INSTITUTE OF FOOD SCIENCE & TECHNOLOGY

Report on

POLLUTION OF GROUND WATER

FROM

PIT - LATRINE

IN

BANGLADESH

BANGLADESH COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
NEW ELEPHANT ROAD, DHAKA-5.
BANGLADESH

ifst DHAKA

INSTITUTE OF FOOD SCIENCE & TECHNOLOGY

Report on

POLLUTION OF GROUND WATER
FROM
PIT - LATRINE
IN
BANGLADESH

BANGLADESH COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
NEW ELEPHANT ROAD, DHAKA-5.
BANGLADESH

A REPORT
ON
POLLUTION OF GROUND WATER FROM PIT-LATRINE
IN
BANGLADESH

(A Collaborative Project with the Department of Public Health Engineering (DPHE), Govt. of Bangladesh, Assisted by WHO and UNICEF)

by

S.F. Rubbi (Principal Coordinator)

G.K. Joarder

A. Majid

M. Khatun

and

*G.B. Sarkar.

Institute of Food Science and Technology(IFST),
Bangladesh Council of Scientific and Industrial Research
(BCSIR),
Dhaka-1205
1987

* WHO - Dhaka

FOREWARD

The task of providing drinking water and sanitation to all people in the region within the period of the International Drinking Water Supply and Sanitation Decade (1981-90) is a great challenge. Low cost technologies that satisfactorily work are within the reach of most countries. Two of the important requirements of the success of low cost technologies are social acceptance by the users and proper operation and maintenance of the systems.

Ground water is the main source of safe drinking or potable water in Bangladesh. But this source may be polluted by various environmental conditions and human activities. At present, in Bangladesh, installation of hand pumped shallow tube-wells by DPHE, Govt. of People's Republic of Bangladesh with the help of UNICEF is going on in wide scale. In parallel with this programme, the installation of pit-latrine to dispose faecal matters which are the sources of many diseases, has also been taken up by the same agencies. Both the programmes are expected to benefit the people enormously. But there is a possibility of contamination of shallow aquefer from pit-latrine and from this aquefer level water is drawn by the hand pumped shallow tube-wells. To assess this problem, this study was taken up in collaboration with DPHE assisted by WHO and UNICEF. During this study it was keenly felt that the active collaboration/participation of microbiologists, chemists, hydrogeologists, sanitary engineers, etc. are essentially required for successful completion of such studies. But unfortunately this could not be properly achieved mainly due to unavailability of the services of the hydrogeologist. The other difficulties encountered including the shortcomings of the Project protocol have been discussed in the report.

However, some valuable data have been obtained. But according to this report based on these data, this study can not be termed as 'completed one' rather it indicates that further studies following the much more well planned programmes should be carried out to assess the situation and solve the problems. To help in this matter two chapters "A short Review of Literature" and "Recommendationsand Guidelines" in which some similar important studies and studies on the related problems have been discussed, and a good number of suggestions have been made for proper designing of project programmes on such study.

We, regret that a considerable amount of delay has occurred due to reasons beyond our control.

Hope, this report will be found beneficial for further study as mentioned above and for the scientists who are engaged in Ground Water Pollution Research.

Dated : Dhaka
June 1987.

(Dr. S.F. Rubbi)
The Principal
Co-ordinator of
the Project

and

Director,
Institute of Food
Science and Technology
(IFST), Bangladesh
Council of Scientific
and Industrial Research,
(BCSIR), Dhaka.

Acknowledgement

We are grateful to the following persons for their help and Co-operation during the study :

WHO, Dhaka, Bangladesh.

Dr. Z. Sostak, Representative,
Mr. Aung Myat, Representative,
Mr. V.P.N. Nayar, S.T.C.,
Mr. D.N. Vigeyaratne, S.E.,
Dr. Ali Basaran, S.W.,
Mr. S. Szabo, Sanitarian, and
Mr. K.M. Minnatullah, N.S.E.,

UNICEF, Dhaka, Bangladesh.

Mr. Ken Gibbs, Chief WES,
Mr. Collin Glenie, Chief, WES, and
Mr. A.S. Azad, Programme Officer,

DPHE, Dhaka.

Mr. M.H. Khan, Chief Engineer,
Mr. Waheed Asgar, S.E. Planning,
Mr. Fariduddin Ahmed, S.E., Planning,
Mr. M.A. Karim, S.E. Planning
Mr. Khurshed Alam, E.E.,
Mr. A. Rahman, Asstt. Eng.,
Mr. Mahiuddin Khan, Sr. Hydrogeologist,
and the Technical Staffs of DPHE and others.

We are specially indebted to Mr. P. Morand, WHO expert for his technical help in adopting the Tube Technique of sampli and also thank the other WHO experts who visited Banglades in connection with this project.

Contd.

Acknowledgement(contd.)

IFST (BCSIR) Dhaka,

We are thankful to the following colleagues of IFST, BCSIR for their services rendered during this study:

Mr. Md. Mujibur Rahman, SSO,
Miss. Majeda Begum, SO,
Dr. S.A. Ahmed, P.S.O.,
Dr. M.F. Rahman, SRO,
Mr. A. Mahbub Ghani, SO, (Statistician)
Mr. Chowdhury Abdur Rashid, Tech.,
Mrs. Rehana Begum, Jr. Tech.
Mr. Azhar Ali Khan, Jr. Tech.
Mr. Abdul Wahed Miah, Jr. Tech.
Mr. Anwar Hossain, Lab. Attdt.,
and the Officers and Staffs of the Administration of the Institute. We also thank Late Dr. S.G. Qadir, CSO and Mr. M. Mansur Ahmed, Artist, of Dhaka Labs. BCSIR and others.

We specially thank Miss. Majeda Begum, SO, IFST. for determination of iron and conductivity.

We are thankful to Dr. M.B. Rahman, Ex-Chairman and Prof. S.S.M.A. Khorasani, Chairman BCSIR for their kind permission to undertake the work.

CONTENTS

Contd.

CONTENTS (contd)

1. GENERAL INTRODUCTION

1.1 The cheap and easy ways to supply safe drinking water to rural people and to dispose human faecal matters in the rural area in developing countries like Bangladesh where water-borne diseases are most prevalent, are the installations of hand operating shallow tube wells and pit-latrines respectively.Department of Public Health Engineering (DPHE), Government of People's Republic of Bangladesh with the assistance of UNICEF and WHO are already active in installing such systems .

1.2 But if the ground water is contaminated by faecal pollutants from the pit-latrine, it is very likely that shallow tube well will not supply safe drinking water. Some pioneering works have already been done in different countries to monitor the travel of pollution from underground faecal matter disposal systems, causing pollution to the underground waters, but hardly any such work has been done in Bangladesh. Accordingly,the above mentioned agencies prepared a project ("Pollution of Ground Water from Pit-latrine") and IFST, BCSIR was requested to do the chemical and microbiological analytical works as prescribed in the work-plan of the project, BCSIR was not involved in the preparation of the project.

1.3 Unfortunately, the work plan of the project did not take into account to create ideal experimental conditions and it was not possible to recast the work-plan as it was needed with the progress of works, for unavoidable reasons.

However, some modifications were done, but these did not produce the expected results. Moreover, hydrogeological studies (for which IFST,BCSIR was not responsible) of the project have not been carried out though repeated requests were made to the concerned agencies by IFST,BCSIR. Consequently, though some valuable results were obtained, it has not been possible to establish the fact whether the pit-latrines were responsible for the contamination of the monitoring tube wells, hence the ground water. These points have been discussed in more details in appropriate chapter of this report alongwith other difficulties faced during the investigations.

1.4. The works done by IFST, were periodically discussed by a review committee constituted by the representatives from IFST,DPHE, UNICEF and WHO and studies were carried out according to the decisions of the committee in the light of the work-plan of the project.

1.5 In this report, the results of chemical and bacteriological analyses of a large number of water samples collected from the selected monitoring shallow tube wells have been described along with recommendations and guidelines for further studies in future.

2. A Short Review of Literature

2.1 General Considerations :

There are not many published communications directly dealing with the subject "Ground water pollution from pit-latrine".But there are a number of publications dealing with the factors which are connected with this problem. Lewis et al (1980) reviewed many of such publication in a report which has dealt with the vital aspects of the subject. It is clearly shown that the bacteriology of low cost sanitation as this, which comprises of installations of shallow tube wells for water supply specially in the rural area and unsewered faecal disposal systems such as the use of pit-latrine require thorough studies involving many factors which may be broadly divided into three groups of studies (a) hydrogeological (b) chemical and (c) microbiological of course, the technological aspects concerning the installations of such systems should also be given proper considerations. The need for such low cost sanitation measures dealing with the supply of safer or hygienically pure water to the masses specially in the rural areas and disposal of human faecal matters could not be over emphasized in developing countries like Bangladesh because the alternative ways, the supply of piped water or sewearage system for disposal of faecal matters clearly involve such high cost not feasible in our sitiation. However, they have also pointed out that the establishment of such systems (low cost sanitation) are clearly influenced by hydrogeological and materiological conditions of the particular area.

2.2 Water-Borne Diseases and Diseases Caused by the Faecal Matters :

Feachem et al (1980), Salvato (1972) and Bradley (1977) have compiled comprehensive list of such diseases. The most of the water borne diseases are of enteric types and most prevalent in Bangladesh. The causative agents are generally (a) bacteria (b) viruses, (c) protozoa and (d) helminths. They are traced to be of faecal origin. Many of the deseases may be vector borne but water polluted by faecal matters are particularly responsible. These facts indicate the vital need for hygienic disposal of faecal matters as well as supply of pure domestic water. As said above, the installations of hand operated shallow tube well and pit-latrine may be regarded as the most practical and cheap solution. But there is one potential danger, faecal maters from the pit-latrine may be transmitted to the ground water and consequently, the water supplied by the shallow tube well may be contaminated by the pathogens of faecal origin. If this occurs, the whole aim of prevention of these diseases are in zeopardy and many authors have shown that this can happen if the proper precautions are not taken. The diseases caused by protozoa and helminths by ground water are not likely as they are supposed to be eliminated by soil profiles because of their relatively bigger sizes. (Lewis et al, 1980).

There is another type of disease of babies called matheomoglobinaemia which may be originated by water, polluted by excessive nitrate content of faecal matters transmitted to ground water from septic tank type latrines (which include pit-latrine also, Lewis et al, 1980 and Woodward et al, 1961) .

2.3 Transmission of Pollutants from Pit-latrine to Ground Water:

Hydrogeological features play great roles in the travel of pollution from pit-latrine to ground water or the aquifer from which water is pumped by hand operated shallow tube wells. The soil space between the pit-latrine and the ground water, lateral or vertical is the major determining factor depending on the soil characteristics. It is apparent that the bottom of the pit-latrine is above the water table so there must be an unsaturated soil profile between the latrine and the ground water. The lateral spacing is directly present and this also is important. Actually the aim of investigations is to find out the suitable vertical spacing between the pit-latrine and ground water and lateral spacing between the shallow tube well and the latrine. However, in some parts of this country the water table is very high and during the flood seasons it may be higher than the bottom of the pit-latrine. So the finding out of the optimum lateral spacing between the two systems is most needed. Many factors which influence travel of pollution through the soil profiles are required to be studied to achieve this objective. The soil profile which to be taken into account in this connection may be divided into two zones, (a) unsaturated which is above the water table and (b) the saturated zone i.e. the soil of the aquifer.

2.3.1 Filtration and Adsorption of Pollutants in the Soil :

Soil is a natural barrier to the travel of pollution to the ground water and in the ground water itself. Filtration and adsorption play a great role in this respect (Boars, 1957, Hagedorn, 1978, Buchan, 1956, Mc Ginmis, 1983, Caldwell and Parr, 1937, Lewis et al, 1980). Filtration of microoraganisms is naturally dependent upon the porosity of the soil, that means smaller is the particle size, more is the filtration efficiency. So the soils containing the clay matters are more effective in this respect. Filtration capacity of the soils around the latrine increases as the clogging of pores occurs due to the film of bacteria as the time passes on.

Free ions in the soils are abundant (specially in clay), the bacteria and viruses may be regarded as colloidal particles. So adsorption of bacteria and viruses on the soil particles naturally occurs.

For chemicals, filtration apparently do not play very significant role but adsorption or absorption help much in removing chemicals from the infiltrating water.

It may be mentioned that in the upper layer of soils, where oxygen is appropriately available, mineralization/ oxidation of microorganisms and chemical occurs significantly. But this natural effective quality of soil has little part to play for the faecal matters deposited in pit-latrine.

2.3.2 Faecal Indicators :

(a) Microbial : Though faecal matters contain protozoa and helminthes which cause many diseases, but they are not much important in ground water as stated above. Moreover the determination of virus is costly and easily adoptable routine methods are not available. So for the determination of pollution caused by microbes to the ground water, the attention is naturally given to the detection and enumeration of suitable bacteria of faecal origin.

Feachm et al (1977) have recognized the following major group of bacteria in human excreta : Enterobacteria, Enterococci Lactobacilli, Clostridia, Bacteroides, Bifidobacteria and Eubacteria. Moore and Haldeman (1974) examined the faecal flora of 20, clinically healthy Japanese Hawaiian males and found 113 distinct types of organisms. As it is not possible to determine all possible types of bacteria in water for routine/monitoring analyses, it is needed to select some group of bacteria which realiably would indicate the contamination of faecal matters in water. These groups of faecal bacteria must fulfil the following criteria:

(a) Normal habitat must be the gut of the warm blooded animals

(b) Present in feces in appropriate numbers so that they can be detected even when highly diluted.

(c) Normally should proliferate extraenteral environment.

(d) Should not be out-survived by the enteric pathogens and the survival charecteristc, in general should be similar to the enteric pathogens.

(e) Their modes of survival in the environment should be appropriately known.

(f) Easily adoptable techniques for their detection and enumeration are available (Resnick and Levin, 1981).

For long time coliform group of bacteria has been used to assess the quality of water refering to faecal pollution. But total coliforms as indicators of faecal have been found to be inappropriate as many members of the coliform bacteria are not of faecal origin (Mcusse, 1965), can survive indefinitely and grow out-side the gut of the warmblooded animals. Inadequency of coliforms as index of water quality has been discussed by Dutka (1973) in detail. He suggested the determination of faecal coliforms and faecal streptococci for better assessment of water quality. In fact, faecal coliforms considered to be an ideal bacterial type for assessment of faecal contamination in water and food. Escherichia coli, which is regarded as exclusively natural bacterial flora of the gut comprises by far the majority of the faecal coliforms. But other bacteria ; giving the typical reaction of E.coli in routine method are also included in this group. Bagley and Seidler (1977) have shown that Klebsiella which occurs also in the environment (Water, Vegetation, etc.) has the fair chance to be recognized as faecal coliforms in the usual detection and enumeration methods. However, this may not be a great problem in case of ground water with reference to pollution from pit-latrine, if direct leakage in the sampling point does not occur or the samples are not contaminated by the matters of the surface environment. But the defferentiation of faecal coliforms into specific types, would, obviously be helpful to exclude other sources of ground water pollution such as ponds, rivers, canals, drains, etc.

Faecal streptococci (including enterococci) are recognized also as good indicators of faecal pollution. Hagedorn et al, (1978), Mallman and Litsky (1951), Cooper and Ramadan,(1955) Barnes, 1956, Allan et al, 1952, Kabler, 1968, Kibbey et al, 1978, McFeters et al, (1974) Mathur and Ramanathan (1966), Medrek and Litsky (1960) have studied the different aspects of suitability of these groups of bacteria as faecal indicator. They have been found to be more stable in water and this makes their relative importance in assessment of quality of ground water in which contamination may not be recent one. But the ratios of faecal coliforms to faecal streptococci which indicate the source of pollution do not hold good for ground water for the same reason. However, the differentiation of faecal streptococci in different species may be considered very helpful to locate the source of pollution as the same specific types live in the gut of human.

In recent times, some other enteric organisms have been given considerable attention to be used as faecal indicators. Lechevalier and Seidler (1980) showed interest in the presence of coagulase positive staphylococcus in drinking water as the strains of staphylococcus produce enterotoxin. Temple et al,(1980) brought Salmonella typhimurium into the picture showing its high survival characteristic. Bifidobacteria is getting attention as faecal indicator (Resnick and Levin, 1981 and Gyllenberg et al, (1960). Reitler and Seligman (1957) studied the occurrence of pseudomonas aeroginosa in drinking water and suggested to take it into account for assessing the quality of drinking water.

Clostridium perfringens (fomerly C. welchii) has been recognized for long time as faecal indicator and being an spore bearing organism it can persist in water for long periods (Feachem et al, 1980) .

Some of these faecal indicators mentioned above may be determined along with faecal coliforms and faecal streptococci, if not routinely but periodically in assessing the pollution of ground water as supporting evidence. There may be difficutlties as easily adoptable methods for the determination as some of these faecal indicator have got to be established.

(d) Chemical : Chemical pollution of ground water have been studied by a number of authors (Baars, 1957, wordward et al, 1961, Buchan and Key, 1956, Woodhull, P.S 1981, Pawley.J.D.1982, Dyer, et al,1945., Reinhard and Velocchi 1982)and others and in ground water pollutants such as nitrate organic wastes, neutral salts, volatile chemicals, oil, solvents, spray substances, surfactants, etc have been found. In fact all the toxic materials deposited on the soil surface or underground may contaminated the ground water eventually, though at surface and in subsoil mineralization process or oxidation breaks these substances considerably depending upon the availablity of oxygen.

It is recognized that chemical pollutants travel far and persist for longer periods in ground water. However when pollution emanating from the pit-latrine is concerned, many of these industrial and agricultural wastes or chemicals do not matter much. Woodward et al, (1961), have put emphasis on nitrate and surfactant to consider as the index of contamination in ground water. Faecal matter is rich in nitrogenous compounds and water containing surfactants used in domestic purposes may be added to the loading of pit latrines. Dyer et al,(1945) determined ammonia, chlorides, conductivity, acidity and pH for assessing faecal contamination of ground water from the experimental latrine. Amongst these determinations of nitrates, chlorides, conductivity and pH may be considered as highly helpful for monitoring faecal contamination from pit latrines. It may be commented that, mostly due to dilution effects and some other factors including the soil characteristics of the unsaturated and saturated zones of soil profiles, these parameters when determined may not be found significant even where bacteriological indicators are reliably found.

2.3.3 Servival of Faecal Organisms (Bacteria and Viruses) in Soil and Ground Water.

The microorganisms specially bacteria and viruses the natural habitat of which is the gut of warm blooded animals do not survive in natural environment for indefinite period unless the growth and survival conditions are available. These are hardly found in ground water. So the rate of survival (rather the rate of death) is correlated with the travel such organisms in the ground water .

A large number of authors (Hagedorn, 1978), Malimam and Litsky (1951), Temple et al, (1980), McFeters, et al, (1974) McFeters and Stuart (1972) Gyllenberge et al, (1960) McFeters et-al, (1972) and others, have studied the survival of enteric microorganisms at different conditions. Lewis et al, (1980) and Feachem et al, (1977) have reviewed the subject extensively. There are conflicting reports about the better survival of the two most used types of faecal indicators, faecal coliforms and faecal streptococci. But generally is accepted that, in ground water, faecal streptococci survive longer than faecal coliforms. Moreover, it is recognized that faecal streptococci hardly proliferate in water.

In soil, survival of bacteria as well as viruses depends much on temperature and moisture contents. Lower temperature and higher temperature both increase their survival periods. The presence of antagonistic bacteria affects the survival of faecal indicators. With increasing acidity, the survival of bacteria decreases. Adsorbed viruses have the possibility of surviving longer period. The presence of nutrient generally in the form of organic matter would obviously increase the survival of bacteria and even regrowth of some faecal indicators such as faecal coliforms may take the place. In laboratory experiments Burke and Mescher (1936) have showed that Escherichia coli may grow in water containing significantly small amount of organic matter.

The informations on the factors affecting the survival of faecal indicators in ground waters are scantly. However, it is apparent that the effect of temperature on their survival is analogous to that of in soil. It is generally found that in ground water bacteria including faecal types survive longer than in surface water. The chemical nature of the ground water such as acidity and salinity may also effect the survival of faecal bacteria but the presence of nutrients would obviously help their survival.

Considering these facts, it is quite obvious that the survival of faecal bacteria and viruses varies much, both in soils and ground water according to the physical and chemical nature of the particular zone. Their survival may even be extended to several months under the favourable conditions.

2.3.4 Determination of Faecal Indicators :

(a) Chemical Indicators : Well defined procedures for the determinations of these parameters have been given in the standard methods (APHA, 1980). Some methods have been modified time to time in the newer editions. However, these procedures may be considered sufficient for the purpose of monitoring ground water pollution chemical from pit-latrine.

(b) Bacterial Indicators : In the above discussion, the determination of faecal coliforms and faecal streptococci have been given the most attention. The determination of other faecal indicator organisms discussed above, may be regarded as supporting evidence but sometimes these may be very helpful specially when confusing or contra-dictory results are obtained.

(c) Determination of Faecal Coliforms : In the recent time, the routine determinations of faecal coliforms and streptococci have been made much easier by using membrane filter (MF) Technique instead of conventional multiple tube most probable number (MPN) technique. The methods of MF and MPN technique for determinations of total coliforms, faecal coliforms and faecal streptococci have been elaborately described in the standard methods (APHA,1986). However, there is always a controversy over the two types of the techniques and though now-a-days, it is well recognized that one-step MF methods have got many advantages over MPN methods specially referring to the saving of time. But this one step technique is facing some well established criticisms specially in the case where the faecal contamination may not be recent in nature as in the case of ground water. For shortening the time of the determination of coliforms by MPN method, Lieber and Martin (1956) have developed method using flourescent antibody. In this method a large number of sample may be examined within short time by examining the slide prepared from 24-48 hours lactose broth culture treated with flourescent antibody. Seidler et. al, (1981), Evans et al, (1981a) Evans et al, (1975), Evans et al,(1981c), Presswood and Strong (1978), Hsu and Williams (1981), Standridge and Delfino (1982) and Grabow et al,(1981) also studied the different aspects of MF technique in determination of coliforms including faecal coliforms and suggested improvements in media and techniques. Their studies show that suitable modifications should be adopted in the conventional MF or MPN methods as found suitable for the type of samples.

It is recognized that the inhibitory effects of some constituents of selective media (such as lauryl sulfate, rosolic acid etc) should be taken into account. Some studies have been carried out on the quality of the membrane filters having different characteristics and manufactured by different companies (Schaeffer, et al, 1974, Biodsky and Schiemann, 1975 and Talin et al, 1980). They have showed the quality of the membrane filters affect, the recovery of coliform group of bacteria to a considerable extent. However, membrane filters having good soaking capability and pore size around 0.45-µm, as suggested in Standard Methods (APHA,1981,/15th edd.) may be considering sufficiently suitable for monitoring the faecal indicators in routine analysis which are required for determining the faecal pollution in ground water. The distribution pattern of the coliforms in water has got direct influence on the assessment of the quality hence the pollution in the samples. Christian and Pipes (1983) and Pipes and Christian (1984) have shown that the frequency distribution of coliforms in water is not in normal or random distribution patterns, rather in negative binomial or lognormal distribution. These findings should be taken into account in the determination of sample-number and sample volumes of in monitoring the faecal indicators in ground water.

The presence of other bacteria in water may greatly influence the determinations of coliforms (Reilly and Kippin, 1983, Franzblau et al, 1984, and Lechevallier and McFeters, 1985) specially in membrane filter technique due to their masking action or over growth on the membrane filter.

The greater are the numbers of non-coliforms the less will be the reocvery of coliforms. Franzblau (1984) suggested and anaerobic membrane filter technique for the improved recovery.

The turbidity of the sample also has the similar effect (Reilly and Kippin, 1983 and Lechevallier et al, 1981). The particles causing turbidity hinders the colony formations by coliforms. In such cases, the determination by MPN method may be adopted or the aseptic prefiltration using membrane having porosity through which indicater organisms can pass, may also be helpful. Turbidity also interferes the chlorination of water (LeChevallier et al, 1981).

In determinations of coliforms of the membranes of the genus Envinia may give abberant results (Elrad,1942), white klebsiclla may produce similar characteristics of faecal coliforms (Bagley and Seidler) in routine detection and enumeration procedures.

It is generally accepted that coliforms do not survive indefinitely in water, so the effect of time passed between sampling and beginning of the experiment is expected to influence the recovery of coliforms adversely. McDaniels et al, (1985) have studied the problem elaborately and suggested that the water sample should be kept in ice and analysed on the same day.

A good number of studies (mostly done recently) have been done on injury of coliforms (including faecal types) which are subjected to stress; and development or modifications of procedures including media for the recovery of such injured coliforms (Milbauer and Grossicz, 1959, Maxcy, 1970, Scheusner et al, 1971, Ray and Speck, 1972, Ray and Speck, 1973a, Ray and Speck, 1973b, Bissonnette et al,1975, Bissonnette et al, 1977, Stuart et al 1977, McFeters et al, 1982, LeChevallier et al, 1983, LeChevallier and McFeters, 1985). This injury which is non-lethal in nature, may be done by chlorine and other sanitizers, freezing, heat and other environmental factors, biological interactions (eg., interactions with other bacteria), lack of nutrients, actions of heavy salts etc. Though in examination of ground waters, routine mehtods have generally been followed, but it should be recognized that some of the factors by which coliforms may be injured exist in under ground conditions specially in the case where the contamination may not be recent one. As such, it is suggested that in monitoring coliforms in ground waters, improved methods developed for the recovery of injured coliforms should be evaluated in parallel with the Standard Methods.

(ii) Determination of Faecal Streptococci :

Faecal streptococci generally occur in chains of different sizes and form colonies on membrane filter or agar plate on individual chain basis. These chains but not the individual cells are regarded as colony forming units (CFU). This chain formation also affects the determination of numbers by MPN method. So in quantitative determinations may sometimes produce conflicting or confusing results, specially in conditions when chains break up and this condition prevails in older cultures which is likely to be found in groundwater.

So, the quantitative aspects of determinations of faecal Streptococci may not correlate with the degree of pollution in ground water.

In the Standard Methods (APHA, 1981), the well established methods for the determination of faecal streptococci have been given. Pavlova et al, (1972) studied different types of media for detection and enumeration of faecal streptococci and suggested a scheme by which different types of faecal Streptococci could be determined. Such differentiation should be considered as very helpful in locating the source. Cooper and Ramadan (1955) also carried out an elaborate study on the differentiation of human and animal types of faecal streptococci. Barnes (1956) suggested the reduction of tetrazolium salts as a means of differentiating Streptococci faecalis from S. faecium as these two types of faecal streptococci share many common characteristics. It may be mentioned that in human faecal streptococci group, S. faecalis is regarded as the most prominent one. So in assessing the pollution of underground water in reference to pit-latrine, the determination of S.faecalis may be very helpful.

It may be mentioned that some influencing factors which have been discussed in connection with the determination of coliforms may also be important for the determination of faecal streptococci, specially, the turbidity of the samples create unfavourable condition for the growth of faecal streptococci colonies on the membrane filter and their examination.

The application of MPN method may be required in such cases.

2.4 Travel of Pollution in Ground Water :

Some important factors ~~influencing~~ the travel of pollution in ground water have already been discussed. It is evident that without carrying out well-designed monitoring covering for a considerable period it would not be wise to predict the distance of travel of pollution in a particular site or locality. The design of such study has been discussed below in short. Caldwell (1938), Caldwell and Parr (1937), Higinnis and Dewalle (1983), Wanger and Lanoix (1958), Salvato (1972), Buchan and key (1956), Hage Jornet et al(1978), Brown et al, (1979), Woodward et al, (1961), Baars (1957), and Dyer et al, (1945a) Caldwell (1937) and Lewis et al, (1980) studied and reviewed the literature, on the travel of bacteria including pathogens and chemicals in underground water from pit latrines or other types of bored hole latrines.

It has been found that the travel of pollution, both bacterial and chemical depend much on the flow rate and volume of the ground water. The immobilization of bacteria and virus is less in saturated soil or the aquifer than that in the unsaturated soil zones. The most notable feature of the travel of bacteria is that the pollution stream becoming narrower with distance mostly, perhaps, (due to) the clogging of the surrounding soils. The distance covered by bacteria and virus is comparatively less than that in cases of chemical pollutants, but it varies from a few meters to more than hundred meters.

The hydraulic gradient and pressure in the aquifer are also effective factor in the travel of the pollution. The load in the latrine also affects the pollution to the water and its travel. Obviously, the pollution travel generally to the direction of the ground water flow, Only a little lateral dispersion or travel against the flow of ground water takes place. This may be effected by heavy abstraction of water (draw-down effect) from the aquifer and this is not likely be happened in case of hand operated shallow tube well.

2.5 Design of the Monitoring of Groundwater Pollution from Pit Latrine :

In the chapter (9) on the Recommendation Guidlines and for Future works, of this report, certain suggestion have been put forward for designing a feasible, realistic and scientifically sound scheme for studying ground water pollution from pit-latrine. Only reviewing literature, it is not possible to formulate such a scheme of study. The availability of funds, existing facilities and trained manpower should be taken into account in these regards. However, the findings of the study described in this report and the informations available in the existing literature could certainly be very helpful.

The classical studies of Dyer and Bhaskaran (1943), Dyer and Bhaskaran et al (1945b) together with the studies done by Caldwell (1937), Caldwell (1938) and Caldwell and Parr (1937) are still regarded as models for carrying out studies on groundwater pollution. Of course, in methodology much improvement has taken place specially in the recent years, but basically the experimental design of these studies should be regarded as primary guidelines. The most essential features of studies of Dyer et al, and others as far as the experimental design is concerned are as follows :

(a) Selection of a suitable site which has not been contaminated by pollutants from borehole type latrine.

(b) Studying the factors which might affect the travel of pollution (Soil characteristics, hydrogeological features, such as ground water flow direction and rate etc.)

(c) Determinations of parameters which were to be studied in connection of monitoring the pollution of ground water, both chemical and microbial, before installation of latrine.

(d) Installation of a borehole latrine in a suitable position of the experimental site.

(e) Installations of monitoring tubewells in ringwise around the latrine at various distances and depths (these monitoring latrine are also required before the installation of the latrine).

(f) Determinations of indicative parameters of pollution, both bacteriological and chemical, for a considerable period of time.

(g) Assessment of pollution by comparing the pollution indicator data obtained before the installation of the latrine with similar data obtained after the installation of the latrine.

These pragmatic approaches should be regarded as primarily essential in formulating any study scheme concerning the determination of pollution of ground water from pit-latrine. At the same time, the most reliable techniques should be followed for studying factors affecting the travel of pollution as well as determinations of faecal pollution indicators, both bacteriological and chemical.

Recently, Ward and Schertenleib (1982) made a summary of the report prepared by Ward and Foster, (On site Sanitation and Ground Water Quality: a methodology by Ward C. F. and Foster S. S. IRCWS, Dubendarf/Switzerland) on the methodology of monitoring ground water quality inconnection with On-Site Sanitation. In this report, the above metioned design parameters are generally accepted. They have suggested a project area of $2Km^2$ size and put emphasis on the following notable aspects :

(a) Back ground water quality of latrine and hydrogeological features should be known ;

(b) Monitoring of rainfall ;

(c) Slotted casing for bore holes ;

(d) Sampling-samples should be truely representative of the aquifer being monitored;

(e) Monitoring period: at least 3 years (monitoring should commence one year prior to the installation of on site sanitation);

(f) Monitoring should be limited to determination of faecal coliforms and streptococci and the chemical studies should be restricted to the determination of chloride, nitrates (in certain cases nitrite; ammonium and iron) in addition to physical characteristics such as temperature and electrical conductivity (done in the field);

(g) Use of field kits, where possible;

(h) Application of standard methods and materials;

(i) The data should be evaluated constantly, so that, the monitoring procedures can be up-dated and the anomalies checked immediately.

(j) Appropriate interpretation of data etc.

From the above discussion and the experience obtained during the study described in this report, it may be concluded that without a well designed programme, it is unlikely to obtain any meaningful results and it is not at all advisable to make random monitoring of ground water quality to assess the pollution done by pit-latrines without the required background informations and other data affecting such pollution.

3. The Project Plan.

3.1 Identification of the Problem :

Bangladesh has an extensive shallow tube well sinking programme. According to UNICEF, Bangladesh has nearly 626,000 shallow tube wells existing in the country of which about 423,000 tube wells have been installed by DPHE in co-operation with UNICEF up to December 1985. An additional 122,400 tube wells have to be sunk during the year 1985-88, to meet the target of one operable tube well per 75 people.

Pit-latrines so far installed by DPHE in collaboration with UNICEF are about 362,000 up to December 1985 and there is a programme to install 375,000 more pit-latrines in the rural areas in near future. It has been observed that some hand tube wells have been located as close as 2-meters to water seal latrines. Some others are located at greater distances but still not more than 10 meters away as presently recommended by DPHE.

In view of the above facts the question of possible source of contamination of tube wells water from water sealed pit-latrines and other potential sources of pollution has been raised. On the other hand the soil of Bangladesh are highly alluvial consisting of clay,silty clay, silty clay loam, silty loam, loam and some very fine sandy clay loam, the possiblity of bacterial contamination of wells of the depth of 80 ft. resulting from the transport through the soil are considered to be low .

However, it has been felt that it would be important that an assessment of the potential hazards associated with the installation .

of pit-latrines should be made. It is an initial move to establish whether or not a potential threat to quality of water of shallow aquifers exists; so, a survey programme of monitoring the quality in existing hand pump tube well was prepared.

3.2.1 Aims and Objectives :

Long term: to assure that the provision of on-site sanitation facilities does not threaten the safety of rural and urban drinking water supplies, which are principally derived from shallow ground waters in Bangladesh.

Phase 1 of the project-To assess the extent of pollution of hand pump tube wells in relation to sources of potential pollution, soil type and variation in water table.

To assess the need for furthermore definative research on travel of pollutants through soils in Bangladesh.

3.3 Original Plan of Work :

3.3.1 Research Approach :

- Survey of water quality in existing and a limited number of new shallow hand pump tube wells.

- To be conducted in areas having sufficient access to Dhaka to permit the return of samples to the laboratory in Dhaka before the close of work on the day of sampling.

- To be conducted in areas representing 3 different soil types to a depth of 1 to 2 meters in which latrines are installed.

a. Red Brown Terrace Soils- Clay soil; pH 5.1-5.3

b. Grey Flood plain Soils, Jonsaline Phase- Clay, Silty clay, silty clay loam; fine pores and roots; pH 6.8 to 7.0

c. Calcareous Alluvium- silt loam, silty clay loam; pH 7.8-8.4

Sites will be selected in two ways.

(a) About 10-20 wells will be selected in each of the three soil type areas. These wells may be private or public tube-wells located at varying distances from existing latrines, but not exceeding 25 meters. Every effort will be made to ensure that wells be selected downstream from sources of pollution. Assistance will be sought through the water Development Board to ensure that this requirement is met in so far as it is reasonably possible to do so. Project areas have been selected representing the three soil types above. The survey data obtained from these sites will be employed to determine the influence, if any, of distance on water quality measurements at the wells.

(b) At least two and perhaps three, densely populated areas in which tubewells are located will be selected for monitoring. Locations of tubewells will be mapped in relation to potential pollution sources. Water quality will be determined in shallow handpump tubewell waters. Where dugwells could affect nearby tubewells, nitrates in the dugwell water will be determined. One site has been selected for this component of the survey (village of Baliapur). This is a community of about 12,000 people which is served by 16 tubewells and an unknown number of dugwells. The limits of this village are very sharply defined by the edge of the mound on which it is situated. The village is very densely populated by people, and at least locally, by cattle, There are 14 water seal latrines and numerous surface latrines in the village, some located close to tubewells.

The samples obtained from all 16 tubewells and a few selected dugwells in this village will come from an area with numerous potential pollution sources and the quality of water should represent the influence of dense population under conditions existing in this area.

Direction of groundwater flow will be determined in-so-far as it is possible to do so.

A second densely populated area with existing shallow tubewells and various single family and community latrines will be selected in the Tongi Refugee Camp (Dattapara). About 20 tubewells will be selected and two new test wells will be provided upstream from the camp area to serve as controls.

It is also proposed to include an area within Dhaka which is served by large diameter tubewells with several on-site excreta/sewage disposal facilities around them.

Results of the surveys in densely populated areas will be employed to determine the influence, if any, of distance on water quality, and also to demonstrate whether there is a larger local effect of numerous, closely associated pollution source on the ground water resource serving these areas.

3.3.2 Research Methods :

(a) Sampling : Sampling will be collected quarterly over a one year period at each of the wells selected. Wells to be sampling must be in good condition at the time of sampling and not require priming. The spouts of the tube wells will be flamed in an appropreate manner and water pumped for a period of five minutes before samples are taken.

(i) Samples will be taken for bacteriological analyses in appropriate sterile sample bottles using aseptic technique. They will be stored at approximately 4°C and returned to the appropriate laboratories on the day of sampling. Where possible, dilution will be made and plating and inoculation of media will be done on the day of sampling. Where this is not possible samples will be kept at 4°C and processed early the following day.

(ii) Sampling for chemical analysis will be processed as far as possible in the field employing appropriate field test kits. Random samples will be preserved appropriately and returned to the laboratory for analysis.

(b) Water Quality Parameters :

Analysis will be limited to these parameters of immediate value for meeting the objectives of survey.

(i) Bacteriological : Samples will be tested for faecal coliforms and faecal streptococci. Membrane filter techniques will be used for each employing m-Fc and

KF agar respectively. Samples will be run at appropriate dilutions and according to Standard Methods for the Examination of Water and Waste Waters.

(ii) Chemical analyses of chemical water quality will be limited to pH, nitrate and chloride. All three parameters will be determined by appropriate methods in the field. About one fourth of the samples will be analysed for nitrate and chloride also in the laboratory using Standard Methods. At least once during the study, a sample will be subjected to more detailed chemical examination.

3.3.3 Other Items :

- Lay out mapping will be done in all survey areas.
- Other data on well sites will be obtained as follows:
- Well-log data will be obtained for wells tested wherever possible.
- Maximum and minimum depth of the water table will be recorded.
- Precipitation data will be recorded.
- Organic nitrogen of the soil will be determined.

3.3.4 Analysis of Results :

(a) Survey of tubewells in relation to pollution sources : the results of this survey will be analyzed to determine whether there is detectable water movement from potential sources of pollution to tubewells based upon No_3 and Cl Concentration. The results will be grouped by distance from pollution source to well and examined to determine whether bacterial or chemical contamination of well waters can be correlated with distance from potential pollution sources, and tests of significance will be applied where applicable. This will be done by distance from source of pollution and season at each site.

(b) Survey of densely populated areas : the results of the survey of urban areas will be analysed in terms of distance from test wells to pollution sources as in paragraph 1 above. Numbers of samples and numbers of wells failing to meet standards will be analyzed according to intervals of distance from pollution sources and tests for significance applied. Contours of nitrate and chloride cocentration and shifts in contours with seasons will be plotted where possible and concentrations will be correlated with locations of pollution sources.

3.3.5 Interpretation of Results :

- The two surveys proposed are designed to demonstrate different aspects of the contamination of ground waters. The first is designed to demonstrate whether contamination may occur in individual wells located close to pollution sources. The second is designed to demonstrate whether there is in fact an identifiable impact of pollution sources in densely populated areas on the drinking water resource as a whole. Study results will be interpreted with this in view.

3.3.6 Follow-up Required :

- The follow-up ~~Required~~ to such a demonstration might be a more rigorous sampling programme using modern techniques and including limited virus isolation so that the true extent of the problem can be established and protective measures implemented. A very large question is that of impacts on the total ground water reservoir. The part of the present project dealing with densely populated areas can demonstrate only whether or not high density of pollution sources may have an impact on the soil and water environment. This must be dealt with further on a large scale and would require modeling

3.3.7 Institutional Arrangements :

- Responsibility for overall design and implementation of the project will be with the DPHE assisted by WHO. This will include mapping, carrying out field work, including chemical testing in the field employing test kits, and coordinating all aspects of the project.

- All membrane filter tests for faecal coliforms and faecal streptococci will be conducted by the IFST, BCSIR, Dhaka.

- Chemical testing in the laboratory will be conducted by the IFST, BCSIR Laboratory in Dhaka.

It may be mentioned that the above work plan would not be entirely followed or fulfilled due to the unavoidable reasons described in subsequent chapters (4-6).

4. Materials and Methods:

4.1 Description of Monitoring Tube Wells :

Hand operated shallow tube wells sunk by DPHE/UNICEF or the public used by the rural and urban inhabitants for drinking purposes, have been used for collecting samples. It consists of a barrel made of caste iron, a piston rod connected with a plunger and valve and fixed on a base. The base is fixed on a 1½" diameter G.P. pipe which is sunk in the soil and has generally a platform about 4ft x 4ft made of concrete (Fig. 1).

4.2 Description of Pit-latrine :

Pit-latrine is made after digging the earth about 6ft. deep, so that 5 concrete or earthen rings can be fixed like a rack (Fig. 2.)

First three perforated rings are used to be fixed underneath and next two are fixed on them up to the surface. Then a platform is made with concrete. After that a commode is fixed on it. The latrine is then covered with cemented wall and roof or with straw and bamboo fencings.

4.3. Experimental Sites :

(a) Shahid Nagar : It is a slum area and low land quite adjacent to Lalbag, Dhaka city and at the vicinity of river Buriganga.

(b) Balirpur : It is about 13 KM in the northwest from Dhaka with a densely populated community of 12,000 people served by 16 tube wells and unknown number of dug wells.

Fig. 1

HAND PUMP TUBE WELL

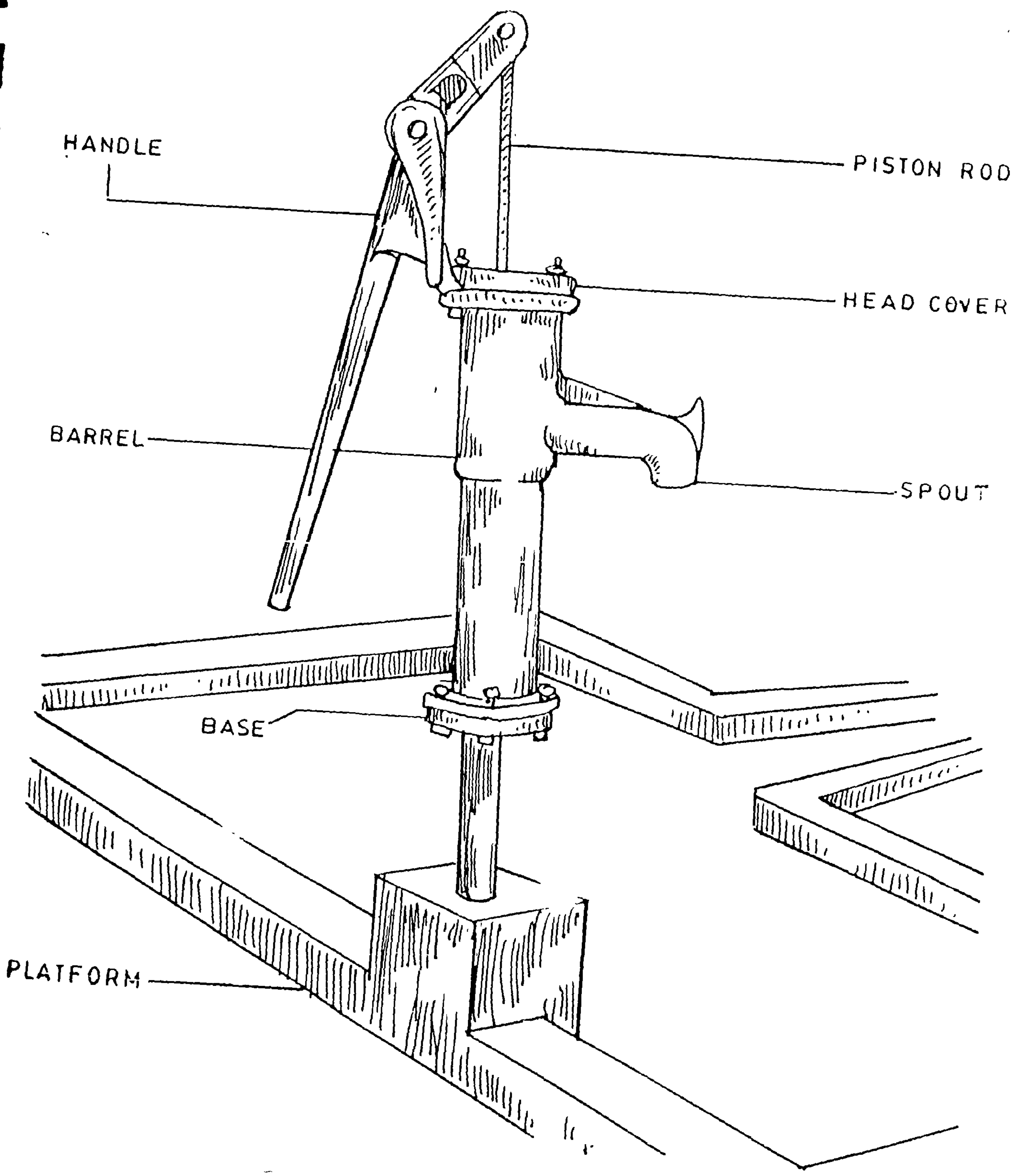
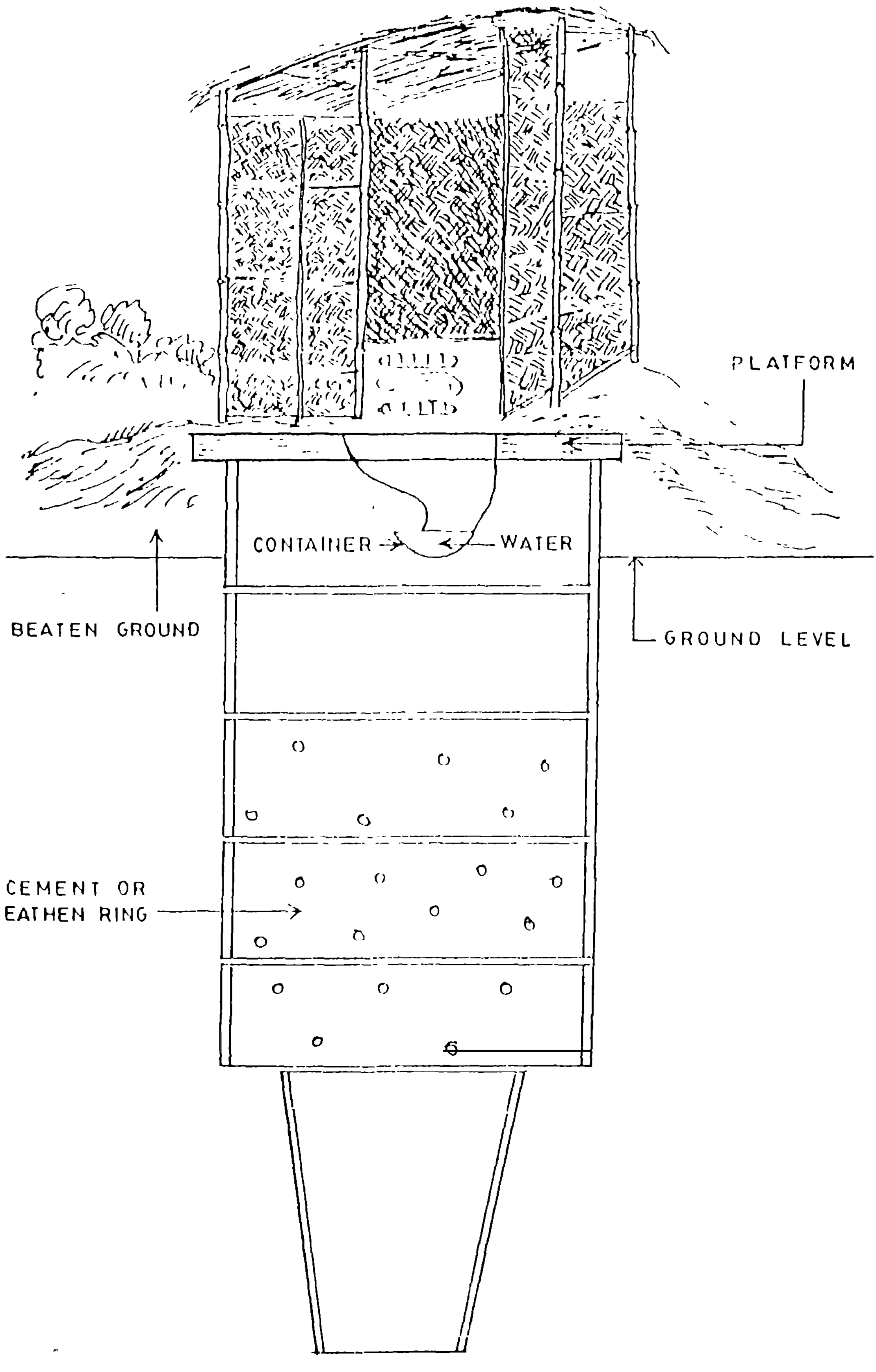


Fig. 2 PIT-LATRINE



(c) Dattapara : It is a bastuhara (refugee) coloney (Ershad Nagar), about 8 KM north to Tongi Bazar. It is also a densely populated area. It has pit-latrines made by Oxfam organization.

(d) Ghior : It is in the district of Manikgonj, 80 KM away from Dhaka. It is also densely populated and has pit-latrines and a few surface latrine.

(e) Ghatail : It is 128 KM away from Dhaka, a village densely populated, having water sealed pit-latrines and a few surface latrines around the tube wells.

4.4 Distances of Pit-latrines from the Tube Wells :

Those hand pump tube wells which have been selected for sampling are closer to pit-latrines at about 2 to 20 meters distances. Shahid Nagar has no pit-latrines system rather it has surface latrines and ditches around the tube wells which are submerged in the rainy season.

It is to be noted that one tube well selected at Health Complex Hospital, Ghior, has a safety tank adjacent to the tube well.

4.5 Sampling Procedures :

4.5.1 Sampling by Conventional Method :

(a) Standard screw cap sample bottles (capacity 200 ml.) were washed well, then wrapped at the mouth with aluminium foils and sterilized in a autoclave at 15 lb pressure for 20 minutes.

(b) Before taking the sample of water from the tube well, the tube well water was purged out for 15 minutes, then the spouts of the well were sterilized by flamming with a spirit lamp.

(c) The water samples were collected in the sterilized sample bottles ascoptically.

(d) The samples collected as above were kept at ice-boxes and transported to the laboratory for investigation on the same day of collection. In case of late receipt of the samples, they were preservod in the refrigrator of the laboratory till next morning.

(e) The water levels were measured after collecting the samples. The pH and temperature of water were measured with HACK KIT and a thermometer respectively.

(f) Sampling after Chlorination :

In the later phase of the study a number of new tube wells (observation wells) were sunk and capped to avoid public use. The tube well water and the platform were chlorinated and kept for 72 hours. The depth and diameter of the water column were determined and volume of water in the pipe was calculated. Then the water was chlorinated and tried to maintain 25-30 ppm of initial chlorine concentration in the tube well pipe.

After 72 hrs. of chlorination, the 1st sample was collected from the tube well without purging, then the tube well was purged out for 4½ hrs. to 5 hrs. to remove the free chlorine if present. Then the samples were collected.

It is to be noted that the samples from these (capped) tube wells were collected by using a conventional barrel. The barrel was specially polished inside and the plunger and other parts were washed with boiling water to avoid contamination .

The priming water used was also chlorinated to about 25-30 ppm concentration and after the required period of purging, the water samples were collected.

4.5.2 Sampling by Tube Technique :

In the last phase of the work, tube technique introduced by P. Morel (WHO expert) has been used. A polythene tube of 4mm dia (approximately) was introduced in to the well pipe up to the middle of the pipe about 40ft-60ft., a weight was tied at the end of the tube so that it remained in water. The top of the tube was fitted on a socket. The mouth of the socket was kept on a bridge fixed between the pipes.

Another socket was connected to a tube. The end of tube was connected to another tube called coupling tube of 2 mm dia. which was connected with the vacuum vessel of 8 litre capacities made of fibre glass. The vacuum vessel was again connected with a pressure tube to the suction pump.

Before operation, the suction pump was connected with vacuum vessel and the vacuum vessel was connected with the coupling tube with a socket (coupling tube and socket were sterilized). The socket was asceptically connected to the mouth of the tube rested on the bridge of the tube well.

After fixing the tube, the vacuum pump was operated. When sufficient vacuum was made inside the vessel, the mouth of the vacuum vessel was opened and due to the vacuum created in side vessel, the water from the tube well started coming through the tubes into the vacuum vessel.

At the time of sampling, fresh and sterile coupling tube with socket was asceptically connected to socket tube rested on the bridge and water sample were taken into the sterilized sample bottles of 500ml capacity.

The sample bottle were fitted with a stopper with one coupling tubes and tubes were fixed with sockets. The stoppers with sockets and the bottles were previously sterilized in the laboratory. The tube wells were chlorinated and purging was done as before.

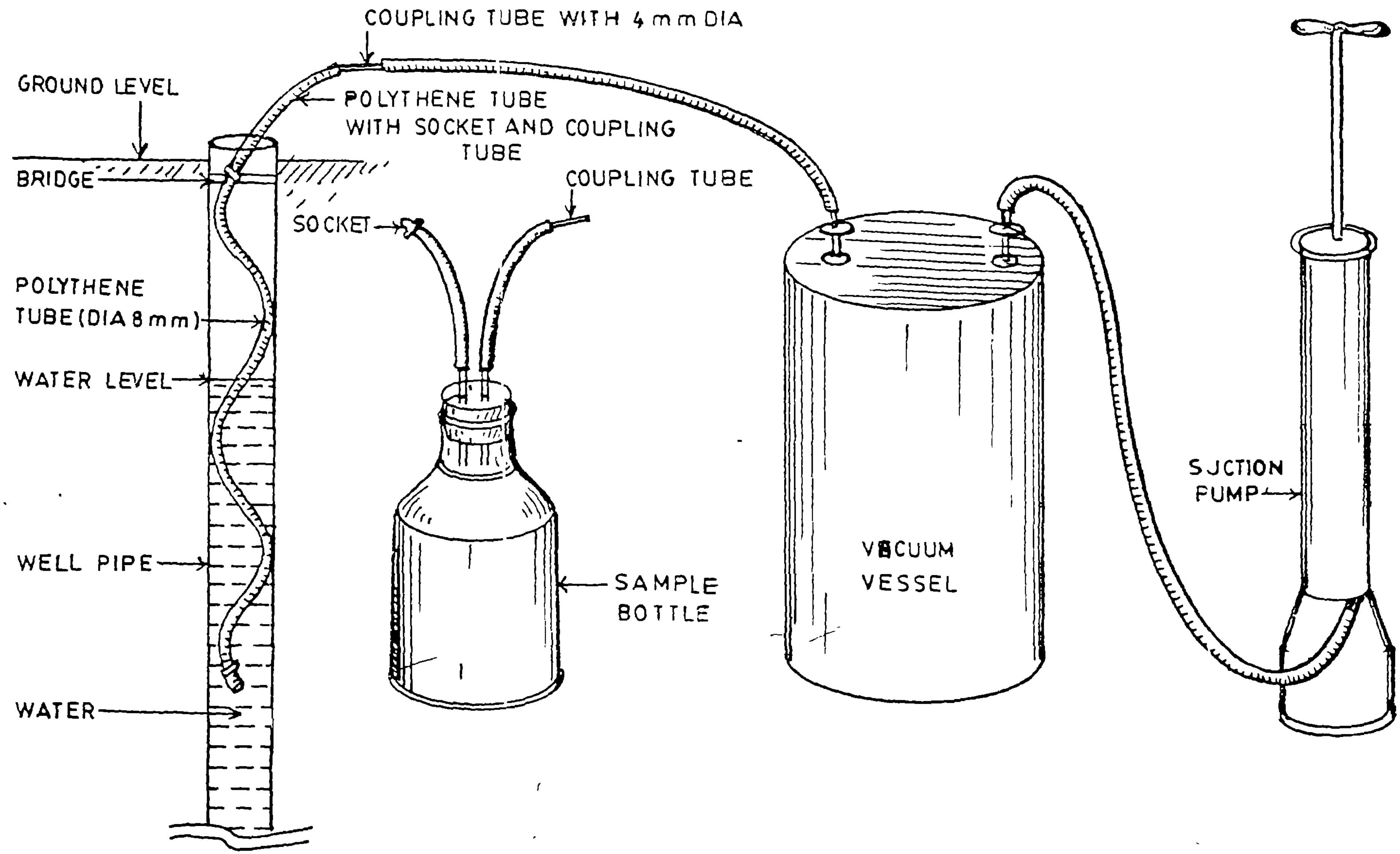
Actually, the principle of the method is to take the samples from the aquifer directly by a tube introduced through the well-pipe up to the strainer and with the help of a vacuum pump; the other end of the tube being directly connected with the sterile bottles thus making a condition so that contamination from external sources may not take place (see fig.3).

4.6 Examination of Water Samples :

4.6.1 Determination of Physical and Chemical Characteristics.

(a) Temperature : Temperature was measured in the field by a standard laboratory thermometer.

Fig. 3 TUBE TECHNIQUE OF SAMPLING



(b) pH : pH of the samples were measured in the field by HACK KIT (Ames, IOWA, USA). In the laboratory the pH was measured by electrically operated pH meter.

(c) Determination of Solids : In analysing water samples collected during the phase I & II, gravimetric bottle was used for determination of solids. This method was adopted to have quick results, but only grossly accurate (10-20% deviations from the accuracy have been found). So in the third phase, solid determinations have been done more accurately as follows :

(i) 100 ml sample was filtered through dried membrane filter, because the generally used filter papers, even of high quality were found to fail to hold the fine clay particles and the residue was dried at 105°C with the filter to constant weight. The weight of the suspended solid was determined by substracting the weight of the membrane filter.

(ii) The filtrate from the above was dried at 105°C to determine the dissolved solid.

(d) Chloride : Determined by Argentometric method, described in Standard Methods (APHA, 1980).

(e) Nitrate : Determined by Brucine Method, described in Standard Methods (APHA, 1965). This method was followed due to operational advantage and duly standardized.

(f) Iron : Determined by Colorimetric Method described in the Manual of Laboratory Techniques (Natl. Inst. Nut., 1971).

(g) Sulfate : Determined by Gravemetric Method (Standard Methods APHA, 1965).

(h) Electric Conductivity : Measured by Conductivity Meter (Griffin U.K.).

4.6.2 Determination of Faecal Indicator Bacteria :

As per suggestion given in the protocal/work programme which was prepared by the expert under the auspices of WHO, two types of faecal indicator organisms were determined from the samples.

A. Faecal Coliforms:

B. Faecal Streptococci:

(a) Determination of faecal coliforms : The membrane filter method described in Standard Methods (APHA, 1980) has been followed for the quantitative determination of faecal coliforms as suggested. The medium used was mFC broth manufactured by Difco laboratories (Detroit, Michigan, U.S.A). The filter membrane (pore diam 0.45µm) and soacking pad manufactured by Gelman Sciences, Inc. (Ann. Arbor, Michigen) were used. The incubation temperature and period were 44.5 ± 0.3°C and 24 ± 2 hrs. respectively in water bath as per instructions.

The sample was filtered by standard membrane filtering apparatus in two portions of 100 ml each and the average results (per 100 ml of the sample) were taken. The typical colonies were counted when not exceeding the limit (80 colonies/membrane). When the count exceeded the limits the results were recorded as TNTC (too numerous to count).

For atypical colonies and also for typical colonies at the initial period of the study, standard tests followed in MPN Method were done for further confirmation. (Standard Method, 1980).

(b) <u>Determination of Faecal Streptococci</u> :- In this case also the method described in the Standard Methods (APHA,1980) was followed according to the suggestion of the work-programme mentioned above.

The medium was KF- streptococci agar supplied by BBL Microbiology/system. (Becton Dickinson and Co. Cockeysville). The incubation temperatures and period were respectively 37°C and about 48 hrs. The incubation was done in air heated incubator. Sample volumes filtered were the same as stated above. The further confirmation of the typical and atypical colonies were carried out when required. Faecal streptococci colonies grown on the membrane exceeding the limit (i.e.100 colonies/membrane) were recorded as TNTC as stated above.

In both the cases of determination of faecal indicators the controls were run .

5. Results

5.1 The first or Initial Phase of Investigation :

The table I, shows that the monitoring tube wells are situated in environments where not only the pit latrines but other sources of faecal pollutions including different types of latrines exist. Moreover, in many cases several pit latrines are installed in the vicinity of the monitoring tube well. These conditions clearly indicate that if ground water is found to be polluted, it would be very difficult to locate the exact source of the pollution. This difficulty could be minimized to some extent if the flow direction of the ground water would have been determined. Unfortunately, this could not be done. This problem has been discussed elsewhere of this report.

As far as the monitoring tube wells are concerned, they have been found not in good conditions in many cases, platforms have been found cracked or otherwise defective, some did not have even cemented platforms. It was also found that for priming the tube wells polluted waters were used, so contamination of ground water from external sources and by human activities have been prominently present. These reasons become very important when in this initial phase of the investigation, all the samples were found to be contaminated by the faecal indicator organisms (table 2B). So far the next phase of the investigations, attempts were made to eliminate these possible external sources of pollution and some new tube wells (observation tube wells) were installed near to some monitoring tube wells as described above. The results of bacteriological findings have been given in table 2B and it is clear that all the tube wells are contaminated by faecal indicator organisms, but their quantitative aspects are not correlated apparently with the distances of the pit latrines. Of course, such correlations are only valid when at least the flow direction of the ground water is known.

Table-I : Description of Selected Monitaring Wells at Different Experimental Sites.

A. Running Tubewells:
Site : Dattapara

Sl. No.	Tubewell No.	Total Depth in meter	Condition of Platform	Distances of Pit-latrine and Direction	Other sources of Pollutions	No. of Users	Remarks.
1	2	3	4	5	6	7	8
1.	1	14.0	Pucca	4.8(East) 13.1(North East) 9.5 (S.East)	Waste water filled ditch adjacent to platform	350	
2.	3	14.0	Pucca	4.3 (West) 2.7 (North) 5.8 (N.E.) 10.7([illegible])	Kaccha drain nearby	30	
3.	23	11.0	Pucca	25.0(North) 28.0([illegible])	Kaccha surface drain 1.8m away	500	
4.	32	16.0	Pucca	4.6 (East) 4.9 (S.E) 7.0 (West) 12.0(S.W.)	Surface drain 4.6m away & stagnant waste water ditch	150	
5.	RT	17.0	Kaccha	23.2(North)	Kaccha surface drain	50	Pucca platform later
6.	2	140	Pucca	1.8 (S.E.) 3.4 (S.E.) 4.5 (North) 7.6 (West)	Surface drain 1.8m away	500	
7.	28	12.0	Pucca	2.7 (S.West)	Surface drain 1.5m away	150	
8.	33	14.0	Pucca	4.0 (North) 6.4 (S.East) 7.3 (South) 7.9 ([illegible] East) 9.1 (West)	-	500	
9.	BADC	138.0	-	38.1(South)	-	500	Mechanically operated

RT = Reference Shallow Tube well
BADC = Deep Tube Well of BADC
Pucca = Cement Concreate Block of 1.2 X 1.2 X 0.1m.
Kaccha = Without any cemented Block.

Table: 1 (Contd)

1	2	3	4	5	6	7	8
10.	RT	40.2	Pucca-broken	21.3 (N.W)& 6.0 m deep	-	150	
11.	1	40.2	Pucca	2.1 (S.E.) 6.7 (West)	A pond 3.7m away. Flooded with water in rainy season	200	Studied in the 2nd phase also
12.	4	40.2	Pucca	11.9 (South)	-	200	
13.	11	40.2	Pucca	9.6 Dug latrine (South) 13.7 Soak pit, deep 5.5m(West)	12.2m deep dug well and 4.0m away and surface drain 1.8m away	200	
14.	6	43.3	Pucca	6.0 (East) 9.1 away surface latrine (North)	Marshy drain	60	
15.	7	43.3	Pucca	15.? (West)	Rotten muddy land	50	
16.	9	41.5	Pucca	3.7 (North) 7.6 (N.west)	Marshy drain	20	
17.	11(A)	41.5	Pucca	30.5(North)	-	60	
18.	12	11.0	Pucca	4.6 Dug-latrine (S.East) 9.1 Dug-latrine (S.East) 45.7 Dug-latrine (North)	Marshy Surrounding	500	
19.	14	35.4	Pucca	9.1 Dug lat. (South) at elevated level	Marshy surrounding	250	
				Site: Shahid Nagar			
20.	1	20.1	Pucca	3.0 (North) Surface lat.	Adjecent to a Pond & latrine	50	
21.	2	28.0	Pucca	12.2 (North) Surface lat.	Adjacent to a Pond & latrine	50	

Pacca = Cement concreate Block
Kaccha= Without any cemented Block.

Table : 1 (Contd)

1	2	3	4	5	6	7	8
22.	3	34.1	Pucca	3.0 (East) Surface latrine	Adjacent to a latrine in a pond	60	
23.	4	34.1	Pucca	3.6 (S.East) Surface lat.	as above	60	
24.	5	34.1	Pucca	6.0 Surface lat. (N.East)	The well and latrine are in a pond	50	
25.	6	40.2	Pucca	6.0 Surface lat. (West) 9.0 lat. (S.West)	as above	500	
26.	7	40.2	Pucca	6.0 Surface lat. (N.W.)	The well is on the bank of a Pond having a latrine.	200	
27.	8	28.0	Pucca	7.6 (S.E.)	as above	300	
28.	9	43.2	Pucca	7.6 (South)	as above	150	
29.	WASA	DTW	-	7.6 (S.West)	-	Water supply system,mechanically operated.	
				Site : Cheor			
30.	24	40.2	Pucca	45.0 Surface latrine (West)	Ditch near the well	150	
31.	25	38.0	Pucca	30.5 old pit (North)	-	400	
32.	26	32.0	Pucca	6.0 Septic tank (North)	-	30	
33.	27	20.0	Pucca	9.1 Septic tank (North) 14.0 Septic tank (North)	-	100	
34.	29	NA	Pucca	12.0 Septic tank (North)	-	50	
35.	30	14.0	Pucca but broken	10.6 Surface lat. (West)	-	150	

NA = Note available.
DTW = Deep Tube Well water.

Table : 1 (Contd)

1	2	3	4	5	6	7	8
36.	33	14.0	Pucca	7.6 Septic tank (N.W.)	-	200	
37.	RT	35.0	Pucca	6.7 Septic tank (N.E.) 3.0 Septic tank (S.East)	-	500	
37.1	36	28.0	Pucca	12.2 Soak Pit (South)	-	-	Studied in the 2nd phase
38.	35	32.0	Pucca	9.1 Septic tank (West) 15.0 Septic tank (East)	-	200	
39.	36	28.0	Pucca	9.1 Septic tank (S.East) 13.7 Septic tank (S.West)	-	200	
				Site : Ghatail			
40.	24	14.0	Pucca	6.0 Surface lat. (North) 13.7(East)	Surface lat. is on the water filled ditch.	7	
41.	25	17.0	Pucca	4.5 (N.East) 12.0(North)	8.0 away is a Canal	11	
42.	26	16.0	Pucca	3.6 (North)	8.0 away is a canal	~~10~~	
43.	27	14.0	Pucca	4.5 (North)	as above	9	
44.	28	20.0	Pucca	8.0 (North) 11.0(North)	as above	8	
45.	24(A)	14.0	Pucca	3.6 Surface lat.(S.East)	as above	6	Studied in the 2nd phase also
46.	26(A)	20.0	Pucca	8.0 (West)	as above	9	
47.	RT	33.0	Pucca	17.0(N.West)	-	11	

Table : 1 (Contd)

B. Observation Wells[a]

Sl. No.	Tubewell No.	Total Depth in meter	Condition of Platform	Distances of Pit-lat. and Direction	Distance between Running and observation well		Remarks
1	2	3	4	5	6		7
Site: Dattapara							
1.	TDH(East)	11	1.2x1.2 x.076cc block (Pucca)	15.0(N.East)	1.5m	-	Studied in the 3rd phase
2.	TDH(West)	11	1.2x1.2 x.075 cc block	9.0(West) 12.0(West) 13.0(S.W) 14.0(N.W.)	1.5m	Studied in the 2nd phase	"
3.	2	14	as above	4.5(West) 2.0 (.) 4.5 (S.)	6.0m	-	"
4.	KB	60	as above	1.5(North) 3.6 (S.E) 6.0 (East)	1.5m	-	"
Site : Baliapur							
5.	12(East)	40	as above	6.0 (South)	1.5m	-	Studied in the 3rd phase
6.	12(Far-East)	40	as above	4.5 (East)	5.0m	-	"
7.	1	40	as above	2.1(S.E.) 6.7 (West)	1.2m	Studied 2nd phase	
Site: Ghior							
8.	36	28	as above	10.0 Septic tank (West) 14.0 Septic tank (N.W.)	1.2m	Studied in the 2nd phase	
Site : Ghatail							
9.	24(A)	14	as above	6.0 (S.E.)	1.2m.	Studied in the 2nd phase	

a= Newly sunk Tube Wells kept with cap to avoid external contamination

m= Meter .

The results described in table 2A show that the physical characteristics of the samples were not satisfaectory in many cases. Though the degree of turbidity has not been measured, but the visual observation indicate the unsatisfactory level of turbidity in many samples. Other physical characteristics were satisfactory in most cases. The levels of chlorides were found to be satisfactory in most cases, so was the condition for nitrate. The iron content were higher than the desired level in a good number of samples.

The two deep tube wells monitored (one from each sites, Shidnagar and Dattapara) produced no faecal indicators showing that the deep aquifers were not contaminated .

Table: 2A : Results of the Examination of Physical and Chemical Characteristies of water samples (period of sampling Feb-May,1984).

Sl. No.	Tube Well Nos.	Appearance	pH	Total Dissolved solid mg/L	Chloride mg/L	Nitrate mg/L	Sulfate mg/L	Iron mg/L	Electric conductivity mohs/cm	Temperature °C	Water level in meter	Remark
1	2	3	4	5	6	7	8	9	10	11	12	13
Site : Dattapara												
1.	1	Coloured	6.4	490	180	ND	148.00	0.538	260	24	5.8	
2.	3	Clear	6.5	750	61.8	"	5.48	1.385	305	24	5.9	
3.	23	Clear	6.4	780	328.3	"	4.11	0.462	460	24	6.2	
4.	32	Muddy	6.4	520	151.3	"	20.56	0.308	165	25	5.0	
5.	RT	Clear	6.4	730	239.8	"	25.70	1.080	640	26	6.2	
6.	2	Muddy	6.5	670	24.7	"	13.10	0.690	250	26.5	6.4	
7.	28	Muddy	6.7	690	38.1	"	23.10	0.770	320	26.5	4.9	
8.	33	Turbid	6.4	605	121.9	"	24.20	1.690	410	25	5.2	
Sample from BADC pump												
9.	BADC	Clear	6.2	696	19.0	4.0	21.0	0.15	395	29	-	
Site: Ballapur.												
10.	R.T	Clear	6.4	651	45.6	ND	16.4	0.262	190	25	5.7	
11.	1	Clear	6.4	432	28.6	"	6.92	0.308	160	24	5.6	
12.	4	Clear	6.3	581	83.3	"	6.58	0.385	20	24	5.3	

ND = Note done

Table : 2A (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
13.	11	Clear	6.4	560	57.0	ND	11.52	0.308	180	26	6.3	
14.	6	Clear	6.1	630	76.2	8.6	78.164	0.442	130	28	5.8	
15.	7	Clear	6.2	600	45.7	3.0	34.55	0.423	190	28	6.4	
16.	9	Clear	6.4	692	57.1	5.5	37.84	0.442	240	28	5.7	
17.	11(A)	Clear	6.2	714	124.7	6.8	44.42	0.444	320	28	6.2	
18.	12	Clear	6.0	420	60.9	5.8	14.81	0.231	220	27	6.3	
19.	14	Clear	5.9	378	76.1	2.5	12.34	0.385	140	27	5.5	
Site : Shahid Nagar												
20.	1	Muddy	6.6	1420	140.5	Trace	67.45	1.577	1040	28	6.4	
21.	2	Clear	6.5	920	171.2	"	54.70	0.404	560	27.5	8.2	
22.	3	Turbid	6.2	800	129.4	"	57.17	0.808	510	27.5	6.0	
23.	4	Clear	6.4	468	95.2	"	51.82	0.154	470	27.5	8.7	
24.	5	Turbid	6.5	552	91.3	"	66.63	0.615	580	28.0	7.5	
25.	6	Turbid	6.4	540	97.1	"	57.58	0.154	480	28	6.4	
26.	7	Turbid	6.2	834	102.7	0.01	68.28	1.923	180	27	6.8	
27.	8	Turbid	6.3	973	104.7	Trace	45.65	0.096	300	26	5.4	
28.	9	Turbid	6.4	905	79.9	Trace	48.53	0.115	260	26	7.9	
29.	WASA	Clear	6.0	560	104.6	3.5	74.04	0.134	370	-	-	

ND = Note done

Table : 2A (Contd.)

Site : Ghior

1	2	3	4	5	6	7	8	9	10	11	12	13
30.	24	Turbid	6.4	440	26.64	Trace	6.17	7.384	240	27	5.4	
31.	25	"	6.5	372	38.06	"	4.12	7.154	350	27	6.0	
32.	26	"	6.3	612	57.10	"	55.94	10.000	350	28	5.4	
33.	27	"	6.5	665	58.99	"	43.59	15.000	340	29	5.9	
34.	29	"	6.5	376	28.54	"	3.29	22.000	260	27	-	
35.	30	"	6.7	664	58.99	"	65.81	0.078	500	28	5.3	
36.	33	Clear	6.4	532	41.87	"	44.42	5.000	420	29	7.0	
37.	35	Turbid	6.5	480	32.35	"	63.34	22.000	355	29	6.8	
38.	36	"	6.5	308	28.54	"	59.58	19.000	360	29	6.7	
39.	RT	"	5.4	652	24.74	"	43.59	15.000	340	28	7.0	

Site : Ghatail

1	2	3	4	5	6	7	8	9	10	11	12	13
40.	24	Turbid	6.4	800	32.35	Trace	16.45	8.833	200	27	3.3	
41.	25	Clear	6.3	6.6	41.87	"	7.40	0.923	240	27	3.3	
42.	26	Turbid	6.3	448	43.77	"	4.11	3.176	190	27	3.3	
43.	27	"	6.3	768	30.35	"	17.58	9.000	280	26	3.2	
44.	28	"	6.4	460	36.16	"	20.98	1.154	220	28	1.8	
45.	24(A)	"	6.4	838	53.28	"	18.10	4.166	260	26	3.1	
46.	26(A)	"	6.4	560	26.64	2.2	7.40	1.692	220	28	2.0	
47.	RT	"	6.6	560	24.74	0.2	3.29	3.077	230	29	2.3	

RT = Reference Tube Well (Shallow)

Table-2-B: Results of the Bateriological Characteristics of water samples.

Sl. No.	Tube well Nos.	Faecal Coliforms /100 ml	Faecal streptococcies /100 ml	Remarks
1	2	3	4	5
Site : Dattapara				
1.	1	TNTC	TNTC	
2.	3	7	50	
3.	23	19	25	
4.	33	22	70	
5.	RT	4	3	
6.	2	50	15	
7.	28	20	5	
8.	32	13	25	
9.	BADC	0	0	
Site : Baliapur				
10.	RT	30	25	
11.	1	50	17	
12.	4	18	2	
13.	11	7	2	
14.	6	25	11	
15.	7	45	50	
16.	9	7	2	
17.	11	50	45	
18.	12	35	14	
19.	14	25	6	

TNTC = Too Numerous to count.

Table : 2B (Contd)

1	2	3	4	5
Site : Shahid Nagar				
20.	1	25	15	
21.	2	80	50	
22.	3	30	20	
23.	4	35	4	
24.	5	5	0	
25.	6	TNTC	15	
26.	7	15	8	
27.	8	35	20	
28.	9	20	10	
29.	WASA	0	0	
Site : Ghior				
30.	24	20	0	
31.	25	12	4	
32.	26	20	6	
33.	27	18	22	
34.	29	25	20	
35.	30	8	7	

TNTC = Too Numerous to count
RT = Reference tube well (Shallow)
WASA = Deep tube well Mechanically Operated

Table : 2B (Contd)

1	2	3	4	5
36.	33	TNTC	85	
37.	35	8	4	
38.	36	14	25	
39.	RT	2	4	
Site : Ghatail				
40.	24	8	3	
41.	25	7	5	
42.	26	16	24	
43.	27	2	12	
44.	28	50	10	
45.	24 (A)	7	6	
46.	26 (A)	20	5	
47.	RT	1	4	

TNTC = Too Numerous to Count

RT = Reference Tube well

5.2 The Second Phase :

(a) The findings of the initial or the 1st phase of this investigations influenced the subsequent studies substantially. As all the shallow tube wells monitored showed faecal contaminations (even in the tube well which is considerably far from the nearest pit latrine). Naturally the attention was directed on the quality of ground water, (specially the bacteriological quality) extracted by the shallow tube wells in respect of faecal contaminations. It became imperative to get the samples which were truely representative of the ground water. Consequently, the original work plan had been affected considerably.

Under the circumstances, new tube wells (observation tube wells) were sunk adjacent to the existing or running tube wells as decided by the review committee of the project. Adequate cares were taken in the sinking and up-keep of these observation wells to avoid the contamination by external sources. The conventional use of cowdung for the stabilization of the tube holes was avoided during sinking of the wells. The platforms were carefully constructed and the necessary repairs of the platforms of the selected running tube wells were carried out also. The observation wells were not allowed to be used by the public and kept in a capped condition. Only during the sampling, the cap was taken away and the pump was joined to the pipe after taking necessary steps to decontaminate the pump. More exacting care was also taken during sampling so that the samples might not be contaminated by the existing unhygienic environment. The experimental site Shadinagar was excluded because of its very unsatisfactory sanitory conditions and this location is flooded over during rainy season.

In the first step of this phase of the study (the 2nd phase to observe whether the observation tube well gave better quality of water, one pair of tube wells (one running and one observation tube well installed near to the running tube wells) was selected from each site and the three rounds of sampling were made during March-February, 1985. To get truely representative samples of the ground water, prolonged purging of water was done (15 minutes and 30 minutes). The results have been given in table 3A and 3B.

To avoid the external contamination, the hand pump was decontaminated with hot water and at the site with the chlorinated water. Chlorinated water was used also for priming and sufficient water was purged out to remove the chlorine used in the process.

Though the samples taken during the first and the second round of sampling from the observation tube wells apparently gave comparatively satisfactory results in respects of faecal indicators but the samples taken from the observation wells during the third round of sampling were found to be contaminated with faecal indicators in most of the cases. As found before, all the old tube wells were found contaminated by faecal indicators (table 3B). No significant effect of purging time (between 15 minutes and 30 minutes) could be ascertained.

As for other factors determining the quality of the water samples, nothing new is to be said; they were satisfactory in the most cases excepting the turbidity and color which had been found in considerable number of samples (table 3A).

It may be noted that during this step of investigation the new (observation) tube wells had no pucca platforms. In the next step of experiment this deficiency was rectified by constructing proper platforms.

Table-3A: Physical and Chemical Examinations of water samples after Installation of Observation Tube Wells .

Site : Dattapara   Period of Sampling Feb-March'85.

Sl. No.	Tube well No.	Sampling	Water Temp. C°	pH	Water level in meter	Appearance	Dissolve solid mg/L	Chloride mg/L	Nitrate mg/L
1	2	3	4	5	6	7	8	9	10
1.	TDH (West) (Running)	1st	(a) 24	6.5	6.7(c)	Clear	800	297	Trace
			(b) "	6.5		clear	800	297	trace
	TDH(West) (Observation)		(a) 24	6.6	6.7	Turbid	988	354	0.8
			(b) "	6.5		Turbid	980	354	0.9
2.	TDH(West) (Running)	2nd	(a)25.5	6.6	6.9	Clear	432	304	0.5
			(b) "	6.7		Clear	452	301	0.7
	TDH(West) (Observation)		(a)25.5	6.6	6.9	Turbid	464	357	1.1
			(b) "	6.6		Turbid	330	362	1.2
3.	TDH(West) (Running)	3rd	(a)*	-		-	-	-	-
			(b)*	-	-	-	-	-	-
	TDH(West) (Observation)		(a)26.0	6.6	7.0	Turbid	516	342	1.1
			(b)"	6.7		Turbid	556	325	1.0

Site : Baliapur

Sl. No.	Tube well No.	Sampling	Water Temp. C°	pH	Water level in meter	Appearance	Dissolve solid mg/L	Chloride mg/L	Nitrate mg/L
1.	No-1 (Running)	1st	(a) 24	6.0	5.8	Clear	1532	27.0	2.2
			(b) 24	6.1		Clear	1472	27.0	2.5
	No-1 (Observation)		(a) 24	6.2	5.8	Turbid	1420	19.0	2.7
			(b) 24	6.3		Turbid	1500	19.0	3.0

(a) = After 15 min. Purging

(b) = After 30 min. Purging

(c) = Water levels were measured for Running Tube wells only and it was assumed that adjacent Observation Tube Well would have the same Water level.

(*) = Out of order.

Table 3A (Contd)

1	2	3	4	5	6	7	8	9	10
	No-1		(a) 25	6.0	6.4	Clear	1200	30.0	3.8
2.	(Running)	2nd	(b) 25	6.0		Clear	1480	29.0	2.6
	No-1		(a) 25	6.2	6.4	Turbid	1320	21.0	2.8
	(Observ.)		(b) 25	6.2		Turbid	1304	23.0	3.0
	No-1		(a) 25	6.0	6.8	Clear	1268	32.0	2.9
3.	(Running)	3rd	(b) 25	6.0		Clear	1524	38.0	2.8
	No-1		(a) 25	6.0	6.8	Turbid	1340	34.0	3.0
	(Observ.)		(b) 25	6.1		Turbid	1136	31.0	3.1
Site : Ghior									
	No-36		(a) 26	6.5	(c) 6.0	Coloured	800	23	Trace
1.	(Running)	1st	(b) 26	6.6		,,	1004	21	,,
	No-36		(a) 26	6.7	6.0	,,	820	23	,,
	(Observ.)		(b) 26	6.7		,,	700	21	,,
	No-36		(a) 26	6.5	6.4	,,	1144	13.0	,,
2.	(Running)	2nd	(b) 26	6.5		,,	1184	12.0	,,
	No-36		(a) 26	6.6	6.4	,,	1040	12.0	,,
	(Observ.)		(b) 26	6.6		,,	952	12.0	,,
	No-36		(a) 24	6.4	6.5	,,	1532	19.0	,,
3.	(Running)	3rd	(b) 24	6.4		,,	1528	21.0	,,
	No-36		(a) 24	6.4	6.5	,,	1348	19.0	,,
	(Observ.)		(b) 24	6.5		,,	1372	21.0	,,

(c)= Water levels were measured for Running Tube wells only and it was assumed that adjacent Observation Tube Wells would have the same water level.

Table : 3A (Contd)

1	2	3	4	5	6	7	8	9	10
Site : Ghatail									
	24-A		(a) 25	6.4	(c)	Clear	1352	44.0	0.1
1.	(Running)	1st	(b) 25	6.4	5.3	Clear	1380	42.0	Trace
	24-A		(a) 25	6.5		Clear	1336	61.0	0.25
	(Observation)		(b) 25	6.5	5.3	Clear	1344	61.0	0.3
	24-A		(a) 24	6.2		Clear	1508	29.0	0.2
2.	(Running)	2nd	(b) 24	6.2	5.4	Clear	1520	23.0	0.25
	24-A		(a) 24	6.3		Clear	1468	53.0	0.25
	(Observation)		(b) 24	6.3	5.4	Clear	1408	52.0	0.2
	24-A		(a) 26	6.7		Clear	1508	27.0	Trace
3.	(Running)	3rd	(b) 26	6.7	5.6	Clear	1300	25.0	Trace
	24-A		(a) 26	6.5		Clear	1512	57.0	Trace
	(Observation)		(b) 26	6.6	5.6	Clear	1412	53.0	Trace

Note :- (a) = After 15 min. purging.

(b) = After 30 min. purging.

(c) = Water level were Measured for Running Tube Wells only and it was assumed that adjacent Observation Tube Wells have the same water level.

Table-3 B: Bacteriological Examination of Water Samples after Installation of Observation Tube Wells.

Site : Dattopara — Period of Sampling Feb-March'86.

Sl. No.	Tube Well No.	Sampling	Faecal Coliforms /100 ml.	Faecal Streptococci /100 ml.
1	2	3	4	5
1.	TDH (West) (Running)	1st	(a) TNTC	46
			(b) TNTC	85
	TDH (West) (Observation)		(a) 25	15
			(b) 8	0
2.	TDH (West) (Running)	2nd	(a) TNTC	86
			(b) TNTC	61
	TDH (West) (Observation)		(a) 30	8
			(b) 15	3
3.	TDH (West) (Running)	3rd	(a) *	*
			(b) *	*
	TDH (West) (Observation)		(a) TNTC	11
			(b) 75	10

Site : Baliapur

Sl. No.	Tube Well No.	Sampling	Faecal Coliforms /100 ml.	Faecal Streptococci /100 ml.
1.	No-1 (Running)	1st	(a) 20	4
			(b) 14	2
	No-1 (Observation)		(a) 0	0
			(b) 0	0
2.	No-1 (Running)	2nd	(a) 7	1
			(b) 5	2
	No-1 (Observation)		(a) 15	54
			(b) 15	33

(a) = After 15 min. purging.

(b) = After 30 min. purging.

(*) = Out of order

TNTC = Too numerous to count.

Table : 3B (Contd)

1	2	3	4	5
	No-1		(a) 3	5
3.	(Running)	3rd	(b) 3	3
	No-1		(a) TNTC	29
	(Observation)		(b) TNTC	10
Site : Ghior				
	No-36		(a) 38	2
1.	(Running)	1st	(b) 23	1
	No-36		(a) 0	0
	(Observation)		(b) 0	0
	No-36		(a) 4	2
2.	(Running)	2nd	(b) 3	1
	No-36		(a) 0	0
	(Observation)		(b) 0	0
	No-36		(a) 14	2
3.	(Running)	3rd	(b) 6	4
	No-36		(a) 7	6
	(Observation)		(b) 4	2
Site : Ghatail				
	24-A		(a) TNTC	25
1.	(Running)	1st	(b) TNTC	12
	24-A		(a) 2	0
	(Observation)		(b) 2	0
	24-A		(a) 2	0
2.	(Running)	2nd	(b) 1	0
	24-A		(a) 0	0
	(Observation)		(b) 0	0
	24-A		(a) TNTC	6
3.	(Running)	3rd	(b) 32	1
	24-A		(a) 23	7
	(Observation)		(b) 8	2

TNTC = Too numerous to count

(b) In the next step, more stringent measures were taken for the observation wells mentioned above (4.2.1), to observe whether the samples taken from these wells were improved in their bacteriological quality. Accordingly, the observation wells were disinfected by introducing chlorinated water into the pipes in estimated concentration and volume, so that the whole pipe contained the chlorinated water having bactericidal range of chlorine. Then they were kept at the capped conditions for 72 hours before sampling. More prolonged purging of water was carried for the observation wells and samplings were made (a) before purging, (b) after 4½ hrs. of purging and (c) 5 hrs. of purging. In case of the running tube wells, the samples were taken as before (4.1.1). The results have been shown in the table 4A and 4B.

In this case also, though a number of samples taken from the observation wells as well as the running wells, showed the absence of faecal indicators organism, but the over all results were not significantly different from those obtained in the previous experiments. All tube wells, both the observation and running were found contaminated by faecal indicators. So the chlorinated procedure, in general, failed to improve the bacteriological quality of the samples. The effects of purging were variable and as before it also failed to improve the bacteriological quality of the samples to any significant level.

In this experiment also a good number of samples were found turbid and or coloured apparently to the undersirable level. In respect of pH and contents of chloride and nitrate, the samples were not generally unsatisfactory.

Table-4A: Physical and Chemical Examinations of Water Samples after Chlorination of Observation Tube Wells .

Site : Dattapara   Period of Sampling April-July'85.

Sl. No.	Tube Well No.	Sampling	Water Temp. °C	pH	Water level in meter	Appearance	Dissolve solid mg/L	Cloride mg/L	Nitrate mg/L	Remarks
1	2	3	4	5	6	7	8	9	10	11
	TDH(West)		(0)27	6.6		Turbid	708	390	Trace	
			(a)26	6.5	7.0	Clear	738	290	0.8	
1.	(Observation)	1st	(b)26	6.5		Clear	740	295	0.5	
	TDH(West)		(a)26	6.5		Clear	750	245	0.8	
	(Running)		(b)26	6.6	7.0	Clear	736	248	Trace	
	TDH(West)		(0)27	6.7		Turbid	772	353	Trace	
			(a)25.5	6.8	7.2	Clear	628	305	1.5	
2.	(Observation	2nd	(b)25.5	6.7		Clear	640	300	1.1	
	TDH(West)		(a)25.5	6.6		Clear	628	308	1.2	
	(Running)		(b)25.5	6.6	7.2	Clear	560	306	1.2	
	TDH(West)		(0)26	7.0		Turbid	600	335	0.9	
			(b)26	7.0	7.3	Turbid	595	298	1.2	
3.	(Observation	3rd	(c)25.5	7.1		Turbid	605	293	0.8	
	TDH(West)		(a)26	7.1		Clear	568	313	0.8	
	(Running)		(b)26	7.1	7.3	Turbid	580	315	0.8	

(0) = Without purging

(a) = After purging for 4:30 hrs. in case of observation Tube wells & 15 min. in case of running tube well.

(b) = After purging for 5:00 hrs. in case of observation wells chlorinated 72:00 hrs. before 1st sampling.

Table : 4A (Contd)

1	2	3	4	5	6	7	8	9	10	11
Site : Baliapur										
	No-1		(O)27	6.6		Clear	696	169.4	Trace	
			(a)26.5	6.7	6.4	Clear	680	43.7	2.5	
1.	(Observation)	1st	(b)26.5	6.6		Clear	696	42.0	2.5	
	No-1		(a)26	6.8	6.4	Clear	664	38.0	3.5	
	(Running)		(b)26	6.7		Clear	716	39.6	3.5	
	No-1		(O)26	6.8		Clear	692	38.0	Trace	
			(a)25.5	7.7	6.5	Clear	756	28.5	3.7	
2.	(Observation)	2nd	(b)25.5	7.6		Clear	732	28.5	3.0	
	No-1		(a)25	7.7	6.5	Clear	696	30.4	3.0	
	(Running)		(b)24.5	7.6		Clear	715	30.5	3.5	
	No-1		(O)25	7.7		Clear	588	30.4	2.1	
			(a)24.5	7.5	6.7	Clear	620	34.2	2.5	
3.	(Observation)	3rd	(b)24.5	7.6		Clear	588	34.2	3.0	
	No-1		(a)24.5	7.7	6.7	Clear	596	36.1	2.5	
	(Running)		(b)24	7.6		Clear	592	36.1	2.3	
Site : Ghior										
	No-36		(O)26.5	6.4		Coloured	429	57.0	Trace	
			(a)26	6.5	5.8	,,	429	19.1	Trace	
1.	(Observ.)	1st	(b)26	6.5		,,	426	17.1	0.06	
	No-36		(a)26	6.7	5.8	Coloured	403	22.8	0.05	
	(Running)		(b)26	6.7		,,	489	21.0	1.0	
	No-36		(O)27	7.8		,,	384	23.0	Trace	
			(a)26.5	7.7	5.9	,,	392	21.0	Trace	
2.	(Observ.)	2nd	(b)26.5	7.7		,,	396	19.0	Trace	
	No-36		(a)26.5	7.6	5.9	,,	392	25.0	Trace	
	(Running)		(b)26.5	7.5		,,	384	23.0	0.07	

Col : Coloured

Table : 4A (Contd)

1	2	3	4	5	6	7	8	9	10	11
	No-36		(O)27	6.5		Coloured	260	28.0	Trace	
			(a)26.5	6.6	6.0	,,	240	27.0	Trace	
3.	(Observ.)	3rd	(b)26.0	6.4		,,	212	27.0	Trace	
	No-36		(a)26.0	6.8	6.0	,,	250	24.7	Trace	
	(Running)		(b)26.0	6.8		,,	264	26.6	Trace	
	Site : Ghatail									
	24-A		(O)25	6.5		Clear	484	67.7	0.2	
			(a)24	6.6	5.5	Clear	540	26.6	Trace	
1.	(Observ.)	1st	(b)24	6.5		Clear	450	26.6	0.4	
	24-A		(a)24.5	6.7	5.5	Clear	468	26.5	Trace	
	(Running)		(b)24.5	6.6		Clear	468	26.6	Trace	
	24-A		(O)25.0	6.6		Clear	525	32.5	0.8	
			(a)24.5	6.7	5.6	Clear	530	32.2	0.3	
2.	(Observ.)	2nd	(b)24.5	6.7		Clear	580	32.6	0.3	
	24-A		(a)26	6.7	5.6	Clear	450	32.2	Trace	
	(Running)		(b)25.0	6.7		Clear	495	32.5	Trace	
	24-A		(O)26	6.8		Clear	520	34.2	Trace	
			(a)25.5	6.9	5.7	Clear	440	34.2	0.5	
3.	(Observ.)	3rd	(b)25.5	6.8		Clear	480	34.2	0.7	
	24-A		(a)25.5	6.8	5.7	Clear	420	36.1	0.8	
	(Running)		(b)25.5	6.8		Clear	435	36.1	Trace	

Note : Col = Coloured

Table-4B: Bacteriological Examination of Water Samples after Chlorination of Observation Tube Wells.

Site : Dattapara   Period of sampling April-July'85.

Sl.No.	Tube Well No.	Sampling	Faecal Coliforms /100 ml.	Faecal Strepto-cocci. /100 ml.	Remarks
1	2	3	4	5	6
	TDH (West)		(0) 65	75	
			(a) 34	4	
1.	(Observation)	1st	(b) 15	TNTC	
	TDH (West)		(a) 3	2	
	(Running)		(b) 4	3	
	TDH (West)		(0) 70	3	
			(a) 18	14	
2.	(Observation)	2nd	(b) 16	10	
	TDH (West)		(a) 1	13	
	(Running)		(b) 0	2	
	TDH (West)		(0) 22	TNTC	
			(a) 22	TNTC	
3.	(Observation)	3rd	(b) 20	65	
	TDH (West)		(a) 55	83	
	(Running)		(b) 26	TNTC	
Site : Baliapur					
	No-1		(0) 34	10	
			(a) 3	3	
1.	(Observation)	1st	(b) 3	2	
	No-1		(a) 4	11	
	(Running)		(b) 3	8	
	No-1		(0) 32	15	
			(a) 15	10	
2.	(Observation)	2nd	(b) 3	4	
	No-1		(a) 0	0	
	(Running)		(b) 0	0	

TNTC = Too numerous to count.

Table : 4B (Contd)

1	2	3	4	5	6
	No-1		(O) 23	4	
			(a) 10	2	
3.	(Observation)	3rd	(b) 28	25	
	No-1		(a) 8	11	
	(Running)		(b) 9	2	
Site : Ghior					
	No-36		(O) 15	4	
			(a) 0	24	
1.	(Observation)	1st	(b) 0	20	
	No-36		(a) 0	2	
	(Running)		(b) 0	2	
	No-36		(O) 2	3	
			(a) 1	40	
2.	(Observation)	2nd	(b) 2	52	
	No-36		(a) 3	4	
	(Running)		(b) 1	2	
	No-36		(O) 3	98	
			(a) 2	TNTC	
3.	(Observation)	3rd	(b) 0	TNTC	
	No-36		(a) 2	20	
	(Running)		(b) 0	11	

Note: (O) = Without purging.
(a) = After purging 4:30 hrs. in case of Observation Tube Well and 15 min. in case of Running Tube Wells.
(b) = After purging 5:00 hrs. in case of Observation Tube Wells.
Observation Tube Wells = All new Tube Wells Chlorinated 72:00 hrs. (3-days) before 1st sampling.

TNTC = To numerous to count.

Table : 4B (contd)

1	2	3	4		5	6
Site : Ghatail						
	24-A		(O)	1	14	
			(a)	0	2	
1.	Observation)	1st	(b)	1	9	
	24-A		(a)	1	10	
	(Running)		(b)	1	57	
	24-A		(O)	80	11	
			(a)	3	5	
2.	(Observation)	2nd	(b)	2	7	
	24-A		(a)	2	25	
	(Running)		(b)	1	55	
	24-A		(O)	TNTC	2	
			(a)	6	2	
3.	(Observation)	3rd	(b)	3	3	
	24-A		(a)	5	3	
	(Running)		(b)	3	27	

TNTC = Too numerous to count

5.3 The Third and Final Phase of the Investigation :

The results so far obtained at different experimental conditions are very discouraging as they clearly indicate that the hand operated shallow tube wells are not producing pure drinking water. The fact needs to be confirmed. In the previous experiments, step by step, and as far as possible, the sources or causes of external contamination have been eliminated. Still, as considered by the review committee, the doubt remained in the validity of the conventional sampling procedure. So in this phase (the third phase) of study, the tube technique (described in Chapter 3) was adapted to get samples directly from the aquifer. Only two sites which are very near to Dhaka, were selected. The results of these have been given in table 5A and 5B the following observations could be made:

(a) Most of the samples taken from the running tube wells have been found contaminated by faecal organisms, though a good number have been found free from such contamination. It may be noted that the conventional method of sampling have been followed in case of running tube well.

(b) The samples taken from the observation tube wells showed less incidence of contamination but quite a number of samples have been found to be contaminated by faecal organisms. In this case, the tube technique of sampling has been followed .

(c) The chloride, nitrate and pH contents of the samples are generally within the limit. The suspended, dissolved and total solids are also generally within the limits.

(d) The results shown in tables 5A and 5B basically follow the trends of the previous results though incidence of faecal contamination may be considered to be less, specially in the case of

Table-5A: Physical and Chemical Examinations of Water Samples after adoptation of Tube-Technique of sampling.

Site : Dattapara — Period of Sampling Jan-May' 86.

Sl. No.	Tube Well No.	Sampling	Water Temp. °C	pH	Water level in meter	Appearance	Solid: Suspuded solid mg/1	Solid: Dissolve Solid mg/1	Solid: Total Solid mg/1	Chloride mg/1	Nitra mg/1
1	2	3	4	5	6	7	8	9	10	11	12
1.	TDH (West)	1st	(R)25	6.5	6.4	Turbid	15	627	652	165.5	0.5
			(0)25	6.6	6.4	Turbid	19	703	722	269.3	0.7
2.	TDH (West)	2nd	(R)25	6.7	7.8	Clear	6	558	664	338.7	Trace
			(0)25	6.6	7.8	Turbid	16	516	532	277.8	0.9
3.	TDH (West)	3rd	(R)25	6.7	6.8	,,	28	492	520	119.9	Trace
			(0)25	6.7	6.8	,,	45	579	624	253.8	0.7
4.	TDH (West)	4th	(R)26	6.8	5.9	,,	21	525	546	357.8	0.9
			(0)26	6.7	5.9	,,	30	536	566	274.0	1.2
5.	TDH (West)	5th	(R) 25.5	6.8	7.5	,,	16	588	604	350.7	1.2
			(0)	6.8	7.5	,,	39	609	648	299.7	1.0
6.	TDH (West)	6th	(R) –	6.6	7.4	Clear	5	586	591	392.1	Trace
			(0)	6.7	7.4	Coloured	16	684	700	263.3	0.8
7.	TDH (East)	1st	(R)25	6.6	6.7	Coloured	5	359	364	238.7	0.8
			(0)25	6.5	6.7	Clear	9	505	514	44.7	1.0
8.	TDH (East)	2nd	(R)25	6.6	6.9	Clear	3	255	268	142.7	Trace
			(0)25	6.6	6.9	clear	9	223	232	44.7	0.9
9.	TDH (East)	3rd	(R)25	6.7	7.1	clear	6	450	456	165.6	trace
			(0)25	6.7	7.1	clear	9	447	456	62.6	0.8
10.	TDH (East)	4th	(R) 25.5	6.7	6.2	Turbid	15	309	324	169.4	1.2
			(0) "	6.7	6.2	clear	8	264	272	58.9	1.5

(R)= Running Tube Wells
(O)= Observation Tube Wells, two samples after the interval of 15 min. have been taken and the average value have been shown.
ND = Not done.
Col= colour .

Table : 5A (Contd)

1	2	3	4	5	6	7	8	9	10	11	12
11.	TDH (East)	5th	(R)26	6.7	7.6	Coloured	8	296	304	140.8	2.6
			(O)26	6.8	7.6	Clear	7	253	260	69.5	2.0
12.	TDH (East)		(R)28	6.6	7.4	Clear	14	336	350	161.7	1.0
			(O)28	6.7	7.4	Col...	10	425	435	132.6	1.3
13.	TDH (East)	7th	(R)27	6.7	ND	Clear	8	285	292	123.7	0.6
			(O)27	6.7	ND	Clear	8	272	280	128.5	0.9
14.	No-2	1st	(R)24	6.7	6.9	Col.	24	464	488	53.3	2.5
			(O)24	6.4	6.9	Turbid	36	648	684	271.2	2.2
15.	"	2nd	(R)25	6.8	7.0	Col.	55	493	548	58.9	2.3
			(O)25	6.8	7.0	Turbid	74	578	652	243.6	2.3
16.	"	3rd	(R)25	6.7	ND	Turbid	88	888	976	58,9	2.4
			(O)25	6.8	ND	Turbid	62	798	860	266.4	1.5
17.	"	4th	(R)26	6.7	7.2	Turbid	96	436	532	60.9	2.5
			(O)26	6.6	7.2	Turbid	50	682	732	253.1	2.0
18.	"	5th	(R)25	6.7	7.5	Turbid	169	466	735	921.4	3.8
			(O)25	6.8	7.5	Turbid	45	690	735	244.3	4.2
19.	"	6th	(R) 25.5	6.7	7.2	Turbid	70	386	456	87.5	4.0
			(O) 25.5	6.6	7.2	Turbid	47	859	906	264.0	4.0
20.	KB(New)	1st	(R)24	6.9	9.3	Turbid	160	452	612	39.9	1.1
			(O)24	6.8	9.3	Col.	45	611	656	117.0	trace

ND = Not done

Col = Coloured

Table : 5A (Contd)

Site : Baliapur

1	2	3	4	5	6	7	8	9	10	11	12
1.	12East	1st	(R)25	6.6	6.6	Clear	12	562	572	[illegible]	[illegible]
			(O)25	6.8	6.6	Clear	10	438	448	158.[illegible]	[illegible]
2.	12-East	2nd	(R)25	6.8	6.9	Clear	20	436	45[illegible]	72.[illegible]	
			(O)25	6.7	6.9	Clear	10	416	426	[illegible]6.[illegible]	[illegible]
3.	"	3rd	(R)ND	6.8	7.8	Clear	7	361	368	[illegible]	2.0
			(O)ND	6.8	7.8	Clear	8	334	342	173.2	1.5
4.	"	4th	(R)26	6.8	6.9	Clear	4	312	316	70.4	2.5
			(O)26	6.7	6.9	Colour	14	223	247	75.3	2.6
5.	"	5th	(R)26	6.7	6.2	Clear	6	206	212	81.8	2.5
			(O)26	6.7	6.2	Colour	8	254	262	75.2	2.0
6.	"	6th	(R)27	6.8	7.0	Clear	7	308	310	91.4	1.0
			(O)27	6.7	7.0	Clear	14	225	239	[illegible]	1.7
7.	12-Far East	1st	(R)25	6.6	6.8	Clear	12	652	664	70.4	2.7
			(O)2[illegible]	6.7	6.8	Clear	12	548	560	57.0	2.6
8.	12-Far East	2nd	(R)25	6.8	7.0	Clear	27	273	280	52.8	4.[illegible]
			(O)25	[illegible].7	7.0	Clear	15	251	266	54.3	3.5
9.	"	3rd	(R)25	6.8	7.5	Clear	10	372	382	78.0	4.1
			(O)25	6.7	7.5	Clear	26	290	316	63.7	3.6
10.	"	4th	(R)27	6.9	7.4	Clear	8	252	260	79.9	2.4
			(O)27	6.7	7.4	Clear	15	211	226	57.0	1.9
11.	"	5th	(R)27	6.6	6.7	Clear	12	252	264	77.0	2.4
			(O)27	6.7	6.7	Clear	9	208	217	66.6	2.5

Note: (R) = Running Tube Wells.
(O) = Observation Tube Wells.
Col = Coloured.
ND = Not done.

Table : 5A (Contd)

1	2	3	4	5	6	7	8	9	10	11	12
12.	12-Far East	6th	(R)27	6.7	5.8	Clear	8	297	305	87.5	2.6
			(O)27	6.8	5.8	Clear	12	232	244	82.0	2.4
13.	No-1	1st	(R)25	6.7	6.2	Clear	16	324	340	38.1	3.0
			(O)25	6.7	6.2	Clear	10	300	310	48.5	2.6
14.	"	2nd	(R)25	6.6	6.6	Clear	20	204	224	56.2	3.2
			(O)25	6.8	6.6	Clear	15	254	269	55.2	3.0
15.	"	3rd	(R)25	6.7	6.9	Clear	10	221	231	55.2	2.6
			(O)25	6.6	6.9	Clear	8	212	220	58.1	2.0
16.	"	4th	(R)26	6.8	6.2	Clear	6	215	221	64.7	1.9
			(O)26	6.7	6.2	Clear	8	192	200	58.0	1.5
17.	"	5th	(R)25	6.7	5.8	Clear	5	147	152	68.5	1.5
			(O)25	6.6	5.8	Clear	5	248	253	59.9	1.0
18.	"	6th	(R)26	6.7	5.3	Clear	8	369	377	53.3	2.0
			(O)26	6.7	5.3	Clear	8	329	337	58.0	1.5

Table-5B: Bacteriological Examination of water samples after Adoptation of Tube-Technique of Sampling.

Site : Dattapara

Period of sampling Jan-May'86

Sl. No.	Tube well No.	Sampling		Faecal coliforms /100ml	Faecal streptococci /100ml
1	2	3		4	5
1.	TDH (West)	1st	(O)*	0	8
			(R)	0	0
2.	"	2nd	(O)	0	6
			(R)	0	0
3.	"	3rd	(O)	0	26
			(R)	0	1
4.	"	4th	(O)	0	25
			(R)	0	0
5.	"	5th	(O)	0	5
			(R)	0	18
6.	"	6th	(O)	0	6
			(R)	0	2
7.	TDH (East)	1st	(O)	0	0
			(R)	0	1
8.	"	2nd	(O)	0	8
			(R)	0	0

Note : O = Observation Tube wells installed for experimental purpose.
R = Running Tube wells installed before & used by the people.
* = In case of observation wells, two samples after 15 min. interval have been taken & average value have been shown.

Table : 5B (Contd)

1	2	3		4	5
9.	TDH (East)	3rd	(O)	0	2
			(R)	0	42
10.	"	4th	(O)	0	6
			(R)	14	25
11.	"	5th	(O)	0	2
			(R)	2	9
12.	"	6th	(O)	TNTC	TNTC
			(R)	29	TNTC
13.	"	7th	(O)	TNTC	44
			(R)	2	17
14.	No-2	1st	(O)	TNTC	TNTC
			(R)	2	TNTC
15.	"	2nd	(O)	TNTC	TNTC
			(R)	31	TNTC
16.	"	3rd	(O)	TNTC	TNTC
			(R)	65	TNTC
17.	"	4th	(O)	TNTC	TNTC
			(R)	25	TNTC
18.	"	5th	(O)	TNTC	TNTC
			(R)	55	TNTC
19.	"	6th	(O)	TNTC	TNTC
			(R)	TNTC	TNTC

Table : 5B (Contd)

1	2	3		4	5
20.	KB(New)	1st	(O)	0	81
			(R)	TNTC	TNTC
Site : Baliapur					
1.	~~12(East)~~	1st	(O)	0	9
			(R)	1	4
2.	"	2nd	(O)	0	0
			(R)	21	TNTC
3.	"	3rd	(O)	0	0
			(R)	0	8
4.	"	4th	(O)	0	40
			(R)	20	20
5.	"	5th	(O)	0	0
			(R)	0	0
6.	"	6th	(O)	0	0
			(R)	0	0
7.	12(Far-East)	1st	(O)	0	0
			(R)	9	8
8.	"	2nd	(O)	2	53
			(R)	35	TNTC
9.	"	3rd	(O)	12	TNTC
			(R)	0	1
10.	"	4th	(O)	0	0
			(R)	3	1

TNTC = Too numerous to count.

Table : 5B (Contd)

1	2	3		4	5
11.	12(Far-East)	5th	(O)	0	0
			(R)	11	10
12.	"	6th	(O)	0	0
			(R)	0	0
13.	No-1	1st	(O)	0	2
			(R)	0	20
14.	"	2nd	(O)	0	0
			(R)	5	61
15.	"	3rd	(O)	0	5
			(R)	0	48
16.	"	4th	(O)	0	0
			(R)	0	2
17.	"	5th	(O)	1	1
			(R)	0	2
18.	"	6th	(O)	0	9
			(R)	0	8

Note : (O) = Observation tube well
(R) = Running tube well

TNTC = Too numerous to count.

samples taken from observation wells.

e) In both the cases of running and observation tube wells, no tube well was found to be free from faecal contamination considering the over all results and faecal streptococci have apparently found to be more persistent than the faecal coliforms.

f) Apparently tube technique is safer but comparatively difficult to handle and time consuming. No concrete conclusion, from these results, may be deducted that this method is significantly superior to conventional sampling method.

g) Still, the source of final contamination could not be located specially as there were many polluting sources around the tube wells. Though, much precaution has been taken to remove the external sources of contamination, specially in case of observation tube wells, could not perhaps, be removed totally. So it could not be concluded from these results whether the source of faecal contamination was pit latrine or not.

One important fact may be mentioned here that the lack of hydrogeological data specially regarding the direction of ground water flow makes the results more difficult to interprete or come to some realistic conclusions. This part of study (hydrogeologioal) has not been done, though it is vitally important for such investigation. It may be mentioned that BCSIR was not entrusted to carry out the hydrogeological studies.

6. Discussion:

6.1 General Considerations :

It is quite apparent that results obtained in this prelimi nary studies give no valid basis to formulate any realistic conclusion on the pollution of ground water from pit-latrines; in other words, these results are not at all sufficient to fullfil the aims and objectives of this project. There may be identified many reasons for not being successful to attain the goal at this stage. These include many apparently minor points, but which in reality created difficulties in the progress of works, such as transport problems, lack of proper logistical supports, environmental conditions, installation of tube wells in standard ways, defects in platforms, delay in getting supplies of chemicals, media etc. However, the majour factors which affected the proper progress hence the achievement of the goal may be described summarily as follows :

6.1.1 Insufficiency in the Original Protocol Project Plan :

The programme/protocol which was handed over to the investigators was not formulated with sufficient background knowledge and practical experience specially regarding conditions natural to Bangladesh. The pioneering works of Caldwell et al (1937), Dyer and Bhaskaran (1942,1943[b]) and Dyer et al (1945a) are quite useful in designing such studies. But in this original work plan their studies were not taken into account. Rather a shortcut way of monitoring underground water pollution was programmed. In the studies, they selected sites which were apparently free from faecal pollution . Latrine was installed in a selected place of the experimental sites and tube wells were installed around this latrine at different distances and depths for proper monitoring of the travel of pollution (see also Recommendation and Guidelines) Actually, the proposal for creating such experimental condition was put forward by the investigators but this was not agreed upon by the review committee, perhaps mainly, because it would drastically change the original work plan and require more funds. So it was tried to get the meaningfull results by some minor modifications which have been discussed in suitable places. Rigid time schedules have been set which were found to be almost impossible to follow. No radical change, if necessary, was visualized and as such, there was hardly any scope for any major changes in the programme. So the investigators, according to the suggestions of the advisory Review Committee of the project comprises of the representatives of IFT.(BCSIR), DPHE, WHO and UNICEF made some minor modifications optimistically but these failed to produce the cherished results.

6.1.2 Experimental Sites and Sampling points:

This type of study requires, as said in recommendations, special experimental conditions specially regarding site selection and creating standard conditions for investigations. In absence of standard experimental site it is only natural that the data obtained may not produce the expected conclusions. This has been pointed out in the discussions during the meeting of the Review Committee but such experimental site could not be created because as said above major changes in the programme were difficult to be considered at this stage.

Moreover, the sites selected are situated in such environments where pollution sources of faecal matters other than pit-latrines exist prominently with the good possiblity of contamination of ground water from such sources. So in interpreting the data it is not possible naturally to locate the particular polluting source, specially to make any valid reference to pit latrine where the samples showed positive indication of faecal contamination. As in the case of site selection the sampling points (hand operated shallow tube wells) were selected not on the basis of any properly designed study plan as stated above. However, they were selected on account of the existence of pit latrine near by (in some cases other type of latrines also). But in the vicinity of these selected monitoring tube wells, almost in all cases other types of potential pollution sources such as other types of faecal matter disposal systems, ditches, notable drains etc are located and the over all environmental conditions are deplorable. This makes complication in interpreting the results particularly with reference to pit latrines above.

All the monitoring tube wells are running tube-wells and they are used by the public. This increased the possiblity of external contamination to a great extent. More over, it is also reported that polluted water are used for priming these tube wells and in many cases there are fissured platforms and possibilities of leakage around the pipe of the tube well were also noted. These factors, would no doubt influence the results very much. Of course, in the course of the study specially in the second and third phases, attempts were made to eliminate some of these factors by repairing the platforms, preventing the possible leakage, etc.

As described above, in the second phase of the study, observation tube wells which were kept at capped conditions and the public were not allowed to use them were installed in the neighbourhood of the running tube wells to eliminate the external contaminating factors. As they were installed very near to the running tube wells (for parallel study), it was likely that they might also get contaminated when the running tube wells were contaminated. As the over all results showed that though some of the samples taken from these observation tube wells were found to contain no faecal indicator organisms, they were found to be eventually contaminated by faecal indicators. So the above mentioned point (pollution of observation tube well from the running tube well) can not be overlooked. So such a system should not be considered ideal for such study.

It may be mentioned that the selection of experimental sites and sampling points (i.e. the monitoring tube wells) was not done by IFST (BCSIR).

6.1.3 Lack of Hydrogeological Data :

Though it was repeatedly pointed out that in this type of study, hydrogeological findings are vitally important also, but no such study has been done. Even the direction of flow of the ground water could not ascertained due to lack of manpower or some other reason. But such data are most important in interpretating the data of microbiological and also chemical investigations. If such investigation would have been done, whatever data we have in hand, it could have been attempted to analyse the data to locate the source of pollution with social reference to pit latrine. It may be mentioned, here, that the Institute of Food Science & Technology,BCSIR, where the microbiological and chemical investigations were done, has no manpower or experience in hydrogeological studies. This fact was taken into consideration when agreement was achieved between BCSIR and DPHE regarding this project.

However, this investigation has revealed some important informations on the quality of tube-well water. The results of this investigations, has pointed out many vital aspects of such study and provides good basis for further realistic, meaningful and scientifically sound programming for assessing the actual situation. It has greatly helped in formulating the suggestions and recommendations necessary for drawing the future plan of studies which are considered to be very important for rural water supply by hand operated shallow tube wells and installations of pit-latrine to ameliorate the present conditions of disposal of faecal matters. Lewis et al (1980) in their general review on the risk of ground water pollution from pit latrine and pour flash type latrine, put great emphasis on the hydrogeological characteristics regarding the travel of pollution from such latrines through unsaturated and saturated zones. In the unsaturated zone filtration and adsorption play a great role in preventing bacteria and viruses to travel vertically or horizontally to contaminate the ground water. The soil characteristics are most important in these respects. The adsorption of bacteria and viruses in clay soil is greater. The pore sizes of the soil determine filtration rate (see literature review) the smaller are the pores, more is the filtration capacity of soil. In the saturated zone, the flow direction virtually determine the travel of pollution . The dispersion effect of pollutant from the source is not much, they travel generally according to the direction of the ground water flow. The rate of flow of ground water also influence the rate of travel and concentration of the pollutants. These facts clearly show the importance of determination of the required hydrogeological parameters to reach conclusions about the polluting capacity of pit latrines in respect of ground water and this will certainly vary according to the differences in soil profiles and aquifer characteristics of different zones. As these studies have not been done, it is impractical to correlate the bacteriological and chemical findings of the analyses of the samples taken from a quite large number of monitoring tube wells with the pit latrine with total accuracy. This becomes more complicated because of the presence of other sources of pollution existing in the vicinity of the monitoring wells as stated above.

6.2 Evaluation of the Findings of the Investigations Carried Out:

6.2.1 Physical Parameters

Some samples were found turbid and coloured. The former characteristics is attributed to the fault in the strainer or some other leakage, however, this is undesirable for such study as the many authors (see literature review) have found that turbid samples masked the colony formation on the membrane in the MF technique which was followed in this study. Turbid water is also aesthetically undesirable. The measurement of the degree of the turbidity should be included in the future work. Most of the tubid samples contained very fine clay materials which even the high quality filter paper could not hold. So the filtermembrane used in MF technique was used in the measurement of suspended solid content in the last phase of the study and the previous results were discarded. In the measurement, of the dissolved soild, to get quicker results in the first two phases of this investigations which was regarded as preliminary ones the gravimetric method was followed (More attention was focussed on the determination of the faecal indicators). The results showed considerable variations when compared to standard method of drying the measured quantities of filtered samples. This method was adopted in the third phase of the investigations and the solid contents, specially the dissolved solid contents which is directly related to the conductivity (and the higher conductivity is sometimes may be indicative of faecal pollution) were not found unusual and could not be evaluated for indication of pollution. In case of pH, the same general conclusion may be reached. In general the temperatures of the samples were above 20°C. These temperatures may not be regarded as favourable for the survival of faecal indicators if the regrowth of faecal coliforms has not taken place. It has been found by some authors (see the literature review). That lower temperatures specially near to 4°C favoured the survival of faecal indicators for longer periods.

In conclusion, it may be stated that the physical parameters of the samples which have been studied have not been found meaningful regarding the indications of pollution from pit latrine.

6.2.2 Chemical Characteristics :

The excessive nitrate content in drinking water is highly undesirable because it causes a disease named Methaemoglobinamia and nitrate pollution of ground water from septic type latrine (including pit latrine) is quite possible (Lewis et al, 1980). But the results showed no unusual concentration of nitrate in the samples studied. The chloride content of human faecal matters is quite high. So it is expected that ground water contaminated by pit latrine should content higher concentration of chlorides. As in the case of nitrate no such unusual concentration of chloride in the sample has been found. But both the nitrate and chloride concentrations in the samples are subjected to many factors including soil characteristics, dilution rates (directly related to the flow rate of the ground water which has not been determined), etc. So in this cases also no conclusion could be reached regarding the pollution of ground water from the pit latrine in these investigation. It may be noted that in some samples the iron content has been found higher than desirable. This is regarded as regional characteristics of the soil. However, these concentrations are not expected to cause any serious troubles in comparison with the pollutions caused by pathogens.

6.2.3 Bacteriological Findings :

Actually in this study, comparatively more attention has been given on the bacteriological findings which consisted of determinations of conventional faecal indicators i.e faecal coliforms and faecal streptococci by the standard methods of MF technique.

When at the first phase of the investigations, most of the samples showed the presence of faecal indicators, incriminating all the monitoring tube wells as polluted, naturally, attention was focussed on the possiblity of external pollution as discussed above. But in the second phase of the study (which was done after taking possible precautions to exclude the external pollution and installations of observation tube wells) the picture was not altered to any significant level, though more samples showed the absence of faecal indicators, (mostly in respect of faecal coliforms), specially in the samples taken from observation wells (but not much significantly). So it was tried to improve the sampling technique which might be the cause of such widespread contamination. On this consideration, more sophisticated and well guarded tube technique of sampling method was introduced in the third or last phase of the work. However, in this case also, though a good number of samples taken from the running as well as observation tube wells showed the absence of the faecal coliforms but all the tube wells were found to be contaminated considering the overall results. It was noted that faecal streptococci were more prevalent. This is not unexpected or unusual as some authors (see the literature review) found that faecal streptococci survived longer than faecal coliforms in some special environments and conditions .

These bacteriological findings clearly showed that the tube wells were not giving safe drinking water and contamination of ground water or the aquifer can not be ruled out at all. But concrete and highly reliable conclusions can not be reached on these data regarding the contamination of the ground water by pit latrine as the sole source of such contamination because of the reasons stated above which include the lack of necessary hydrogeological studies. Even these findings could not be compared with those may be found in the standard conditions (i.e. having the absence of pit or other types of latrines, other polluting sources etc.). This indicates the insufficiency of the work-plan of the project as discussed elsewhere in this report .

However, one solid conclusion does come out from these findings that the shallow/tube-well water should not be regarded as safe or hygienically pure as drinking water under the prevailing circumstances in which these investigations were carried out. As such, the expectation of providing good drinking water to the people by installation of shallow tube wells as found in these investigations is in doubtful condition. It is also required that the installation of pit latrine should not be done in haphazard or complaissent way. All these require a well designed study to find out the ideal conditions for installations of shallow tube wells and the pit latrines (as their apparent usefulness can not be disregarded). For such study some guidelines/recommendation have been included in this report .

7. Summary

7.1 In the first phase of the investigation which included the monitoring of the selected tube wells of five sites were studied for faecal indicator organisms and all the tube wells were found to be contaminated with these organisms.

7.2 It was considered that such faecal pollution might be caused by using polluted priming water, unsanitory use of tube wells, leakage through platforms etc. So in the second phase of the study the measures were taken to eliminate or improve these undersirable conditions and it was decided to install separate monitoring tube well with extraordinary care (observation tube wells), very near to the existing monitoring tube wells. These new installed tube wells were not allowed to be used by the people and kept capped. They were properly chlorinated before sampling. However, though some of the samples taken from these observation tube wells were found to be free from faecal indicator organisms, but over all results showed they were also contaminated by faecal organisms. Old monitoring tube well (running tube wells) showed the same trends of the results as before regarding faecal indicator organisms .

Shahidnagar which was flooded over, was kept out of further investigations.

7.3 Such a widespread contamination gave rise to the doubt about the validity of conventional sampling method, so a rather sophisticated tube sampling mehtod was adopted for the observation tube wells in the third phase of study. However, the trends of results regarding contamination by faecal indicator organisms were almost as before, though quite a number of samples showed the absence of these organisms. From the results it was not firmly established that the tube technique of sampling was better than the conventional method of sampling.

7.4. The chloride and nitrate contents of the samples taken from all monitoring locations were more or less within the limits i.e. they were not in high concentration. So such findings could not be considered as indicator of faecal pollution in either way.

7.5. A few samples in the initial phase were analysed for iron content. In some cases, this was found to be high .

7.6. In the vicinity of the most of the monitoring wells, there existed not only the pit latrine (which was required for the study) but other undesirable sources of pollution, such as open latrine, ditches, drains etc.

7.7. The hydrogeological studies including such vital parameters as determination of flow directions and rates were not done.

7.8. Considering the above two points 7.6 & 7.7 it was, apparently not possible to locate conclusively the source of contamination i.e. whether the faecal indicators were introduced from the pit latrine. So it could not be established whether the ground water was contaminated by pit-latrines or not. However, it was clearly indicated by the findings that, the tube wells of the experimental areas were not supplying the desired pure drinking water to the consumers .

7.9. All these facts point out that this study was inconclusive. So further studies, much more carefully designed, are needed to be carried out . Some guidelines/recommendations for future investigations on this subject are incorporated in this report .

8. Conclusion

8.1. The results obtained in these investigations clearly indicate that the hand operated shallow tube wells of the experimental sites did not produce good drinking water i.e. the water of these tube wells were found to be contaminated by faecal pollutants.

8.2. Though, this faecal pollution of shallow tube well water (i.e. the under ground water) can not be correlated with pit-latrines because of insufficiency and or of absence of some vital data (eg. hydrogeological, etc.) to a considerable degree of certainty; the possiblity of pollution from pit-latrines is strong enough considering that the major sources of faecal pollution were the pit latrines situated in the vicinity .

8.3. Further study in this field is certainly necessary.

8.4. For such a study, the investigation procedures should be well-planned and based on the available informations.

9. Recommendations and Guidelines for Further Studies :

9.1. Introduction :

The rather unsucessful completion of the investigation described in this requires, naturally, a further broad based study to achieve useful informations. It should be recognized that in this study, not only the pollution of ground water is investigated, the particular source of pollution i.e. pit-latrine must be taken into account. In fact, this source of pollution is, in this study, recognized as virtually the most important factor of ground water pollution. So this adds a new dimension of importance to this study making it a very special one.

Considering these, the plan/programme of the study should be prepared very carefully. Informations gathered from literature describing such or allied studies (including those which are important for methodology and data interpretation) may be much helpful in these regards. Special attentions may be given to the experimental designs followed by Dyer and Bahaskaran (1943, 1945a/1945b) and recommendations of Ward and Foster cited by Ward and Schertenteib (1982). Of course, the experience achieved in the investigations described in this report will also be very much educative and eventually considerably useful. But actual plan should not be prepared only on the above facts. Preliminary studies (also carefully carried out according to the requirements) must be done to chalk out a worthy and workable plan. The following recommendations/guidelines are prepared for giving the primary direction of such planning. They are in no case, a complete plan, or unalterable programmes. Suitable modifications, additions, deletions, should be made by a group of people who have at least some first hand knowledge in such type of study together with the responsible people who would do or direct the future work.

<u>However the recommendations/guidelines concerns the following area:</u>

a. Suggestions for preliminary study which actually is the selection and preparation of experimental location.

b. The suggestion for carrying out the main study i.e. the pollution of ground water from pit-latrine.

c. Suggestions and discussions on the Methodology and Requirements : Evaluation and interpretation of findings and their application and also the follow-up study (including periodical monitoring).

d. Personnel required for carrying out the necessary investigations .

e. Additional Remarks :

Funding is another vital aspect which has not been discussed much. It may only be said that without proper funding, such study is bound to take the shape of a miniature or truncated one which is hardly expected to produce the standard informations .

9.2 Selection and Preliminary Studies of the Experimental Sites: These should fulfil the following criteria and findings.

9.2.1 <u>Hydrogeological</u> :

a. There should be no source of pollution within at least 60 m diam. of the field selected for the study;

b. The field should be flat if there is any topographical inclination, that should be determined;

c. The contours of the field are to be determined;

d. The characteristics of the aquifer level including its seasonal flactuation are to be determined;

e. Determination of the slope of the aquifer;

f. Determination of flow direction of water in aquifer;

g. Determination of low rate (velocity) of water in aquifer;

h. Determination of vertical penetration of water through soil above the aquifer;

i. Parameter d - h should be studied for such a period so that the seasonal changes can be evaluated.

9.2.2 <u>Chemicals and Physical Studies</u> :

a. Determination of chemical and physical characteristics of soil with special reference to the study for pollution; eg. chloride, nitrate, nitrite, ammonia, organic compounds, iron, calcium,conductivity, pH, porosity, capillary characteristic, grain size and uniformity coefficient, clay and sand contents etc. (seasonal variations where relevant should be evaluated). Soils taken from various depths should be analysed.

b. Determination of physical and chemical characteristics of ground water, eg. chlorides, nitrates, solids (dissolved and suspended) ammonia, nitrite, iron, calcium and other relevant chemicals, pH, temperature, conductivity, organic matter, etc. (Seasonal variation should be evaluated).

9.2.3 Bacteriological :

a. Faecal indicators (faecal coliforms and faecal streptococci) should be determined with reference to seasonal effects for the soils taken from various depth (at least 3-5m depths from and above the aquifer). Additional faecal indicators such as *Pseudomonas aeroginosa*, *Clostridium perfringens*, ~~*Bacteroides*~~, ~~*Bifidobacterium*~~ etc. may be studied.

b. Determination of total counts of bacteria.

c. If possible, determination of types of bacteria.

d. Experiments a-c are to be carried out for the ground water after installation of tube wells.

e. Seasonal effects are to be determined.

9.2.4 Determination of travel of pollution :

a. Experimental pit latrine should properly be installed (the depth should be above the aquifer) in the middle of the experimental sites and the rings of tube wells at various distances (eg. 2m, 4m, 6m, 10m, 15m, 20m, etc.) should be installed for monitoring the ground water. In the rings, distances between the tube wells should be generally about 1m or as required. The depths of the tube wells should be as follows : (i) touching the level of the aquifer, (ii) going well in to the aquifer and (iii) going deep into the aquifer. In the latrine, some indicator chemicals (eg. common salt (NaCl) or a flourescent dye, such as Auramin B) should be put and samples should be analysed periodically (1-7 days) to determine the flow pattern of pollution. Seasonal studies should also be carried out.

9.2.5 Sampling :

The correct sampling is critically important. For chemical and physical parameters of soils and waters, extraodinary precautions to prevent contamination or mixing may not be taken, but for bacteriological studies, contamination problem should be seriously considered. It is rather difficult to collect samples of soils at different depths without contaminating them, however some standard techniques as used by Dyer and Bhaskaran (1945b) may be adopted. For bacteriological analysis of water, the sampling procedures has been discribed below. The sampling points have also been described above. This arrangement may be modified as found suitable in the preliminary studies. Another vital aspect of sampling, is the number of samples to be studied. These concerns also the number of points of sampling as well as intervals of sampling. However, sampling must be statistically sound. It is proposed that for analyses to find out physical and chemical as well as bacteriological characteristics of soils, 4 seasonal periods may be sufficient and 5-10 points in each zone may be selected for sampling. But fo water, the frequency of sampling should be increased much more, at least once in a week and if possible daily for the tube well in the ring near the latrine and number of points should increase 2-3 fol Actually, this may be determined after a few round of preliminary sampling.

9.3. The Experimental Location in Operation for Studying Pollution of Ground Water from Pit-latrine :

9.3.1 Establishment of Experimental Pit-latrine :

The bored hole which is centrally placed in the experimental field is to be converted into a pit latrine and sufficient number of people are to be found to use it for proper charging it with faecal matter. Dyer et al (1945a) converted the experimental bored hole into a latrine charging it with night soil bringing from somewere but such rechar-ging is considered to be difficult in this case. However, if this is to be adopted, then the bored hole shoul be converted into a latrine which in every vital respect would be similar to a pit latrine which are in use in this country.

9.3.2 Control Tube Wells :

As it is almost certainly established that the pollutions travel with the ground water flow direction, some diffusion may occur. The drawdown effect caused by the tube wells from which sufficient amount of water to be pumped out daily (to simulate the tube wells actually in use), may make the pollution travel to some extent against the flow direction. But this distance is expected to be very limited, eg. 1-2m. Under these conditions, the wells just opposite to the flow direction, installed at various distances from the latrine (in a ring) may be used as control.

9.3.3 Parameters to be studied :

a. Chemical and physical - as described above.

b. Bacteriological - as described above.

9.3.4 Period of study :

It would be ideal if the study is contiaued to three years, then not only the seasonal variations could be checked, the yearly variations may also be evaluated. Considering the time required for pre-study (selection and preparation of the experimental location) and the period suggested for actual pollution study plus the necessary follow up study and evaluation of results and report writing which will need at least 6 months to a year; the whole period of study comes down to 5 years. It may seem a long time for a study. But for successful completion of such study should as expected, produce very reliable results. In the meantime, the intermediate results may be very useful and if the significant results are found, the study period may be cut short.

9.3.5 Sampling :

In both pre-pollution and after-pollution studies, the sampling of water has got three aspects :

(a) The number of samples studied : These should be statistically reliable. These may be determined after preliminary studies. However, it is proposed that experimental tube wells situated near the latrine (2-4m) should be studied at least once in a week and the tube wells which situated far (6-10m or more) once in a month. The control tube wells should also be similarly studied. In this case the number of tube wells may be reduced to half (comparing with the experimental tube wells in each case of distance).

(b) Procedure of sampling : This is vitally important specially for bacteriological examinations. The conventional method (described in the report) has not been proved un-useful if it is done carefully. The advantage of this type of sampling is that it is very simple and large number of samples may be taken in a single day. However, the tube technique of sampling (described in the report) in no doubt scicntifically more perfect, but necessary modifications such as mechanical operation system instead of manual operation may have to be incorporated. It would bo good if the two procedures are compared in identical conditions, since small error in the case of former may be disregarded if the faecal indicators are studied further to ascertain their source (see below).

(c) Volume of Water to be Examined : For physical examination, this is not a problem and for chemical analyses, the volumes may be determined as per standard procedures. But for bacteriological analyses specially for faecal indicators SFV (Standard Filtration Volume) should be determined according to the standard procedures.

9.4. Methodology (apart from the sinking of tube wells, installation of pit-latrine, etc., i.e. the engineering aspect, the study may be divided into three broad area :

a. Hydrogeological investigations,

b. Physical and chemical analyses,

c. Bacteriological examinations,

Of course, the methods for above studies obviously will remain limited to the monitoring and evaluation of pollution from pit-latrine to the ground water, but such limitations should not be considered obligatory, these should have much margin of flexiblity as occasions may arise involving many factors which do not directly involve the project but necessarily are related to it .

9.4.1 Hydrogeological Investigations :

The parameters of such have been described above in general. Actually, the whole aim of these investigations is to extablish a proper experimental set-up to collect representative and necessary samples and to interprete the findings of other investigations for formulation of suggestions/recommendation for establishment of pit-latrine and shallow hand operated tube systems in useful and applicable ways.

The proper methods for studying the required parameters as suggested will not be elaborated here. We hope that conventional methods may be sufficiently useful in these regards. A senior hydrogeologist specially having experience on the land characteristics of Bangladesh with special reference to underground water system should be consulted to chalk out the methods for the determinations of the above mentioned parameters.

9.4.2 Physical and Chemical Analyses of Soil and Water Samples :

The parameters cited above regarding such analyses are available in standard books. A soil chemist may be consulted for analyses of soil samples as required and the methods given in

Standard Methods for Examinations of Water and Waste Water (1980) may be considered sufficiently useful in these regards.

Though chemical and physical analyses of water samples will mainly remain confined to the monitoring of pollution coming from the latrine, (i.e. human faecal matters), it is a good idea to study some parameters which concern aesthetics as well as other chemical aspects of potable water criteria, such as contents of salts of various metals, toxic substences etc., if possible.

9.4.3 Bacteriological Investigations :

It is accepted that the changes of physical and chemical characteristics of ground water sampled through the monitoring tube well may give good indications of pollutions caused by faecal matter deposits i.e., latrines and it is also an established fact that chemical pollutants may travel further than the bacteria (see the literature review). Still, evidences may be confusing, vague and influenced by so many known and unknown factors. Moreover, the dilutions of pollutants may become such that analytical procedures adopted may not be able to evaluate or detect them. Therefore, much more attention has been given to bacteria, natural habitats of which are human gut and they are excreted in the faeces in such a number that dilution effect influence the monitoring with much less significance.

Faecal coliforms (mostly Escherichia coli) are recognized for a long time to evaluate the hygienic quality of water. Faecal streptococci are also given much importance. Clostridium wellchi (cl. perfringens) and recently Pseudomonas aeruginosa and bifid-bacteria (Bifidobacterium) are also taken into considerations.

Natural habitats of all these organisms are warm blooded animals (with some exceptions) and so they are called "faecal indicators". Established methods for detecting and enumerating faecal coliforms and faecal streptococci have been established long before. But controversy over the most effective or suitable methods has not been over, specially, recently much studies have been done on the improvement of the routine methods as it has been found that a large number of factors which have not been given importance before, can affect the routine procedures, sometimes rather drastically, specially where the pollution is not recent or the organisms are under stress. The latter cause has been given much attention and suitable methods have been attempted to develop for better detection and or enumeration (see the literature review). So, comparatively more elaborate attention should be given in this area of investigations.

For routine investigations, it is not possible to monitor all the faecal indicators mentioned above. As it has been done in the investigations described in this report, detection and enumeration of faecal coliforms and faecal streptococci may be considered as sufficient. Other faecal indicators may be determined periodically. Total bacterial count or standard plate count and determinations of total coliforms are helpful to determine the extent of pollution. The characterization of the organisms isolated from this count plate would give a good picture of bacterial pollution of under ground water, specially when compared with the spectra of organisms of the soils and latrine contents, a good number of pollution characteristics is expected to come out.

To be more specific, the following recommendations are described below :

a. Determination and Enumeration of Faecal Coliforms :

As it has already been mentioned above that the microorganisms when present in the under ground are under stress. So, special recovery method for the recovery of injured cells may be necessary. In this case modified membrane filter method (see the literature review) may be adopted. In the preliminary investigations, this should be checked. Turbidity masks the colony formation by faecal coliforms (see the literature review). So either prefiltration method should be adopted for these samples or MPN (most propable number/tube dilution technique) may be followed. It is recognized that all the faecal coliforms are not Escherichia coli, so differentiation of faecal coliforms isolated periodically (say, once in a month) will give more specific picture concerning the source of pollution e g. pit latrine.

b. Determination of total coliforms :

Though recently the determination of total coliforms as indicative of water quality has been disputed by many authors (see the literature review), such study would show generally the extent of pollution and when compared with the faecal coliforms, the source of contamination may be better explained. Usual membrane filter technique may have to be modified as per preliminary investigations as in the case of faecal coliforms to recover the possible injured cells. For turbid samples, prefiltration or MPN technique may have to be used as also in case of faecal coliforms and faecal streptococci.

c. Detection and enumeration of faecal streptococci :

Faecal streptococci survive apparently longer in water and hardly proliferate outside the gut. So their detection and enumeration has got some added advantage. It is also recognized that faecal coliforms and faecal streptococci ratio give a good indication of the source of pollution specially in recent contamination (see the literature review). The standard method of membrane filter technique using KF streptococcus agar may usually be followed, subject to modification in case of turbid samples, However, it would be advantageous if the faecal streptococci are differentiated further some of the streptococci recognised as faecal streptococci in routine procedures, may not be of faecal origin (soil or plant types). Human types, naturally, would be more suitable indicator to locate source of pollution, in this case, the pit-latrine. This differentiation of faecal streptococci may also be done as recommended in the case of faecal streptococci.

d. Standard Plate Count :

This may be done as routine procedure. The implication of total count has already been discussed.

e. Detection and Enumeration of Other Faecal Indicators :

The detection and enumeration of Pseudomonus aeroginosa, Clostridium perfringens bacteriods Bifidobacterium etc. may be done periodically (once in a month). But this will depend on the loads of works and should not be considered as obligatory.

f. Indentification of Bacteria Isolated from the Count Plate :

This work may also be done periodically (once in a month) following the standard method and criteria described in Bergey's Mannual of Determinative Bacteriology (the latest edition) at least upto the genus level. The application of this study has been discussed above.

9.5. Evaluation of Findings :

9.5.1 Hydrogeological Studies :

The following facts from the findings should be established soundly :

a. The relationship between the inclination of water table (i.e.aquifer level) and their possible effects on the flow of underground water and the pollution.

b. Relationship of the soil characteristics, porosity,capillary action, pH, typification (on the basis of sand clay etc. contents) and their characteristics eg. grain size, uniformity etc, general chemical and other physical characteristics with the horizontal and vertical flow of pollution and the capacity to make barrier to the travel of pollution.

c. Establishment of direction and rate of flow and their relationships with the travel of pollution, both chemical (which is supposed to flow farther then the bacterial pollution) and bacterial pollution. As it is apparently an established fact that the pollution does not travel against the flow direction to any considerable extent, the experimental wells installed to the opposite direction of the ground water flow are to be used as controls. This fact should be firmly established. The rate of flow is also important as it may have direct relationship with the extent of travel of pollution. In both cases, the seasonal effects are to be determined with reference to the travel of pollution. Moreover, the effects of various depths on the pollution characteristics are also be considered .

d. Relationship between height of water table (seasonal effect on the aquifer level) and the travel of pollution .

e. Evaluation of the changes of hydrogeological features with reference to migration of pollution with progress of time (as the study should continue for at least 3 years, this point should be considered as particularly important).

f. Possible effect of rainfall (the data on the rainfall should regularly be recorded or made to be available from the materiologi-cal department concerning the experimental zone) .

g. From the findings, attempts should be made to determine the width, and contoures, if any, of the pollution stream.

9.5.2 Physical and chemical studies :

In the above discussion, the implication of the findings of physical and chemical studies has already been considered.However, the following points should be considered and evaluated with reference to pollution travel and effects .

a. The effect of temperature on the survival of bacterial pollution flow .

b. The similar effect of pH, (the change in the pH of the wate samples compared with control may be considered as an extra indication of pollution .

c. Relationship between chloride and nitrate contents with bacterial pollution indicators (faecal indicators) : These compounds themselves may be considered as indicators of pollution when considerable variations (increases) are found comparing with the controls .

d. Effect of turbidity on the enumeration of faecal indicators

e. Implication of the presence of organic matters on the survival of faecal indicators and effect on pollution characteristics,

f. Effects of physical and chemical characteristics (conductivity, suspended and dissolved soilds, contents of inorganic salts etc.) on these survival and travel of faecal indicators.

g. Overall quality assessment on the basis of physical and chemical characteristics considering not only the hygienic aspects but aesthetic, laundry and other useful parameter also. Comparision between the extent of travel of chemical and bacteriological pollutions .

9.5.3 Bacteriological Studies :

In this case also, bacteriological findings have been involved in the above discussion. However, the deliberation and evaluation of the following points are vitally important :

a. Checking the methodology with the references to qualitative and quantitative aspects of the determination of faecal indicators, recovery of injured cells where necessary, comparison between MPN and MF methods (where MPN method is required to apply as in the turbid sample) and other relevant factors .

b. Determination of travel of faecal indicators with and against the flow directions (including lateral directions also to a limited extent). No doubt, this aspect of the study is the most vital one and the most determinating factors for drawing the final conclusions on the study. In this case, the findings on the differentiation of faecal indicators, both faecal coliforms and faecal streptococci should be taken into account and these would indicate more definitely the source of pollution .

c. Evaluation of determinations of other faecal organisms, such as Pseudomonus aeroginosa, Clostridium perfringens. bacteroides, etc. as faecal indicators (if such studies are done).

d. Relationship of standard plate counts with the occurrence of faecal indicators in the samples and consideration of standard plate counts as, additional criteria to determine the bacteriological contamination .

e. Evaluation of taxonomical findings (typification) of ground water bacterial flora (both qualitative and quantitative) when compared with controls and soil flora, as additional indicators of pollution.

It may be mentioned here that though human faeces contain many pathogens other than bacteria such as protozoa, helminths and viruses, only bacteriological studies have been suggested in these recommendations and guidlines because of the following reasons :

(i) It is considered that the filteration capacity of soil may easily prevent penetration of protozoa (eg.causing dysentery) and helminths (worms), because of their considerable bigger sizes, to the ground water if it is not grossly polluted vertically by some leakage directly to the aquifer. It is recommended that such chance should be eliminated during the study.

(ii) Viruses cause quite a number of diseases including infectious hepatitis, poliomyeletis, diarrhoeal diseases etc. and they are more resistant to antimicrobial agents such as chlorine and they can survive in soil for a considerable period. But it has also been found that inactivation of viruses is much more at the surface. Elaborate information on the survival of viruses in ground water are not available and it is considered they do not most probably, survive much longer than the bacterial pathogens. However, the study on the occurence and travel of viruses in the ground would be, no doubt valuable, but this will make the project much more expanded.

Moreover, few virologist is available in this country. So it is considered that concentrating on only bacterial flora in microbiological investigation will be sufficient to achieve the meaningful and practical informations.

However, it is quite welcome to carry out studies on protezoa, helminths and viruses, if the scopes and funds are available.

9.6. Personnel :

The report itself and the recommendations/guidelines clearly points out that a team of scientists from different disciplines (eg. Microbiology, Hydrogeology, Chemistry, Engineering, etc.,) should carry out the study . Their assistants should be given at least some preliminary training on such study and it is expected that they would be sufficiently trained after the completion of the preliminary phase of the study.

For the proper installations of monitoring tube wells and pit latrines and also for their maintenance, the services of sanitory engineers and mechanics are also necessary. So they should also be included into the investigating team.

The number of personnel should be determined according to the loads of work. It is suggested that chemists should be given adequate training to carry out routine microbiological tests and microbiologists should also be given training to carry out the routine chemical tests, because in case of emergency or if the loads of works become unusually high, the progress of work does not face difficulties.

It is also suggested that a overall supervisor of the calibre of a senior scientist and well conversant with the whole studies should be appointed. He may act also as project coordinator if the different agencies are involved.

If the study is being done by an established Institution where both microbiological and chemical investigations are to be done (such an Institution is suggested), many of the personnel described above may not have to be recruited, but they must be deputed by the concerned authority, on fulltime or part-time basis as required, for the project.

9.7. Conclusion :

The recommendations and guidelines for further study apparently include some experimental items of secondary importance or important only in special cases. These suggestions directed to a broad based study which is necessary considering the importance of the problem. However, the study-plan may be shortened to some extent according to the availablity of funds, facilities and manpower, but the following essential features should not be avoided :

(a) Creation of standard experimental conditions including proper selection of sites, installation of monitoring tube wells and the pit-latrine as recommended above.

(b) Determination of soil characteristics and the derection and rate of the flow and the level of the ground water.

(c) Determination of the most important faecal indicator organisms (i.e. faecal coliforms and faecal streptococci) in the experimental water samples.

(d) Determination of primary physical characteristics of the water samples such as pH, temperature, turbidity, conductivity, solid contents etc.

(e) Determination of nitrate and chloride concentrations in the water samples.

(f) Sampling should be made in such a way so that they are considered to be the true representatives of the ground water.

(g) The study period should cover such a length of time so that the data obtained may clearly indicate whether pit latrine contaminate the ground water and the manner of such contamination when found; it would also give enough scope to determine the seasonal variations of experimental parameters.

(h) The study-plan should have the flexiblity to include any experimental item, when found necessary.

10. REFERENCES

1. Allen, L.A., Pasley, S.M. and Pierce, M.A.F. 1952. Some Factors Affecting the Viablity of Faecal Bacteria in Water. J. Gen. Microbiol 7 , 36-43.

2. APHA, AWWA, WPCF. 1965 and 1980. Standard Methods for the Examination of Water and Waste Water (the 12th and 15th Eds). American Public Helth Assoc. Washington, D.C. USA.

3. Baars, G.K. 1957. Travel of Pollution and Purification en route in sandy soils. Bull. Wld. Hlth Org. 16 , 727-742.

4. Bagley, S.T. and Seidler, R.J. 1977. Significance of Fecal Coliform Positive Klebsiella. App. Environ. Microbiol. 33, 1141-1148.

5. Barness, E.M. 195?. Tetrazolium Reduction as Means of Differentiating Streptococcus faecalis from Streptococcus faecium J. Gen. Microbiol. 14, 57-58 .

6. Bissonoette, G.K., Jezeski, J.J., McFeters, G.A. and Stuart, D.G. 1975. Influence of Environmental Stress on Enumeration of Indicator Bacteria from Natural Waters. Appl.Microbiol. 29, 186-194.

7. Bissonnette, G.K., Jezeski, J.J., McFeters, G.A.and Stuart, D.G. 1977. Evaluation of Recovery Methods to Detect Coliforms in water Appl. Environ. Microbiol., 33 590-595 .

8. Bradley, D.J. 1977. Health and Water Quality. In water wastes and Health in Hot Climates (Ed,by Feachem, R., McGarry,M and Mara,D.J.). Wiley and Sons, London.

9. Brodsky, M.H. and Scniermann, 1975. Influence of Coliform Source on Evaluation of Membrane Filters. Appl. Microbiol. 30, 727-730 .

10. Broun, K.W., Walf, H.W., Donelly, K.G. and Slawey, I.F. 1979. The Movement of Fecal Coliforms and Coliphages below Septic Lines. J. Environ. Qual. 8, 121-125.

11. Buchan, S. and KY, A. 1956. Pollution of Ground Water in Europe Wld. Hlth. Org. 14, 949-1006 .

12. Burke, V. and Taschner, L.1936. Growth of *Escherichia coli* in a Small Amount of Organic Matter. J. Bacteriol. 32,124-125.

13. Caldwell, E.L.1937. Pollution from Pit Latrines When an Impervious Stratum Closely Underlies the Flow. J. Infectious Dis. 61, 270-288.

14. Caldwell, E.L. and Parr, L.W. 1937, Ground Water Pollution and Boared Hole Latrine. J. Infectious Dis. 61, 148-183.

15. Caldwell, E.L. 1938. Studies of Subsoil Pollution Relation to Possible Contamination of Ground Water from Human Excreta Deposited in Experimental Latrine. J. Infectious Dis.62, 272-292.

16. Christian, R.R and Pipes, W.O. 1983. Frequency Distribution of Coliforms in Water Distribution Systems. Appl.Environ. Microbiol. 45, 603-609.

17. Cooper, K.E. and Ramsden, F.M. 1955. Studies in the Differentiation between Human and Animal Pollution by Means of Faecal Streptococci. J. Gen Microbiol. 12, 180-190.

18. Dutka, B.J. 1973. Coliforms are an Inadequate Index of Water Quality J. Environ. Health, 36, 39-46.

19. Dyer, B.R. and Bhaskaran, T.R. 1943. Investigation of Ground Water Pollution. Part I. Determination of Direction and Velocity of Flow of Ground Water. Indian J. Med. Res. 31, 231-243.

20. Dyer, B.R., Bhaskaran, T.R. and Sekar, C.C. 1945a. Investigation of Ground Water Pollution. Part III. Ground Water Pollution in West Bengal, India. Indian J. Med. Res. 33, 23-62.

21. Dyer, B.R. and Bhaskaran, T.R. 1945b. Investigations of Ground Water Pollution. Part II. Soil Characteristics in West Bengal, India at the Site of the Ground Water Pollution Investigations. Indian J. Med. Res. 33, 17-22.

22. Elrod, R.P. 1942 The Erwinia-Coliform Relationship. J. Bacteriol. 44,433-440.

23. Evans, T.M. Waarvick, C.E., Seidler, R.J. and Lechevallier, M.W. 1981a. Failure of the Most Probable Number Technique to Detect Coliforms in Drinking Water and Raw Water Supplies. Appl. Microbiol. 29, 532-536.

24. Evans, T.M., LeChevallier, M.W., Waarvick, C.E. and Seidler, R.J. 1981b. Coliform Species Recovered from Untreated Surface Water and Drinking Water by Membrane Filter, Standard and Modified Most-probable Number Techniques. Appl. Environ. Microbiol. 41, 657-663.

25. Evans, T.M., Seidler, R.J. and LeChevallier, M.W. 1981c. Impact of Verification Media and Resuscitation on Accuracy of Membrane Filter Total Coliform Enumeration Techniques. Appl. Environ. Microbiol. 41, 1144-1151.

26. Feachem, R.G. Bradley, D.J., Garelick, H. and Mara, D.D.1977. Appropriate Technology for Water Supply and Sanitation. Health Aspects of Excreta and Sullage Management-A State-of-the Art Review. World Bank. Washington, D.C. USA.

27. Franzblau, S.G., Hinnebusch, B.J., Kelly, L.M. and Sinclair, N.A. 1984. Effect of Noncoliform on Coliform Detection in Potable Ground Water: Improved Recovery with an Anaerobic Membrane Filter Technique. Appl. Environ Microbiol. 48, 142-148 .

28. Gyllenberg, A., Niemela, S. and Sormunen, T. 1960. Survival of Bifid Bacteria in Water as Compared with that of Coliform Bacteria and Enterococci. App. Microbiol. 8, 20-22.

29. Grabow, W.O.K., Hilner, C.A. and Caubrough, P. 1981. Evaluation of Standard and Modified M-FC, McConkey and Teepol Media for Membrane Filtration Counting of Fecal Coliforms in Water. Appl. Environ. Microbiol. 42, 192-199.

30. Hagedorn, C., Hansen, D.T. and Simpson, G.H. 1978. Survival and Movement of Faecal Indicators Bacteria in Soil under Conditions of Saturated Flow. J. Environ. Qual. 7, 55-59.

31. Hsu, S.C. and Williams, T.J. 1982. Evaluation of Factors Affecting Membrane Filter Technique for Testing Drinking Water. Appl. Environ. Microbiol. 44, 453-460.

32. Kabler, P.W. 1968. Microbial Considerations in Drinking Water. J. Am. Water Works Assoc. 60, 1173-1180.

33. Kibbey, H.J., Hagedorn, C. and McCoy, E.L. 1978. Use of Faecal Streptococci as Indicator of Pollution in Soil. Appl. Environ. Microbiol. 35, 711-717.

34. Lanoix, J.N. and Wagner, E.J. 1958. Excreta Disposal for Rural Areas and Small Communities. WHO, Geneva.

35. LeChevallier, M.W. and Seidler, R.J. 1980. Staphylococcus aureus in Rural Drinking Water. Appl. Environ. Microbiol. 39, 739-742.

36. LeChevallier, M.W., Evans, T.M. and Seidler, R.H. 1981. Effect of Turbidity on Chlorination Efficiency and Bacterial Persistence in Drinking Water. Appl. Environ. Microbiol. 42, 159-167.

37. LeChevallier, M.W., Cameron, S.C. and McFeters, G.A. 1983. New Medium for Improving Recovery of Coliform Bacteria from Drinking Water. Appl. Environ. Microbiol. 45, 484-492.

38. LeChevallier, M.W., and McFeters, G.A. 1985. Interactions Between Heterotrophic Plate Count Bacteria and Coliform Organisms. Appl. Environ. Microbiol. 49, 1338-1341.

39. LeChevallier, M.W. and McFeters, G.A. 1985. Enumerating Injured Coliforms in Drinking Water. J.Am. Water Works Assoc. 77, 81-87.

40. Lewis. W.J., Foster, S.S.D and Draser, B.S. 1980. The Risk of Ground Water Pollution by on-Site Sanitation in Developing Countries (a Literature Review). Int. Reference Centre for Waste Disposal. Duehendorf, Switzerland.

41. Lieber, M. and Martin, A.J. 1965. Detection of Coliform Organisms by the Flourescent-Antibody Method. J. Am. Water Works Assoc. 57, 99-106.

42. Mallman, W.L. and Litsky, W. 1951. Survival of Selective Enteric Organisms in Various Types of Soil. J. Pub. Hlth., 41, 38-44.

43. Mathur, R.P. and Ramanathan, K.N. 1966. Significance of Enterococci as Pollution Indicator. Environ. Health. VIII, 1-5.

44. Maxcy, R.B. 1970. Non-Lethal Injury and Limitations of Recovery of Coliform Organisms on Selective Media. J. Milk. Fd. Technol. 33, 445-448.

45. McDaniels, A.E., Bordner, R.H., Gartside, P.S., Haines, J.R., Brenner, K.P., and Ranking, C.C. 1985. Holding Effects on Coliform Enumeration in Drinking Water Samples. Appl. Environ. Microbiol. 50, 755-762.

46. McFeters, G.A. and Stuart, D.G. 1972. Survival of Coliform Bacteria in Natural Water : Field and Laboratory Studies with Membrane Filter Chambers. Appl. Microbiol. 24, 805-811.

47. McFeters, G.A., Bissonnette, G.K. Jezeski, J.J., Thomson, C.A. and Stuart, D.G. 1974. Comparative Survival of Indicator Bacteria and Enteric Pathogens in Well Water. Appl. Microbiol. 27, 823-829.

48. McFeters, G.A., Cameron, [illegible].C. and LeChevallier, M.W. 1982. Influence of Diluents, Media, and Membrane Filters on Detection of Injured Waterborne Coliform Bacteria. Appl. Environ. Microbiol. 43, [illegible]-46.

49. McGinnis, J.A. and [illegible], F. 1983. The Movement of Typhoid Organisms in Saturated, Permeable Soil. J.Am. Water Works Assoc. 75, 1266-1279.

50. Medrek, T.F. and Litsky, W. 1960. Comparative Incidence of Coliform Bacteria and Enterococci in Undisturbed Soil. Appl. Microbiol. 8, 60-63.

51. Milbauer, R. and Grossowicz, N. 1959. Reactivation of Chlorine Inactivated *Escherichia coli*. Appl. Microbiol. 7, 67-70.

52. Moore, W.E.C. and Holdeman, L.V. 1974. Human Faecal Flora : The Natural Flora of 20 Japanese-Hawiians. Appl. Microbiol. 27, 961-979.

53. Moussa, R.S. 1965. Type Distribution of Coliforms Isolated from Faecal and Non-Faecal Habitats. Indian J. Med. Res. 53, 629-637.

54. National Institute of Nutrition, 1971. A Mannual of Laboratory Technique. Natl. Inst. Nutrition, Indian Council of Med. Res. Jamia Osmania, Hyderabad, India.

55. Pavlova, M.T., Brezenski, F.T. and Litsky, W. 1972. Evaluation of Various Media for Isolation, Enumeration and Identification of Faecal Streptococci from Natural Sources. Health Lab. Sci. 9, 289-298.

56. Pawley, J.D. 1982. Ground Water Pollution : a Case Study. J.Am. Water Works Assoc. 74, 405-407.

57. Pipes, W.O. and Christian, R.R. 1984. Estimating Mean Coliform Densities of Water Distribution Systems. J.Am. Water Works Assoc. 76, 60-64.

58. Presswood, W.G. and Strong, D.K. 1978. Modifications of FM-FC Medium by Eliminating Rosolic Acid. Appl. Environ. Microbiol. 36, 90-94.

59. Ray, B. and Speck, M.L. 1972. Repair of Injury Induced by Freezing Escherichia coli as Influenced by Recovery Medium. Appl. Microbiol. 24, 258-263.

60. Ray, B. and Speck, M.L. 1973a. Discrepancies in the Enumeration of Escherichia coli. Appl. Microbiol. 25, 494-498.

61. Ray, B. and Speck, M.L. 1973b. Enumeration of Escherichia coli. in Fzozen Samples after Recovery from Injury. Appl. Microbiol. 25, 499-503

62. Reilly, J.K. and Kippin, J.S. 1983. Relationship of Bacterial Counts with Turbidity and Free Chlorine in Two Distribution System J.Am. Water Works Assoc. 75, 309-312.

63. Reinhard, [illegible] and Belocchi, A.J. 1982. Movement of Organic Contaminant in Ground Water. J.Am. Water Works Assoc. 74, 406-413.

64. Reitler, R. and Seligmann, R. 1957. Pseudomonas aeruginosa in Drinking Water. J. Appl. Bact. 20, 145-150.

65. Resnick, J.G. and Levin, M.A. 1981. Assessment of Bifidobacteria as Indicators of Human Faecal Pollution. Appl. Environ. Microbiol. 42, 433-438.

66. Rose, R.E., Geldreich, E.E. and Litsky, W. 1975. Improved Membrane Filter Methods for Faecal Coliform Analysis. Appl. Microbiol. 29, 532-536.

67. Salvato Jr., J.A., 1972. Environmental Engineering and Sanitation Wiley Interscience, New York.

68. Schaeffer, D.J., Long, M.C. and Janardan, K.G. 1974. Statistical Analysis of the Recovery of Coliform Organisms on Gelman and Millipore Membrane Filters. Appl. Microbiol. 28, 605-607.

69. Scheusner, D.L., Busta, F.F. and Speck, M.L. 1971. Injury of Bacteria by Sanitizers. Appl. Bacteriol. 21, 41-45.

70. Seidler, R.J., Evans, T.M., Kaufman, J.R., Waarvick, C.E. and Lechevallier, M.W. 1981. Limitations of Standard Coliform Enumeration Techniques. J.Am. Water Works Assoc. 57, 99-106.

71. Standridge, J.H. and Delfino, J.J. 1982. Underestimation of Total Coliform Counts by the Membrane Filter Verification Procedure. 44, 1001-1003.

72. Stuart, D.G., McFeters, G.A. and Schillinger, G.E. 1977. Membrane Filter Technique for the Quantification of Stressed Fecal Coliforms in the Aquatic Environment. Appl. Environ. Microbiol. 33, 590-595.

73. Temple, L.K., Kamper, K.A. and McFeters, G.A. Survival of Two Entero-bacteria in Feces Buried in Soil under Field Conditions. Appl. Environ. Microbiol. 40, 794-797.

74. Tobin, R.S., Lomak, P. and Kushner, D.J. 1980. Comparison of nine Brands of Membrane Filter and the Most Probable Number Methods for Total Coliform Enumeration in Sewage-Contaminated Drinking Water. Appl. Environ Microbiol. 40, 186-191.

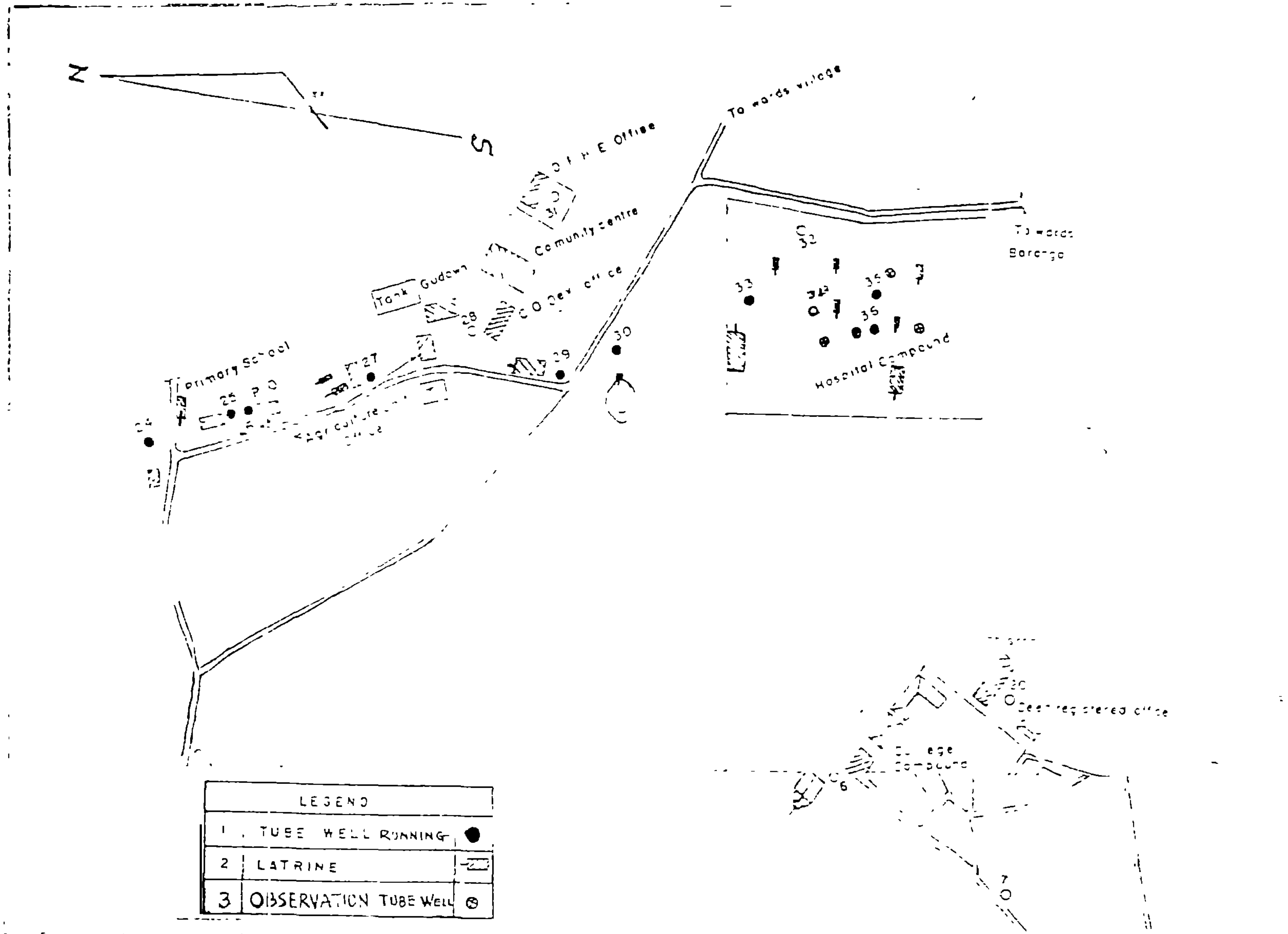
75. Ward, C.F. and Schertenleib, R. 1982. On-Site Sanitation and Ground Water: The Pollution Risk (Executive Summary of Two IRCWD Reports). IRCWD, News, No. 16.

76. Woodhull, R.S. 1981. Ground Water Contamination in Connecticut. J.Am. Water Works Assoc. 73, 188-189.

77. Woodward, F.L., Kilpatrick, F.J. and Johnson, P.B. 1961. Experience with Ground Water Contamination in Unsewered Areas in Minnesota. Am.J. Pub. Hlth., 51, 1130-1136.

11. APPENDIX :

The Maps of the Experimental Locations.



of ground water from pit latrine

Particulars of tube wells

Name of care Taker		T.W. No.	R.L.
Sanitary inspector quarter	0	24	96.00
Great primary school	0	25	98.00
RADC inspectors office	0	26	96.90
C.O's ... quarter	0	27	98.60
Azhar Ali	0	30	93.5[illegible]
Health Complex	0	33	[illegible]
"	0	35	97.58
"	0	36	100.00

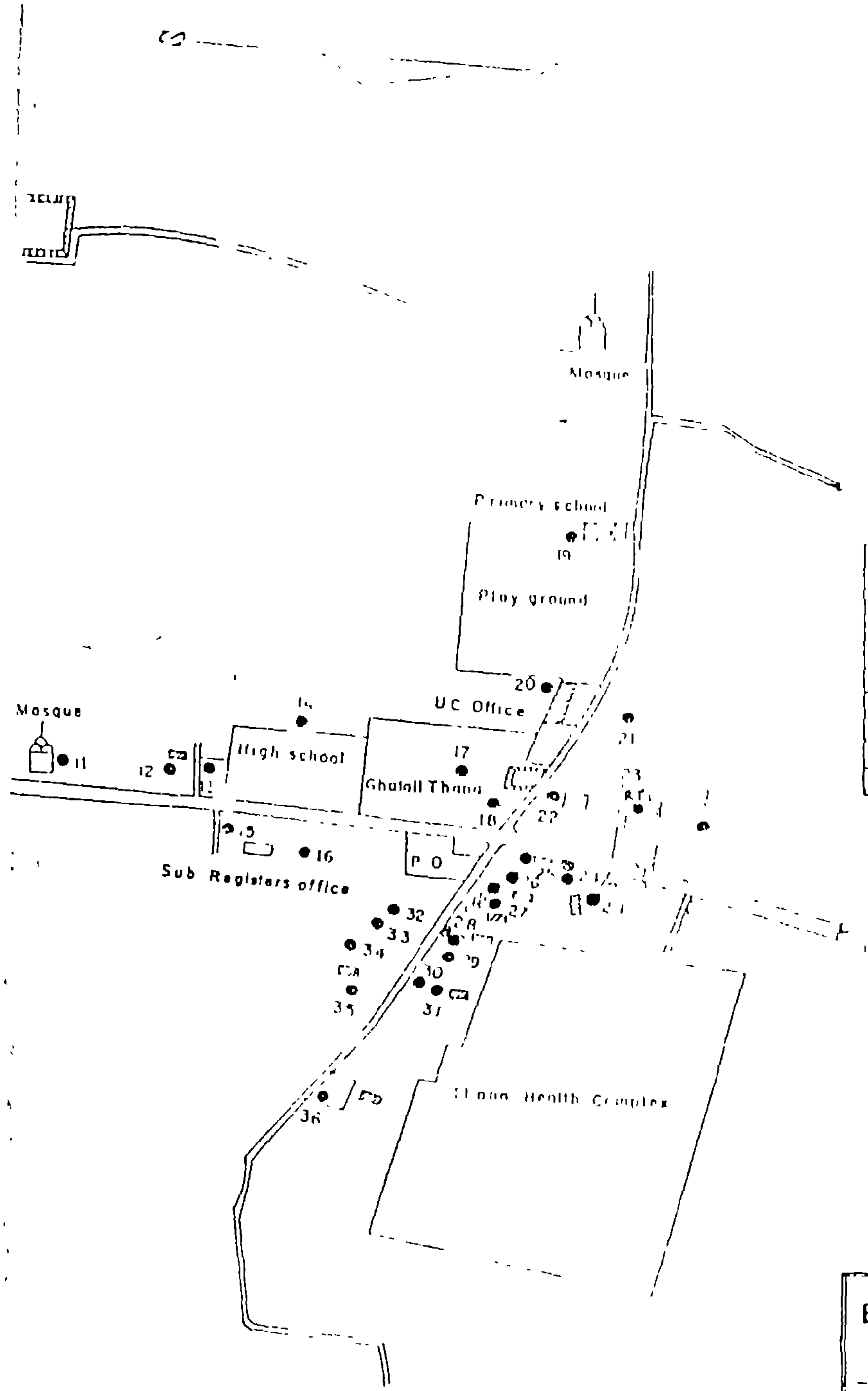
BASE MAP OF GHIOR AT MANIKGONJ

P H E DESIGN DIV

Date, Oct/83

Scale 1 = 330

P H E DESIGN DIV.



PARTICULARS OF TUBE WELL

Name of caretaker	T. W.	Nos	R. L.
MATILAL ALI	●	[illegible]	19.62
A. JALIL	●		[illegible] 66
A. GAFUR	●	[illegible]	[illegible]
A. JALIL	●		[illegible] 24
JALIL	●	[illegible]	[illegible]
SUJAT ALI	●	[illegible]	[illegible]
MAJAM ALI	●		[illegible]

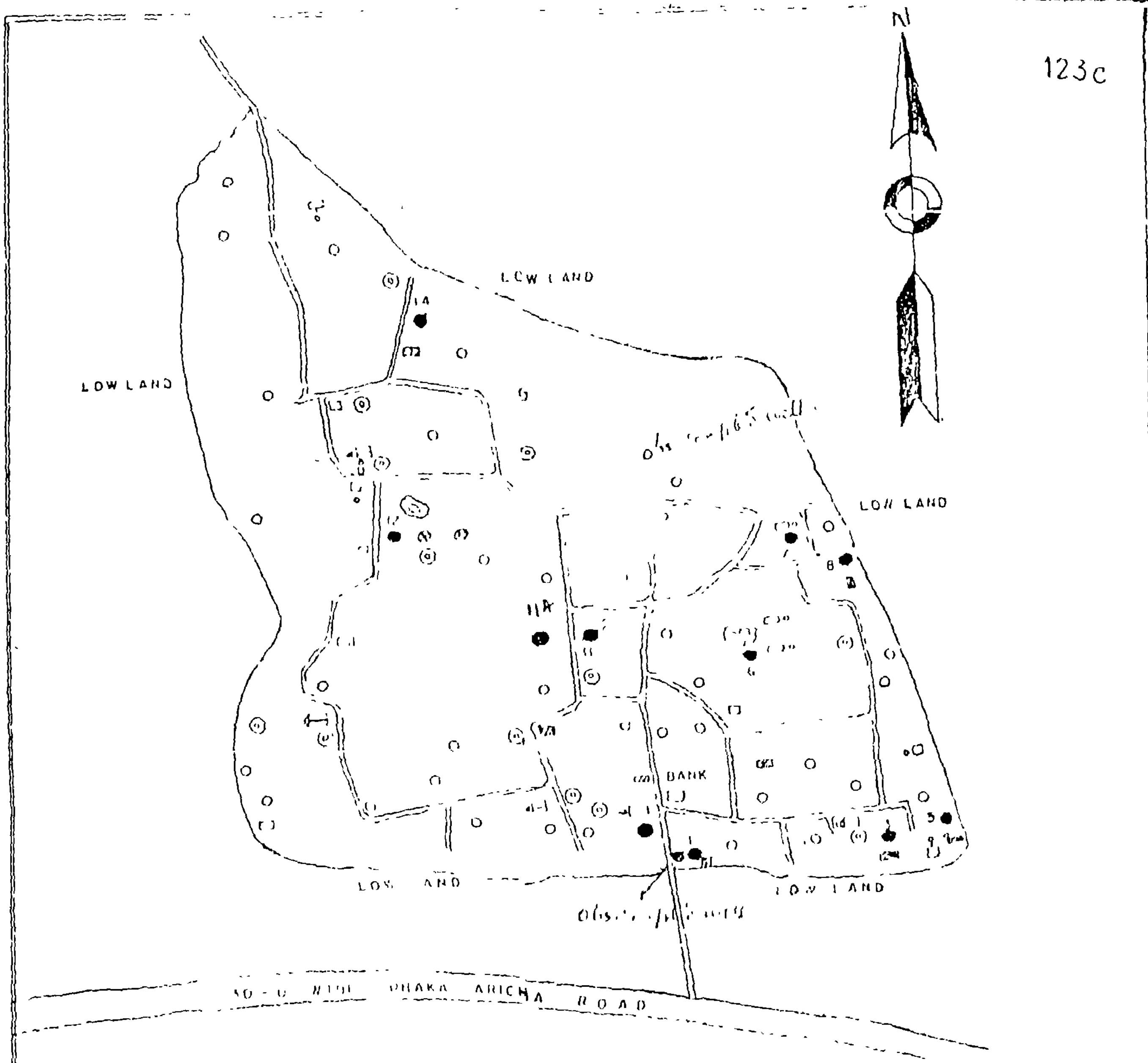
	LEGEND	
1	RUNNING TUBE WELL	●
2	LATRINE	▭
3	OBSERVATION WELL	⊖

BASE MAP OF GHATAIL AT TANGAIL
P. H. E. DESIGN DIV.

Date - Oct/83
Scale 1" = 330

P. H. E. DESIGN DIV.

123c



RESEARCH STUDY
POLLUTION OF GROUND WATER
FROM PIT LATRINES

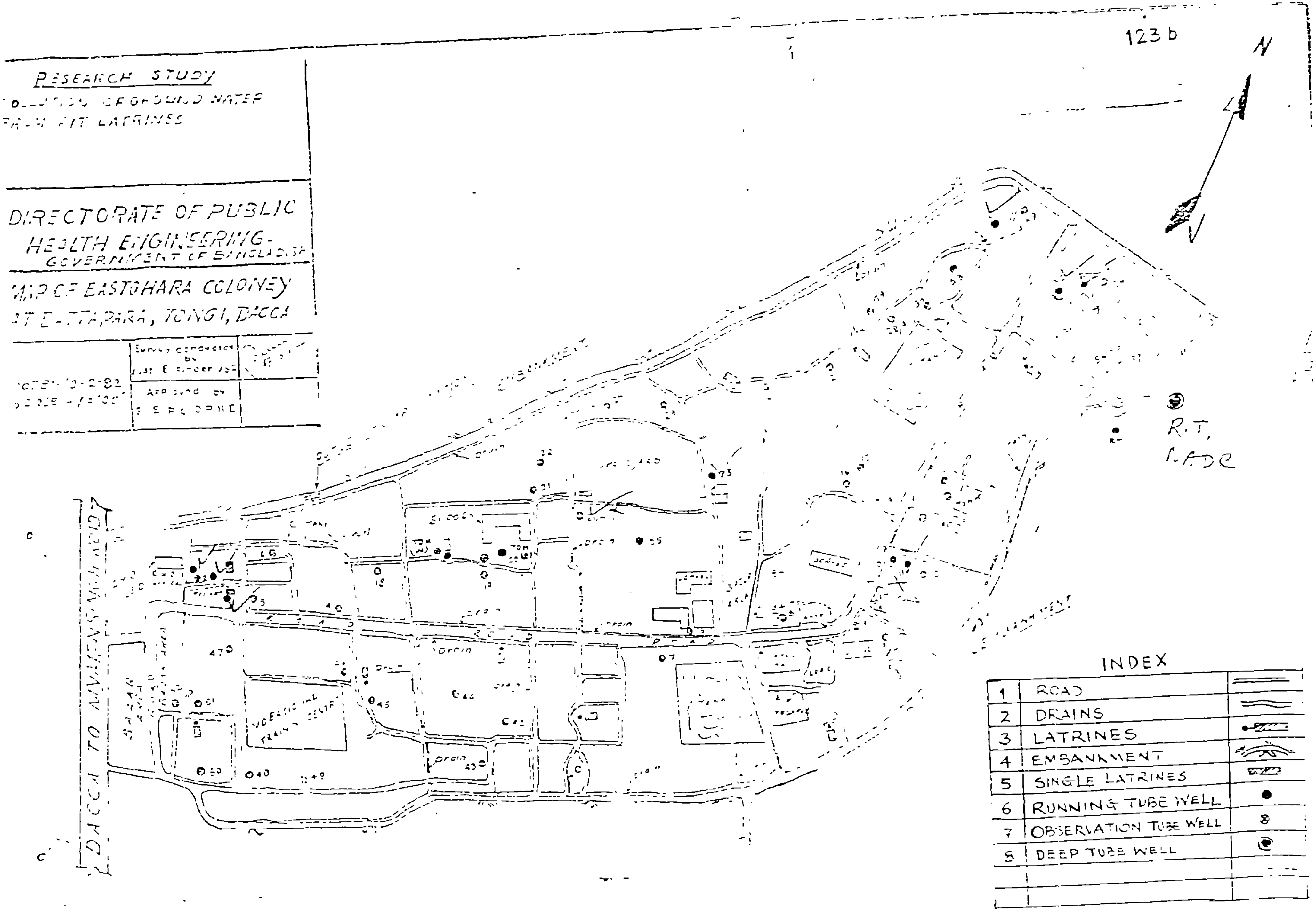
INDEX

TUBE WELL (GOVT)	O
TUBE-WELL (PRIVATE)	O
KUTCHA DUG-WELL	O
PUCCA DUG-WELL	O
SANITARY LATRINE	
KUTCHA LATRINE	
MOSQUE	
DITCH	
TUBE WELLS RUNNING.	●
OBSERVATION WELL	

DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH

BALIAR PUR

Scale - 1" = 330'		Survey conducted by Asst Engineer VS II	
		Approved by— S E P C DPHE	


123 b
N
RESEARCH STUDY
DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH
MAP OF EASTOHARA COLONEY
Survey conducted by
Approved by
EMBANKMENT
ROAD
Drain
SCHOOL
VOCATIONAL TRAINING CENTRE
R.T. MADE
DACCA TO MYMENSINGH ROAD
INDEX
1 ROAD
2 DRAINS
3 LATRINES
4 EMBANKMENT
5 SINGLE LATRINES
6 RUNNING TUBE WELL
7 OBSERVATION TUBE WELL
8 DEEP TUBE WELL

RESEARCH STUDY

POLLUTION OF GROUND WATER
FROM PIT LATRINES

LEGEND

- KUTCHA LATRINE
- TUBE-WELL (Govt)
- TUBE-WELL (Private)
- DITCH
- PASSAGE
- DRAIN
- TUBE-WELL RUNNING

DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH

SAHID NAGAR
LALBAGH, DACCA

Date
10-2-82
Scale
1"=100'

Approved by

File #403
10 November 1987

NOTE FOR THE RECORD

Groundwater Pollution from Pit Latrines

Introduction

UNICEF and WHO have assisted a study on the pollution of groundwater from pit latrines, conducted by the Bangladesh Council of Scientific and Industrial Research (BCSIR). UNICEF provided some of the funding and was represented on the Review Committee. The report of this study makes statements which, if taken out of context and reported without any balancing statements, could be used to cast doubt on the suitability of handpump tubewells as a source of domestic water and of pit latrines as a method of excreta disposal in Bangladesh. This Note for the Record has been prepared to counter such a suggestion.

The report states that, because the majority of samples tested indicated some measure of faecal pollution, "shallow tubewell water should not be regarded as safe or hygienically pure as drinking water under the prevailing circumstances in which these investigations were carried out"(p.87).

However, the report is inconclusive as to whether pit latrines are the source of the pollution and recommends further study to investigate this.

The report attributes the apparent inconclusiveness of the study to external factors outside the control of BCSIR, namely the inadequacy of the project design, the nature of the sites and sampling points and the failure to obtain hydrogeological data. However, the report ignores or plays down the problems deriving from the unreliability of many of the earlier sampling and testing techniques used in the study, as evidenced by the inconsistency of many results and the significant improvement achieved when improved techniques were introduced.

The presentation of the report itself is rather confusing to the reader : the tubewells are numbered inconsistently, the tables are poorly laid out, the data are not rigorously analysed, leading to what I feel are erroneous findings and the omission of some important conclusions.

contd....2

The Study

The study was intended to measure the quality of groundwater. In the first phase of the study, samples were taken from 45 handpumps used by the public and the results indicated a significant degree of contamination. Out of 45 handpumps tested for faecal coliforms per 100ml, 3 indicated TNTC (too numerous to count), 1 indicated 80, and the other 41 indicated 50 or less, with 13 registering 10 or less.(see Table 2B).

It was thought that these results may be due to external contamination rather than contamination existing within the groundwater itself so, in the second phase, observation wells were installed near some of the existing wells. The observation wells were not used by the public and extra precautions were taken during sampling, including washing the handpump with hot chlorinated water, and priming the handpump with chlorinated water. The sampling procedure was repeated three times for 4 running wells and their 4 observation wells. The results (Table 3B) in 2 of the 4 sites suggest serious sampling contamination or testing errors, because of the close proximity of TNTC results alongside very low figures. Apart from these apparently freak results, the samples from observation wells were generally less contaminated than from the running wells,,suggesting strongly that contamination is introduced by the users - a finding that is alluded to but not seriously discussed in the report. From UNICEF's point of view this is an extremely important factor. Furthermore, if the apparently freak TNTC result on the observation well of Baliapur No.1 is discounted, the average of the observations of the 3 least contaminated observation wells is less than 5 FC per 100ml, while only one observation well (TDM West) exhibits consistently significant pollution levels.

The procedure was repeated, this time with yet more stringent measures to reduce the risk of external pollution, including construction of pucca platform, disinfection of the observation tubewells with chlorinated water, and capping for 72 hours followed by purging. The results given in Table 4B indicate very little improvement in the quality of samples from the observation wells, but a significant improvement in the quality of samples from running wells.

contd....3

In general the quality from the observation wells is similar to or, surprisingly, worse than from the running wells. This suggests that while overall sampling and testing techniques have improved, they are still not completely reliable. It is significant to note that the average of all readings on the running tubewells is 5.6 faecal coliforms per 100ml, which is not a serious level of pollution in Banglac If contamination was due to pollution of the groundwater one might expect greater contamination in this phase which was conducted in the wet season, than in the previous phase conducted in the dry season.

In the last phase of sampling, a visiting consultant from the International Reference Centre for Waste Disposal (IRCWD) in Switzerland introduced the tube-technique for sampling, which improves the chances that the water sampled is from the aquifer itself, rather than from the (possibly contaminated) tubewell. Unfortunately, this technique was used on only one of the tubewell sites reported in Tables 3B and 4B, so it is not possible to measure directly the improvement brought about by this technique.The method was used on 7 running wells and their 7 observation wells. The result are given in Table 5B. It is not clear exactly which wells in Table 2-B correlate with those in Table 5B, because of inconsistencies in tubewell numbering. The results show one site (Dattapara No.2) consistently polluted, with the observation well,surprisingly, more polluted than the running well.

Of the other six sites, one site (TDM East) recorded TNTC in 2 samplings of the observation well against zero for the other 5 samples from the same well, suggesting the TNTC are spurious results due to external contamination. One site (KB new) recorded TNTC in the running well against zero for the observation well, again suggesting a spurious result due to external contamination. Considering the six observation wells, and discounting the two spurious results, 27 results were zero, and only three results positive (being 1, 2 and 12 FC per 100ml, suggesting that these six observation wells were basically unpolluted. Considering the six running wells, and discounting the one spurious result, 19 results were zero and 12 results positive (being 1,2,2,3,5,9,11,14,20,21,29,35) indicating generally low levels of pollution, probably from external sources (i.e.not groundwater).

contd....4

The one consistently polluted site (Dattapara No.2) is a tubewell of relatively shallow depth (14 metres), the running well is situated within 7.6 metres of 4 latrines and the observation well is within 4.5 metres of 3 latrines. If the pollution is caused by the proximity of these latrines, the combination of a shallow depth with such a large number of latrines within such a short distance is extremely rare (probably onl likely in urban squatter situations) that one can only conclude that the risk of pollution of groundwater from pit latrines is insignificant on a national scale in the foreseeable future.

It is clear that the results from the tube-technique for sampling are significantly more accurate, though the report plays this down. It should be noted that the tube-technique sampling was conducted in the dry season, so the results should be compared with Table 3-B (Feb-March) rather than Table 4-B (April-July).

The above analysis does not take into account the results of testing for faecal streptococci (FS). A brief review of FS results suggests similar or slightly lower numbers of FS than FC in the first two phases of sampling (Tables 2-B and 3-B), but slightly higher levels in the third and fourth phases (Tables 4-B and 5-B). Generally, the FS results do not appear to change the picture suggested by the FC results, though more detailed analyais (not done in the report) might reveal further insights.

Conclusions

The study has not been as inconclusive as the authors of the report claim. A more objective analysis of the data would lead to the following general conclusions:

a. There is no evidence to suggest a serious risk of pollution of groundwater by pit latrines at normal population densities, even with 100% coverage by latrines. (NB: current coverage level of pit latrines is about 10%, including non-sanitary types.)

b. There is evidence to suggest that under extremely dense housing conditions, pollution of the groundwater may reach a tubewell within, say, 10 metres of three or four latrines, if the tubewell is in an aquifer of 15m depth or less. (The risk may be considerably reduced by sinking the tubewell into deeper aquifer).

c. There is considerable evidence to suggest that pollution of tubewell water by the users themselves is common and more significant than the pollution of the aquifer by pit latrines.
(Users may pollute their water by introducing contamination

contd....5

into the tubewell or handpump during priming, by touching the spout with dirty hands and by using dirty water containers and failing to protect water in the containers from further pollution before consumption).

d. While the study indicates no cause for alarm as far as pollution of groundwater is concerned, further study is desirable to try to quantify the relative risks more accurately. However, such a study should not be undertaken unless the sampling and testing techniques are guaranteed to be reliable.

Furthermore, it could be postulated that:

e. The possible pollution of groundwater and the more common pollution of the tubewell water by the users is still significantly less than the gross pollution levels commonly found in surface water sources, which are the only alternative to tubewells in most of Bangladesh.

f. Epidemiologically, the proportion of pathogens transmitted specifically by drinking polluted tubewell water is likely to be insignificant compared to the proportion transmitted by poor hygiene, hand washing and food handling practices, and by drinking water from surface sources.

g. It is difficult to measure faecal contamination of tubewell water in field conditions, because of the risk of accidental contamination of the sample and the difficulty in ensuring that the sample is representative. The tube-technique is clearly the most accurate method for sampling.

Colin E. R. Glennie
Coordinator, WES Section
UNICEF - Dhaka
10 November 1987

Swiss Federal Institutes of Technology

IRCWD International Reference Centre for Wastes Disposal
WHO Collaborating Centre associated with EAWAG*

Mailing address:
IRCWD/EAWAG
Ueberlandstrasse 133
CH-8600 Duebendorf
Switzerland

Telephone (01) 823 50 18/17
Telex 56 287 EAWA CH

Mr. Mohan Lal Gupta
Chief, Promotion of Env. Health
WHO-SEARO
World Health House
New Delhi 1.10.002 / INDIA

Your ref. BAN CWS 001/D Our ref. RSCH/bh 15-202 Duebendorf: 16th December 1987

Subject: Report on Pollution of Groundwater from Pit Latrines in Bangladesh

Dear Mr. Gupta,

Thank you very much for sending us a copy of the report on the above subject. Please excuse this tardy reply.

After going through the report, we would like to make the following comments:

- There is probably a tiping error in the second paragraph on Page 12: "Lower temperature and higher moisture (not temperature) both increase their survival periods.

- We are wondering if there is not a confusion between "observation" and "running" in table 4B (p. 65 ff). It does not make any sense that the fecal contamination in the running tube wells are suddenly very low whereas the counts of fecal coliforms in the observation wells are consistantly much higher.

- After looking at all the data, we do not quite agree with the main conclusions given in the report. It is obvious that the sampling procedure had a significant influence on the results obtained. With the exception of tubewell No-2 in Dattapora, 27 out of 32 samples from observation tubewells had 0 fecal coliforms (FC) per 100 ml, one sample had 1 FC/100 ml, an other had 2 FC/100 ml and in one sample 12 FC were counted. In the remaining two of the 32 samples there were "too many fecal coliforms to be counted", that means more than about 100 FC/100 ml. These two samples must have been contaminated during sampling or during the analysis. If the observation

*Swiss Federal Institute for Water Resources and Water Pollution Control

9.85 2000 32610/2

tubewell TDH-East would be contaminated by a pit-latrine, one would not have observed five times zero FC-counts and suddenly more than 100. It is also possible that the sudden high counts are due to contamination from the top because of heavy rainfalls. Unfortunately we have no information if the two samples were taken before or after the rainy season started.

As we mentioned already in our letter of 23 July 1986 to Dr Myat, the results obtained from the observation tubewell No.2 in Dattapora are not astonishing considering the hydrological situation at this observation point. The data correspond to the observation made by Mr. Morand at the site. It seems that the dirty drainage/surface water which is literally flowing over the tubewells does contaminate them from the top. This is also why Mr. Morand did not select these observation tubewells for the tests as he expected contamination from the top.

In summary, only one out of 32 samples showed a fecal coli count of more than 2 FC per 100 ml. In addition, at the site where once 12 FC/100 ml were counted, 4 other samples showed zero FC/100 ml. Therefore, with regard to fecal coliforms, it can be definitely concluded that the water in all except one (No. 2 in Dattapora) observation tubewells is not contaminated by fecal material.

This conclusion is obviously contradicting to the interpretation of the results by the authors of the report. In their opinion, the results obtained in the investigations clearly indicate that the water of the tubewell is contaminated by fecal pollutants. This interpretation is mainly based on the counts of fecal streptococci (FS). However, the usefullness of FS as indicator for fecal contamination is now very much open to question because some strains of nonfecal streptococci are indistinguishable from true fecal streptococci under routine detection or counting procedures. Especially at densities below 100 FS per 100 ml, the ubiquitous *S. faecalis var. liquefaciens* has been reported as the predominant biotype (s. enclosed literature). By far most of the FS counts in the tubewells were even below 50 FS/100 ml. In fact, we observed in other projects that the analysis of fecal streptococci in groundwater samples is not a reliable indicator for fecal pollution. Even in cases where fecal contamination of the groundwater could be excluded, we often found FS in groundwater samples. In the report, the discrepancy between FC counts and FS counts is attributed to the fact that FS survive longer in water than FC. This is basically true. However, pit latrines are a continuous source of pollution. With a continuous recharge of fecal organisms into the ground it is very unlikely that in case of fecal contamination practically all have died.

As a whole, we believe that the results obtained in these investigations indicate quite clearly that the fecal contamination of the groundwater at the experimental sites (except at tubewell No.2 in Dattapora) is minimal and cannot be attributed to the pit latrines. The relatively low nitrate concentrations in all samples are also indicating that there is no fecal contamination from the pit latrines.
Therefore, we are not at all convinced that there is any need for conducting more elaborate studies as suggested in the report. On the other hand, we realized that in the last phase there were samples taken only in the dry season. The most critical situation with regard to pollution however, occurs during and especially towards the end of the rainy season when the groundwater table is highest. Unfortunately, there is very little information in the report about the situation during the rainy season. It would be very important to know how much the groundwater level rises. The most critical factor for pollution is the minimal distance between the highest groundwater level and the bottom of the pit. Therefore, we believe it would be worthwhile to make another sampling campaign during the second half of the next rainy season. The level of the groundwater should then also be monitored. This would also be a good opportunity to find out if the fecal streptococci could be further differentiated. In our opinion, a decision on further, more systematic and elaborate studies should be based on these results obtained during the rainy season.

These are our most important comments to the report of the BCSIR on the pollution study in Bangladesh. Please keep us informed about further developments.

With kind regards

Sincerely yours,

Schertenleib

R. Schertenleib
Director IRCWD