Jakarta might be expected to cost in

the order of 300 million dollars at today's prices. A reasonable first stage program might be about 100 million dollars. Adding about 50 percent to the present Jakarta master plan engineering budget of $460,000 would make it a more realistic $700,000. This higher figure still is less than 1 percent of a reasonable first stage program. It would appear obvious that a competent, experienced engineer would be able to save his client more than the total expanded fee with little difficulty.

We hope WHO will consider these matters in preparing budgets for future projects. We would appreciate your comments on this letter and also on the possibility of entering into a dialogue with FIDIC. If so, we would be pleased to bring this matter to the attention of FIDIC.

Very truly yours,

CAMP DRESSER & McKEE INTERNATIONAL INC.

Donald E. Cullivan

Donald E. Cullivan
President

DEC/jrs

ASSOCIATION | RECONSTRUCTION AND DEVELOPMENT | CORPORATION

OFFICE MEMORANDUM

OP - PUBLIC UTILITIES: WATER SUPPLY & SEWERAGE
W. LL - INTER-AMERICAN DEV. BANK

TO: Mr. Harold R. Shipman (PBPDR) DATE: June 4, 1974

FROM: Joseph Freedman (EGR, LCPWS)

SUBJECT: Rural Water Supply Projects of IDB

Background

During 1961 to February, 1973, IDB made 15 loans for rural - water supply and 5 loans for water supply with a rural water supply component. These loans were made to national water supply agencies and Ministries of Health in 11 countries. The total amount of loans for rural water supply in these projects was US$69.9 million for a total project cost of US$130 million. As a result of experience obtained from these projects, general criteria and policies were developed.

Definition and Objectives

The individual country definition for rural communities was accepted. The size of the community generally ranged from 300 to 2,000 inhabitants. The rural water supply projects included the design, construction, and placing into operation within a stated period of time, water systems to serve a large number of rural communities. These systems could serve individual communities, or under favorable circumstances several villages. The projects also included the investigation and development of water sources, engineering, community development, and technical assistance for institution building, training, and planning.

Design Criteria and Level of Service

Each country has developed criteria which include the type of materials to be used, the per capita consumption by house connections and public standpipes, service pressure, service storage requirements, design period, and estimates of future growth. In the early loans, the level of service was based on public hydrants to be used by the families within a distance of 100 to 150 meters. However, because of the demands of the communities as well as the difficulties of charging for the water and controlling waste, more systems came to be built based on the major use of water through house connections. The systems are generally designed and built with at least 50% of the houses provided with house connections and financing within the project is provided for making house connections to as much as 70% of the houses. In some of the larger communities a few meters have been installed for the large consumers and flow-control devices for the others.

Water Quality

Preference is given to gravity supplies from safe sources that require no treatment such as springs and infiltration galleries and then

deep wells with pumps. Sources that require filtration or special treatment are used as a last resort. Disinfection by chlorination is practiced where there is technical support from a regional or district office and chemicals are not difficult to obtain.

The physical and chemical standards employed are those of the country and are similar to those of the WHO International Standards. In some areas where it is difficult to obtain water, such as parts of Argentina, higher concentrations of chemicals are allowed. Bacteriological standards such as those of WHO are used as a basis for the initial selection of the sources but infrequently applied once the systems are built.

Criteria for Selection of Communities

In the initial loans the basic country criteria for selecting the communities were accepted, and some refinements have been added over a period of years but not materially changing the basic factors.

The essential factors are that community desire and participation are required for undertaking the water system and the cost must be reasonable.

In more recent loans, attempts have been made to develop a priority rating system for the villages. Many factors such as, accessibility of water, density of population, accessibility of village, cost of the system, nearness to other villages, health conditions and population growth of the village are given relative weights; and a rating for each village is obtained. From these ratings a preliminary list is worked out. The value of such a refinement may be doubtful because the visits to the villages to develop the desired information raises the villagers' expectations and should their particular village be of a low priority rating so that construction is postponed -- they may lose interest in the project.

Community Participation

Community participation includes the decision to have a system, the formation of a group to operate the system, the contribution to the construction, and the payment for receiving service from the system.

The contribution to the construction of the system has been found to be the equivalent of 3 - 20% and generally 10% is now accepted as the range of the required community contribution. The contribution has been in the form of services such as storage areas, transportation of materials; materials such as sand, gravel, rock, bricks and lumber, labor; and cash.

Range of Conditions for Rates and Charges

For each project a system of rates and charges is required that takes into account the socioeconomic level of the villagers and usually does not exceed 3 - 5% of the head of the families' income and produces a revenue sufficient to pay at least operation and maintenance of the systems.

The upper range for the system of rates and charges would be one that produces a revenue sufficient to pay the cost of operation, maintenance and depreciation.

The experience in these projects has shown that in very few cases have the communities been able to pay rates exceeding this upper range.

cc: Messrs. Geli (LCPDR)
Kalbermatten (LCPWS)
Hotes (LCPAG)
Luhman (LCPAC)

JFreedman:saf
IBRD

Mr. Vincent J. Riley

May 2, 1974

Harold R. Shipman

UNDP Special Interest Projects - Water Supply and Sewerage

It has been our practice in commenting on UNDP projects on water and sewerage to recommend to the UNDP and WHO that the cost of final engineering not be included in the UNDP project; that on special interest projects which we eventually finance, these costs should be picked up in the credit or loan. There appears to be a need to change this position.

Over the past couple of years we have experienced substantial delays because final engineering could not be undertaken until after loan signing. This occurs where the country does not have the funds to advance against the cost of consultants. I have discussed this matter with all of the Water Supply Division Chiefs and find that they agree that a change is desirable. This agreement is based on the belief that some of the problems which have been encountered when final design was undertaken at too early a stage, can be overcome through proper attention to the procedures which have been worked out between WHO and IBRD and through project staging of the engineering work. I would therefore like to propose the procedure outlined below as the one which will be recommended to UNDP on any projects concerning water and waste in the future and on which we express special interest.

Studies of water and sewerage financed by UNDP which will lead to investment should include, among other things, the costs of not only preliminary engineering and feasibility but final design. The project documents and any contracts entered into with consulting firms should clearly indicate that all work related to final design and preparation of specifications in bidding documents will be undertaken as a second stage and only after the investment agency has identified the project which it plans to finance.

We would be happy to discuss this proposal in more detail with both UNDP and WHO should they feel it desirable. A copy of the initial memo which I circulated to the Water Division Chiefs is attached and gives further background to the proposal.

I am sending a copy of this memo to WHO for any comments which it might wish to make. It would be useful for us to know what UNDP's views are.

HRShipman:ar

Attach.

cc: Mr. Kent
All Reg. Div. Chiefs

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

OFFICE MEMORANDUM

O P P.U. Water + Sewerage

TO: Files

DATE: April 16, 1974

FROM: Benson Varon BV

SUBJECT: Village Water Supply

1. A working level discussion of the paper "Lending for Village Water Supply" was held among Messrs. Vibert and Varon (Policy Planning & Program Review Department) and Messrs. Jennings and Shipman (Public Utilities Department), on Thursday, April 11, in Mr. Varon's office.

2. It was suggested that in justifying a more active Bank role in this sub-sector, it would be desirable to elaborate on the implications for the Bank's lending program (number of operations, timing, country focus, and volume of assistance). In addition, in establishing the criteria for the selection of village water supply projects, the paper should specify what target groups of the rural population would be benefited. In this context the concept of ability to pay should be elaborated. How would it affect project design, village selection, the target group reached, etc.

3. It would also be useful for the paper to expand on the possible 'productive uses' of village water supply. As a matter of presentation it would be desirable in the summary to specify which recommendations (if any) entail a change in past Bank policies and practice. The paper should also refer, possibly in an annex, to the experience of other agencies (e.g., the IDB) with such projects.

4. Messrs, Jennings and Shipman indicated that they were in the process of revising the paper substantially at the request of Messrs. Baum and van der Tak, and that the above suggestions would be taken into account in the new draft. They hoped to complete the revision so that significant slippage would not occur in the existing schedule.

BVaron:ms

WATER SUPPLY 2 SEWERAGE

November 1, 1974

Professor B. Kesic
Director
Andrija Stamper School of
Public Health
Medical Faculty
University of Zagreb
ZAGREB, Yugoslavia

Dear Branco:

A considerable amount of time has passed since our last meeting and I hope that things are going well with you. Your name has come up several times in connection with various assignments within the Bank but until now, nothing has materialized to the point where official enquiries could be made. I heard indirectly that you were doing some consulting work for the World Health Organization, but the nature of the assignments was not clear.

My reason for writing you at this time is to informally enquire whether you would be available and have interest in an assignment for the Bank as a member of an expert panel that would look into the general question of measurement of health benefits associated with water supply. You may recall that on several occasions in the past we discussed with you the possibilities of a study in Kosovo Province on the effects of the water systems in the Ibar Project on absenteeism in industry. For a number of reasons this study was never activated but it, and others which would have similar objectives, have been under discussion on a continuing basis within the Bank. We have recently had a Paper prepared by Dr. Bradley of the U.K. entitled: "Measuring the Health Benefits of Investments in Water Supply".

It has been proposed that using the Bradley Paper as a basis for discussion, we should now form a panel of experts for review of the Paper and submission of comments. The comments prepared by each panel member would be exchanged with the other panelists and following this, a meeting of the panel for approximately two days would be convened in Washington sometime in March of next year. A Report would then be prepared reflecting the views of the panel and which we would hope might be a rather basic position paper on which our future actions in respect to the evaluation of water projects could be guided. In particular, we would like to be able to take a position on the feasibility of carrying out, or asking our borrowers to carry out, health impact studies either prior to or in parallel with major water supply investments.

I would visualize that if you were to accept the assignment, two or three days would probably be required for reading of the Paper and preparation of comments sometime in the next couple of months. It might involve another day's review of comments prepared by other panel members when they are circulated in advance of the March meeting. Assuming travel time and the actual meeting approximately one week would be required in March, and following that meeting, probably another day for review of the draft panel report and comments on needed changes. I would very much appreciate hearing from you as early as possible as to whether you feel that you could undertake this assignment should the Bank decide to proceed along the lines mentioned above. A decision will be taken by us as soon as we have heard from the various panel members now under consideration, and I would expect we could give you a firm indication of intent within approximately a month after we hear from you.

Please accept my best personal regards and convey my greetings to your family and to those members of the Faculty of the Institute as may still recall my visits to Zagreb.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

HRShipman:cfa

cc: Messrs. Rovani
Warford
Saunders
Peters

WATER SUPPLY & SEWERAGE

November 1, 1974

Mr. Berndt Dieterich
Director
Division of Environmental Health
World Health Organization
1211 GENEVA 27
Switzerland

Dear Berndt:

As a part of its continuing interest in water supply investment and in order to be better prepared to establish the economic justification for projects in this field, the Bank requested Dr. Bradley, with whom you are acquainted, to prepare a Paper entitled: "Measuring the Health Benefits of Investments in Water Supply". We have now received this Paper and after discussing the next steps that need to be taken, it has been proposed that we formulate an expert panel which would both review the Paper as a background document and to then prepare comments and recommendations. These would relate to the general question of the design of studies which would facilitate prediction of the impact of water supply and sanitation projects on health, thereby contributing to the economic evaluation of such investments.

It is visualized that the comments of the various panel members would be made available to the other panelists in preparation for a meeting which we would propose to convene for a couple of days in March 1975. A report would be prepared by the panel as a result of the meeting and hopefully, this report could then be a position document for guidance of the Bank in the actions which it might take thereafter as the part of the appraisal and evaluation process in our projects. Hopefully, we would gain from the panel its conclusions as to the usefulness of additional studies and the nature and design of such studies if they are concluded desirable.

My reason for writing you is to first inform you of the proposal at this stage, and secondly, to enlist the support of WHO in providing a highly competent epidemiologist who could serve on the panel. In discussing this question with Dr. Wolman when he was in the Bank the day before yesterday, he mentioned the name of a Czechoslovakian epidemiologist who is on the WHO staff in Geneva and who Dr. Wolman feels would make an excellent contribution to the work of the panel. We are wondering whether you could identify the name of the doctor which had momentarily escaped the memory of Dr. Wolman, and secondly, to determine whether you feel it would be possible that he could be made available for this assignment. We visualize that two or three days might be required within the next few months to review Dr. Bradley's Paper

and to prepare comments and recommendations on it. A few hours would probably also be required to review the comments of the other panelists at such time as they become available in advance of the March meeting. The meeting in March would be for approximately two days and assuming travel time, would probably require the better part of a week. Following the panel meeting in March, a few hours would then be required to review the panel report in draft and to submit any comments for consideration in preparing the final report.

From the Bank's side, we would be prepared to consider any arrangement which would be agreeable to WHO with respect to supporting the panel member coming from your staff. The simplest arrangement I would expect would be for us to pick up his travel and per diem costs and for him to stay on the WHO payroll. However, should any other arrangements be considered desirable we would be very happy to do whatever is necessary.

As a part of the foregoing exercise, I expect that there will be a number of the Bank staff members who will have an interest in sitting in on the panel meetings, and we would certainly wish to extend to WHO an invitation to sit in if you feel it worthwhile. We would expect that the panel report would come out as a document reflecting the views of only the panel and which would not necessarily reflect our, or WHO's views.

The foregoing is a rather abbreviated explanation of what we are thinking about. However, with the Terms of Reference for the Bradley Paper (copy attached) it may serve as a basis for you to explore the matter further within WHO and give us an indication of WHO's position and what we might expect in terms of your interest and support.

I appreciate that the above may extend outside the responsibilities of your Division, but since our channel of communication is normally to you and the PIP Unit, I am taking the liberty of imposing on you for assistance in the initial action required. Perhaps you could then inform us as to the channel best suited to WHO's needs if we move forward with the project.

Please accept my best personal regards.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

Attachment:

HRShipman:cfa

WATER SUPPLY & SEWERAGE

November 1, 1974

Professor David Bradley
London School of Hygiene and
Tropical Medicine
Ross Institute of Tropical Hygiene
Keppel Street (Gower Street)
London, W.C.1.E 7HT
England

Dear David:

Thank you very much for your letter of October 23. I received the remainder of Chapter III from Charles Weiss, and look forward to receiving Appendix B.

We have had an in-house review of your paper, and have decided that it should be sent out to the panel as it is (plus of course Appendix B when it arrives). Although we all have our quibbles about it, the paper is very much what we had in mind in framing your terms of reference, and it will be an excellent basis from which the panel can work in helping us formulate a policy in this field.

With the exception of Professor Wolman, who has agreed to be a panel member and rapporteur, we have not yet approached other reviewers, although a tentative list of six people has been agreed on. We intend to send the paper out for review as soon as possible, then circulating individual reviews among the various panel members prior to a meeting in Washington next March. Should everything go according to plan we would like you to attend such a meeting - two or three days should be sufficient - for which you would be paid at your present daily rate plus expenses. At this time things are somewhat tentative but we would like your reaction to this proposal, letting us know any dates during March 1975 which are definitely out of the question for you.

We have arranged for the $40 expenses to be paid: you should be receiving a cheque from us shortly.

Again, many thanks for your help. I look forward to hearing from you soon, and hope that the foregoing arrangements are suitable for you.

Sincerely yours,

J. J. Warford
Economic Adviser
Public Utilities Department

Cleared with & cc: Mr. Shipman
cc: Mr. Jeurling

JWarford:pjk

C.P.H.A. Water & Sewage

Mr. Harold Shipman

February 19, 1974

W. J. Cosgrove

Fluoridation of Water Supplies

1. As per your suggestion I have talked with Mr. Franz Maier on the subject of fluoridation of water supplies, the possible sources of fluoride compounds and the toxicity threshhold.

2. One of the reasons why fluoridation may not have been widely practiced in developing countries to date was the foreign exchange cost of imported fluoride compounds. Mr. Maier pointed out that many developing countries have fluoride compounds available.

3. For example, countries producing phosphate for fertilizers are probably wasting fluoride by disposing of it with their plant effluent. (He recently was on a mission to Egypt whose purpose was to determine methods of reducing fluoride discharges from phosphate plants to the Nile.) I talked with Mr. Roger Carmignani of Industrial Projects who advised that in Morocco they had originally considered the installation of equipment to recover silicofluoride from the plant effluent. The capital cost would have been $2 million. However, industrial tests of the rock indicated that they would only be able to recover 20,000 tons/year of silicofluoride whereas they had originally anticipated recovery of 100,000 tons per year. The apparently relatively low fluoride content of phosphate rock in Morocco coupled with an unstable world market price led the Moroccans to decide against the installation of the recovery equipment. Since the 4 m^3/sec water treatment plant we are helping to finance in Morocco would consume only 250 tons/year (at a cost of between $20,000 - $40,000 per year), this local consumption would not improve the economics of recovering silicofluoride in Morocco. Space has been left in the phosphate plant so that the fluoride recovery equipment can be installed if the fluoride content proves to be higher under operating conditions.

4. A second possible source of fluoride is fluospar (fluorite) which is found in quantity in Latin American countries. Mr. Maier tells me that a process for reacting fluospar with aluminium sulphate has proven feasible and could be carried out in water treatment plants. It might be of interest to obtain more information from him on this subject.

5. Mr. Maier indicates that the continuous concentration of fluoride which is toxic would be nearly 5,000 times the recommended concentration of one ppm of fluoride ion. This is ten times higher than the level referred to in Cox "Operation and Control of Water Treatment Processes". Mr. Maier agreed that if the fluoride feeder is correctly sized it is impossible for the feeder to be operated in such a way as to produce toxic concentrations in the water supply. He added that no new arguments have been presented against fluoridation in the past ten years and that there is more than adequate evidence to refute any arguments that have been raised.

6. During my forthcoming supervision mission to Morocco I intend to explore with ONEP the interest for Morocco in spending $20,000 - $40,000 per year to sharply reduce dental caries by 60% - 70% among children drinking treated water. At the same time I will try to obtain some rough statistics on the cost of dental care in the country (which is admittedly probably very low) in order to try to arrive at a first order of magnitude of a benefit/cost ratio which would result from introducing this type of preventive medicine in Morocco.

WJCOSGROVE:sw
IBRD

cc: Messrs. Haynes, Thys, Williams, Heyland, Warford, Guillot-Lageat, Carmignani
EMENA Files
Division Files
Chron. File

OP-PUBLIC UTILITIES-WATER + SEWERAGE

Mr. Rovani

February 12, 1974

Harold R. Shipman

Willoughby Report - Recommendation on Public Utilities in Evaluation Reports Z17 and Z18

One item of the Willoughby report, I believe it is the last recommendation, recommends that the Bank continue to give emphasis on investment in water distribution systems.

I have reviewed the projects which the Bank has financed during the past year in water supply and find that the amount of distribution system investment which is included in our loans is about the optimum amount which can usefully be constructed at the time of the project. We have discouraged utilities from extending the distribution systems to undeveloped areas, since this means investment which lays idle and deteriorates until such time as people move into the area and can make connections. Therefore in the assessment of amount of distribution system to be included in our projects the habitable areas of the city where water is required, and where immediate customers can be anticipated, is usually the guide which determines the extent of the area to be served. In many instances the work of extending the distribution system to all parts of the city is so great that is necessary that the distribution extensions be carried out in two or more stages.

In the case of the Bangkok project, the Bank is financing no distribution, this aspect being taken care of through the Asian Development Bank loan. The other projects which are listed below and on which investment has been undertaken over the course of approximately the last fifteen months all have continued the emphasis on distribution system improvements and appear to follow the recommendations contained in the Willoughby report.

Morocco - Casa-Rabat
Colombia - Medium Cities
Gabon - Libreville
Kuala Lumpur
Damascas
Bombay
Amman

HRS:lc

OR PUBLIC UTILITIES - WATER F
+SENEGAL

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SecM74-6

FROM: The Secretary

January 4, 1974

WATER DESALINATION

At the meeting of the Executive Directors held on May 22, 1973 information was requested on the work that is being done in different parts of the world on developing desalinising facilities to combat shortage of water. The attached note, prepared by the Central Projects staff, provides this information.

Distribution:

Executive Directors and Alternates
President
Senior Vice President, Operations
Vice Presidents, Bank, and Officers of IFC
Directors and Department Heads, Bank and IFC
Mr. J. Adler
Mr. W. Clark

WATER DESALINATION

1. Summary and Conclusions

(i) Desalination has been increasing in importance in various areas of the world and there are today about 800 desalting plants in operation with capacities in the 100 m^3/d to 30,000 m^3/d range. By comparison with conventional water plants, desalination is providing only a modest amount of water, primarily for domestic and industrial uses. Existing output capacities total about 4 million m^3/d, an amount equivalent to the daily consumption of 20 to 30 million people.

(ii) Well organized research activities in various countries are directed to improving the technology and reducing the cost of the product water. Research and development work has advanced sufficiently to ensure that the most important design, construction, and operation risks have been eliminated for distillation plants smaller than 40,000 m^3/d. Further work is required and in progress on larger plants, and on such processes as reverse osmosis, freezing, vapor compression, and electrodyalysis.

(iii) Records of operating costs of existing desalination plants show that reduction of costs can be achieved through economies of scale; by multipurpose application particularly when linked to power generation; and by extended plant life and lower maintenance requirements. Sea water conversion plants of recent design are capable of operating in the US \$0.25 to \$0.60/m^3 cost range while plants converting brackish water usually operate at costs somewhat lower.

(iv) Despite the considerable progress achieved over the past 10 to 15 years through basic and applied research, the costs of product water from the various desalting processes remain high. Costs range from 5 to 10 times higher than those experienced from conventional alternatives. There are no major technological breakthroughs in prospect and further cost reductions through economies of scale, from geothermal and nuclear energy applications, from improved efficiencies, from reduced down times, and from lowered operating costs, will probably appear in the form of a modest and gradual lowering of costs rather than a dramatic drop.

(v) Dual purpose (power and desalination) plants offer cost advantages over separate desalination plants particularly in the savings realized through common management and operations, and maintenance personnel. Comparison of individual water and power costs in dual installations with alternative sources is made difficult because of the need to equitably allocate capital and operating costs between the two operations.

(vi) Desalination as an alternative to fresh water transported by pipelines should be considered when pipelines longer than 200 km are required. For distances in the 100 to 200 km range, pipelines will usually prove more economic unless unusually high pumping costs are involved or unless the combination of factors involved in desalting operations are particularly favorable. Desalination will rarely be the most economic alternative where pipelines of less than 100 km in length can be employed.

(vii) The use of desalinated water for urban and industrial purposes will increase with time as existing low water sources become fully utilized. On the other hand, based on even the most favorable water costs projected for very large scale multipurpose plants not yet built, it appears unlikely that desalination will prove feasible for production of irrigation water in any but a very few specialized situations.

(viii) When deciding on the feasibility of desalination and between alternative desalting processes, all criteria normally applied to evaluation of other water projects should be employed. Emphasis on good management and conservation of existing fresh water resources needs to be stressed, to postpone the more expensive and sophisticated approaches required when desalination is adopted.

2. Introduction and Background

The most common process of removing salt from sea water has been in use for centuries. Ship captains and others faced with the need to obtain fresh drinking water, boiled sea water and collected the condesate on cool surfaces. Examples of stills functioning on solar heat go back to the last century. It has been only recently however, that the need to provide large quantities of fresh water from sea and brackish sources in certain areas has led to improvement of processes which now make it possible to convert water of any saline content and of nearly any volume to fresh water suited to human, animal, agricultural and industrial needs.

While the technology exists to produce nearly any quantity of fresh water, the application of such technology is restrained because of the costs involved.

In the last decade, large sums have been expended on research and development of the desalination processes. The general public, and particularly officials in many of the water scarce areas of the world, have been led to believe that we are entering an era where conversion of sea and brackish water to fresh water for human, agricultural and industrial uses can be accomplished at costs which are lower, or at least only slightly higher, than those from conventional sources. Unfortunately, these expectations cannot be fulfilled if results from existing installations are used as an indicator. There is promise of reduced costs as accomplishments of the research effort are gradually incorporated in new designs. Substantial reductions in costs can be achieved through economies of scale, through improved load and use factors, and through improved efficiencies. However, a breakthrough in the technology which could lead to major cost reductions is unlikely. For example, a prize of US $50,000 offered by a Swiss Foundation (DESARES) in 1960 for a significant contribution to reduction of the cost of desalting water, is still unclaimed.

Objective cost comparisons between desalination processes are made difficult because data are usually inconsistent. Plant and operating costs differ between installations according to the salinity of feed waters and the mineral content in product water; depreciation and interest charges are seldom treated in the same manner; fuel and site costs, brine disposal costs, and the allocation of shared costs in dual purpose installations vary from one plant to another.

These differences are sometimes the result of the costing method employed, and in others the result of differences specific to the installations. Comparisons of conventional and desalted water costs further require that allowance be made for costs of delivery to the customers or to the point of use. Consequently, meaningful analysis can only be done with a reasonable degree of accuracy in relation to a specific need, in a specific location.

A UN survey of desalination plants around the world, made in 1965 and updated by information obtained on certain selected plants in 1973, indicates that there are today in operation around 800 plants with capacities of over 100 cubic meters per day (m^3/d). Of these about 55 have capacities between 4,000 and 125,000 m^3/d. For comparison, large size conventional water treatment plants for urban use have capacities ranging from 1 to 4 million m^3/d.

Data for desalination plants tabulated in a UN survey show that plants built in the late '50s and early '60s have water costs ranging from US \$0.14/m^3 to \$10.00/m^3; with the average for all plants about \$0.70/m^3. For plants built in the late '60s and early '70s, costs are in the range of \$0.25 to \$0.50/m^3 with an average of about \$0.40/m^3. These costs of water can be compared with those recorded from some of the large conventional municipal treatment plants which show a range of from \$0.006/m^3 for large plants to \$0.05/m^3 for small plants.

There is some consistency in the percentage breakdown of the unit cost of desalted water for all types of plant and conditions of operation, and it is reasonable to conclude that fixed charges (capital costs) average about 33% of the total cost of water produced, with energy, operation, and maintenance costs averaging around 67%. A more detailed breakdown of these costs is presented in Annex 3.

3. Desalination Technology

3.1 Salinity Limits and Tolerances

Waters may be classified into four broad categories according to salinity as follows (in milligrams of salt per liter):

Sweet water	0 to 1,000 mg/l
Brackish water	1,000 mg/l to 10,000 mg/l
Salty water	10,000 mg/l to 30,000 mg/l
Sea water	30,000 mg/l to 35,000 mg/l +

Humans, animals and crops show varying tolerances for the common salts found in water. Humans show least tolerance, and the permissible upper limit set by WHO is 500 mg/l for public systems. However, it is known that tolerance to salinity varies with climate and that in some arid regions water with salinities of up to 3,000 mg/l is being consumed. WHO has recognized this by setting 1,500 mg/l as the maximum allowable concentration, beyond which potability is seriously impaired.

The range of salinities for animals and fowls extends from 2,800 mg/l for poultry to 12,900 mg/l for certain adult dryland sheep. A general limit of 5,000 mg/l for most animals is used.

Crops vary in tolerance because of interrelations with soil type, drainage characteristics, and the quantities of water applied. In general, 1,500 mg/l appears to be the limit for most crops, but with favorable conditions and proper crop selection, considerably higher levels can be used. Date palms and other tolerant crops have been cultivated with water having up to 10,000 mg/l salinity.

Current and foreseeable future costs of desalination, even where local water requires only limited processing to reduce salinity to acceptable levels, appear unattractive for agricultural use (see Chapter 7). This confines present considerations to application of desalinated water to human, animal and industrial purposes.

3.2 Desalination Processes

Desalination processes can be described as those which use evaporation (distillation), membranes, freezing or chemical means for separation of salt from water. These processes can be classified (a) by type of energy required, (b) by properties, and (c) by levels of salinity to be removed (see Annex 2). Using these classifications about 12 different basic processes can be identified.

Each of the processes and their modifications have advantages and disadvantages. For example, waters of low salinity require less energy for salt removal than those with high salt content. In the case of low salinity waters, selection of a process which has an energy input varying with the salt to be removed has an advantage. It may be, however, that as the volume of water required increases, the advantages of a reduced energy input give way to savings in capital costs for another process even though the latter may require essentially the same energy regardless of salt content.

While there has been much hope for the development of solar stills using raw water from the sea, costs are high at present ($.80 to $1.00 per cubic meter) mainly due to the need for large amounts of capital and a large land area to produce even small amounts of fresh water. This constrains the use of solar stills to small domestic installations.

Dual purpose plants which combine power and desalination are in operation in a number of countries. Since these plants almost always take steam from power generation facilities as the heat source for evaporation, one of the distillation processes is normally employed for desalting in dual purpose installations.

3.3 Operational Aspects

While the technology of desalination is, in itself, not complex, experience with existing plants shows that maintenance and operation are major problems because of corrosion and scaling of equipment, clogging of membranes, and mechanical failures, all leading to excessive periods of "down time" and lowered efficiencies. Equipment life and the operational characteristics of each process also require attention in selection and costing of facilities.

3.4 Corrosion and Scaling

Saline water is extremely corrosive to metals and because of the high solids content of sea water, scaling of heat transfer surfaces also is a cause of major problems for any process which involves brackish solutions. Use of corrosion resistant metals and chemical conditioning of feed waters have been prime subjects for research, and are the means most commonly employed by desalting plants to combat these two problems. Of the 59 plants in a UN survey[1/] over two-thirds reported scaling and half reported corrosion as major causes of shutdowns. "Down time" caused by scaling and corrosion in many of the newer pilot and experimental plants proves that these problems are still not completely resolved. Other causes of plant shutdowns include failure of pumps and drives, and blockages or fouling due to inadequate screening of sea water.

3.5 Equipment Life

Desalination processes frequently employ equipment for which a normal operating life is not well established. Even ten years' life may be optimistic without major expenditures on maintenance. On the other hand, those parts of plants which generate steam as the means for effecting vaporization employ equipment which has undergone many years of development for use in thermal power stations. In the distillation processes it is the surfaces and units which convey the heat from the steam to the saline water which cause most problems. Pumps, pipes, valves, surfaces and other appurtenances coming in contact with the saline water are the critical elements. Development of corrosion resistant metals for desalting use is well advanced; the effect of introducing these materials is usually to increase plant costs, while reducing maintenance and prolonging plant life.

3.6 Plant Personnel

While the technology of desalination itself is straight forward, operations are made difficult because of the sensitivity of most of the processes to (a) the proper conditioning of feed water; (b) the maintenance of temperatures, pressures, or vacuums within rather narrow ranges; (c) servicing of membranes and ion exchange beds; (d) close monitoring of performance; and (e) initiation of critical corrective actions when required. These duties require much more highly skilled technicians than those employed in conventional water treatment facilities. This will pose a problem in certain developing countries, and will likely require employment of expatriate staff for a considerable period of time. This means higher costs. Selection of the process best suited to any given circumstances must take account of how the plant is to be operated, and the availability and costs of labor, local and foreign.

1/ United Nations Desalination Plant Survey, 1969.

4. Desalination Cost Considerations

In the UN survey of desalination plants published in 1969[1/], it was found that of the cost per cubic meter of fresh water for both distillation and membrane (electrodialysis) processes, about 33% can be assigned each to capital and labor with the remaing 34% broken down into energy (16%), chemicals (10%) and maintenance (8%). These proportions represent the average of 59 desalination plants, 25% dual purpose and 75% single purpose, located in different parts of the world, as noted in the table produced in Annex 1. Thirty per cent of the plants showed a cost of US $.25 to $.50/$m^3$ of water produced and 40% costs of $.75 to $1.00/$m^3$. Very few plants (10%) reported costs of less than $.25/$m^3$, and two reported costs of $7.50 to $10.00/$m^3$.

In other technical literature, costs of US $0.20 to $0.40/$m^3$ are shown for plants ranging in size from 1,200 m^3/d to 15,000m^3/d.

Data[2/] from plants recently constructed, while difficult to interpret because of research activities frequently incorporated, show that for sea water conversion, costs of well over US $0.40/$m^3$ are not uncommon when all costs are taken into consideration.

Capital costs of desalting plants are affected to a great extent by the size of the installations, decreasing in cost per m^3 of water produced as size increases. Rough figures for plants in the USA in 1965-67 show for small plants, investment of around US $500/$m^3$ per day of installed capacity. For large plants around US $400/$m^3$ and for very large plants an estimated US $250/$m^3$. These figures are 6 to 10 times larger than those reported for medium-sized conventional water treatment plants.

The wide variation of unit costs makes it difficult to select a realistic average figure to use when comparing different alternatives, even when comparing plants of about the same size.

While the foregoing figures confirm that present costs are high, there is considerable evidence to indicate that there is a downward trend which will continue, although without dramatic drops. Some of the lines of development which have been explored, and some which give encouragement to lowered costs are noted below.

4.1 Energy Costs

There have been hopes of a breakthrough in reducing energy requirements but physicists and chemists have maintained that the laws of thermodynamics determine the theoretical energy required to remove salts from a solution, given any specified conditions of salinity and temperature. They contend that it is not scientifically possible to reduce energy requirements below these levels. There is no evidence in the extensive research conducted over the past fifteen years that this contention is wrong. This leads to the conclusion that only

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1/ First UN Desalination Plant Operation Survey - ST/ECA/112-NY-1969.

2/ Unpublished data collected by correspondence - August 1973.

by finding a lower cost energy source for any given installation and by reducing energy losses through improved efficiencies, can costs be lowered. In the long run, research and development work in nuclear and geothermal energy gives promise of reducing energy costs for certain installations. Efficiencies have been improving and further progress can be anticipated. The outlook for the immediate future suggests only gradual reductions in cost from better efficiencies, and higher costs for operations dependent on fossil fuels for energy.

4.2 Dual Purpose Plants

Dual purpose plants are those built in conjunction with power generation facilities. While the usual practice of taking low pressure exhaust steam to drive the distillation plant in a dual purpose installation undoubtedly offers economies, it demands careful planning of the system to avoid the serious problems arising from a short- or long-term mismatching of power and water demands.

Location of a distillation plant and a power plant on a common site offers considerable advantages even where close coupling of the steam supplies is not practiced. The two functions can share the same management, operation and maintenance facilities; in general, the requirements of the two functions are similar in these three respects. Except for plants of unusually large capacity, it is only on this "shared" basis that the specialized management and maintenance requirements, and the part-time operating labor demands can be met at acceptable costs.

In areas where solid wastes contains a high concentration of combustible matter, combining incineration with steam generation can be considered. Such steam can be used either for desalination, for power generation, or both. In most instances heat recovery from solid waste incineration will not likely be competitive with operations using other fuels. However, where solid waste disposal must be effected at fairly high costs anyway, incineration coupled with steam generation may prove attractive.

Equitable allocation of costs between power and water on dual installations is not easy in practice. Two methods which have been proposed consist of either (a) allocation of annual fixed and variable costs to water and electricity separately, or (b) allocation of total annual costs according to water and electricity production.[1/]

4.3 Plant Utilization

As with power generation facilities, the plant utilization factor is an important determinant of unit output costs in desalting plants. The plant factor is the annual, monthly or daily production as a percentage of plant capacity. While desalting plants may be designed to provide water for peaking purposes, for example, during summer of dry months when demand exceeds the capacity of the conventional facilities, such cases will be rare because alternate sources for supply of peaking water will usually be cheaper than the desalting source.

1/ Joseph Barnea, "A New Method of Cost Allocation for Combined Power and Water Desalination Plants" - Water Resources Research, Vol. 1, No. 1, Washington DC, March 1965.

Desalination systems can accommodate normal daily and other seasonal variations in consumer demand by changing production rates or through storage facilities, whichever is more suitable or economic.

A more common cause of low plant factors is operational outages - planned and accidental. High "down time" results from the need to replace tubing, remove scale, and maintain pumps and other equipment in a highly corrosive environment.

Annual expenditure for capital charges and labor is determined by installed capacity regardless of utilization. The importance of plant factor in determining water costs can be illustrated by the figures reported in the UN survey of 59 plants. The average annual plant factor of the 59 plants was only 53% while fixed charges and labor amounted to two-thirds of the total water costs (see Annex 3). Thus, if those plants could have been operated at full capacity, the costs attributable to investment and labor would have been halved and total unit water costs reduced by one-third. While it is impractical to operate at full capacity, there is a considerable economic incentive to make the plant factor as high as possible. In many steam power plants, and for some desalination plants, factors of 90% can be obtained.

4.4 Economies of Scale

There is no doubt that as the size of plants is increased, unit costs of product water are reduced. Reports prepared in the late '60s which projected costs of very large schemes where nuclear power and desalination plants were proposed, showed water costs at figures around US $0.09 to $0.12/$m^3$. Such figures must be viewed with caution since they have been based on assumptions which have not been substantiated by actual operation. Nevertheless, with improved efficiencies, with lower energy costs from developments in nuclear fuels, economies of scale, and the benefits to be realized from dual purpose installations, costs of desalinated water at the plant can be expected to drop.

5. Desalination Plant Investments and Financing

The decision to finance desalination plants should be based on criteria similar to those employed when any other water facilities are considered. It should be demonstrated that desalination is the least costly method of supplying the water required with the same or comparable level of security. In selecting the alternatives to be compared, the possibility of using long pipelines from known fresh water sources should not be forgotten. The desalination process selected for comparison should be the one which promises the least cost water, taking into account such factors as the capacity of the national technicians to operate and maintain, available fuels, and dependability. A few of the points to be noted in reviewing proposals for desalting projects are summarized below:

(a) Comparison of Costs

Costs of desalted water should be compared with costs of water from treatment plants, springs and wells at the point where each source connects to the distribution system or to a common transmission line.

(b) Plant Factors and Storage

Plant factors should be reviewed carefully because of the poor experience to date for installations of all sizes and types.

Unusually large storage capacity for product water is required where dependable service has to be assured by desalination plant output. One week's storage is not uncommon for urban systems (see Annex 1) and this will be inadequate in some instances. Costs of storage in excess of that used for conventional systems must be added for purposes of comparison with other alternatives.

(c) Depreciation Rates

Depreciation should be based on an average life not longer than fifteen years, unless actual experience from plants in operation provides reliable data for the specific process and plant type to support a longer period.

(d) Interest Rates

Interest rates which approximate the opportunity cost of capital for the country in question should be used for comparing alternate sources and alternate processes.

(e) Costing of Power Facilities in Combined Plants

In nuclear and thermal plants where power generation and desalination are combined, it has been common to use the "going" price of power in the area as a base, and where very large power installations are designed which will generate power at costs below the "going" price, to show the savings as a means for reducing the sale price of the desalinated water. This is not an acceptable approach in making investment decisions. Cost estimates of dual purpose plants should be compared to those of equivalent single purpose installations in order to ensure that, under the given conditions, the dual purpose plant is more economic.

(f) Brine Disposal

Concentrated brine is a product of all desalting operations and its final disposal can be a major problem. Siting of plants, and decisions on the economics of various alternatives should take full account of brine disposal, the costs involved, and the ecological implications.

6. Alternatives

Among the alternatives to desalination which should be considered is that of transporting water by pipeline from distant sources of fresh water. While generalizations are difficult because of variations in terrain and the consequent effects on pumping costs, guidelines can be established which will suggest the significance of pipeline transportation as an alternative.

Vaillant[1] has prepared a table (see below) showing the approximate costs per cubic meter of transporting by pipeline a range of volumes of water per day over different distances.

Dollars per m^3 of Water Transported

Distance in km	Pipe Capacity in 1,000 m^3/day				
	20-25	40-50	100	200	250
25	$ 0.03	0.03	0.03	0.03	0.03
50	0.07	0.07	0.06	0.05	0.04
100	0.12	0.11	0.10	0.08	0.08
200	0.20	0.18	0.16	0.13	0.12
400	0.34	0.30	0.28	0.23	0.22
600	-	0.42	0.38	0.33	0.30

From the above table it will be noted, for example, that for a pipeline 200 km long and with a capacity of 100,000m^3/day, the cost of water would be around US \$0.16/m^3. For volumes of 20,000m^3/d the cost would be about US \$0.20/m^3 for the same distance. Since costs in certain desalination plants where brackish water is converted, are in this range, it would be desirable to analyse the situation further before deciding either in favor of a pipeline or in favor of a desalination plant. For distances of 100 km or less, pipeline transport will almost always be more economic than desalination, and in the volumes of water normally required for expansion of urban water facilities, pipelines will probably be the method of choice for distances up to 200 km, given present technology, and where water of high salinity has to be converted. It will be prudent, however, to examine the feasibility of desalting against pipeline transportation of fresh water, whenever sources of brackish water are immediately available if distances in excess of 100 km are involved.

7. Application of Desalination to Irrigation

Based on the most favorable water costs projected for very large scale multipurpose plants currently under study, it appears unlikely that desalination will prove economic for production of irrigation water in any but a few specialized situations. A recently completed study of agriculture in North America[2] supports this conclusion.

The cost of water onto the land for five irrigation projects financed by the Bank in Malaysia, Colombia, Korea, and Yugoslavia, is estimated to be US \$5, \$25, \$50, \$48, and \$78 per acre foot. These costs include all dams or weirs, wells and pumps, primary and secondary channels, and miscellaneous costs such as service roads, etc. These figures can be compared with an estimated "water only" cost of US \$100-\$200 per acre foot[3] from proposed large scale desalina-

1/ Les Problems du Dessalement de L'eau de Mer et des Eaux Saumatres, J. R. Vaillant, Eyrolles, 1970, Paris, France.

2/ Desalting, Victor Koelzer, USA National Water Commission, May 1972.

3/ Eliason, May 22, 1969 - Water Desalting, Present and Future, AWWA Conference, San Diego.

tion plants, to which must be added the cost of conduits, channels, etc., required to bring water onto the land. Even taking account of the lower mineral content of desalinated water it would have cost in the case of those Bank projects from three to forty times water from natural sources. There are, however, a few specialized applications, of limited scope for developing countries, which might be economically attractive. They involve enclosed environmental systems fabricated from plastic, in effect greenhouses, within which evapotranspiration is controlled and moisture is not lost to the atmosphere. Water consumption is reduced to about one-tenth of that in conventional irrigation. In these applications, high yields of high value specialty produce could more than offset the high cost of desalted water.

Public Utilities Department
Central Projects Staff
December 13, 1973

PLANT IDENTIFICATION AND GENERAL DATA

Location	Process	Year	Purpose	Unit Capacity m^3 per day	Storage Capacity m^3
USA	a	1965	Dual	532	3,800
Ecuador	a	1960	Dual	228	859
Venezuela	a	1961	-	4,104	-
Bahamas	a	1962	Dual	5,559	-
Bermuda	a	1964	Single	627	3,800
Guantanamo	a	1964	Dual	2,850	15,200
Curacao	a	1963	Single	6,080	-
Curacao	a	1963	-	6,498	-
Virgin Islands	a	1958	Single	114	68
Virgin Islands	a	1961	Dual	1,045	-
Gibraltar	a	1964	Single	494	19
Gibraltar	a	1960	Single	277	-
Italy	a	1964	Single	357	380
Libya	a	1962	Dual	190	1,140
Libya	a	1965	Dual	760	3,040
Arabian Gulf	a	1963	Dual	114	-
Arabian Gulf	a	1962	Single	114	1,140
Kuwait	a	1962	Single	190	1,330
Kuwait	a	1959	Dual	1,368	76,000
Kuwait	a	1962	Dual	2,736	76,000
Kuwait	a	1957	Dual	2,394	129,200
Kuwait	a	1960	Dual	4,560	129,200
USA	b	1961	Single	3,800	-
Kuwait	b	1950	Dual	456	76,000
Kuwait	b	1953	Dual	456	129,000
Kuwait	b	1955	Dual	456	129,000
Polynesia	b	1963	Single	61	-
USA	c	1964	Single	152	1,900
USA	c	1964	Single	53	342
USA	c	1963	Single	3,800	760
Peru	c	1955	Single	76	11
Bahamas	c	1956	Single	137	4,788
Bermuda	c	1955	Single	760	30,400
Antigua	c	1965	Single	53	-
Japan	c	1955	Dual	3,401	50,160
Marshall Islands	c	1951	Single	53	1,239
Ascension Island	c	1957	Single	395	1,341

$1m^3$ = 264 gallons

1 gallon = 3.78 liters

Location	Process	Year	Purpose	Unit Capacity m^3 per day	Storage Capacity m^3
USA - Arizona	d	1962	Single	2,470	1,140
USA - California	d	1959	Single	106	380
USA - N. Dakota	d	1960	Single	167	475
USA - Illinois	d	1958	Single	266	228
USA - Montana	d	1961	Single	209	380
Finland	d	1964	Single	49	19

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a Multiflash distillation

b Long-tube vertical distillation

c Vapor compression

d Electrodialysis

Source: First UN Desalination Plant Operation Survey
UN - New York - 1969 - ST/ECA/112

CLASSIFICATION OF DESALINATION PROCESSES

Classification by Type of Energy Required[1/]

A. Processes requiring thermal energy
   - Multiple effect distillation
   - Multiple stage flash distillation
   - Vertical Tube Evaporator (VTE)
   - Solar distillation
   - Supercritical distillation

B. Processes requiring mechanical energy
   - Vapor compression distillation
   - Freeze separation
   - Hydrate separation
   - Hyperfiltration or reverse osmosis

C. Processes requiring electrical energy
   - Electrodialysis

D. Processes requiring chemical energy
   - Ion exchange
   - Solvent extraction

Classification Based on Properties[1/]

A. Processes dependent on phase changes of water

1. Evaporation
   - Multiple-effect distillation, in which the latent heat comes from a solid surface.
   - Multiple stage flash distillation, in which the latent heat comes from cooling of the liquid being evaporated.
   - Supercritical distillation, in which all evaporation occurs above the critical temperature of pure water.
   - Solar distillation in which the latent heat is derived from direct solar radiation.
   - Vapor compression distillation, in which the latent heat is obtained regeneratively.

2. Crystallization
   - Freeze-separation, in which the crystals involved are those of pure water.
   - Hydrate-separation, in which the crystals contain molecules of the hydrating agent.

1/ Howe, University of California, Berkeley, 1968.

B. Processes dependent on the surface properties of membranes in contact with water

1. Electrodialysis, in which the unwanted ions are caused to migrate through membranes due to electrical forces.

2. Hyperfiltration or reverse osmosis, in which water is caused to migrate through membranes preferentially to the salt ions, due to pressure.

C. Processes dependent on the surface properties of solids and liquids in contact with water.

1. Ion exchange, in which unwanted ions are exchanged for less offensive ions loosely bonded to certain double salts in solid form.

2. Solvent extraction, in which certain liquids dissolve water more readily than the salt ions contained in the saline water.

Classification based on Variation of Energy Related to Initial Salinity[1/]

Type of Energy	Conversion Process
Processes in which the energy requirement is essentially independent of initial salinity	Multiple-effect distillation Multi-stage flash distillation Vapor compression distillation Supercritical distillation Vacuum flash distillation Solar distillation Freezing Reverse Osmosis
Processes in which the energy requirement depends on initial salinity	Electrodialysis Ion exchange Chemical precipitation

1/ Howe, University of California, Berkeley, 1968.

DESALINATION COST (Percentage)

	Minimum	Maximum	Average
Fixed Charges	25% a/	45% b/	33%
Labor	18% b/	38% a/	33%
Energy	9% b/	42% c/	16%
Maintenance	2% c/	26% b/	8%
Chemicals	3% c/	16% d/	10%
Resume:			
Capital Cost	25%	45%	33%
Operation and Maintenance	55%	75%	67%

a/ Vapor compression distillation

b/ Electrodialysis

c/ Long-tube vertical distillation

d/ Submerged-tube distillation

Source: First UN Desalination Plant Operation Survey
UN - New York - 1969 - ST/ECA/112

LI-UNICEF
cc PUBLIC UTILITIES - WATER & SEWERAGE

Mr. Riley

January 2, 1974

Harold R. Shipman

UNICEF/IBRD Cooperation on Rural Water Supplies

As a follow-up to a brief meeting which I had with Mr. Bowles of UNICEF in New York three weeks ago, both Mr. Bowles and Dr. Eggers called at my office on December 20 to pursue further the question of possible collaboration between UNICEF and IBRD in the field of rural water supply and sanitation. The following general comments are an attempt at summarizing the points covered in the two meetings.

(1) UNICEF has been actively involved in rural water and sanitation projects for over twenty years, during which period they have accumulated a rather extensive experience. Under the protocol established in the early days it was the role of UNICEF to finance the supplies and equipment necessary for the project, to agree on objectives, timetables, etc, and to ask WHO to provide the technical services secessary to assist the government in carrying out the construction. In the early days of the UNICEF rural water programs the facilities were always confined to hand pumps, spring improvements, and installations where power pumps were not involved. Similarly, it was rare to find projects where water distribution was a part. As time has gone on, exceptions to these policies have been made and in certain countries a fair number of power pump and small elevated tank systems have been constructed with limited numbers of street hydrants. It has also generally been part of the UNICEF policy to make the facilities available in the rural areas at no cost to the people. Each project has certain commitments which need to be met by the government but for the most part within the project area most of the cost of the project, except for the local personnel and facilities, is borne by UNICEF. While there undoubtedly have been exceptions it has been my observation that for the most part UNICEF projects were designed to benefit the areas served by the project but that they were not necessarily concerned with the view of establishing a pattern which could be followed for the rest of the country. In a number of instances the WHO engineers may have worked with government towards expansion of the ideas but because the supplies and equipment came from UNICEF,athere were no arrangements made for reimbursement by the people benefitted (even if UNICEF policies would have permitted). Opportunities for extending the project to other areas have therefore not been tested.

(2) UNICEF believes now that there is need to consider ways by which the projects which they finance can be made to serve a broader purpose than those of the past. They see the possibility of extending and expanding these projects to cover many more rural areas and for this reason are interested in any arrangements that might be worked out with IBRD. Because UNICEF is limited in the amount of funds which it has, it feels that the extent of its role in the rural water projects would be to set up pilot schemes which might serve as the base for extension and expansion to other areas.

(3) I indicated to Dr. Eggers and Mr. Bowles that at the moment we were working on a paper which would attempt to set some guidelines for policies surrounding rural water projects.

(4) I explained that one of the major difficulties based on my experience with past UNICEF projects was that of financial policy. I indicated that while I saw no reason why villages would have to collect from individuals within the village for reimbursement of operation, maintenance, and capital costs of systems, I felt it was rather fundamental that villages contribute by whatever means they could toward these costs and that this aspect would have to be introduced if UNICEF projects were to be made acceptable to us. I understood from Dr. Eggers and Mr. Bowles that they appreciated the significance of the financial side and I further understood that they believed they could find a way to go forward in certain changes of policy.

(5) I indicated that as one of the basic requirements for rural projects it appeared fundamental that the institutional arrangement exists whereby the Bank could be assured along with the country that the facilities constructed would be operated and maintained satisfactorily over a long period of time in order to ensure that the people receive the benefits of the investment. UNICEF equally recognizes this problem and are completely in agreement with the need to have such a basic organization established as the part of any project.

(6) A number of possible approaches were discussed and it was agreed that at this stage it would be better to keep things entirely on an informal basis and to confront individual situations as they develop. I suggested that since the wishes of countries was rather fundamental in the consideration of any project by the Bank in those instances where UNICEF has a rural water project and where the country would like to have IBRD consideration of a larger project, one approach would be for UNICEF and the country to approach the Bank to determine the situation at the time and to clarify whether opportunity exists within the lending program for that country to include the project. If the conditions were generally favorable, we could then proceed to learn about the project and to convey any views we had as to its suitability for financing. UNICEF representatives agreed that this was a reasonable approach.

(7) It was mutually agreed that some time in the near future arrangements would be made to have a meeting with the water supply staff of our regions in order that UNICEF might convey to the staff some of the information concerning UNICEF operations and at that time to broadly discuss the various characteristics of UNICEF projects and the opportunities which might exist to use this mechanism as a means for rural water project development. Such a meeting could probably take place some time during the first quarter of 1974.

HRS:lc

OP. Public Utilities - Water + Sewerage

Mr. Warren C. Baum

November 5, 1973

Y. Rovani Y.Rovani

Desalination Paper

Please find attached a memorandum on Water Desalination prepared by Mr. Shipman in response to a question raised by Mr. Ahmad at the Board in May (memo from Mr. Daury attached).

A fairly long delay occurred since you reviewed the earlier, and quite advanced, draft. This was due to discontinuity in staff and operational priorities of the Water and Wastes Adviser.

I would like your approval for issuing this paper as a Public Utility Note for the benefit of our Regional colleagues.

Attachments

cc: Mr. Shipman

YRovani:em

Excerpt from summary of May 22 Board Discussion of Cyprus Highway Project

"A speaker pointed to the investigation currently being undertaken by Cyprus of the feasibility of establishing desalination plants to overcome the constraints of inadequate irrigation water; he wondered whether, in view of the widespread interest, particularly in the Middle East, the Bank was also studying desalination. The staff replied that the Bank was closely following the research and development undertaken by others in this field in the hope that costs could be brought down from their current high levels to a point where the Bank could recommend desalination plants for water-short countries."

WATER DESALINATION

Water Desalination

As the scarcity and costs of conventional water supply for domestic, industrial and agricultural uses have increased, much hope has been placed by the general public and officials of many countries in the prospects for conversion of sea and brackish water into fresh water. The purpose of this memorandum is to review the State of the Art in this respect.

It includes the following main sections:

1. Summary and Conclusions
2. Background Information
3. Technology
4. Cost Considerations
5. Investments and Financing
6. Main Applications (Alternatives)
7. Possible Use for Desalination Processes for Irrigation

1. Summary and Conclusions

(i) Desalination has been increasing in importance in various areas of the world and there are today over 850 desalting plants in operation with capacities in the 100 m^3/d to 30,000 m^3/d range. By comparison with conventional water plants, desalination is providing only a modest amount of water primarily for domestic and industrial uses. Existing output capacities total about 4 million m^3/d, an amount equivalent to the daily consumption of 20 to 30 million people.

(ii) Well organized research activities are in existence in various countries and with few exceptions each is directing attention to improving the technology and to reducing the cost of the product water. There is little doubt that research and development work has been sufficiently advanced to ensure that the most important design, construction, and operation risks have been eliminated for distillation plants smaller than 40,000 m^3/d. Further work is required and in progress on larger plants, and on such processes as reverse osmosis, freezing, vapor compression, and electrodyalysis.

(iii) Current figures from actual operation of desalination plants show that reduction of costs can be achieved through economies of scale; by multipurpose application particularly when linked to power generation; and through extended plant life and lower maintenance requirements. Cost comparisons between existing and older plants is made difficult because of absence of a uniform costing method used by all plants, by differences in the salinity levels of feed water and final product water, and by escalation of costs over time. Newer plants now in operation and converting sea water are capable of operating somewhere in the US \$0.25 to \$0.60/m^3 cost range. Plants converting brackish water can usually operate at a range of costs of around one half of those for sea water.

(iv) Despite the considerable progress achieved over the past 10 to 15 years through basic and applied research, the costs of product water from the various desalting processes remain high. Costs range from 5 to 10 times higher than alternatives available in most situations to meet domestic and industrial water requirements. No major technological breakthrough appears likely and while further cost reductions will undoubtedly result from geothermal and nuclear energy applications, from improved efficiencies, from reduced down times, and from lowered operating costs, the combined result will probably be a modest and gradual lowering of costs rather than a dramatic drop.

(v) Consideration of desalination as an alternative to fresh water transported by pipelines should always be given when pipelines longer than 200 km are required. For distances in the 100 to 200 km range, pipelines will usually prove more economic unless unusually high pumping costs are involved or unless the combination of factors surrounding the desalting operations are particularly favorable. Desalination will not often prove the most economic alternative where pipelines of less than 100 km in length can be employed.

(vi) The use of desalinated water for urban and industrial purposes will increase with time and as existing low cost water sources become fully utilized. For irrigation, on the other hand, based on the most favorable water costs projected for very large scale, multipurpose plants not yet built, there appears little evidence to suggest that desalination will prove feasible for any but the unusual situation.

(vii) When deciding on the feasibility of desalination and between alternate desalting processes, all criteria normally applied to evaluation of other water projects should be employed. Emphasis on good management and conservation of existing fresh water resources needs to be stressed to postpone the more expensive and sophisticated approaches required when desalination is adopted.

2. Introduction and Background

The process of removing salt from sea water is not a recent innovation and goes back for centuries. Ship captains and others faced with the need to obtain fresh drinking water, boiled the sea water and collected the condensate which resulted when the steam collected on cool surfaces. Examples of stills functioning on solar heat are not unique to recent research but go back to the last century. It has been only recently, however, that the need to provide large quantities of fresh water from sea and brackish sources in certain areas has led to improvement of old ideas and to the research and development of processes which now make it possible to convert water of any saline content and of nearly any volume to fresh water suited to human, animal, agricultural and industrial needs.

While the technology exists to effect the production of nearly any quantity of fresh water required for any need, the application of such technology is restrained because of the costs involved, and the economics of application.

In the last decade, more money has been expended on research and development of the desalination processes than ever before. The general public, and particularly officials in many of the water scarce areas of the world, have been led to believe that we are now entering an era where conversion of sea and brackish water to fresh water for human, agricultural and industrial uses can be accomplished at costs which are lower, or at least only slightly higher, than those from conventional sources. Unfortunately, these expectations cannot be fulfilled if results from existing installations are used as an indicator. There is promise of reduced costs as accomplishments of the research effort are gradually incorporated in new design. There is evidence that substantial reductions in costs can be achieved through economies of scale, through improved load and use factors, and through improved efficiencies. This evidence also suggests, however, that a breakthrough in the technology which could lead to major cost reductions, is unlikely. For example, a prize of US $50,000 offered by a Swiss Foundation (DESARES) in 1960 for a significant contribution to reduction of the cost of desalting water, still awaits a claimant.

To properly understand and interpret information on desalination plant operations, certain characteristics need to be noted. Among these are that the salinity content of the feed water and the final mineral content of the product water vary with each installation and can affect costs and cost comparison. Similarly, the depreciation costs, interest charges, and various

capital costs are treated in different ways and direct comparisons of total costs between plants becomes hazardous. Other characteristics and peculiarities on evaluating costs are noted in Chapter 4. It is because of these variations and the fact that they have not been treated in a uniform manner in available reports that comparison of data and costs from existing installations is made difficult.

A UN survey of desalination plants around the world, made in 1965 and updated by information obtained on certain selected plants in 1973, indicates that there are today in operation around 800 plants with capacities of over 100 cubic meters per day (m^3/d). Of these there are about 55 with capacities between 4,000 and 125,000 m^3/d. For comparison large size conventional water treatment plants for city and regional use have capacities ranging from 1 to 4 million m^3/d.

Data tabulated for desalination plants in a UN Survey[1/] show that on plants built in the late '50s and early '60s, water costs ranged from US \$0.14/m^3 to US \$10.00/m^3 with the average for all plants at about \$0.70/m^3. For plants build in the late '60s and early '70s costs of water produced are in the range of US \$0.25 to \$0.50/m^3 with an average of about \$0.40/m^3. These costs of water can be compared with those recorded from some of the large conventional municipal treatment plants which show a range of from \$0.006/m^3 for large plants to \$0.05/m^3 for small plants.

There is some consistency in the percentage breakdown of the unit cost of desalted water irrespective of the type of plant and the conditions of operation and it is reasonable to conclude that fixed charges (capital costs) average about 33% of the total cost of water produced with energy, operation and maintenance costs averaging around 67%. A more detailed breakdown of these costs is presented in Annex 3.

3. Desalination Technology

3.1 Salinity Limits and Tolerances

Waters may be classified into four broad categories according to salinity as follows (in milligrams of salt per liter):

Sweet water	0 to 1,000 mg/l
Brackish water	1,000 mg/l to 10,000 mg/l
Salty water	10,000 mg/l to 30,000 mg/l
Sea water	30,000 mg/l to 35,000 mg/l +

Humans, animals and crops show varying tolerances for the common salts found in water. Humans show least tolerance with the upper permissible limits set by WHO being 500 mg/l for public systems. However, it is known that tolerance to salinity varies with climate and that in some arid regions water with salinities of up to 3,000 mg/l are being consumed. WHO has recognized this to the extent that it has set 1,500 mg/l as the maximum allowance concentration beyond which potability is seriously impaired.

The range of salinities for animals and fowls extends from 2,800 mg/l for poultry to 12,900 mg/l for certain adult dryland sheep. A general limit of 5,000 mg/l for most animals is used.

1/ United Nations Desalination Plant Survey, 1969.

Crops vary in their tolerance because of interrelations with soil type, drainage characteristics, and the quantities of water applied. In general, 1,500 mg/l appears to be the limit for most crops but with favorable conditions and proper crop selection, considerably higher levels can be used. It is known that date palms and other tolerant crops have been cultivated with water having up to 10,000 mg/l salinity.

Based on current costs of desalination even where local waters require limited processing to reduce salinity to acceptable levels, application to agricultural use appears unattractive for the present and foreseeable future (see Chapter 6). This confines present considerations to application of desalinated water to human, animal and industrial uses.

3.2 Desalination Processes

For purposes of general understanding, the desalination processes can be described as those which use evaporation (distillation), membranes, freezing or chemical means for separation of salt from water. These processes can be classified (a) by type of energy required, (b) by properties, and (c) by levels of salinity to be removed (see Annex 2). Using these classifications about 12 different processes can be identified not including those based on modification of the basic methods.

Each of the processes and their modifications have advantages and disadvantages and the wise selection for a particular project consists in maximizing the advantages and minimizing the disadvantages. For example, waters of low salinity require less energy for salt removal than those with high salt content. In the case of low salinity waters, selection of a process which has an energy input varying with the salt to be removed has an advantage. It may be, however, that as the volume of water required increases, the advantages of a reduced energy input gives way to savings in capital costs for another process even though the latter may require essentially the same energy regardless of salt content.

While much hope has existed for the development of solar stills using raw water from the sea, the cost factor is at present high ($0.80 to $1.00 per cubic meter) due mainly to the need of high capital cost and large areas to produce even small amounts of fresh water. This fact constrains the use of solar stills to small domestic installations.

Dual purpose plants which combine power and desalination are in operation in a number of countries. Since these plants almost always take steam from power generation facilities as the heat source to effect evaporation, one of the distillation processes is normally employed for desalting.

3.3 Operational Aspects

While the technology of desalination is, in itself, not complex, experience with existing plants shows that maintenance and operation are major problems which stem from corrosion and scaling of equipment, from clogging of membranes, and from mechanical failures, all leading to excessive periods of "down time" and lowered efficiencies. Equipment life and the operational characteristics of each process are also factors which require attention in selection and costing of facilities.

3.4 Corrosion and Scaling

Saline water is known to be extremely corrosive to metals. Experience with power installations using sea water for cooling has well documented this fact and there have been few, if any, desalination plants where corrosion has not created difficulties. Because of the high solids content of sea water, scaling of heat transfer surfaces has been found a major problem to overcome. Use of corrosion resistant metals and chemical conditioning of feed waters have been prime subjects for research and are the means most commonly employed to combat these two problems. Of the 59 plants in a UN survey[1/], over two-thirds reported scale problems and half reported corrosion problems as major causes of shutdowns. "Down time" on many of the newer pilot and experimental plants due to these problems proves that these problems are still not completely resolved. Other causes of plant shutdowns include those due to pumps and drives, and blockages or fouling due to inadequate screening of sea water.

3.5 Equipment Life

Desalination processes frequently employ equipment for which operating life is still not well established. Even ten years life may be optimistic without major expenditures on maintenance. On the other hand those parts of plants which generate steam as the means for effecting vaporization employ equipment which has undergone many years of development for use in thermal power stations. In the distillation processes it is the surfaces and units which convey the heat from the steam to the saline water where problems arise. Pumps, pipes, valves, surfaces and other appurtenances coming in contact with the saline water are the critical elements. The development of corrosion resistant metals for desalting use is well advanced. The effect of introducing these materials is usually to increase plant costs while reducing maintenance and prolonging plant life.

3.6 Plant Personnel

The technology of desalination is, in itself, not complex; however, the operations are made difficult because of the sensitivity of most of the processes to (a) the proper conditioning of feed water; (b) to the maintenance of temperatures, pressures, or vacuums within rather narrow ranges; (c) servicing of membranes and ion exchange beds; (d) close monitoring of performance; and (e) the initiation of critical corrective actions when required. These plus numerous other duties of the plant personnel require technicians who must be much more highly skilled than those employed in conventional water treatment facilities. This will pose a problem in certain of the developing countries and will likely require employment of expatriate staff for a considerable period of time. This in turn reflects in higher costs. Selection of the process best suited to any given situation must take account of how the plant is to be operated and the availability and costs of labor.

1/ United Nations Desalination Plant Survey, 1969.

4. Desalination Cost Considerations

In the UN survey of desalination plants published in 1969[1/] it was found that the cost per cubic meter of fresh water for both distillation and membrane (electrodialysis) processes averaged about 33% for capital investment and 67% for energy, operation and maintenance. Labor costs represented about 33% of the total unit cost of water. In other words, of the total cost, about 33% can be assigned each to capital and labor, with the remaining 34% broken down into energy (16%), chemicals (10%) and maintenance (8%). These proportions represent the average of 59 desalination plants located in different parts of the world as noted in the table produced in Annex 1, and which includes 25% dual purpose and 75% single purpose plants.

Thirty per cent of the plants summarized showed a cost of \$0.25 to \$0.50/m^3 of water produced and 40% costs of \$0.75 to \$1.00/m^3. Very few plants (10%) reported costs of less than \$0.25/m^3, and two reported costs of \$7.50 to \$10.00/m^3.

In other technical literature figures of US \$0.20 to \$0.40/m^3 are shown for plants ranging in size from 1,200 m^3/d to 15,000 m^3/d.

Data [2/] from plants recently constructed while difficult to interpret because of research activities and funds frequently incorporated in the figures, show that for sea water conversion, total costs of well over US \$0.40/m^3 are not uncommon when all costs are taken into consideration.

Capital costs of desalting plants are to a great extent affected by the size of the installations decreasing in cost per m^3 of water produced as size increases. Rough figures based on 1965-67 for plants in the USA show for small plants investment of around US \$500/m^3 of installed capacity per day of water produced; for large plants around US \$400/m^3 and for very large plants an estimated US \$250/m^3. These figures are 6 to 10 times larger than those reported for medium-sized conventional water treatment plants.

The wide variation of unit costs makes difficult the production of a good and realistic average figure to be used when comparing different alternatives, even when comparing plants of about the same size.

While the foregoing figures confirm that present costs are high, there is considerable evidence to support the view that the downward trend will continue although without dramatic drops. Some of the lines of development which have been explored and some which give encouragement to lowered costs are noted below.

4.1 Energy Costs

One of the areas where hopes had been expressed that a breakthrough might be achieved in lowering costs is that of reduced energy requirements. Physicists and chemists have stated that by application of the laws of thermodynamics given any specified conditions of salinity and temperature the theoretical energy required to remove salts from solution is fixed. They contend

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1/ First UN Desalination Plant Operation Survey - ST/ECA/112-NY-1969.

2/ Unpublished data collected by correspondence - August 1973.

that it is not scientifically possible to reduce energy requirements to below these levels. There is no evidence based on the extensive research conducted over the past fifteen years that this contention is wrong. This leads then to the conclusion that only by finding a lower cost energy source for any given installation and through reducing energy losses by improved efficiencies can costs be lowered. In the long range, research and development work now in progress directed at nuclear and geothermal energy gives promise of a means for reducing energy costs. Efficiencies have been improving and further progress can be anticipated. The outlook for the immediate future suggests only gradual reductions in cost from better efficiencies and higher costs for operations dependent on fossil fuels for energy.

4.2 Dual Purpose Plants

Dual purpose plants are those built in conjunction with power generation facilities. While the usual practice of taking low pressure exhaust steam to drive the distillation plant in a dual purpose installation undoubtedly offers economies, it does demand careful planning of the system to avoid the serious problems arising from a short or long-term mismatching of power and water demands.

The location of a distillation plant and a power plant on a common site does, however, offer considerable advantages even where close coupling of the steam supplies is not practiced. These advantages are that the two functions can share the same management, operation and maintenance facilities; in general, the requirements of the two functions are similar in these three respects. For distillation plants of anything but unusually large capacity, it is only on this "shared" basis that the rather specialized management and maintenance requirements and the part-time operating labor demands can be met at acceptable costs.

In areas where solid waste contains a high concentration of combustible matter, consideration can be given to the benefits of combining incineration with steam generation. Such steam can be used either for desalination, for power generation, or both. In most instances heat recovery from solid waste incineration will not likely be competitive with operations using other fuels. However, where solid waste disposal must be effected at fairly high costs anyway, incineration coupled with steam generation may prove attractive.

Equitable allocation of costs between power and water on dual installations has encountered a number of difficulties in practice. Two methods which have been proposed consist of either (a) allocation of annual fixed and variable costs to water and electricity separately, or (b) allocation of total annual costs according to water and electricity production.[1/]

4.3 Load and Use Factors

As with power generation facilities, load factors are of importance to desalting plants. The load factor can be stated as the annual, monthly or daily production as a percentage of plant capacity. While it is possible

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1/ Joseph Barnea - "A New Method of Cost Allocation for Combined Power and Water Desalination Plants" - Water Resources Research, Vol. 1, No. 1, Washington DC, March 1965.

that situations may develop where desalting plants will be designed and installed to provide water for peaking purposes, for example, during summer or dry months when demand exceeds the capacity of the conventional facilities, such cases will usually be very few because alternate sources for supply of peaking water will usually be cheaper than the desalting source. Where desalination is the cheapest source for peaking water, however, a low load factor would result by design. In all other cases, however, the objective is to have the highest possible load factor.

While much of the literature on desalination speaks of load factors to mean also use factors, for the reason stated in the foregoing paragraph a distinction between load and use factors appears to be desirable. Use factors relate to the normal daily and other seasonal variations in consumer demand. The system can accommodate these variations by changing production rates or through storage facilities, whichever is more suitable or economic. Load factor is related to plant production including not only accommodation to demand but also to the effects of operational outages - planned and accidental - on plant availability. This latter has proven to be quite the most significant factor in desalination plants. Because of the operational problems encountered with many desalting plants over the past decade, much "down time" has been experienced in order to replace tubing, remove scale, and to maintain pumps, feed water equipment, etc.

Annual expenditure on fixed charges and on labor for a desalination plant is determined by installed capacity regardless of utilization because labor required to operate a plant is essentially the same whether the plant operates at partial capacity or at full capacity. Even periods of complete shutdown for a few days or weeks give very limited possibilities for transferring staff and their costs elsewhere.

The importance of load factor in determining water costs can scarcely be over-emphasized. The average annual load factor of the 59 plants included in the UN survey was only 53%, resulting in load factor dependent costs for fixed charges and labor amounting to two-thirds of the total water costs listed in Annex 3. Thus, if those plants could have been operated at full capacity, the costs attributable to investment and labor would have been halved and total water costs reduced by one-third. While it is impractical to arrange for operation at full capacity, there is, nevertheless, a considerable economic incentive to make the load factor as high as possible (e.g., in many steam power plants and for some desalination plants factors of 90% can be obtained) and to take this factor into account in planning desalination installations.

4.4 Economies of Scale

There is no doubt that as the size of plants is increased, unit costs of product water are reduced. Reports prepared in the late '60s which projected costs of very large schemes where nuclear power and desalination plants were proposed, showed water costs at figures around US $0.09 to $0.12/m^3. Such figures must be viewed with caution since they have been based on assumptions which have not been substantiated by actual operation. Nevertheless, with improved efficiencies, with lower energy costs from developments in nuclear fuels, economies of scale, and through the benefits to be realized from dual purpose installations, costs of desalinated water at the plant can be expected to drop.

It can be concluded that for the present there remains a very wide gap between the theoretically achievable goals and those actually experienced on desalting plants constructed to date.

5. Desalination Plant Investments and Financing

The decision to finance desalination plants should be taken using criteria similar to those employed when any other water facilities are considered. It should be demonstrated that desalination is the least cost method of supplying the water required with the same or comparable level of security. In arriving at the alternatives to be compared, the possibility of using long pipelines from known fresh water sources should not be forgotten. Where desalination is decided upon, that process should be selected which will not only assure the least cost water but which takes into account such factors as the capacity of the national technicians to operate and maintain, available fuels and dependability. A few of the points to be noted in reviewing proposals for desalting projects are briefly summarized in the following paragraphs.

5.1 Comparison of Costs

Frequent misconceptions develop in reviewing cost data for desalinated water. Cost of desalination should be compared with costs of water from treatment plants, springs and wells at the point where each connects to the distribution system or to a common transmission line.

5.2 Load Factors and Storage

Full consideration has to be given to the load factors because of the poor experience to date for most installations of all sizes and types.

Unusually large storage capacity for product water is required where dependable service has to be assured by desalination plant output. One week's storage is not an uncommon figure used for design (see Annex 1). This will be inadequate in some instances. Costs of storage in excess of that used for conventional systems must be added for purposes of comparison with other alternatives.

5.3 Depreciation Rates

Depreciation should be based on an average life of not longer than fifteen years unless actual experience from plants in operation provides reliable data for the specific process and plant type to support a longer period.

5.4 Interest Rates

Interest rates, which represent the opportunity cost of capital for each country, should be used for purposes of comparing alternate sources and alternate processes.

5.5 Costing of Power Facilities in Combined Plants

In nuclear and thermal plants where power generation and desalination are combined, it has been common to use the "going" price of power in the area as a base, and where very large power installations are designed which will generate power at costs below the "going" price, to show the savings as a means

for reduction of the sale price of the desalinated water. This is not an acceptable approach in making investment decisions. Cost estimates of dual purpose plants should be compared to those of equivalent single purpose installations in order to ensure that, under the given conditions, the dual purpose plant is more economic.

5.6 Brine Disposal

Concentrated brine is a product of all desalting operations and its final disposal can be a major problem. Siting of plants and decisions on the economics of various alternatives should take full account of the brine disposal solution, the costs involved, and the ecological implications.

6. Alternatives

Among the alternatives to desalination which should be considered is that of transporting water by pipeline from distant sources of fresh water. While generalizations are made difficult because of the variations in terrain and the consequent effects on pumping costs, certain guidelines can be established which will suggest the significance of pipeline transportation as an alternate.

Vaillant[1/] has prepared a table (see below) showing the approximate costs per cubic meter of transporting by pipeline varying volumes of water per day over different distances.

Dollars per m^3 of Water Transported

Distance in km	Pipe Capacity in 1,000 m^3/day				
	20-25	40-50	100	200	250
25	$ 0.03	0.03	0.03	0.03	0.03
50	0.07	0.07	0.06	0.05	0.04
100	0.12	0.11	0.10	0.08	0.08
200	0.20	0.18	0.16	0.13	0.12
400	0.34	0.30	0.28	0.23	0.22
600	-	0.42	0.38	0.33	0.30

From the above table it will be noted, for example, that for a pipeline 200 km long and with a capacity of 100,000 m^3/day, the cost of water would be around $0.16/$m^3$. For volumes of 20,000 m^3/d the cost would be about $0.20/$m^3$ for the same distance. Since costs in about this range have been experienced on certain desalination plants where brackish water is converted, it would be desirable to analyze the situation further before deciding either in favor of a pipeline or in favor of a desalination plant. Usually for distances of 100 km or less, pipeline transport will almost always be more

1/ Les Problems du Dessalement de L'eau de Mer et des Eaux Saumatres, J. R. Vaillant, Eyrolles, 1970, Paris, France.

economic than desalination, and in the volumes of water normally required for expansion of urban water facilities, pipelines will probably be the method of choice for distances up to 200 km given present technology where water of high salinity has to be converted. It will be prudent, however, whenever sources of brackish water are immediately available to examine the feasibility of desalting against pipeline transportation of fresh water if distances in excess of 100 km are involved.

7. Application of Desalination to Irrigation

While very large plants which might be used to convert sea water for irrigation are only in the design and experimental stage, there do not appear to be any major technical problems which could not be overcome. The big obstacle is that of cost and there is not much evidence from current operations and developments that this difficulty will be easily overcome or that application of desalination to irrigation is just around the corner.

The most optimistic estimates for large nuclear multipurpose power and water installations, not yet designed or tested, show costs in the range of US $40 to $90/acre ft. which are greatly in excess of average prices for irrigation water currently being charged ($2 to $10/acre ft. for Colorado River water) and greatly in excess of the estimated value added by irrigation of even specialized crops in Arizona, USA, computed at $27 to $36/acre ft. Experience to date on the preliminary design of a large San Diego plant and a large Northeastern United States facility[1] suggests that the $40 to $90/acre ft. estimate will more likely approach or exceed the $100 to $200/acre ft. range when final design and construction are effected.

The foregoing pessimistic outlook for application of desalting processes to irrigation is presented with the full recognition that a simplistic comparison of the cost of desalinated water with that of natural waters of fairly high mineral content is not valid because studies have shown that nearly twice as much water is needed when irrigating with water of high mineral content as with desalted water in order to wash out salts left behind in evapotranspiration and in order to reduce moisture tensions which inhibit higher yields.[2] The types of soils, climatic conditions and nature of crops among other things enter into any analysis and will affect the answers.

There are also specialized applications for high cost water such as those where enclosed environmental systems fabricated from plastic are used and which in effect are greenhouses within which evapotranspiration is controlled and moisture is not lost to the atmosphere. Consumptive use is reduced to about one-tenth of that encountered in conventional irrigation.

The present position regarding general irrigation by desalted water which seems correct in the face of all the evidence may be summarized by quoting from the report of the US National Water Commission: "The preceeding discussion is not intended to indicate that irrigation use of desalted water has any degree of certainty of being economic. There are many questions to be answered before this can occur and certainly, significant irrigation use is not justified with present or immediately foreseen technology."

1/ Eliason - May 22, 1969 - Water Desalting, Present and Future, AWWA Conference, San Diego.

2/ Desalting, Victor Koelzer, USA National Water Commission, May 1972.

PLANT IDENTIFICATION AND GENERAL DATA

Location	Process	Year	Purpose	Unit Capacity m^3 per day	Storage Capacity m^3
USA	a	1965	Dual	532	3,800
Ecuador	a	1960	Dual	228	859
Venezuela	a	1961	-	4,104	-
Bahamas	a	1962	Dual	5,559	-
Bermuda	a	1964	Single	627	3,800
Guantanamo	a	1964	Dual	2,850	15,200
Curacao	a	1963	Single	6,080	-
Curacao	a	1963	-	6,498	-
Virgin Islands	a	1958	Single	114	68
Virgin Islands	a	1961	Dual	1,045	-
Gibraltar	a	1964	Single	494	19
Gibraltar	a	1960	Single	277	-
Italy	a	1964	Single	357	380
Libya	a	1962	Dual	190	1,140
Libya	a	1965	Dual	760	3,040
Arabian Gulf	a	1963	Dual	114	-
Arabian Gulf	a	1962	Single	114	1,140
Kuwait	a	1962	Single	190	1,330
Kuwait	a	1959	Dual	1,368	76,000
Kuwait	a	1962	Dual	2,736	76,000
Kuwait	a	1957	Dual	2,394	129,200
Kuwait	a	1960	Dual	4,560	129,200
USA	b	1961	Single	3,800	-
Kuwait	b	1950	Dual	456	76,000
Kuwait	b	1953	Dual	456	129,000
Kuwait	b	1955	Dual	456	129,000
Polynesia	b	1963	Single	61	-
USA	c	1964	Single	152	1,900
USA	c	1964	Single	53	342
USA	c	1963	Single	3,800	760
Peru	c	1955	Single	76	11
Bahamas	c	1956	Single	137	4,788
Bermuda	c	1955	Single	760	30,400
Antigua	c	1965	Single	53	-
Japan	c	1955	Dual	3,401	50,160
Marshall Islands	c	1951	Single	53	1,239
Ascension Island	c	1957	Single	395	1,341

$1 m^3$ = 264 gallons

1 gallon = 3.78 liters

Location	Process	Year	Purpose	Unit Capacity m^3 per day	Storage Capacity m^3
USA - Arizona	d	1962	Single	2,470	1,140
USA - California	d	1959	Single	106	380
USA - N. Dakota	d	1960	Single	167	475
USA - Illinois	d	1958	Single	266	228
USA - Montana	d	1961	Single	209	380
Finland	d	1964	Single	49	19

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a Multiflash distillation

b Long-tube vertical distillation

c Vapor compression

d Electrodialysis

Source: First UN Desalination Plant Operation Survey
UN - New York - 1969 - ST/ECA/112

CLASSIFICATION OF DESALINATION PROCESSES

Classification by Type of Energy Required[1/]

A. Processes requiring thermal energy
   - Multiple effect distillation
   - Multiple stage flash distillation
   - Vertical Tube Evaporator (VTE)
   - Solar distillation
   - Supercritical distillation

B. Processes requiring mechanical energy
   - Vapor compression distillation
   - Freeze separation
   - Hydrate separation
   - Hyperfiltration or reverse osmosis

C. Processes requiring electrical energy
   - Electrodialysis

D. Processes requiring chemical energy
   - Ion exchange
   - Solvent extraction

Classification Based on Properties[1/]

A. Processes dependent on phase changes of water

1. Evaporation
   - Multiple-effect distillation, in which the latent heat comes from a solid surface.
   - Multiple stage flash distillation, in which the latent heat comes from cooling of the liquid being evaporated.
   - Supercritical distillation, in which all evaporation occurs above the critical temperature of pure water.
   - Solar distillation in which the latent heat is derived from direct solar radiation.
   - Vapor compression distillation, in which the latent heat is obtained regeneratively.

2. Crystallization
   - Freeze-separation, in which the crystals involved are those of pure water.
   - Hydrate-separation, in which the crystals contain molecules of the hydrating agent.

1/ Howe, University of California, Berkeley, 1968.

B. Processes dependent on the surface properties of membranes in contact with water

1. Electrodialysis, in which the unwanted ions are caused to migrate through membranes due to electrical forces.

2. Hyperfiltration or reverse osmosis, in which water is caused to migrate through membranes preferentially to the salt ions, due to pressure.

C. Processes dependent on the surface properties of solids and liquids in contact with water.

1. Ion exchange, in which unwanted ions are exchanged for less offensive ions loosely bonded to certain double salts in solid form.

2. Solvent extraction, in which certain liquids dissolve water more readily than the salt ions contained in the saline water.

Classification based on Variation of Energy Related to Initial Salinity

Type of Energy	Conversion Process
Processes in which the energy requirement is essentially independent of initial salinity	Multiple-effect distillation Multi-stage flash distillation Vapor compression distillation Supercritical distillation Vacuum flash distillation Solar distillation Freezing Reverse Osmosis
Processes in which the energy requirement depends on initial salinity	Electrodialysis Ion exchange Chemical precipitation

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1/ Howe, University of California, Berkeley, 1968.

DESALINATION COST (Percentage)

	Minimum	Maximum	Average
Fixed Charges	25% a/	45% b/	33%
Labor	18% b/	38% a/	33%
Energy	9% b/	42% c/	16%
Maintenance	2% c/	26% b/	8%
Chemicals	3% c/	16% d/	10%

Resume:

Capital Cost	25%	45%	33%
Operation and Maintenance	55%	75%	67%

a/ Vapor compression distillation

b/ Electrodialysis

c/ Long-tube vertical distillation

d/ Submerged-tube distillation

Source: First UN Desalination Plant Operation Survey
UN - New York - 1969 - ST/ECA/112

LT- UNACC
CC: OP- LIBRARY - MEDICINE + METEOROLOGY
✓CC: OP- N.R. - WATER + GENERAL
CC: OP- TECHNOLOGY

November 1, 1973

Dear Mr. Lister:

With reference to your letter of June 22, 1973 (SG 313 (6)) relating to the "Comprehensive Plan of Action" for the development of natural resources called for in the Economic and Social Council resolution 1761 (LIV), I am pleased to send to you herewith a paper on the Bank Group's activities in that field.

If you need any additional information in this respect, please do not hesitate to let us know.

Sincerely yours,

Ernesto Stahl-Holguin
Special Representative for
United Nations Organizations

Enclosure

Mr. Frederick H. Lister
Secretary of the Administrative
Committee on Co-ordination
Office for Inter-Agency Affairs
and Co-ordination
United Nations
New York, N.Y. 10017

cc: Mrs. Boskey, IRD (with enclosure)
Monika Bovani, Pub UT "
Kalamanoff, IRD "
Shipman, Pub UT "
Friedmann, Pub UT "

KFranco:ee

ACTIVITIES OF THE WORLD BANK GROUP FOR THE DEVELOPMENT OF NATURAL RESOURCES

Many of the types of assistance listed in the "Guidelines for Actions to be Taken in the Development of Natural Resources," approved by the Committee on Natural Resources, are financed by the World Bank Group as components of water, energy and mineral projects financing. By way of illustration with respect to water resources, this is true for such kinds of assistance to member countries as modernizing and strengthening services for data collection, storage and retrieval (i)[1/]; assessment of future requirements (ii); support for exploration (v); and studies of technological developments (viii).

The promotion and strengthening of institutional operational efficiency is an objective of Bank Group project financing in all fields. Environmental considerations are now viewed as an integral element in the planning, formulation and appraisal of projects; measures to avoid industrial pollution and to avoid or reduce water pollution, as well as measures to protect health, are built into Bank Group-financed projects where appropriate.

Studies are under way directed toward establishing a Bank-wide methodology for the economic analysis of projects. Quantification of the costs in money and staff time of the various types of activities listed in the "Guidelines," both for the past and the immediate future, is difficult, since the activities in question cannot readily be isolated from other project aspects.

1/ Numbers in parenthesis are keyed to numbers of items in the "Guidelines" relating to water development.

There is set forth below a brief indication of what the Bank Group has done and, insofar as it is possible to do so, of what is envisaged for the immediate future, in respect of the kinds of activities of concern to the Committee on Natural Resources in connection with development of water, energy and mineral resources. Because the "Guidelines" are broken down into these three fields, this submission is similarly presented.

A. Water Resources Development

The proper development of water resources has been a matter of major interest to the Bank Group since its inception. The Bank and IDA have financed various types of water resource projects: irrigation, urban water supply and sewerage, hydroelectric power generation, ports and harbors and inland water transportation. In a few instances, as an adjunct to certain multi-purpose projects, flood control has also been involved. The Bank has been a key figure in some of the world's largest water resource projects, including the Mangla and Tarbela Dams on the Indus river. These multi-purpose projects benefit millions of persons through their irrigation, power and flood control components. Currently the Bank is taking part in the Mekong studies and in other multi-purpose water resource activities in Africa, Latin America, the Middle East, the Philippines and Yugoslavia.

Proper appraisal of water resource projects requires extensive information, over a long and uninterrupted period, on such hydrological factors as stream flows, ground water potential, meteorological and run-off data, seasonal and annual variations in flows and lake levels, and water quality.

There are few countries in which collection, storage and retrieval of valid hydrological data are satisfactory. Even fewer have adopted a water resource policy and a national water resource plan. It is also uncommon to find well-established water resource commissions or agencies which take into account and are responsible for the national interest in preserving and making proper use of water resources. Both for planning and appraisal work, the lack or shortage of reliable data have been a serious handicap, and the Bank has encouraged its borrowers to address this problem. If a member government expresses interest in moving forward with the establishment of systems for routine collection, storage and retrieval of water resource data, the Bank is prepared to consider incorporating appropriate financial support within water resource projects.

As noted above, institutional and manpower development are a principal objective of Bank loans and IDA credits. Where a need for training of water resource personnel is identified, appropriate provision is made for such training within the loans or credits. Increased attention is being given to this particular aspect.

The Group has put particular emphasis on the technical and economic analysis of water resource projects, since that analysis is essential to a determination of the implications for national development and the solution of national and regional problems. Technology for economic analysis of agricultural projects involving irrigation has developed to a reasonably high level. Analysis of urban and rural water projects, for human needs and for power, is usually approached through identifying the "least cost" way by which the problems may be dealth with and benefits to consumers and users may be maximized.

The Bank takes particular care to ensure that water resource development projects do not have an adverse effect upon public health and other aspects of the environment. For example, irrigation and drainage projects in Cameroon, Egypt, Malawi and Sudan incorporate anti-schistosomiasis measures to bring water-related disease under control. In Brazil, the Bank has financed its first pollution control project, devised to cleanse the waters of what has been a river of raw sewage. The Bank works closely with FAO and WHO in this connection, and has associated itself with the activities of the UN Environmental Programme.

The Bank has financed drainage projects to reclaim water-logged, saline lands in a number of countries, notably in Pakistan, using tubewell drainage, and in Egypt and Iraq, using tile drainage on a very large scale. A project financed by IDA in Egypt to install tile drainage in one million acres of the Nile Delta is the largest tile drainage project ever undertaken.

In connection with development of appropriate technology for semi-arid agriculture, the Bank plans to support investigation into the most effective uses of water at the farm level, especially in water-deficient areas. It is already assisting one such investigation in Mexico.

The Bank has financed flood control projects in Pakistan and Guyana, and has been involved both in studies and in the financing of multi-purpose projects in several other countries where flood control has been, or is, important for economic development. It is associated with assistance to Pakistan, following the recent floods.

Because, as already noted, many governments lack a well-conceived national water resources policy and water management program, it is difficult to perceive the implications of any one project for the total natural resource. The Bank has encouraged a number of its member countries to undertake basin-wide studies with a view to determining the most equitable allocation of water between competing users, or special studies concerning ground water, river pollution, and data collection. Where water is in short supply and/or where costs of water are already very high, studies have been instituted on the utilization of waste waters after treatment for industrial and agricultural reuse. While the Bank has not, to date, financed construction of desalination facilities, it is prepared to consider doing so where appropriate studies have been carried out and where it is established either that no other water source is available or that desalinated water is the "least cost" solution in a particular situation.

The Bank has consistently directed attention to the institution-building aspect of water projects. It has provided technical assistance to its member governments through, e.g., studies of water organizations and review of proposed legislation. Financial support has been provided for organization, management and technical studies.

In 1962, the year in which the Bank first financed community water supply, a total of $8.4 million was provided; in 1973, the Bank/IDA provided over $355 million. Loans and credits for such projects to date aggregate over $873 million, for projects with a total cost of about $2 billion. Increasing attention is being given to sewerage and waste

disposal projects. Through the Bank/WHO Cooperative Program, assistance is being given to developing countries in carrying out sector studies, which can serve as a basis for national planning, a better organized approach to investment decisions and initiation of sound manpower training and institutional development programs. Sector studies concerned with water supply and sewerage take account of the country's general situation with regard to water resource utilization and policy. Where appropriate, the government is advised on steps which should be taken to strengthen water resource management, including approaches to the UN and other specialized agencies for coordinated assistance.

Mention should be made of the special assistance being provided to the countries in the Sahelian Zone, for a variety of schemes including construction of wells, small-scale irrigation works and other drought-prevention or drought-alleviating measures.

B. Energy Resources Development

During FY69-73 the Bank provided $2.4 billion for electricity projects alone. This has involved about 54 projects in 32 countries. Another 110 projects in a significantly larger number of countries are under consideration for FY74-78. There has been a small amount of financing for pipeline systems (both oil and natural gas), and for coal facilities.

Where lack of data on resources are a serious obstacle to good planning, the Bank has financed national or regional surveys.

Member countries have begun to address the broader issues of national energy policy -- fuel pricing, imports, taxation, etc. -- and to ask for

Bank assistance for this purpose. Since the Bank lacks direct experience in this broader field, it will concentrate on helping governments to draw up appropriate terms of reference for reviews of energy policy and to find consultants to undertake the reviews.

The Bank has underway a program to encourage borrowers to examine periodically their standards and methods of demand forecasting, and to improve its own capacity to evaluate demand projections critically. It is also endeavoring to improve its capacity to evaluate borrowers' projections of market development and annual investment and operating costs.

The general thrust of the Bank's lending program in the past has been directed principally toward power generation and transmission, although it has also sought assurance that appropriate complementary investments were planned for distribution facilities. The Bank is now gradually, but increasingly, shifting its emphasis towards the distribution aspects of the system it helps to finance, to facilitate access of the lower income groups of the population, both in urban centers and rural areas, to power supply. Recognizing that there are benefits to society not adequately measured by the price which customers may be able to pay for electricity, the Bank has taken greater interest in such programs, and particularly in those for village electrification. A recent loan to Ecuador, for example, provides funds for village electrification, and supports the plans of the local authorities to carry out studies so that the total economic and social value of this type of electrification scheme can be better measured. Simultaneously, research to measure the benefits of electrification in

low-density areas is being conducted in El Salvador, with Bank sponsorship. Having found that pricing policies are sometimes regressive and/or penalize certain classes of consumers, the Bank is helping electric utilities to evolve tariff structures which are not only economically efficient but which help to accomplish social objectives, such as access to service by low income groups, or income redistribution.

The need to husband very carefully the scarce energy resources of countries as well as of the world as a whole is a growing concern of the Bank. So that it may be in a better position to advise member countries on these matters, it is developing guidelines for overall energy sector studies and is keeping abreast of all significant developments in new energy sources, nuclear, geothermal and solar. The Bank was one of the sponsors of a recent survey by the International Atomic Energy Agency of the market for small and medium nuclear power installations in developing countries. It has also recently financed a first geothermal plant in El Salvador.

C. Mineral Resource Development

The Bank has been actively engaged in the financing of mineral resources for many years. It has financed mineral production (nickel, manganese, potash, bauxite, aluminum and coal) through loans totaling $481 million. The International Finance Corporation has made loans and investments in the mineral sector totaling $58 million for mining and production of copper, nickel, aluminum and iron ore.

Financing has principally been limited to the exploitation stage; technical assistance loans have been made for the final stages of exploration and the preparation of feasibility studies. The objects of financing have been not only mining and beneficiation facilities, but also townships, road and rail transport facilities, port loading facilities, and electric power generation.

While the main thrust of the Bank's efforts has been directed toward the financing of production and infrastructure facilities, the Bank has also assisted governments to review the mineral sector of their economies. In some cases, the Bank has helped governments to collate geologic knowledge of the country's mineral reserves, to determine the mineral potential and to identify promising projects. In other cases, it has helped governments to assess the effectiveness of administrative arrangements, policies and legislation in the sector.

Recognizing that in many countries with mineral occurrences there has been little, if any, effort to assist small and medium-sized miners, the Bank has of late been exploring new avenues of assistance to the latter. For example, it is now providing technical assistance in the establishment of funds for mineral exploration in several countries. It has under consideration lending to national development institutions -- established development banks or new mineral development banks -- for relending to small and medium-sized miners to whom credit has not been readily available. The proceeds of these loans could be made available for mining or processing equipment, perhaps ultimately for regional processing facilities.

There appear to be many countries, principally among the least developed, which have mineral possibilities but do not have funds available for exploration, given other more urgent developmental needs. The Bank is keeping itself informed of developments in the UN consideration of a revolving fund for natural resources exploration.

The Bank has also been following developments affecting exploitation of seabed mineral resources, and familiarizing itself with the technical, legal and economic issues and implications of the use of those resources.

Developing countries often lack the resources and experience to make effective arrangements for the exploitation of their mineral resources. The Bank is currently studying the assistance now available from the UN and elsewhere to try to develop a means whereby developing countries can be given access to the necessary expertise required in this connection.

The Bank expects to continue its financing of mineral projects and technical assistance in this field. To increase the effectiveness of its own program and provide the technical expertise for an expanded role in the sector, it is now working toward the establishment of a separate mining division in its Industrial Projects Department with increased specialized staff. A policy paper incorporating proposals for an expanded role for the Bank Group in the mineral sector, and indicating the general directions which increased activity might take, is in process of preparation. It is scheduled to be considered by the Bank Group's Executive Directors before the end of 1973.

November 1, 1973

Q P. P.U Water + Sewage

Mr. Warren C. Baum August 16, 1973

Yves Rovani Y.Rovani

Memorandum on Desalination

Attached is a memorandum on Desalination which Mr. McNamara requested. Should you wish any changes please advise.

HRS:lc

MEMORANDUM ON

DESALINATION

WATER DESALINATION

In the mid 1960s a Swiss foundation (DESARES) offered a prize of US $50,000 to the person or persons who could make a significant contribution towards finding a breakthrough in the technology for economically desalting water. This prize still awaits a claimant.

In the last decade, more money has been expended on research and development of the desalination processes than ever before. The general public, and particularly officials in many of the water scarce areas of the world have been led to believe that we are now entering an era where conversion of sea and brackish water to fresh water for human, agricultural and industrial uses can be accomplished at costs which are lower, or at least only slightly higher, than those from conventional sources. Unfortunately, these expectations cannot be fulfilled if results from existing installations are used as an indicator. There is promise of reduced costs as accomplishments of the research effort are gradually incorporated in new design. There is evidence that substantial reductions in costs can be achieved through economies of scale, through improved load and use factors, and through improved efficiencies. The purpose of this memorandum is to discuss successively salinity tolerances and limits for plants, animals and humans; desalting technology including processes and operational aspects; and costs of desalination. These aspects are then summarized to serve as a guide for the consideration of projects which involve desalination.

Salinity Limits and Tolerances

Waters may be classified into four broad categories according to salinity as follows (in milligrams of salt per litre):

Sweet water	0 to 1,000 mg/l
Brackish water	1,000 mg/l to 10,000 mg/l
Salty water	10,000 mg/l to 30,000 mg/l
Sea water	35,000 $\pm$ mg/l

Humans, animals and crops show varying tolerances for the common salts found in water. Humans show least tolerance with the upper permissible limits set by WHO being 500 mg/l for public systems. However, it is known that tolerance to salinity varies with climate and that in some arid regions water with salinities of up to 3,000 mg/l are being consumed. WHO has recognized this to the extent that it has set 1,500 mg/l as the maximum allowable concentration beyond which potability is seriously impaired. The range for animals and fowls extends from 2,800 mg/l for poultry to 12,900 mg/l for certain adult dryland sheep. A general limit of 5,000 mg/l for most animals is used. Crops vary in their tolerance because of interrelations with soil type, drainage characteristics, and the quantities of water applied. In general, 1,500 mg/l appears to be the limit for most crops but with favorable conditions and proper crop selection, considerably higher levels can be used.

Based on current costs of desalination even where local waters require limited processing to reduce salinity to acceptable levels, application to agricultural use appears unattractive for the present and foreseeable future. This confines present considerations to application of desalinated water to human, animal and industrial uses.

Desalination Technology

There are today an estimated 800 desalination plants in operation throughout the world whose capacities range from 100 m^3/d up to 28,500 m^3/d. (1 m^3 = 264 US gallons.) It is estimated that the current total desalting plant capacity of all plants is rapidly approaching 3.8 million m^3/d (1 billion US gallons per day). A large number of small plants are in use by industry, tourist areas, and for research and development purposes.

Desalination Processes

Processes employed in the desalting of water can be classified in a number of ways.. Annex 2 shows three classifications: by the type of energy required; by properties; and by levels of salinity to be removed. The following list gives a broad view of those processes either now in use or in various stages of development:

Multiple effect distillation	Freeze separation
Multiple stage flash distillation	Hydrate separation
Vertical Tube Evaporator (VTE)	Hyperfiltration or reverse osmosis
Solar distillation	Electrodialysis
Supercritical distillation	Ion exchange
Vapor compression distillation	Solvent extraction

This list while, in itself, imposing, does not include the names of numerous processes based on modification of many of those shown. For purposes of general understanding the desalination processes can be described as those which use evaporation (distillation), membranes, freezing, or chemical means for separation of salt from water. Each process has advantages and disadvantages and the objective of selection is to choose the one which maximizes the first and minimizes the second. For example, waters of low salinity require less energy for salt removal than those with high salt content. In the case of low salinity waters, selection of a process which has an energy input varying with the salt to be removed has an advantage. It may be, however, that as the volume of water required increases, the advantages of a reduced energy input gives way to savings in capital costs for another process even though the latter may require essentially the same energy regardless of salt content. As a generalization in reviewing costs of water produced by plants in operation, it appears that for low salinity waters (less than 5,000 mg/l) in limited volumes, the membrane processes (electrodialysis, reverse osmosis) may have an advantage. For high salinities and large volumes the distillation processes seem to be the methods most commonly preferred. Because of the developmental work underway and because of the many variables that enter into plant selection, it is premature to conclude that any one of the foregoing generalizations will be valid for any given situation either now or in the future. The problem of selecting a particular process is further complicated by conflicting claims, and the difficulty of obtaining data which are comparable and reliable.

While much hope has existed for the development of solar stills for generation of low cost water from the sea, present installations not only require very large land areas, in the order of one square meter per m^3 (264 US gallons) of water produced per year, but also entail relatively high capital costs resulting in total costs of US $0.78 to $1.05 per m^3 ($3 to $4 per 1,000 gallons) for water produced.

Dual purpose plants which combine power and desalination are in operation in a number of countries. Since these plants almost always take steam from power generation facilities as the heat source to effect evaporation, one of the distillation processes is normally employed for desalting.

Operational Aspects

While the technology of desalination is, in itself, not complex, experience with existing plants shows that maintenance and operation are major problems which stem from corrosion and scaling of equipment, from clogging of membranes, and from mechanical failures all leading to excessive periods of "down time" and lowered efficiencies. Equipment life and the operational characteristics of each process are also factors which require attention in selection and costing of facilities.

Corrosion and Scaling Saline water is known to be extremely corrosive to metals. Experience with power installations using sea water for cooling has well documented this fact and there have been few, if any, desalination plants where corrosion has not created difficulties. Because of the high solids content of sea water, scaling of heat transfer surfaces has been found a major problem to overcome. Use of corrosion resistant metals and chemical conditioning of feed waters have been prime subjects for research and are the means most commonly employed to combat these two problems. Of the 59 plants in a UN survey,1/ over two-thirds reported scale problems and half reported corrosion problems as major causes of shutdowns. "Down time" on many of the newer pilot and experimental plants due to these problems suggests that these problems are still not completely resolved. Other causes of plant shutdowns in the UN survey included those due to pumps and drives, and blockages or fouling due to inadequate screening of sea water.

Equipment Life Desalination processes frequently employ equipment for which operating life is still not well established. Even ten years life may be optimistic without major expenditures on maintenance for certain equipment and certain waters. On the other hand those parts of plants which generate steam as the means for effecting vaporization employ equipment which has undergone many years of development for use in thermal power stations. In the distillation processes it is the surfaces and units which convey the heat from the steam to the saline water where problems arise. Pumps, pipes, valves, surfaces and other appurtenances coming in contact with the saline water are the critical elements. The development of corrosion resistant metals for desalting use is well advanced. The effect of introducing these materials is usually to increase plant costs while reducing maintenance and prolonging plant life.

1/ United Nations Desalination Plant Survey, 1969.

Plant Personnel As previously mentioned, the technology of desalination is, in itself, not complex. However, the operations are made difficult because of the sensitivity of most of the processes to the proper conditioning of feed water; to the maintenance of temperatures, pressures, or vacuums within rather narrow ranges; to servicing of membranes and ion exchange beds; to close monitoring of performance; and to the initiation of critical corrective actions when required. These plus numerous other duties of the plant personnel require technicians who must be much more highly skilled than those employed in conventional water treatment facilities. This will pose a problem in certain of the developing countries and will likely require employment of expatriate staff for a considerable period of time. This in turn reflects in higher costs. Selection of the process best suited to any given situation must take account of how the plant is to be operated and the costs of labor.

Desalination Costs

The major cost elements in the desalination processes consist of fixed charges (depreciation, interest, taxes, insurance), land, energy, labor, maintenance, feed water, and brine disposal. Some idea of the contribution of each to these elements to the cost of product water can be obtained by noting the results of an analysis of costs made in the UN survey of 59 plants operating in various parts of the world and built in the late '50s and early '60s. The total cost of water produced from these plants is shown in Annex 1. While it is recognized that plants built in the late '60s and early '70s will likely show lower costs for water produced, the breakdown of costs, percentage-wise, should not be too different between old and newer installations.

Of the 59 plants in the UN survey, the most dominant factor in the cost of water was the fixed charges on investment which accounted on average for more than one-third of water costs. For over half the plants fixed charges accounted for between 35 and 45 per cent of water costs. Labor accounted for between 25 and 35 per cent of water cost; energy costs averaged 16 per cent; maintenance costs averaged 8 per cent (2-6 per cent on larger plants); and chemical costs 11 per cent. Costs of brine disposal were not taken into account.

Capital costs of desalting plants are to a great extent affected by the size of the installations decreasing in cost per m^3 of water produced as size increases. Rough figures based on 1965-67 figures for plants in the USA, show, for small plants investment of around US \$500 per m^3 of water produced; for large plants around \$400 per m^3 and for very large plants an estimated \$250 per m^3. These figures can be compared with an average investment of around US \$40/m^3 for a medium-sized conventional water treatment plant.

Costs of water from desalination plants now in operation are high if the figures shown in Annex 1 are an indication. Reports on newer plants while not presenting figures which can be easily interpreted, suggest total costs on waters of high initial salinity of well over US \$0.40/m^3 (\$1.50/1,000 gallons) if all costs are taken into consideration.

While the foregoing figures confirm that present costs are high, there is considerable evidence to support the view that the downward trend will continue although without dramatic drops. Some of the lines of development which have been explored and some which give encouragement to lowered costs are noted below.

Energy Costs

One of the areas where hopes had been expressed that a breakthrough might be achieved in lowering costs is that of reduced energy requirements. Physicists and chemists have stated that by application of the laws of thermodynamics given any specified conditions of salinity and temperature the theoretical energy required to remove salts from solution is fixed. They contend that it is not scientifically possible to reduce energy requirements to below these levels. There is no evidence based on the extensive research conducted over the past fifteen years, that this contention is wrong. This leads then to the conclusion that only by finding a lower cost energy source for any given installation and through reducing energy losses by improved efficiencies can costs be lowered. In the long range, research and development work now in progress, directed at nuclear energy gives promise of a means for reducing energy costs. Efficiencies have been improving and further progress can be anticipated. The outlook for the immediate future suggests only gradual reductions in cost from better efficiencies, and higher costs for operations dependent on fossil fuels for energy.

Dual Purpose Plants

Dual purpose plants are those built in conjunction with power generation facilities. While the usual practice of taking low pressure exhaust steam to drive the distillation plant in a dual purpose installation undoubtedly offers economies, it does demand careful planning of the system to avoid the serious problems arising from a short- or long-term mismatching of power and water demands.

The location of a distillation plant and a power plant on a common site does, however, offer considerable advantages even where close coupling of the steam supplies is not practiced. These advantages are that the two functions can share the same management, operation and maintenance facilities; in general, the requirements of the two functions are similar in these three respects. For distillation plants of anything but unusually large capacity, it is only on this "shared" basis that the rather specialized management and maintenance requirements, and the part-time operating labor demands, can be met at acceptable costs.

In areas where solid waste contains a high concentration of combustible matter, consideration can be given to the benefits of combining incineration with steam generation. Such steam can be used either for desalination, for power generation, or both. In most instances heat recovery from solid waste incineration will not likely be competitive with operations using other fuels. However, where solid waste disposal must be effected at fairly high costs anyway, incineration coupled with steam generation may prove attractive.

A problem arises in the equitable allocation of costs between power and water on dual installations. This can be done either by the allocation of separate annual fixed and annual variable costs to water and electricity respectively, or by allocating total annual costs according to water and electricity production. The latter method is favored in the desalination plant costing procedures proposed by the UN. Under this proposed approach the total annual costs of a dual-purpose plant should be allocated to water and power in proportion to the respective annual costs incurred in the cheapest possible alternative

single purpose plants producing the same quantities of marketable output as are obtained from the combined operation.1/ By employing this procedure, joint cost allocation is simplified; furthermore, no technical parameters are brought to bear on the calculation. As stated, the method requires a breakdown of costs for alternative single purpose plants. These figures should be easily available since the costs of dual purpose plants are usually compared to those of equivalent single purpose installations in order to ensure that, under the given conditions, the dual purpose plant is more economic than single purpose installations.

Load and Use Factors

As with power generation facilities, load factors are of importance to desalting plants. The load factor can be stated as the annual, monthly or daily production as a percentage of plant capacity. While it is possible that situations may develop where desalting plants will be designed and installed to provide water for peaking purposes, for example during summer or dry months when demand exceeds the capacity of the conventional facilities, such cases will usually be very few because alternate sources for supply of peaking water will usually be cheaper than the desalting source. Where desalination is the cheapest source for peaking water, however, a low load factor would result by design. In all other cases, however, the objective is to have the highest possible load factor.

While much of the literature on desalination speaks of load factors to mean also use factors, for the reason stated in the foregoing paragraph a distinction between load and use factors appears to be desirable. Use factors relate to the normal daily and other seasonal variations in consumer demand. The system can accommodate these variations by changing production rates or through storage facilities, whichever is more suitable or economic. Load factor is related to plant production including not only accommodation to demand but also to the effects of operational outages - planned and accidental - on plant availability. This latter has proven to be quite the most significant factor in desalination plants. Because of the operational problems encountered with many desalting plants over the past decade, much down time has been experienced in order to replace tubing, remove scale, and to maintain pumps, feed water equipment, etc.

Annual expenditure on fixed charges and on labor for a desalination plant is determined by installed capacity regardless of utilization because labor required to operate a plant is essentially the same whether the plant operates at partial capacity or at full capacity. Even periods of complete shutdown for a few days or weeks give very limited possibilities for transferring staff and their costs elsewhere.

The importance of load factor in determining water costs can scarcely be over-emphasized. The average annual load factor of the 59 plants included in the UN survey was only 53%, resulting in load factor dependent costs for fixed charges and labor amounting to two-thirds of the total water costs listed in Annex 1. Thus, if those plants could have been operated at full capacity, the

1/ Joseph Barnea, "A New Method of Cost Allocation for Combined Power and Water Desalination Plants", Water Resources Research, vol. 1, No. 1 Washington, DC, March 1965.

costs attributable to investment and labor would have been halved and total water costs reduced by one-third. While it is impractical to arrange for operation at full capacity, there is, nevertheless, a considerable economic incentive to make the load factor as high as possible (e.g., in many steam power plants and for some desalination plants factors of 90% can be obtained) and to take this factor into account in planning desalination installations.

Economies of Scale

There is no doubt that as the size of plants is increased, unit costs of product water are reduced. Reports prepared in the late '60s which projected costs of very large schemes where nuclear power and desalination plants were proposed, showed water costs at figures around US $0.10/m^3 (US $0.35/1,000 gallons). Such figures must be viewed with caution since they have been based on assumptions which have not be substantiated by actual operation and frequently will not stand analysis. Nevertheless, with improved efficiencies, with lower energy costs from developments in nuclear fuels, economies of scale, and through the benefits to be realized from dual purpose installations, costs of desalinated water at the plant can be expected to drop.

It can be concluded, that for the present there remains a very wide gap between the theoretically achievable goals and those actually experienced on desalting plants constructed to date.

Investment Considerations

The decision to finance desalination plants ought to be taken using criteria similar to those employed when any other water facilities are considered. It should be demonstrated that desalination is the least cost method of supplying the water required. In arriving at the alternatives to be compared the possibilities of using long pipelines from known fresh water sources should not be forgotten. Where desalination is decided upon, that process should be selected which will not only assure the least cost water but which takes into account such factors as the capacity of the national technicians to operate and maintain, available fuels, the economics of the situation, and dependability. A few of the points to be noted in reviewing proposals for desalting projects are briefly summarized in the following paragraphs.

Comparison of Costs

Frequent misconceptions develop in reviewing cost data for desalinated water. Cost of water from desalination plants should not be compared with the cost of water from other processes when the latter costs include delivery to the consumer. The cost of water from a desalination plant should be compared with costs of water from treatment plants, springs, wells, or pipelines at the point where each connects to the distribution system or to a common transmission line.

Load Factors and Storage

Full consideration has to be given to the load factors because of the poor experience to date for most installations of all sizes and types.

Unusually large storage capacity for product water is required where dependable service has to be assured by desalination plant output. One week's storage is not an uncommon figure used for design. This will be inadequate in some instances. Costs of storage in excess of that used for conventional systems must be added for purposes of comparison with other alternates.

Depreciation Rates

Depreciation while still a controversial cost in desalination ought to be based on an average life of not longer than fifteen years unless actual experience from plants in operation provides reliable data for the specific process and plant type to support a longer period.

Interest Rates

Certain reports in the current literature projecting costs of desalination contain figures based on 3-5 per cent interest rates. Interest rates which represent the opportunity cost of capital for each country should be used for purposes of comparing alternate sources and alternate processes.

Costing of Power Facilities in Combined Plants

In nuclear and thermal plants where power generation and desalination are combined, it has been common to use the "going" price of power in the area as a base, and where very large power installations are designed which will generate power at costs below the "going" price, to show the savings as a means for reduction of the sale price of the desalinated water. This is not an acceptable approach in making investment decisions. Cost estimates of dual purpose plants should be compared to those of equivalent single purpose installations in order to ensure that, under the given conditions, the dual purpose plant is more economic.

Brine Disposal

Concentrated brine is a product of all desalting operations. This can be not only a major problem in finding a point of disposal but costly. Siting of plants and decisions on the economics of various alternatives should take full account of the brine disposal problem, the costs involved, and the ecological implications.

Alternatives

Pipelines supplying water from distant sources should not be forgotten as possible alternates to desalination plants since Vaillant[1/] has calculated that for volumes of water of 500,000 m^3/d (132,000,000 gal/d) a pipeline of 100 km could be built and could supply water at an equivalent cost. For smaller volumes where economies of scale of desalting plants are reduced, the length of pipeline which can be built to provide water at an equivalent cost, rapidly rises. Vaillant calculates that a desalination plant of 25,000 m^3/d (6,500,000 gallons) would yield water equivalent in cost to a 200 km pipeline. For purposes of rough comparisons at the present stage of development, it is believed

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1/ Dessalement de l'eau de Mer, 1970, Eyrelles Press, Paris.

that on most urban water projects on which the Bank invests, whenever water is available within 200 km of the city, a pipeline will prove more economic and be better suited to local technology, than desalination. Beyond 200 km, or in unusual circumstances such as very high pumping costs or, of course, where no other sources are available, desalination must be considered.

Harold Shipman
Water Supply Advisor
Public Utilities Department

August 1973

WATER PRODUCTION COSTS ON 59 DESALINATION PLANTS IN THE WORLD[1/]

(Dollars per 1,000 gallons)

Water Costs	Number of Plants
0- .99	3
1.0-1.99	19
2.0-2.99	3
3.0-3.99	23
4.0-4.99	0
5.0-5.99	3
6.0-6.99	0
7.0-7.99	0
8.0-8.99	1
9.0-9.99	0
10.0-19.99	4
20.0-29.99	1
30.0-39.99	2
	59

1/ United Nations Desalination Plant Operation Survey, 1969

CLASSIFICATION OF DESALINATION PROCESSES

Classification by Type of Energy Required[1/]

A. Processes requiring thermal energy
   - Multiple effect distillation
   - Multiple stage flash distillation
   - Vertical Tube Evaporator (VTE)
   - Solar distillation
   - Supercritical distillation

B. Processes requiring mechanical energy
   - Vapor compression distillation
   - Freeze separation
   - Hydrate separation
   - Hyperfiltration or reverse osmosis

C. Processes requiring electrical energy
   - Electrodialysis

D. Processes requiring chemical energy
   - Ion exchange
   - Solvent extraction

Classification Based on Properties[1/]

A. Processes dependent on phase changes of water

1. Evaporation
   - Multiple-effect distillation, in which the latent heat comes from a solid surface.
   - Multiple stage flash distillation, in which the latent heat comes from cooling of the liquid being evaporated.
   - Supercritical distillation, in which all evaporation occurs above the critical temperature of pure water.
   - Solar distillation in which the latent heat is derived from direct solar radiation.
   - Vapor compression distillation, in which the latent heat is obtained regeneratively.

2. Crystallization
   - Freeze-separation, in which the crystals involved are those of pure water.
   - Hydrate-separation, in which the crystals contain molecules of the hydrating agent.

B. Processes dependent on the surface properties of membranes in contact with water

1. Electrodialysis, in which the unwanted ions are caused to migrate through membranes due to electrical forces.

2. Hyperfiltration or reverse osmosis, in which water is caused to migrate through membranes preferentially to the salt ions, due to pressure

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1/ Howe, University of California, Berkeley, 1968

C. Processes dependent on the surface properties of solids and liquids in contact with water.

1. Ion exchange, in which unwanted ions are exchanged for less offensive ions loosely bonded to certain double salts in solid form.

2. Solvent extraction, in which certain liquids dissolve water more readily than the salt ions contained in the saline water.

Classification based on Variation of Energy Related to Initial Salinity[1]

Type of Energy	Conversion Process
Processes in which the energy requirement is essentially independent of initial salinity	Multiple-effect distillation Multi-stage flash distillation Vapor compression distillation Supercritical distillation Vacuum flash distillation Solar distillation Freezing Reverse Osmosis
Processes in which the energy requirement depends on initial salinity	Electrodialysis Ion exchange Chemical precipitation

1/ Howe, University of California, Berkeley, 1968.

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

O.P.P.U. Power
cc - P.U. Water + Sanitation

OFFICE MEMORANDUM

TO: Mr. Y. Rovani

DATE: July 6, 1973

FROM: E. Friedmann

SUBJECT: Public Utilities Sector Work Program - Power, Water (Preliminary Analysis)

Background

1. On various occasions and particularly during the review of the FY73/74 work programs of CPS Sector Departments, Mr. McNamara has stressed the importance of systematic country sector work as a solid basis for guiding the Bank's future operations. He asked for the preparation of a five-year (FY74-78) program of sector studies, and instructions to this effect were issued December 27, 1972 to all Operational Vice Presidents in a memorandum from Mr. Knapp.

2. The sector work programs were to be prepared by each Region in consultation with CPS. The CPS Sector Departments were thereafter to consolidate the five regional programs into Bank-wide sector programs. The present report reviews in a preliminary way the information already made available in connection with the Power and Water sectors.

3. We plan, however, to go beyond this preliminary review. We propose to develop objective criteria (in the form of a combined checklist and data set) to evaluate the adequacy of sector knowledge. Furthermore, we want to test this objective criteria for a sample of these countries in each region, which in the opinion of the regional staff are representative of the three basic situations -- satisfactory, fair, unsatisfactory -- so that we can cross-compare the unformalized criteria employed by the regions both amongst them and against our proposed method.

State of Sector Knowledge

4. The state of knowledge summarized in this paper has been taken from the information contained in standard questionnaires (Annex 1) which were distributed in the regions as a part of the preparation of the five-year sector work program. The questionnaire distinguished among three states of knowledge: "A" satisfactory; "B" considerable (some additional work needed); and "C" unsatisfactory (major effort needed). The staff was asked to assign one of these classifications to three aspects of sector knowledge: Data base, Sector policies, Project planning. This latter refinement proved to be (at least in the public utility sectors) of no additional significance, as in practically all cases the same classifications (A, B, or C) applied to all three aspects. Finally, the questionnaires asked for identification of the reports containing the best and most recent sources of sector knowledge.

5. On the basis of (i) the questionnaires, (ii) current lending programs (CPPs) and (iii) the proposed regional sector work, we have prepared Annexes 2 - 11 summarizing for each region, country and sector the Status of Knowledge, Source, Lending Programs and Sector Work programs. A regional summary indicating number of A, B, C type countries, number of countries in lending program and in sector work program, is given in Tables 1a and 1b (see pages 3 and 4).

6. In addition, the Department has collected the listed source documents mentioned in the Annexes 2 - 11 in order to initiate and maintain for future use Country/Sector Information Files.

7. Before commenting on the above-mentioned Tables and Annexes it may be convenient to summarize the Regional views on the objectives and methods to be utilized in their Sector Work. We take them in an almost verbatim manner from their respective reports.

8. Objectives Stated by Regional Offices[1]/

ASIA

Sector Work should be operationally oriented and be directed to identify more sharply policies and issues likely to be crucial in the identification, preparation and evaluation of projects.

EMENA

Enhance sector knowledge so as to contribute more substantially to the formulation of country policies as defined in CPPs and to assist member countries in formulating sector development strategies.

LAC

The purpose of Sector Work is to investigate major sector problems, analyze policies and study overall investment requirements. In addition, it should help to identify major areas for future Bank lending and, where possible, specific projects.

WEST AFRICA

Sector Work should help to resolve basic sector issues. The single most important issue would seem to find the right balance between extending and improving essential services in the rapidly growing urban areas, and the urgent need to provide such basic services to the rural areas as a part of a general attack on rural poverty. Another important issue is to find the adequate institutional approach (National sector authority, Integrated multi-sectoral regional/municipal institutions, Mixes, etc.).

1/ East Africa's comments on this are not yet available in writing.

TABLE 1a
REGIONAL SECTOR KNOWLEDGE
POWER

	Status of Knowledge	Number of Countries	Countries in Lending Program	Countries in Sector Program
ASIA				
	A	5	3	0
	B	4	4	1
	C	2	0	0
	Ø 1/	2	1	0
		13	8	1
E. AFRICA				
	A	7	5	1
	B	4	2	4
	C	3	1	2
	Ø	2	1	1
		16	9	8
EMENA				
	A	14	10	0
	B	7	1	1
	C	10	1	4
	Ø	0	0	0
		31	12	5
LAC				
	A	11	10	4
	B	8	6	4
	C	2	1	0
	Ø	1	0	1
		22	17	9
W. AFRICA				
	A	5	5	not available
	B	7	4	" "
	C	7	0	" "
	Ø	0	0	" "
		19	9	" "
		101	55	23

1/ No questionnaires filled for these countries. Presumed C or less.

Public Utilities Department
June 1973

TABLE 1b
REGIONAL SECTOR KNOWLEDGE
WATER

	Status of Knowledge	Number of Countries	Countries in Lending Program	Countries in Sector Program
ASIA				
	A	4	4	2
	B	2	1	1
	C	7	4	4
		13	9	7
E. AFRICA				
	A	3	2	0
	B	4	3	0
	C	9	3	4
		16	8	4
EMENA				
	A	3	2	0
	B	9	7	5
	C	16	3	5
	Ø 1/	3	0	0
		31	12	10
LAC				
	A	2	2	0
	B	1	1	0
	C	6	2	3
	Ø	13	0	0
		22	5	3
W. AFRICA				
	A	1	1	not available
	B	7	6	" "
	C	11	0	" "
		19	7	" "
		101	41	24

1/ No questionnaires filled for these countries. Presumed C or less.

Public Utilities Department
June 1973

9. Method[1/]

The various approaches planned by the regional offices are: comprehensive sector surveys; sector participation in economic missions; special studies; initial reconnaissance type surveys; sector up-dating and analysis within the context of continuous appraisal and supervision work. The regional views on the appropriate mode of work derive naturally from the existing state of knowledge in the different countries of the region. Their views are as follows.

ASIA

Sector Work will shift away from general sector surveys toward sub-sector survey and special (issues-oriented) missions. Field sector work will be carried out mainly during appraisal and supervision missions.

EMENA

We propose to concentrate our Sector Work on the 15 large and medium sized countries with active operations programs. A general change from infrequent massive deployment of sector talent to that of continuing issues-oriented analysis with more frequent, even though less comprehensive, synthesis is already indicated.

LAC

The knowledge we require can be obtained almost wholly through regular (project) operational missions. Thus we need to organize sector missions only intermittently when particular problems have to be studied.

WEST AFRICA

The entire Sector Work program has to pass through a phase of reconnaissance of and familiarization with the countries and conditions of the particular sector. (This work would take most of available resources for Sector Work in FY74.)

10. Staff Time Allocated

Table 2a below summarizes the Programming and Budgeting Department estimates of man weeks which will be dedicated to Sector Work in each region by "mode" of work in FY74. This data is preliminary and probably wrong as some regions (e.g. LAC) appear to have left out Sector Work done in conjunction with appraisal and supervision missions. PNB has offered to produce a more consistent set of information shortly. Table 2b gives present estimates of total Sector Work man-weeks for the six-year period FY74-79.

1/ In an OM draft on Sector Work dated June 25, 1973, Messrs. van der Tak and Hendry have given a more precise definition and classification of these approaches.

TABLE 2a

SECTOR WORK
By Region, Sector and Type of Activity
FY74
Manweeks

	E. Africa	W. Africa	Asia	EMENA	LAC	Bank
Power						
Surveys	60	-	25	-	-	85
Eco. Missions	-	-	-	-	15	15
Special Studies	-	-	35	-	-	35
Other[1/]	10	5	5	10	5	35
Total	70	5	65	10	20	170
Water						
Surveys	140	-	140	35	60	375
Eco. Missions	-	-	-	-	-	-
Special Studies	-	-	-	-	15	15
Other[1/]	15	20	5	10	5	55
Total	155	20	145	45	80	445

TABLE 2b

SECTOR WORK
By Sector and Region
FY74-FY79
Manweeks

Sector	FY74	FY75	FY76	FY77	FY78	FY79
Power	170	220	110	110	80	110
Water	445	200	190	225	155	280

Comments

11. Sector-wise the state of knowledge is considerably higher in power than in water. Country knowledge at stages A, B, C (including Ø) are 42, 30, 28% for power; and 13, 23, 64% for water. That is, knowledge of the power sector is unsatisfactory in less than 1/3 of the 101 countries included in the survey, while for the water sector knowledge is unsatisfactory in practically 2/3 of the cases. It is then quite natural that a much higher sector effort is programmed in water than in power (see Tables 2a, 2b).

[1/] Includes estimated work on sector briefs, "notes", "country sector strategy papers" and some special desk studies.

12. The state of sector knowledge appears to be very similar in all regions with the notable exception of Latin America where it is shown as well above average for power and lower than average for water.[1] For power, knowledge is unsatisfactory 31% in Asia and East Africa, 32% in EMENA, 37% in West Africa and only 14% in LAC. For water the percentages are 54% for Asia, 56% for East Africa, 58% for West Africa, 61% for EMENA, and strangely enough 86% for LAC.

13. Comprehensive sector reports represent a minimal part of the Bank source of knowledge. They exist both for power and water in only 9 out of the 101 countries. Most of the information, when it exists, is summarized in sector briefs, appraisals, reconnaissance, supervision and economic mission reports (see Annexes 2 to 11). As knowledge is considered fairly satisfactory in about 64 countries for power and 37 for water, it is obvious that other than comprehensive sector missions have been providing the necessary information. This situation would support the very general view of the regions that P.U. sector knowledge to a great extent can and should be obtained in the course of operational work. In this respect, P.U. sectors are rather different from others as they are generally managed through a few -- and sometimes one -- institution which in most cases is the Bank's borrower.

14. If we assume that any lending operation and/or sector work and/or special consultant study in a country will do no less than remove it from category C towards B or A, the presently proposed lending and sector work programs would have the following effect in the period FY74-FY78.

No. of "C" Countries[2]

	Power		Water	
	Today	1978 (end)	Today	1978 (end)
LAC	3	1	19	15
Asia	4	1	7	1
East Africa	5	0	9	3
EMENA	10	5	19	4
"C" Sub-total	22	7	54	23
% of Total	27%	8.5%	41.5%	28%

The above figures show that power sector knowledge will cover almost all Bank countries by FY78. In water, the situation should also improve substantially, though LAC would seem to remain as an interesting exception (see footnote 1).

1/ This might be the result of different and perhaps a more demanding criteria in the Latin America region with respect to what is satisfactory sector knowledge. As mentioned in para. 3, we intend to look into this matter later.

2/ West Africa not included as work program not yet defined.

15. In conclusion, it would appear that regional views on the objectives, approaches to and efforts needed to carry out Sector Work are fairly homogenous. Notable differences are only the Latin American relatively smaller water sector program and West Africa's undefined power/water program (which, however, cannot become more precise until the reconnaissance stage is covered). Let us note finally that until the additional work described in paragraph 3 (page 1) is carried out, we have to suspend judgment on the quality and depth of present sector knowledge as well as on the adequacy of the intensity -- and approaches -- of the proposed five-year Sector Work program.

Attachments
Annexes 1 - 11

EFriedmann:pfa

cc: Messrs. van der Tak, Armstrong, Arnold (2), Krombach (2), Morse (2), Sheehan (2), Wyatt (2), Howell, Jennings, Shipman, Berrie, Warford, Anderson, Rydell.

OP Public Utilities - Power

INTERNATIONAL DEVELOPMENT ASSOCIATION | INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT | INTERNATIONAL FINANCE CORPORATION

cc P.U. Water + Sewerage

OFFICE MEMORANDUM

TO: Public Utilities Staff (Power and Water Supply) DATE: July 5, 1973

FROM: Y. Rovani YR 7/11/73

SUBJECT: Public Utility Note No. 5
Pricing in Power and Water Supply

I am attaching herewith Public Utility Note No. 5 dealing with Pricing in Power and Water Supply. This Note is intended as only the first step in a program of exchange of information and discussion between public utilities staff in the Regions and Public Utilities Department on the subject of pricing. Other steps in the program are expected to be seminars, discussion groups, write-ups from operational work, papers on methodology and data collection, and further Notes.

This is the fifth of a series of "Notes" which are neither policy statements nor working instructions. They have been designed as a simple and flexible vehicle of communication, primarily with public utilities staff, amongst other things to frame and comment on issues of general interest in the public utilities sectors.

The practice has been established to have these Notes reviewed by ad hoc panels including representatives of the utilities divisions as well as other staff. Their contribution is hereby acknowledged.

Your comments and specially any suggestions for subjects to be covered in further Notes would be extremely helpful and welcome.

Attachment

TWBerrie:pfa

O.P. Public Utilities
Water + Sewerage

January 29, 1973

Dr. Michael G. McGarry
Associate Professor
Environmental Engineering Division
Asian Institute of Technology
Henri Dunant Street
P.O. Box 2754
Bangkok
Thailand

Dear Dr. McGarry:

This will acknowledge your letter of December 15 in which you indicate that you intend to obtain external funding to conduct a study of wastewater collection and disposal systems for developing countries. You indicate that the objective of this study will be to provide improved approaches and solutions to the provision of such facilities. In connection with your investigation you solicit our cooperation by way of providing information and our permission to discuss experiences with respect to the Dacca, Chittagong, Singapore and Djakarta sewerage schemes. You indicate that you will require access to such information as may be found in the form of master plans and reports and that you would wish to follow up a review of this information by a one-week visit to Washington to hold discussions with our staff.

We are naturally interested in providing any assistance that is possible without interfering too much with the heavy work load imposed on our technical staff. Since each of the schemes on which you are particularly interested is located in our Asia region discussions with the technical staff of the water supply section of that region only would be involved. I have checked with Mr. Rajagopalan head of the water section of the Asia region and find that he believes it would be very difficult for them to spare much time in the next few months for discussions. He would, however, try to make available a little time on each project by the staff involved.

Concerning the documentation on the projects, which you specifically mention, we believe that about the only thing which would be available here in connection with the Dacca, Chittagong and Singapore projects are the appraisal reports. These reports are on file in the Bank and on the occasion when you came in we could make them available to you for review. With respect to the master plans and the technical aspects of these projects, since these documents are not available in the Bank, in the case of Dacca and Chittagong they would have to be obtained from the consulting engineers who are Ralph Parsons of Los Angeles. In the case of Singapore you would have to obtain the plans from the

Public Works Department of the Singapore Government. In the case of Djakarta, we have not financed a project there and, so far as we know, there are no engineering plans prepared on a sewer system for that city at the present time. A UNDP project is being proposed for this purpose.

I am sorry to be so unhelpful in connection with your request but hope you will find the information of some use. I look forward to hearing from you if you feel that éven with the noted limitation, we can be of help to you.

Please accept my best regards.

Very truly yours,

Harold R. Shipman
Water Supply Advisor
Public Utilities Department

Cleared with and cc: Mr. Rajagopalan - with copy of incoming

O.P. Public Utilities - Water + Sewerage

January 11, 1973

Dr. Ralph Turvey
Scientific Control Systems Ltd.
Sanderson House
49-59 Berner's St.
London W1P 4AQ
England

Dear Ralph:

Thank you for the notes and letters which you sent in December. I spent the week before Christmas in El Salvador, last week skiing and had flu between and after, so this is the first real chance I've had to look at them.

We are now making the arrangements for your visit to D.C., which we are looking forward to, and have set for Feb. 12 to 15/16. You'll no doubt hear from the Travel Office shortly. Regarding the next case study, I'm now trying to fix it for May, since I'll be in El Salvador for much of March, and April is out for you. (We are sounding out the possibilities of a study in Iceland (mainly hydro) and of course other countries.)

I liked your paper on shadow pricing and have circulated it to the various Projects Departments with a covering memo, contrasting the second best worlds in which they operate and the first best worlds which much of the Bank's work on shadow pricing assume.

Your note on mixed hydro-thermal systems was just the thing to shake my thinking out of a rut - I was really stuck. (I don't know how you do it - to respond so fully in such a short time.) I'm unsure about making water inflows proportional to storage, since the ratio of storage to water inflows is a decision variable (dam height); however it may well simplify our analysis to regard this as a decision variable exogenously set (as we did in Turkey) and I'll follow up your line of thought, and redraft my notes accordingly.

Some comments are attached on the indivisibility problems discussed in your draft on Costs and Charges in Water Supply and in your letter of December. Jerry also thinks:

para. 3 mention external effects - the health benefits from washing, sanitation and potable supplies may be over-riding at low levels of consumption;

para.9 spell out why the cost of the increment, y, is not sufficient as a basis for setting price;

para.14 a gradual increase of charges up to the capacity points might be better;

para.23 the caveat about storage needs more discussion: each gallon consumed, whatever the time, may place an equal burden on storage (e.g. one rainy season, storage for whole year). (Incidentally, I think storage in water supply is possibly easier to handle analytically than hydro storage - no production alternatives.)

To these I would add:

para.14 "least damaging" needs more qualification (relative price elasticities, etc.)

para.20 Doesn't your result assume that indivisibilities are constant in size, whereas they probably increase directly with the system's size?

If D.o.E have no objections, we'd be most interested in following the progress of your work on water.

Will shortly be writing to you on the IER of power projects; the issues are boiling up again.

Yours sincerely,

D.A.

Dennis Anderson
Public Utilities Dept.

cc: Messrs. Rovani
Warford (with copy)
blue book, files

DAnderson:mds

OP. P.U. Water & Sewerage

Mr. John M. Kalbermatten LA

January 5, 1973

K. Ringskog KR LA

Proposed Bank Approach for Lending to Semi-Rural
Water Supplies in the Latin America and the Caribbean Region

Introduction

1. During the decade following the Punta del Este Conference in 1961, the population served by public water supplies in Latin America increased from some 70 million to 150 million in 1971. The share of the total population served rose from a third to slightly over a half. The accompanying sanitation investments undertaken amounted to some 2 billion US dollars. Global figures conceal regional differences. For instance, the population served in countries like Haiti and Paraguay is less than 10% whereas a few developed countries like Costa Rica, Uruguay and Venezuela have practically all its population served. In reality, the major part of the Latin American population, namely 230 million or some 85% of the total, live in countries where less than 50% of the population is served by public water supply. Furthermore, of the some 150 million served, only 3/4 are served from house connections and the water quality and service provided vary considerably. In short the global picture is not as bright as one might wish.

2. There are many reasons why progress in the sector has not been more rapid. Generally, there has often been lack of coordination and global planning on the national level resulting in a piecemeal approach. The responsibility for water supply has in too many cases been decentralized, usually with the municipality responsible for its own water supply. This has meant a waste of scarce manpower resources as a great number of institutions have competed for a limited supply of skilled staff. This has resulted in poor institutions and an absence of efficiency of scale, resulting high costs and ensuing unrealistically high tariffs. The sector has had little success in attracting needed talent and the result has been a slow trickling down of new sanitation technology and deficiencies in studies necessary for project implementation.

3. It must be concluded that the concept of each city of the municipality managing its own water supply system is erroneous and has failed except in the case of very large cities. The same conclusion is reached when one looks at the financial side. Due to excessive political interference by elected councils, the water supply entities have constant difficulty in raising capital (tariffs) for its needed investments. When capital has been provided, it has often been in a haphazard way, dictated by short-term political advantages. The resulting stop go investment policy lacks continuity and results in waste. The tariff setting powers often remain with the political body.

4. Unfortunately, the Bank's approach to lending in the sector has not been very much better. The lending has been done on a piecemeal approach and usually only the largest projects available have interested the Bank.

This policy is justified if the Bank wishes to employ its scarce staff to achieve maximum capital transfers to the region. Large investments remain to be undertaken to supply populations in large urban areas in Latin America with sanitation services. However, if the Bank is to aid development by institution building and, as Mr. McNamara pointed out recently, by reaching the population living in medium size or small urban communities, not to speak about rural population, it will have to modify its lending approach substantially. The lack of sufficient qualified Bank staff will make it necessary to employ new techniques such as developing institutions which will eventually handle most of the work presently undertaken by Bank staff. The purpose of this memo is to outline such a proposed new methodology.

Proposed New Methodology

5. The new kind of loan that will be necessary can be characterized as a hybrid between a program loan and a project loan and could be called sector program loan. In general terms the new approach would imply a shift in emphasis away from technical and financial aspects towards institutional, human resource and socio-economic aspects. An example of such a loan is the upcoming Bahia State Water Supply loan which will be a test case for the Bank. The methodology might have to be modified in view of the experiences of this project. The Bahia loan is to be made to the National Water Supply entity in Brazil (the National Housing Bank) which will in its turn relend the funds to the Bahia State Water Supply Company, EMBASA. The latter will implement the project that consists of some 350 subprojects, thus covering all the urban communities in the 8 million state of Bahia in Brazil's poor northeast. The institutional framework for this loan already established under the Planasa program by the National Housing Bank is more fully described in the Thys/Ringskog Full Report of June 15, 1972. In this connection it may suffice to say that the main idea is to make a loan to an institution, after having appraised mainly the quality of the institutional set-up and its staff, and not to appraise the subprojects in the same detail as is usually done in Bank projects. This would mean a much larger delegation of responsibility to the borrower than is ordinarily the case with Bank projects.

Major Problems to be solved

6. Generally, for such a centralized lending approach to be successful, a number of problems have to be overcome:

(a) one central institution (be it on the national or regional level or a combination) will have to be established and the individual systems will have to give up much of their autonomy to the central entity,

(b) a global flexible and dynamic programmation of work will have to be instituted,

(c) human and financial resources have to be mobilized on a national level via the central entity,

(d) a tariff policy has to be implemented that will not only be approximately economically efficient, but also take the broader political aspects into consideration such as (1) consumer categories that would on financial grounds be able to afford public water supply, (2) and thereby achieve income redistribution on the national or regional level. Such a tariff would be optional in the long run.

(e) a permanent solution to the financial problems has to be found, and the establishment of revolving funds, free from political influence, seems to be the most promising way to achieve this,

(f) a mixture of sources of funds (loans and grants) might be necessary,

(g) to lower production investment costs centralization is necessary to achieve maximum efficiency of scale, increase productivity, benefit from the latest technological advances and achieve a more rational machinery to study and design the separate subprojects. Over time when the supply of skilled human resources increases, the system could gradually become more decentralized to avoid the danger of excessive bureaucracy.

Implications and Issues for the Bank Project Work

7. The consequences for the Bank in its project work are hard to fully evaluate at this stage but tentatively it can be said that the following changes will take place:

(i) The identification part of a project will now concentrate on finding an institution capable of doing the job outlined under para. (6) or an institution that could be transformed into a satisfactory one.

(ii) Before or during preappraisal a unit or a division in the central institution or outside the institution will have to be set up that will be capable of making preliminary studies so as to serve as a basis for a Bank loan. Preappraisal is likely to become more extensive and more important as it is desirable to develop the borrowing institution prior to appraisal.

(iii) The appraisal will concentrate on evaluating the quality of the institution and its staff and only for subprojects above a certain size will the usual close technical examination be made. Increased emphasis will certainly be attached to the training needs of the institution, and to this end a closer cooperation with the Pan American Health Organization seems desirable. In the long run it may prove advantageous to establish a cooperative program so as to bring PAHO earlier into the Bank's project work. Such a program is already established with WHO in Geneva but staff with experience in Latin America is lacking there.

(iv) For the tariff schedules to have an income-redistributive effect, the philosophy that each subproject should be financially viable by itself will have to be abolished. A national water supply tariff of this kind would complement other public resource transfers, which often do not take place because of lack of political will and poorly developed public revenue-raising mechanisms.

(v) The loan to be presented to the Board as a result of such an appraisal will be more in the form of a credit line from the Bank to the central water entity. Conditions of effectiveness and disbursement will be contingent upon certain institution building improvements achieved or commenced and for studies for subprojects above a certain size to be ready.

(vi) Bidding will be made by the central water supply entity, hopefully resulting in savings and the possibility for international contractors and suppliers to enter more easily as before, as the aggregated project size will be larger than hitherto.

(vii) Project supervision responsibilities would eventually be handled by the central water entity and the Bank's staff should ideally supervise only the institution and, if time permits, the larger subprojects.

(viii) In the initial phase, when institutions will be built up, and much technical assistance and training is needed, the short-man Bank staff productivity will decrease implying requirements for larger numbers and variety of Bank staff. Managerial and planning experience would be in greater demand. As the institutions become mature Bank staff productivity would increase above present levels.

(ix) Future lending through said mature institutions would be done through reviewing their project pipelines and simply financing a percentage of corresponding investments. Substantial capital transfers could thus be achieved into areas which could, with the present piecemeal approach, not be reached.