Appropriate Water Supply and Sanitation Technology for Developing Countries in Tropical Monsoon Climates

HARVEY F. LUDWIG and GREG BROWDER*

P.O. Box 8–101, Bangkok 10800, Thailand

Summary

In the past, the water supply and sewage services for the urban regions of developing countries have been provided, in the main, only for the more affluent areas of these cities. This paper, dealing especially with those countries with tropical monsoon climates, advocates the construction of more comprehensive systems.

Experience drawn from a wide range of projects and a review of the relevant literature provokes the authors to emphasise the need for suitable manuals of appropriate technology for use in these developing countries. These manuals should provide a full set of environmental guidelines for the design of water supply and sewage/sanitation systems for use in these countries.

Introduction

Water supply and sewage services for urban regions of developing countries have historically tended to focus on serving the more affluent areas of cities because of the relative ease in this approach from the financial, political and engineering points of view. Environmentally, however, attention should be given to providing the less affluent areas, despite the more difficult financing and engineering problems involved.

It is being recognised that water supplies should offer a service to the entire community. This may involve the use of public taps in areas unable to afford house connections. A 'sewerage and sanitation' approach is also more appropriate environmentally, with the target of achieving 100 percent management of excreta in the service area. This was first recognised in the early 1970s with the implementation of the Jakarta Sewerage and Sanitation Project, which focused on the Setia Budi sub-region of Jakarta, representing about one-tenth of the total megalopolis.

Basis of Study

Over the past two decades, the authors have been involved in numerous water supply/sewerage and sanitation projects in countries in the tropical monsoon region of South-East Asia, including Thailand, Indonesia, Malaysia and the Philippines, as well as countries in Africa and in the Asian sub-continent countries of India, Pakistan and Sri Lanka. This work has focused on (1) preparation of feasibility studies and on critical reviews of feasibility studies for numerous projects; (2) evaluation of the institutional, economic, socio-economic and financial limitations associated with continuing development of water supply and sanitation infrastructures in these developing countries; and (3) preparation of manuals/guidelines on technologies considered to be appropriate/affordable for use in these counties. The various projects which have been evaluated involve assistance to developing countries from a wide range of international assistance agencies, including the development banks, the UN group of agencies, bilaterals and others. Some of the pertinent publications are included in the

* Dr Harvey F. Ludwig is Chairman and Greg Browder is Environmental Engineer for SEATEC International Consulting Engineers, Bangkok, Thailand.

Fig.1 Poor community housing in the heart of Bangkok, Thailand. The area lacks proper drainage, sanitation or solid waste management.

accompanying list of references.

The present paper presents the conclusions and recommendations gleaned from these various studies. The authors hope that interested agencies will sponsor some of these recommendations and projects in the future.

Sewerage and sanitation

Socio-economics

Most developing countries have made very limited investment in urban sewerage and sanitation (Fig.1). While numerous feasibility studies have been made, most of the recommendations have yet to be implemented. This attitude can be expected to continue unless something can be done to persuade the decision makers to assign a much higher priority to the subject.

Some of the specific findings are as follows:

(1) Part of the country's planning effort should be to review the macro-economics involved in terms of the country as a whole. How does the county's investment record compare with other developing countries, and what levels of such investment have been found to be affordable (as a percentage of the gross national product) in those countries (Table 1).

(2) The term 'sewerage' should be replaced for developing countries by the term 'sewerage/sanitation', to show that the basic intent of the investment is management of all excreta in the urban area of concern. In the Western World, 'sewerage' has meant a 100 percent service, but in developing countries the investments have tended to be limited to affluent areas which can readily finance the sewerage facilities. To achieve meaningful public health protection, including protection for those living in affluent sectors, the need is for total management of all excreta produced in the service area.

(3) To make the best case possible for emphasising the need for investment in sewerage/sanitation projects, the project feasibility study should include an economic evaluation. This should include:

(i) An estimate of the approximate project cost for the municipality, as related to experience in developing countries in general.

(ii) An estimate of the cost per family as a percentage of the family income, especially for the non-affluent population sector, as related to the experience of other developing countries.

(iii) A benefit/cost analysis which should include due consideration of all real benefits, including estimates of property value increases and public health improvements.

To facilitate (iii) above, a "Manual of Guidelines for Economic Analysis for Developing Countries Sewerage/Sanitation Projects" should be prepared. Most project feasibility studies to date have not included such an analysis, which greatly weakens their case. The procedure for making the analysis needs to be defined in manual form to make it readily applicable to specific projects.

When the 'level of affluence' in a developing country urban centre has been evaluated, the decision makers may become interested and willing to invest in municipal sewerage facilities. Bangkok is an example where, along with the current economic boom in the megalopolis, the Government now seems seriously interested, for the first time, in making such an investment. Various feasibility studies have been prepared over the past years, dating back to 1968, but only now is the need for full a sewerage/sanitation system being given serious attention.

Table 1 Environmental macro socio-economic considerations in water supply and sewerage/sanitation projects.

Urban sewerage/sanitation

1 Total investment in urban facilities over past two decades.
2 Amount of (1) as a percentage of gross national product.
3 Comparison of (2) with experience in other developing countries.
4 Distribution of (1) between capital region and secondary cities.
5 Estimates for recommended percentage of allocation of gross national product which should be expended for sewerage/sanitation facilities.
6 Recommended distribution of (5) between capital region and secondary cities.

Urban water supply

1 Total investment in urban facilities.
2 Amount of (1) as a percentage of gross national product.
3 Comparison of (2) with experience in other developing countries.
4 Distribution of (1) between capital region and secondary cities.
5 Unit price of water (per m^3) in capital area and secondary cities.
6 Amount of (4) as percentage of family income.

Engineering planning and design

The major planning and design problems of environmental concern related to sewerage and sanitation were found to be the following:

The urban poor. Because sewerage technology used in developing countries has been borrowed from the industrialised countries, engineers who plan and design the systems commonly fail to recognise the hazards involved in this type of 'transfer' of technology. Sewerage service in the industrialised countries means 100 percent coverage, but in developing countries this tends to be limited to affluent areas which can afford the finance. This lack of attention to the management of excreta from the 'non-sewered non-affluent' areas endangers the entire community.

The use of on-site sub-surface disposal units for buildings not served by sewers fails to observe the industrialised country's practice that all such units should function effectively, and when they no longer do so (because of increasing density of development), it is required that they should be replaced with sewers. Because there can be no such 'replacement by fiat' in many urban development areas, dependence must continue to be placed on the use of sub-surface leaching units. A special maintenance programme is then required so that those relatively few leaching pits, which function poorly because of soil impermeability and/or a high ground-water table, can be desludged as frequently as needed to enable them to function effectively. This is essential for the protection of public health, because the overflow of excreta from such badly maintained pits can contaminate an entire neighbourhood (Ludwig, 1977; World Bank, 1983).

It must be recognised that the greatest hazard to overall community public health stems from the the lack of decent sanitation for the urban poor. Limiting sewerage services to the affluent does not solve public health problems.

The use of combined sewer systems. Because of the absence of separate sanitary sewer systems in most developing countries, the proposed sewerage systems often make use of the 'combined drainage systems'. This means there will be occasional overflows of untreated mixed storm-water and sewage during storms. However, this represents a very minor part of the overall sewage pollution problem, and may be considered quite acceptable from the environmental point of view (as was the case in the USA up to only some 30 years ago). The savings in construction costs, compared to using separate sanitary sewers, are very large. Separate sanitary sewers may be appropriate, however, for new development areas without existing drainage facilities. The salient point is that health hazards related to excreta are, in relative terms, very great in the dry season compared to the rainy season, so that any limited investment should be focused on the dry season situation.

The adequacy of environmental impact assessments. The reviews of feasibility studies and associated environmental impact assessments (EIA) show that the environmental analyses are quite inadequate. This is due to the continuing tendency of many civil engineers to consider the

Table 2 Checklist for environmental coverage in urban project planning for sewerage/sanitation.

Socio-economic considerations
Provision for non-affluent urban dwellers.
Affordability (per family costs).
Benefit/cost analysis.

Siting consideration
Sewer routing to minimise adverse effects on existing utilities/traffic/buildings.
Selection of sites for pumping and treatment plants to minimise adverse effects on adjoining properties.
Resettlement problems.
Encroachment into precious ecological resources.
Encroachment into historic/cultural sites.
Impairment of environmental aesthetics.

Design stage
Appropriateness of design criteria including consideration of:
- Operation and maintenance constraints.
- Sulphide corrosion hazards.
- Use of appropriate alignment/man-hole spacing.
- Adequacy of buffer zones.
- Storage/handling of chlorine.
- Minimum use of pumping plants.

Overflow hazards due to overloading or power failure.
Protection of receiving waters.
Inappropriate receiving-water standards.
Sludge-disposal adequacy.
Hazardous materials discharged to sewers.
Industrial wastes discharged to sewers.

Construction stage
Silt runoff during construction.
Resurfacing of exposed areas.
Other construction hazards.
Provisions for including environmental requirements in construction contract.
Provisions for construction-stage monitoring.

Operations stage
Workmen's health and safety.
Nuisances to adjoining properties.
Provision of operations-stage monitoring including effects on receiving environment.
Adequacy of operation and maintenance skills and provisions for upgrading.

Individual on-site sub-surface disposal systems
Overflow hazards.
Ground-water pollution hazards.
Adequacy of desludging service.
Adequacy of sludge disposal.

EIA as a kind of 'add on' to project planning rather than as an integral part of this planning. None of the studies cover the salient environmental issues as listed in Table 2. The feasibility studies for all sewerage/sanitation projects should include provisions for a full-scale EIA based on application of such a table.

Design manual. To facilitate the use of appropriate technology a "Manual of Environmental Guidelines for Design of Urban Sewerage/Sanitation Projects in Developing Countries" is certainly needed, and it is recommended that the international assistance agencies consider sponsoring such a manual. It could be based on the use of existing technology suitably adapted to the needs of developing countries. It should include the use of the following studies already in hand:

• Design criteria for prevention of serious sulphide corrosion in sewers, force mains, and treatment and pumping plant (Ludwig, 1980). Serious sulphide corrosion (especially of concrete pipes and structures) occurs in all regions of warm climate (including those with tropical monsoon climates). Without appropriate design a large portion of the sewerage investment will only have a short term life, and far less than the possible planned design period.

- Design criteria for appropriate buffer areas around sewage treatment and pumping plants (Bradley, 1987).
- Provisions for management of those industrial wastes to be discharged into municipal sewerage systems (Ludwig, 1978). This is a complex problem and the Industrial Waste Permit System as described by Ludwig is a feasible solution.
- Use of appropriate effluent standards for municipal sewage treatment plants (SEATEC International, 1988). This is necessary to enable the use of the least cost appropriate treatment systems noted below.
- Design criteria for sewage treatment to match the appropriate standards, in order to achieve minimum costs (including capital and operations and maintenance costs). An excellent evaluation of the various sewage treatment processes used in industrialised countries, in terms of their appropriateness for use in developing countries, for conditions of final disposal to confined inland, estuarine and open marine waters is given by the World Bank (1988). Information on disposal of sanitary and industrial wastes into open marine waters is given by Ludwig and Gunaratnam (1988).

Water Supply

Socio-economics

Investment in water supply improvements in cities in most developing countries, unlike the situation for sewerage/sanitation, has been appreciable, no doubt because communities can hardly function without public water supplies. Even so, the overall situation merits evaluation from the macro-economic point of view. The level of water supply system investment in percentage terms of the country's gross national product may be compared with other developing countries. Each project feasibility study should consider the *per capita* water allowance (it should meet the country's 'minimum acceptable standard' and be affordable by the urban non-affluent), and should devote attention to the urban poor who will not be served by house connections (Table 1).

Most of the feasibility studies reviewed show concern with increasing the percentage of population served, but few give attention to those who were not served. If the argument is made that a primary reason for urban water supply improvement is for protecting public health, then some meaningful service must be made available to the urban poor (such as by the supply of public taps), so that all of the population will be able to get and afford clean/safe water at least for drinking and cooking purposes. If this is not done and these poor people continue to be dependent on shallow surface/ground water (which is always heavily contaminated), it must be recognised that communicable diseases initiated by the poor people will pose serious disease hazards to the entire community. It is a lack of sanitation facilities (including the water supply) to the urban poor which poses the primary hazard to overall community public health (Figs 2 and 3).

Engineering planning and design

There seems to be little understanding by developing country officials of the need to deliver safe water to the household tap. There is common negligence with respect to (1) chlorinating the water at the treatment plant; (2) the use of chemicals for corrosion control at the treatment plants (to avoid pitting of pipes and leakage in the distribution system); (3) maintaining adequate pressures in the distribution system to avoid inflow of contaminants; (4) the use of special pipe materials in areas where soils are corrosive; (5) competent operation of treatment filtration systems; and (6) maintaining a positive chlorine residual in the distribution system to offset inflow of contaminants, including re-chlorination if necessary at selected points. A common misbelief is that if the water leaving the treatment plant contains a chlorine residual, so will the water reaching the household tap. Many municipal water supply systems deliver an acceptable level in quantity of supply, but do a very ineffective job in terms of the safety and quality of the water reaching the household taps (Figs 4 and 5). This is despite of the fact that a sizeable portion of the total investment is provided for facilities for treating the water to produce and deliver water of acceptable safety and quality.

The reasons for this are similar to those for poor sewerage engineering practice, including the use of appropriate design criteria, use of pipe and other materials of insufficient quality,, lack of operation and maintenance skills, *etc.* (Table 3). For these reasons there is critical need for a project to prepare a "Manual of Environmental

Fig.2 A squatter community in Dhaka, Bangladesh, use wastewater discharge from a steel wire factory for washing clothes and dishes; illustrating both uncontrolled effluent discharge and the lack of an adequate water supply for poor people.

Guidelines for Design of Urban Water Supply Projects in Developing Countries" to match the similarly needed manual of sewerage/sanitation. One part of this manual should include a re-oriented design of the typical rapid sand filter used in industrialised countries, with changes for the minimum of sophisticated operation and maintenance skills, dispensing with many of the expensive control panel meters which are commonly used and which soon fall into disrepair (Ludwig, 1984a, 1986). Another need is to call attention to the importance of pH adjustment for corrosion control, especially where cheaper pipe materials are used in the distribution system.

Problems of Operation and Maintenance

A very serious problem with public works systems in developing countries, which again stem from 'industrialised country borrowing', is the lack of recognition by the designer that the borrowed technology he uses, including water treatment systems, were developed to match the level of operation and maintenance skills which are available in industrialised countries. The operation and maintenance budget levels available in developing countries are generally much less (Engineering Science Consortium, 1985). As a result, the facilities are doomed to non-function and deterioration, and hence the project does not attain its objectives. Simpler technologies which match the operation and maintenance skills available should be utilised, and the levels of operation and maintenance capabilities should be boosted to match these minimum needs.

Often an assumption is made that the answer to improving operation and maintenance capabilities is in training. However, training alone does not make up for inadequate salaries, and this problem has yet to be recognised and faced up to by both developing countries and international assistance agency officials. A "Facts of Life" study is needed on this subject to pin-point the roots of the problem so that it can be solved wisely, either by strengthening the governmental waterworks operations capability or by the use of the private sector (Ludwig and Friedman, 1984). Such a study could make a detailed analysis of a selected number of typical systems to delineate the specific operation and maintenance gaps, the reasons for them, and how the can be realistically corrected.

Monitoring

"No monitoring, no compliance" is a well known adage in industrialised country practice in government regulation. Both developing country and international assistance agency officials have yet to consider this seriously. Most of the project reports give 'lip service' only to this problem. They propose operations monitoring programs which are hardly realistic in terms of the history of developing countries. To be meaningful, the feasibility studies should spell out the necessary specifics to implement the program and make the case that these are the minimum recommendations which are essential. For continuing periodic operations monitoring, the studies or EIA should (1) delineate the minimum monitoring requirements, including checking on system performance and consequent effects on the environment as distinct from the monitoring of the environment, to be carried out by governmental regulatory agencies; (2) discuss the skills needed to carry out the monitoring; (3) estimate its costs; and (4) make provisions for financing these costs as an integral part of the project's core budget.

Most EIAs and some feasibility studies for water supply and sewerage/sanitation projects in

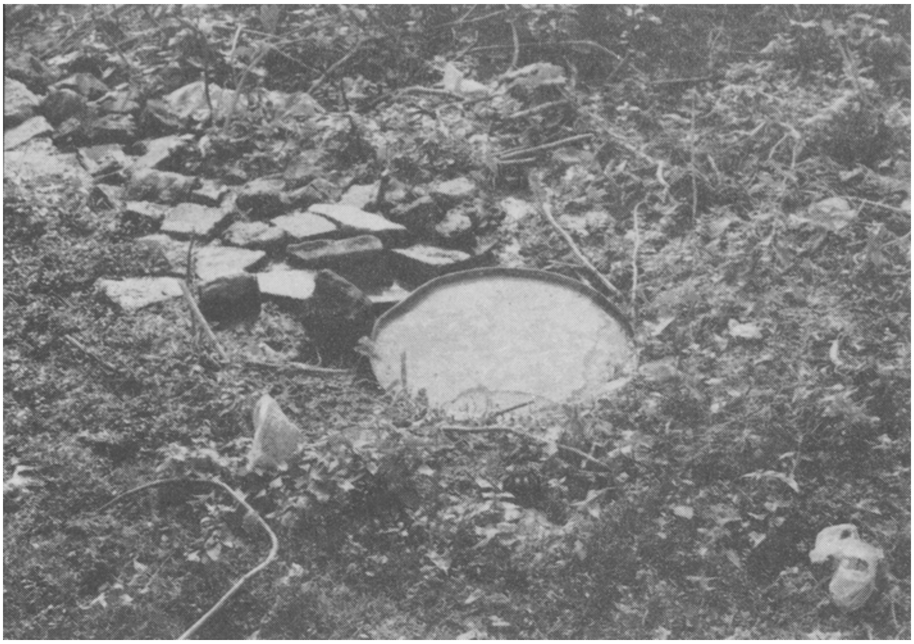

Fig.3 A shallow well used for a potable water supply by a squatter community in Dhaka, Bangladesh. The ground water is probably very contaminated by industrial and domestic wastes.

Fig.4 A water supply pipe line passes through a sewage contaminated drainage canal in Bangkok, Thailand. Possible dangers of sewage infiltration into the water supply are obvious.

Fig.5 The necessity of maintaining a positive chlorine residual in water supply pipe lines is emphasised, for here in Bangkok, Thailand, the pipe passes through a sewage contaminated drainage canal.

Table 3 Checklist for environmental coverage in urban project planning for water supply.

Socio-economic aspects
Provision for non-affluent urban areas (for homes not served by house connections).
Benefit/cost analysis.
Unit water cost affordability.

Siting considerations
Pollution of raw-water source.
Water rights/use conflicts.
Land subsidence from ground-water overdraft.
Resettlement problems.
Impairment of historic/cultural sites.
Impairment of precious ecology.
Impairment of environmental aesthetics.

Design stage
Appropriateness of design criteria (including consideration of operation and maintenance constraints) so that water delivered to homes will be safe to drink.
Adequacy of *per capita* water-use allowance.
Selection of piping with materials of suitable quality to protect against pitting/corrosion/leakage.
Prevention of delivery of unsafe water to households.
Prevention of pollution of raw-water source.
Algae in reservoirs in distribution system.
Excessive unaccounted water losses.
Inadequate pressures in distribution system.
Increased sewage production.
Inadequate treatment plant sludge disposal.
Unsatisfactory raw-water mineral quality.
Inadequate buffer zones around facilites.
Inadequate provisions for storing/handling chlorine.
Soil erosion from inadequate resurfacing of exposed areas.
Provision of auxiliary power standby.
Provision of storage for accommodating breakdowns in water production.

Construction stage
Erosion and silt runoff during construction.
Resurfacing of exposed areas.
Other construction-stage hazards.
Provisions for incorporating requirements into construction contracts.
Provisions for construction-stage monitoring.

Operations stage
Problems due to faulty operations:
- Production of unsafe water delivered to distribution system.
- Maintenance of chlorine residual in distribution system.
- Prevention of corrosive water delivered to distribution system.
- Prevention of excessive water losses.

Provision of adequate operations monitoring.
Adequacy of operation and maintenance skills and provision for upgrading.

developing countries have included monitoring requirements, but the actual follow-up performance has been almost nil. Monitoring and guidelines on this should be included in the proposed design manuals.

References

ADB (Asian Development Bank). 1987. *Environmental Guidelines for Development Projects.* Asian Development Bank, Manila, Philippines.

ADB (Asian Development Bank). 1988. *Guidelines for Regional Environmental Development Planning.* Asian Development Bank, Manila, Philippines.

Bradley, R. 1987. Buffer zones for sewage treatment plants in developing countries. *Newsletter of Asian Society for Environmental Protection,* August. AIT, Bangkok, Thailand.

Engineering Science Consortium. 1985. *Reappraisal and Review of Kuala Lumpur Master Plan for Sewerage and Sewage Disposal,* 3 vols, May. Engineering Science Consortium for City of Kuala Lumpur.

Engineering Science Consortium/SEATEC International. 1987. *Final Report, Klang Valley Environmental*

Improvement Project. Engineering Science Consortium/SEATEC International for Asian Development Bank/Department of Environment, Kuala Lumpur.

J. Taylor Consortium. 1985. Songkhla Lake Basin Planning Study. J. Taylor Consortium for NESDB/NEB, October.

Ludwig, H.F. 1977. Immediate Programme for Sanitation, Comprehensive Plan of Sewerage and Sanitation for Metropolitan Jakarta. For Nihon Suido for UNDP/WHO.

Ludwig, H.F. 1978. Guidelines for Regulating Industrial Waste Discharges for Municipalities in Indonesia. For UNDP/IHE/DRGWRD, Bandung, May.

Ludwig, H.F. 1979. Report on IBRD Supervisory Mission for Kampung Improvement Projects of Indonesia, Urban II/III Water Supply for Jakarta and Surabaya. For World Bank, October.

Ludwig, H.F. 1980. Report on Maintenance Aspects of Indonesian KIP Programs at Jakarta and surabaya for Roads, Footpaths, Drains, Water Taps and MCKs. For World Bank.

Ludwig, H.F. 1982. Report on Evaluation and Monitoring of Water Pollution Control Program for Metropolitan Abidjan. For Government of Ivory Coast/IBRD, November.

Ludwig, H.F. 1983. Evaluation of Benefits and Costs of Public Taps in Urban Slum Areas in Asia. For World Bank, March.

Ludwig, H.F. 1984a. Proposed Design Criteria for Government Settlement (Felda) Schemes in Malaysia. For World Bank, April.

Ludwig, H.F. 1984b. Placing Water Supply and Sewer Mains in Same Trench. *Environmental Sanitation Reviews*, December, ENSIC, AIT, Bangkok.

Ludwig, H.F. 1986. Report on the Feasibility Study for Municipal Water supply Improvements in Province of Johor (Klang Municipal System. For World Bank.

Ludwig, H.F. 1987. Technical Guidelines for Design of Septic Tank/Leaching systems. *Newsletter National Environment Board*, Bangkok, January.

Ludwig, H.F. and Friedman, D. 1984. Final Report on PWA Corporate Planning Consulting Team. For PWA/World Bank, Bangkok, July.

Ludwig, H.F. and Guneratnam, D. 1988. Marine Waste Disposal for Optimal Regional Economic-cum-Environmental Development. ENSEARCH Seminar on Marine Environment, Department of Environment, Kuala Lumpur, April.

Ludwig, R.G. 1980. Design Criteria for Control of Sulfides in Sewers. Encibra Consulting Engineers, Rio de Janiero, Brazil.

Panayotou, T. 1988. Thailand, Management of Natural Resources for Sustainable Development: Market Failure, Policy Distortions and Policy Options. For USAID/Thailand, May.

SEATEC International. 1983. Urban Sewerage and Excreta Disposal Planning for Chonburi and Thailand, 2 Vols. For WHO/GTZ/PWD, Bangkok, April.

SEATEC International, 1984. Evaluation and Recommendations Relating to Use of Anionic Detergents in Thailand. For NEB, Bangkok.

SEATEC International. 1988. Guidelines on appropriate Environmental Standards for DMC Use, Phase I Study. For Asian Development Bank, September.

SEATEC International. 1989. Environmental Impact Assessment for Thailand Accelerated Water Supply and Sewerage Project. For Associated Engineering Consultants/Asian Development Bank.

World Bank. 1983. Report No.P–3394–IND on Jakarta Sewerage and Sanitation projects. World Bank, Washington, DC, USA. January.

World Bank, 1988. Korea, Sewerage and Wastewater Management Issues, Options and Recommendations. World Bank, Washington, DC, USA, April.