Water Supply, Sanitation and Health Education Programmes in Developing Countries: Problems of Evaluation

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There are several methodological problems related to evaluating the impact that improved water supply, sanitation and health education projects have on public health. Fifteen studies of intervention programmes, one by the present authors, are discussed. Since non-intervention studies of water supply are difficult to assess, a valid study design must include an intervention programme, even though such studies are more costly and time-consuming. Detailed descriptions of programmes, study plans, and analytical methods are often lacking, and different studies reach greatly diverging conclusions. It may be proposed that studies based on "weak" methodology give a more positive impression of improved public health after improvement of water supply than do before–after studies using comparison groups.

Key words: Health impact evaluation, evaluation methods, study design, intervention projects, literature review, developing countries, water supply, sanitation, health education.

The anticipated health benefits of improved water and sanitation facilities have initiated a number of intervention studies of communities in the Third World. However, the results of these studies vary with regard to their proposed impact on health. The validity of conclusions is likely to be affected by the choice of evaluation method.

In view of experiences gained and problems encountered in a recently completed project in Malawi (1), fourteen other intervention studies have been reviewed.

The Malawi project was a prospective cohort study of children under five years of age, in eleven villages, during the year before and the year after the introduction of an improved method of water supply. For parts of the population, the water supply was not changed during the study period. The prevalence of diarrhoeal diseases and skin and eye infections, as well as anthropometry, were used as health indicators.

The methodological review has been made with regard to study design, types of health indicators used, method of data collection, and how background variables were taken into account. The aim was to discover if the design and method of data collection used in an evaluation have any systematic effects on the results.

METHODS OF STUDY REVIEW

Three major criteria may be used to characterize a study design: if the investigation is in control of the "treatment" (e.g. the water supply); if "treatments" may be randomized (e.g. whether chance alone decides who should get the improved water supply); if the time perspective is cross-sectional, prospective, or retrospective. In contrast to clinical trials, epidemiological studies are usually both non-experimental and non-randomized. Occasionally, however, quasi-experimental settings in which the input variable is known, e.g. how much water or health education are provided, may be utilized. Longitudinal studies may be concerned with cohorts or may be designed as case-control studies. Cohort studies following individuals from exposure to disease, can be prospective (futuristic) or retrospective (historic). In cross-sectional studies, a possible cause and effect are measured at the same time. Case-control studies are retrospective, since the disease studied has already occurred (2).

This review is confined to intervention studies. By this term, we mean studies designed to assess the health impact of intervention programmes mainly concerned with water supply, sanitation and health education (cf. 2). Studies comparing groups using varying methods of water supply or varying sanitation facilities, have therefore been excluded. Fourteen studies of the impact that a water supply and/or sanitation project had on public health were found and evaluated. The studies were carried out during the last 30 years and were in English, and two of them were unpublished reports from ongoing studies.

REVIEW OF INTERVENTION STUDIES

The reviewed studies are classified as prospective cohort, retrospective cohort, and case-control studies. The prospective cohort studies are carried out either both before and after an intervention with or without a comparison group, or only after an intervention.

Prospective cohort studies—before–after, with comparison group

In Santiago de Chile, Brunser et al. (3) studied a group of people, the intervention group, before and after they moved to new housing with piped-in water, bathrooms, and flush-toilets. A control group composed of slum-dwellers with community taps and pit latrines was also studied. The monthly incidence of diarrhoea did not differ for the two groups, but intestinal pathogens, especially Shigella and Giardia, were less prevalent in the intervention group (Table I).

Magnani et al (4) studied two urban societies in the Philippines before, shortly after, and again five years after an intervention programme, consisting of an improved water supply with piped-in connections, community taps and pumps. People using the urban water supply were compared with non-users, both on an areal and a household basis, and taking socio-economic factors into consideration. After examining the proportion of malnourished children under four years of age, the impact of the intervention seemed to be equivocal, although positive trends were reported.

McCabe & Haines (5) studied a town in southern Georgia, USA, to see what effects improved disposal of human excreta had on the prevalence of Shigella, before and after an intervention consisting of the construction of bore-hole privies. A control group without improved disposal was studied for comparison. After the intervention, the Shigella rate decreased 52% in the intervention group.

Rubenstein et al. (6) studied the prevalence of infant diarrhoea in a Hopi Indian village, in Arizona, by assessing the number of visits and admissions to a nearby hospital. One group of village residents chose to install piped-in water and toilets in their homes, while the other did not. The infants of the former group made significantly fewer hospital visits after the intervention than before, while the latter group showed no change in the number of visits.

Strudwick (7) studied the Zaina Environmental Project in Kenya, which included water supply, sanitation, and housing. An evaluation was undertaken before this intervention and again four years after. A control area that was unaffected by the scheme was also studied. Gastrointestinal illnesses decreased from 23% to 20% of total illness in infants and from 31% to 18% for children 1–2 years old (8). This study is difficult to interpret, because the methods the evaluation used before and after the intervention differed.

Trivedi (9) studied the effects chlorination of wells had on water-borne diseases in three villages near Kanpur, Uttar Pradesh, India. Morbidity data were collected from the records of two clinics and partly by home-visits. The part of the population served by chlorinated wells showed significant decreases in the incidence of water-borne diseases when compared with the part of the population using unchlorinated wells.

Prospective cohort study—before–after, without comparison group

Bokkenheuser & Richardson (10) studied the prevalence of Salmonella and Shigella in a group of 6–16 year old children in Western Transvaal, South Africa. Richardson et al. (11) repeated the study eight years later, after water quality had been improved; deep, enclosed wells had been provided for the population. The mean infection rate, however, remained practically unchanged, i.e. 4–5%.

Prospective cohort studies—after intervention

In the Philippines, Azurin & Alvero (12) measured the effects that an improved water supply and/or sanitation had on the incidence of cholera by studying four communities; three were subjects of different interventions and one unaffected community served as a comparison. It was suggested that clean, piped water alone led to a 73% reduction of cholera, that improved sanitation alone gave a 68% reduction, and that a combination of the two resulted in a 76% reduction when compared with the community with poor water supply and sanitation.

Henry (13) studied children in three areas of St. Lucia, West Indies. In two of the areas, improvements had been made, consisting of a piped water system with yard taps. In one of these two areas, water-seal latrines had also been installed. The third area, lacking improvements, served as a control. Diarrhoeal diseases, anthropometry, and parasitic infections were studied. In the area where both water supply and sanitation had been improved, rates of diarrhoeal diseases and parasitic infections were reduced and the children had better growth.

Kahn (14) studied the effects that health education had on Shigella transmission in Bangladesh. The intervention in this case consisted of instructions in personal hygiene, mainly to wash hands with soap and water before eating and after defecation. Shigella-positive patients were studied. There was a 67% reduction in secondary infections for the intervention group when compared with a control group which had not received hygiene education.

Rahaman et al. (15) studied a group of villages in Bangladesh which were supplied in a step-wise manner with water from handpumps, pour-flush water-sealed latrines, and sanitary education. Comparison was made with villages without intervention programmes. In the intervention area, the occurrence of diarrhoea among children under 4 years of age was reduced by 11–28%. Children living in households less than 150 yards from the handpumps, had diarrhoea considerably less often than those living farther away.

Schiffman et al. (16) studied two villages in Guatemala; in one, an intervention programme had introduced piped water to homes, and the other served as a control. The intervention village also received health education aimed at changing sanitation behaviour, improving food and water storage, and increasing water use. After the intervention, morbidity was studied by monthly interviews based on two-week recall. No decrease in the incidence of waterborne diseases in association with the intervention was reported.

Retrospective cohort study

Bahl (17) analysed the incidence of typhoid fever and diarrhoeal diseases in Lusaka, Zambia, by studying clinical records. Morbidity data from before and after an intervention consisting of the introduction of a piped water supply, were compared. Both types of diseases were found to decrease considerably after the intervention.

Case-control study

Young & Briscoe (18) studied the effects that improved water and sanitation had on diarrhoeal diseases in children under five years of age in a rural area in Malawi. This was done by chosing a clinic in an area where part of the population used a piped water supply and part used traditional water sources. The type of water source and sanitary facilities of households of children visiting the clinic due to diarrhoeal diseases were compared with these conditions in households of children with non-water-related diseases. The solitary improvement of water supply or of sanitation had no effect on the occurrence of diarrhoea, but a combined improvement of the two produced positive effects.

The present study

A programme for the introduction of piped water into a rural area of Malawi has been studied. The technical construction, community participation, and water usage in this programme were known to be successful (19). Health education and sanitation promotion were recently added to this programme.

The prospective study of three groups of villages during a dry and a rainy season, was made before and after the initiation of the programme. In the eleven selected villages, all households having children that were under five years of age at the beginning of the survey were included, and no new households were added later. The three groups consisted of about 150, 150 and 220 households. The three study areas were chosen, because they were as similar as possible, with regard to socio-economic and environmental conditions before the intervention.

The study of the period before the intervention was planned for February 1983 to January 1984, and the study after for February 1984 to January 1985. According to the plans of the intervention programme, it was intended that the water supply of two of the three areas would be improved at the beginning of 1984, while the third area would act as a comparison area, i.e. the water supply would not be improved until the evaluation study was completed. One of the two areas with the improved water supply, would also receive health education.

Due to changes in the time schedule of the water project, the study period after the intervention was delayed by six months. In addition, the design had to be changed, since the improved method of water supply was introduced at the beginning of the inter-

Table 1. *Studies evaluating an intervention with improved water supply, sanitation and/or health education*

Reference	Type of study	Health indicator	Data collection	Environmental variables
Brunser et al. (1983)	A	Diarrh. morb., fecal pathogens	Home-visit/3 days, stool samples	Water quality, excreta disposal
Magnani et al. (1984)	A	Nutr. status	Home-visits, weight & height	Water quality & availability
McCabe & Haines (1957)	A	Diarrh. morb., Shigella prev.	Monthly home-visits, monthly rectal swabs	Excreta disposal
Rubenstein et al. (1969)	A	Diarrh. morb.	Clinical records	Water availability & excreta disposal
Strudwick (1962)	A	Gastro-intest. illness	Biweekly home-visits	Water quality & availability
Trivedi (1971)	A	Water-borne diseases	Clinical records, (home-visits)	Water quality
Bokkenheuser & Richardson (1960) Richardson (1968)	B	Salm.-Shig.-prevalence	4 stool samples during a year	Water quality
Azurin & Alvero (1974)	C	Cholera incidence	Daily home-visits, rectal swabs	Water quality, excreta disposal
Henry (1981)	C	Diarrh. morb., nutr. status, parasitic inf.	Monthly home-visits, monthly weight & height	Water quality, excreta disposal
Kahn (1982)	C	Shig. secondary inf. rate	Rectal swabs	Hand washing
Rahaman et al. (1983)	C	Diarrh. morb., nutr. status	Weekly home-visits, rectal swabs, biannual weight & height	Water, latrines, health behaviour
Schiffman et al. (1978)	C	Diarrh. morb.	Monthly home-visits	Water quality
Bahl (1976)	D	Diarrh. morb., typhoid incid.	Clinical records	Water quality, water quantity
Young & Briscoe (1986	E	Diarrh. morb.	Interview at clinic and home	Water quality

A = prospective cohort study, before–after intervention, comparison group,
B = prospective cohort study, before–after intervention, without comprison group,
C = prospective cohort study, after intervention, comparison group,
D = retrospective cohort study,
E = case-control study.

Background variables	Results
Literacy	Diarrh. no change, less bacteria, parasites, rota-virus in stools
Socio-econ. data	No signif. health impact but pos. trends
Popul. similar in age, race, environment	52% reduction of Shigella
Different behaviour not considered	About 50% reduction of hospital visits
Socio-econ. data	Diarrh. decrease of 20–23% in 0–1 yr and 18–31% in 1–2 yrs children as % of tot. morb.
Not stated	Lower incidence of water-borne disease after chlorination
Not stated	Mean infection rate unchanged
Not stated	Sanit. 68% diarrh. reduction, water 73% diarrh. reduction, both 76% diarrh. reduction
Study and control areas, similar socio-econ. data	50% reduction of diarrhoea with increased water quantity + sanitation
Matched for age, sex, socio-econ. data	Sec. inf. rate 10% in study and 32% in control group
Socio-econ. data	Children living >150 yds from handpump more diarrhoea
Socio-econ. data	No improvement
Not stated	Incid. 338/1000/yr before and 212/1000/yr after intervention
Age, sex, socio-econ. data	Less risk of diarrhoea with improved water and sanitation

vention period in some parts of all three areas, and later in other parts. During the second period of the study, households shifted from the comparison to the intervention group, as they started to use the new water supply. During each home-visit, it was recorded which water-source the household used.

Socio-economic data were collected for all households at the beginning of the study and at the start of the after-intervention period. Health status of children under five was used as a measure of community health. Measurement of health status included examining the children with regard to nutritional status, total morbidity and morbidity caused by diarrhoeal diseases and skin, eye, and respiratory infections. The morbidity study was comprised of fortnightly interviews based on 24-hour recall; they were carried out by field assistants with secondary school education (20, 21). Nutritional status was anthropometrically measured twice a year. Quantities of water used and bacteriological quality of the water were examined.

Improved water supply had a positive effect on total morbidity, while no trend could be shown for diarrhoeal diseases when multivariate methods of analysis were used. However, variation between the eleven villages was large, indicating that other factors influence the effects of an improved water supply. The effects on nutritional anthropometry also varied considerably between the villages, and after standardization for village, no statistically significant difference was found between those using and those not using piped water. For details of study design, data collection and results, see Lindskog & Lindskog (1).

DISCUSSION

A methodological review by Blum & Feachem (22) examined problems related to the following: lack of adequate control; one to one comparison; confounding variables; definitions of health indicators; health indicator recall; failure to analyse by age; failure to record usage of facilities. It was concluded that it is preferable to concentrate on 'opportunistic studies' (studies seizing an experimental opportunity arising in an existing intervention programme). By taking the impact evaluation into consideration at the planning stage of the intervention project, it may be possible to choose at random which groups in a population will be benefiting from the intervention project.

In a review of literature on water and human health (23), it was pointed out that impact studies are often too short to allow detection of changes, even significant ones, and that they lack adequate refinement to distinguish between "signals" and background "noise". It was recommended that quantitative evaluations should be limited to research projects with substantial resources.

The problems discussed here are illustrated by the reviewed studies. The disease variable, e.g. diarrhoea, is not always defined. The interval between interviews varied from 24 hours to 1 month and the recall period from 24 hours to 2 weeks. Since it is difficult to remember episodes of diarrhoea, it is likely that the reliability of the answers decreases as the length of the recall period increases. Therefore, recall periods longer than 24 hours cannot be recommended.

In some studies, a gradual decrease in morbidity in both the intervention and comparison groups were noted (1, 15). This might be effects of the study itself, both a placebo effect and a real effect due to increased knowledge mediated by the study project. Thus, in studies without a comparison group, it is impossible to know whether a decline in disease rate is an effect of the intervention or of the evaluation study. In after-intervention studies, it is difficult to know to what extent the areas were comparable before the intervention. Improved water supply is not provided at random.

Studying clinical records is haphazard and can only be used for detecting substantial changes or serious diseases. For example, it might be a justified method when using cholera, typhoid fever or serious diarrhoeal disease as health indicators, if the health facilities are easily accessible to the entire population.

The methodologies of the reviewed studies varied considerably. In some carefully made prospective cohort studies using diarrhoeal morbidity as a health indicator, it was not possible to show any significant health impacts (3, 4). However, positive effects were shown in some other studies based on "weaker" methods, i.e. three studies using clinical records (6, 9, 17). This indicates that a positive impact is more easily revealed by reports with a "weaker" methodology, which has previously been pointed out by Brorsson & Wall (24). Studies in which a single pathogen was used as a health indicator, showed that interventions caused considerable health impact.

This is understandable, since they deal with a homogeneous indicator, which is not the case with diarrhoeal diseases. Some of these studies are ongoing projects, making final evaluation impossible at present. In a review of studies evaluating health impacts of improved water supplies and facilities for excreta disposal (25), large reductions in diarrhoeal morbidity rates were found (27% in the "better-designed" studies). However, this review included a heterogeneous group of studies, and was not limited to intervention projects in which the effects of improved water supplies and hygiene should be most obvious.

A method which has recently been proposed for evaluating the impact of improvements in water supply, hygiene and sanitation on public health, is the case-control study (26, 27, 28). A case-control study does not require the same population to be studied both before and after an intervention, which means that field work can be limited to a shorter period of time than in a prospective study. In a cohort study, in order to have a 90% chance of detecting a 30% reduction in morbidity at a significance level of 5%, 6000 individuals are needed in each group if the frequency of disease is 5%, and 3000 if the frequency of disease is 10% (29). In a case-control study, about 600 cases and 600 controls would be needed to detect the same reduction (30). Thus, a case-control study is a cost-effective way to evaluate an intervention, and it can give quick and reliable results. The limitations of this type of study are that only the chosen health indicator can be studied, and that, in contrast to a cohort study, the broad information of a complex situation cannot be obtained.

The present study included an intervention and a comparison group, which were examined for slightly more than one year before and one year after the intervention, making it possible to adjust for background variables and seasonality. This study design is, however, laborious, time-consuming and expensive. During such a long study period, there is a risk that the study itself will affect the examined population. However, we found no reason to believe this study design, in which people having access to an improved water supply lived geographically mixed with those who did not, influenced the intervention and comparison groups in different ways.

The source and amount of water used by each household were recorded regularly, and the bacteriological quality of the water sources was examined several times. Since a large part of the contamination of the household water occurred during storage in dwellings, it would have been desirable to monitor the water quality there. However, with the resources available, only about 200 samples could be examined. Therefore, the actual quality of water at the time of consumption was not known.

The population of the study area had a positive attitude to the evaluation study. It was very important to follow a socially accepted procedure when coming to the villages; this included first visiting the chief, the village headman, and the party leaders, and carefully explaining the purpose of our study to them. Misunderstanding and suspicion easily arose concerning certain questions, e.g. about income and hygiene habits, or about collection of stool specimens or blood samples.

It was also important to take an interest in village life; medical help or transport to hospital was given when needed, and many visits were made to express condolences. (The normal interviews could not be made on a day when someone in a village had died, because people were mourning and taking part in the funeral.) Conflicts in the villages were frequent but were usually not connected with the water project or the evaluation study.

The seven field assistants employed were strongly advised of the importance of proper behaviour. They were to have good relations with the villagers but not to become too involved, which proved difficult to keep in balance. On one occasion, a field assistant became "bewitched", but this problem was solved with the assistance of a witch-doctor.

The design of an evaluation study of an intervention programme affecting water supply and providing health education, is extremely dependent on the type of intervention. It is therefore difficult to find an ideal design. The intervention should not be affected by the evaluation project in such a way that it will become non-representative of projects being implemented in the country. The evaluation should be planned in cooperation with those planning the intervention, but the evaluation should not influence the intervention or vice versa. A time-schedule complying to the needs of the evaluation study and the intervention programme is needed, but, as can be seen in our study, field conditions in Third World countries may necessitate changes; projects are often dependent upon personnel and technical equipment from abroad.

Our study was planned and implemented cooperatively by a pediatrician, a social geographer, and a statistician; the causal relationships in community studies are very complex and require an inter-disciplinary approach. This cooperation made it possible to study various aspects connected with the intervention project, e.g. social processes in a village, attitudes to and usage of the new facilities, and the concept of health and measuring of health status.

Several, well-designed studies have failed to show clear-cut results, probably because a change is multifactorial, i.e. an intervention is only one of several influential factors. In conclusion, the study design should be carefully planned, since it is crucial for the validity and interpretation of the results. Prospective before–after studies with intervention and comparison groups from several communities should be chosen, if a cohort design is to be applied. With "weaker" designs it is not possible to standardize for confounding factors, which are frequent in community studies.

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