SOCIO-ECONOMIC UNITS, KERALA

KERALA WATER AUTHORITY

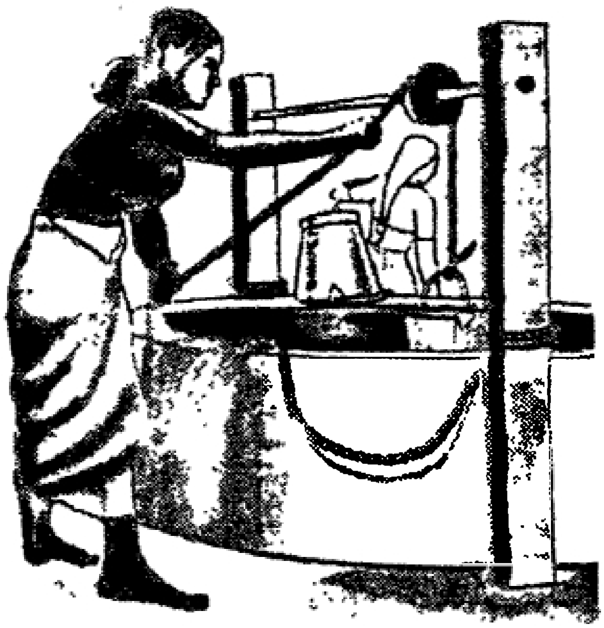
INTEGRATED WATER SUPPLY & SANITATION PROGRAMME

Co-ordinating Office :
Post Bag 6519, Vikas Bhavan P. O., Thiruvananthapuram 695 033
[illegible] 68 [illegible] Telex [illegible] 435) - 879 Fax 91 - 0471 - 65347

[redacted]

RESEARCH REPORT No. 6

THE BACTERIAL QUALITY OF WATER IN SELECTED WELLS IN KERALA: an investigation



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KERALA STATE POLLUTION CONTROL BOARD

SOCIO-ECONOMIC UNITS OF THE KERALA WATER AUTHORITY

Co-ordinating Office:
Post bag 6519, Vikas Bhavan P.O.
Trivandrum 695 033
Phone (0471) 68907 Telex (435) - 375

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No.3 Survey of Data on Water-Borne and Water-related Diseases in the 73 panchayats of the KWA/SEU Project area, Kerala Statistical Institute, 1989.

No.4 Drinking Water in Kerala - Facts, Figures and Opinions on the use, availability and treatement of water, R. Suresh, 1989

No.5 Jeevadhara (Fountain of Life), Report on the evaluation of radio brodcast on protected water supply and environmental sanitation, K.Balachandra Kurup and M.L. Leena, 1991.

In case of interest in any of these or future reports, please contact the Executive Co-ordinator, SEU-Kerala at the address overleaf.

PREFACE

The quality of drinking water, often reflecting the sanitary consciousness of the user, is a direct indicator of the quality of life of any society. It is also indicative of the status of the environmental quality in the particular region. Even though monitoring of various environmental variables, including drinking water sources, is one of the functions of the State Pollution Control Board, priority considerations and infrastructure shortages prevented the State Board from extending its activity in the monitoring of drinking water sources. In this context it was with a sense of fulfillment that the Board accepted the suggestion of the Socio-Economic Units, Kerala Water Authority to undertake the present study aimed at assessing the quality of the drinking water sources viz. selected wells in the three zones where the units operate.

This study has helped to assess the quality of water in the wells of Kerala that are used as drinking water sources. The study also attempted to identify specific casual factors related to the quality of well water. One of these, the data indicates is the open nature of the wells themselves. However, beyond this, it was not possible to detect the specific factors or the mix of factors contributing to pollution because of the complexity of the local environments in the 150 randomly selected wells and limitations of a study of such short duration. However, the findings of the present study I am sure will be of great help in planning related studies in future.

I express my profound gratitude to Ms. Kathleen Shordt and Mr. K. Balachandra Kurup of the Socio-Economic Units for entrusting this important study to the Board and also to the staff members of the SEU who have been very helpful in the study.

I also place on record the initiative and dedication of Mr.R. Raveendran Pillai, Environmental Scientist of the Board who was the Officer in charge of the study and his team of Scientists in the Central Laboratory. I also acknowledge the good work done by Dr.C. Geevarghese, Assistant Environmental Scientist of the Head Office of the Board. Special mention has to be made of the guidance given by Dr. Balachandran, Senior Environmental Scientist of the Central Laboratory throughout the execution of the project.

(J.VENUGOPALAN NAIR)
MEMBER SECRETARY.

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INVESTIGATIONS ON THE BACTERIAL QUALITY OF WATER IN SELECTED WELLS IN KERALA

EXECUTIVE SUMMARY

This investigation, designed and executed by the Kerala State Pollution Control Board, sought to make an assessment of the bacterial quality of water with reference to fecal coliforms in open dug wells in Kerala. It also attempted to determine the extent to which factors influencing water quality (such as soil type, depth of well, presence of latrine pit or cattle shed, water use pattern) contributed to fecal contamination.

In total 150 wells were monitored, fifty each from the south, central and northern zones of the Socio-Economic Units of the Kerala Water Authority. Of these 150 wells, 144 are open wells and 6 are closed with hand pumps. Among the 144 open wells, 103 have SEU latrines in the vicinity while another 30 wells have other types of pits or septic tanks. Eleven open wells without any pits in the vicinity were also monitored. Water samples from the wells were analyzed four times, at intervals of approximately 2 weeks, during the period of December 1990 to April 1991. Along with fecal coliforms, three other parameters of water quality namely pH, conductivity, total dissolved solids were also monitored.

Based on the levels of fecal contamination in the water, the wells were classified into four quality classes. These classes are discussed in relation to factors which might influence the quality of water.

The general conclusions from the study are:

1. Water in none of the open wells investigated is of drinking water quality standard as prescribed by the Bureau of Indian Standards.

2. Water analyzed from covered wells with hand pumps that were as close as 5 meters to the SEU latrine pits were found to contain no fecal coliforms.

3. The open character of the wells and the conventional maintenance habits are found to be responsible for fecal pollution in them.

4. Pit latrines with average family load factor (5 members) at a distance of 5 meter from wells are found to make no contribution to the pollution of well water.

Though the study is limited to the three areas of Kollam, Thrissur and Kozhikode where the Socio-Economic Units of Kerala Water Authority operates, the observations can be generalised since the study has covered varied geological, social and cultural variables applicable to the State as a whole.

With these conclusions in mind, it is suggested that there should be a system for monitoring the quality of well water, since habits of poor maintenance overtake the programmes for disinfection and protection of wells resulting in water quality deterioration. As the present study is focussed on existing wells selected at random, it needs to be followed by a detailed study on the effects of leachates from latrine pits in different soil types at definite intervals of distance and time.

Implications of the Study: an addendum by the Socio-Economic Units

At the request of the Socio-Economic Units, this research study was reviewed, in draft form, by several professionals. We are thankful for their responses. Among these, two questions arose about the implications of this study. These are addressed in the following paragraphs:

Question: How is it possible that not one open well satisfied the Bureau of Indian Standards guideline for the bacterial quality of drinking water? Was the sampling procedure wrong in the study?

Indeed, none of the 144 open wells satisfied the Bureau of Indian Standards guideline which requires that every sample of water be free of fecal coliforms (that is. zero fecal coliforms per 100 ml). The conclusion, therefore, is that there is a high probability that open wells in Kerala are polluted with fecal matter.

The 144 open wells were selected at random. The only criteria for selection were that the wells could not have been chlorinated in the preceding 3 months and that the wells be located in areas where the Socio-Economic Units work. In fact the 144 wells in this study are located in 7 panchayats scattered around the state, in Kozhikode, Thrissur, Kollam and Thiruvanadapuram districts. These are in areas having a wide diversity of physical, social and economic conditions. The conditions, therefore, are not different from that in other panchayats in the low-land areas of Kerala. Thus it is unlikely that the results of the study are due to sampling error. It is worth mentioning that the samples were taken (December to April) at a time when the bacterial quality of well water may be *better* than at other times, such as at the onset of the monsoon.

While the five closed wells (with handpumps) were free from fecal coliforms, the same was not, in fact, expected of the open wells. It was expected that most open wells would not meet Indian or international standards for microbacterial quality of drinking water. To quote from two well-known sources:

> "...WHO(1971 and 1984) recommended that small water supplies should contain zero *E. coli* per 100 ml. The great majority, if not all *untreated* water supplies in the developing countries will not meet this requirement".* "Untreated water sources are almost invariably contaminated with fecal matter and contain fecal coliforms and other indicator bacteria".**

What was surprising in the results of the study was the proportion of wells in the sample (58% or 83 out of 144) which were in the high pollution class. In other words, more than half of the wells had three or four samples with more than 100 fecal coliforms per 100 ml. Clearly steps should be taken soon to reduce the level of pollution. Even if it is not possible to eliminate

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* Cairncross, S. et al. *Evaluation for village water supply planning. Technical Paper Series No. 15.* International Reference Centre for Community Water Supply and Sanitation. The Netherlands. 1980. 177 pages. Quote from page 73.

** Cairncross, S. and R. G. Feachem. *Environmental health engineering in the tropics.* John Wiley & Sons. 1983. 271 pages. Quote from page 31.

all bacterial pollution, efforts should be made to ensure that drinking water has a bacterial quality not exceeding a certain level, for example, of 100 f. coliforms per 100 ml.

Another question which was asked about this study was: If drinking water from wells is polluted, why are there not more diseases in Kerala?

There are three responses to this. Firstly, following internationally-recognized procedures, this study tested for the presence in well water of an 'indicator bacteria', fecal coliforms.

These are bacteria which are always excreted in large numbers by warm-blooded animals in their feces, whether they are healthy or sick. Thus, if a sample of water contains the indicator bacteria, then it is contaminated from the feces of animals or people. It should be understood that most fecal coliforms are *not*, in themselves, disease carrying. Their presence in water means that other disease-causing agents might be present.

Secondly, in Kerala there are, usually on a seasonal basis, water-borne diseases such as cholera and typhoid. However, incidence of major diseases does appear to be lower in Kerala than in many other parts of the nation. Many of these diseases are water-washed as well as water-borne (that is, their incidence is a function of quantity as well as quality of water). The incidence of major diseases would be greater without the high per capita use of water and relatively better hygiene which prevails in Kerala.

Thirdly, it is very important to note that polluted water does not only cause major diseases such as cholera and typhoid. There are other ailments which are not in themselves life threatening, but are nonetheless debilitating. In fact, the health status in Kerala has been characterized by professionals as one of chronic, low-level morbidity. This is often not fully understood or recognized by the population. One example which may illustrate this relates to frequent episodes of low-level diarrhoea. "Loose stools" are accepted by many people as being unremarkable or almost normal. This is, of course, not correct. The implications for children are particularly important. For children in particular, diarrhoea and 'loose stools' are reflected in minor illnesses, reduced absorption of important nutritious elements and so on. The child or adult is not dramatically ill, but not fully healthy.

One step which will help to improve this is to protect drinking water sources and, of course, to store and use water in ways that ensure it remains of high quality. The protection of open wells, in particular, may include: covering wells completely and raising water with a handpump or, if this is not possible, maintaining very hygienic conditions around the well and chlorinating at regular intervals. Maintaining cleanly conditions around the well should include: cleaning the well periodically; keeping the sides of the well in good repair; having clean walls above the well; having a cemented or cleanly apron around the well; ensuring that a separate bucket is used to draw water and that the bucket is kept clean; keeping cattle sheds and latrines as far from the wells as possible and certainly more than 10 meters; cutting back trees which hang over wells, and so on. Steps such as these will ensure that the bacterial quality of well water provides less risk for everyone.

1. INTRODUCTION

The State of Kerala has the highest density of open, hand-dug wells in India and perhaps in the world. This is a reflection of the high population density and the hydrological conditions of the State. During the dry season when wells tend to run dry and in areas where ground water become brackish, the demand for piped water is high. With the advent of the rains this demand drops as the rural population continues to use largely unprotected well water for drinking as well as bathing and cleaning.

The Socio-Economic Units (SEU's) of the Kerala Water Authority have a mandate for work in 73 panchayats (with a population of about 2 millions) where piped water systems are being developed with the financial support of the Governments of Denmark and the Netherlands. In their work, the SEU's involve communities in continuing education programmes which attempt, among other things, to distinguish between drinking water (from a clean source such as piped system or properly protected wells) and water for other purposes (bathing and cleaning). However, field experience has shown that drinking water from unprotected sources in often preferred by the communities.

Unfortunately there is little data to support the SEU education programme related to the quality of well water. Some related studies undertaken by the CWRDM (Calicut) focussed on mineral/chemical quality of water in coastal regions. However, there has been little organized research on the bacterial quality of well water, particularly the fecal contamination which is a major cause of diarrhoeal diseases. Some research undertaken by the Pollution Control Board (TAG/ICWD)[2] showed substantial fecal contamination, in wells situated at a close distance (3m) to sources of pollution.

This project is a rapid study of the bacterial quality of 150 wells in the areas of the Dutch-Danish supported water schemes. The results of this study will be directly fed back into the Socio-Economic Units' education programmes and, as appropriate, the education programmes of other institutions.

1.1 The parameters and their significance

1.1 a pH

pH is a measure of the hydrogen ion concentration or, in other words, the hydrogen ion activity of water which renders it either acidic, neutral or alkaline in character. The measurement scale for pH extends from O (very acidic) to 14 (very alkaline) with the middle value of 7 corresponding to exact neutrality.

The pH of natural waters under usual circumstances lies in the range of 4.5 to 8.5. This balance is brought about by the carbon dioxide-bicarbonate-carbonate equilibria. Disturbance to this equilibria, for example by humic substances, bio-activity of plants or intrusion by wastes, will result in the depression or elevation of pH values. The Bureau of Indian Standards (B.I.S)[3] prescribes a limited pH range of 6.5 - 8.5 for drinking water.

1.1 b Conductivity

Conductivity, sometimes referred to as electrical conductivity, is a measure of the concentration of electrolytes in water. It is related to the nature of the various dissolved substances and to a limited extent to the concentration of such substances. Most inorganic salts, acids and bases when dissolved in water make it a good conductor but most organics do not. The relation between electrical conductivity and dissolved salts depends on the quantity of salts involved. For a comparison, freshly distilled water has a conductivity of 0.1 to 0.2 mS/m (milli siemens per meter) or less, while most fresh and finished water falls in the range of 5 to 50 mS/m. The Bureau of Indian Standards does not prescribe any limit for this parameter.

1.1 c Total Dissolved Solids (T.D.S)

This is a measure of dissolved substances in water. Water with high T.D.S is unsuitable for drinking due to its inferior palatability and unfavourable physiological reactions in the consumer organisms. Highly mineralised water is unfavourable for domestic purposes also. The Bureau of Indian Standards prescribes a limit of 500 mg/litre maximum of T.D.S. for drinking water.

1.1 d Fecal Coliforms

Fecal coliforms generally refer to the coliform bacteria inhabitant in the gut and feces of man and other warm blooded animals. Their presence in water or other food stuff indicates contamination with fecal matter and suggests the possibility of the presence of pathogens. Fecal coliforms by themselves are not disease causing (although some strains are known to cause infantile diarrhoea). When released into the environment they die off with time especially in presence of sunlight or get adapted to the environmental conditions (thus losing their ability to ferment lactose at 44.5° $\pm$ .2° C which indicates that they inhabit of the gut and feces of warm blooded animals). Their presence in water indicates recent contamination with fecal matter. The Bureau of Indian Standards permits a maximum limit of 10 coliform organisms per 100 ml for drinking water and that too not repeatedly. The importance of ensuring absence of fecal coliforms in drinking water is however stressed in the B.I.S Standards.

1.2 Scheme of study

The present study was conducted during the period of December 1990 - April 1991 in the 3 zones of the Socio-Economic Units. In the South and Central zones, sampling and analysis started in the 3rd and 4th week of December 1990 respectively and at the north zone during the 1st week of January 1991. During the period of study, 4 samples were taken from each well at an interval of approximately two weeks.

2. METHODOLOGY

As the objective is to study the bacterial quality of well water with respect to fecal coliforms and also to determine the contribution to fecal contamination of environmental or domestic factors, data on these factors were collected by field observations. Water samples collected during the field visits were analyzed for fecal coliforms and also for the other three parameters.

2.1 Selection of Wells

In total, 150 wells have been monitored, 50 each from the South, Central and Northern regions of the Socio-Economic Units as selected by researchers with the respective units. All except for 17 of the wells were used for drinking as well as other domestic (washing and bathing) purposes. Reflecting the seasonal scarcity of water in Kerala, it was reported that 40 of the wells (26% of the total) ran dry for part of the year.

Out of the total, 144 were open wells and 6 were closed and had hand pumps. Among the open wells, 103 had SEU latrines in the vicinity and 30 were related to other types of leach pit/septic tanks. All the hand pumps also were at measured distance from SEU latrines, while the remaining 11 open wells were not near any latrine pit.

Among the 103 open wells with a related SEU pit, 53 are in laterite, 12 in sand, 14 in clay and 24 in sandy clay soil types. The distribution of the other 30 wells with a related pit but not from the SEU programme are 9 in laterite, 3 in sand, 3 in clay and 15 in sandy clay. All the six closed wells with hand pumps are in sandy clay. On further classification of the 133 wells with pits according to distance between the well and latrine pit, 81 wells are more than 10 meters(m) distance from a latrine pit, 42 in the range of 5 to 10 meters distance and 10 less than 5 meters distance from the pit. Table 1 below shows the distribution of wells monitored according to soil type and pit distance.

Table - 1

Distribution of open wells in relation to type of soil and type/ distance of latrine pit

Type of pit	Pit distance from well in meters		
	< 5 m	5-10 m	>10 m
SEU pits			
Laterite	3	12	38
Sand	4	4	4
Clay	-	7	7
Sandy Clay	1	7	16
Other pits			
Laterite	1	5	3
Sand	-	-	3
Clay	-	1	2
Sandy Clay	1	6	8

2.2 Sampling and Analysis

Four samples from each well were taken at approximately 2 week intervals following standard procedures [4,5]. The samples for bacterial examination were drawn from open wells using sterilised and light protected bottles with attached strings. The end of the sterilised string was tied to a master string so that the bottles would reach the water. Care was taken to keep the master string sufficiently above the water surface to avoid well-to-well contamination. Bottles were closed and covered for light protection immediately after collection. The samples for the physical and chemical parameters were drawn separately with the help of clean ground glass joint bottles with enough capacity.

There were 6 covered wells with hand pumps. From the hand pumps samples were collected after sterilizing the mouth of the pipe with alcohol vapour flame.

All samples were kept under refrigeration and transported to the Central Laboratory at Ernakulam for analysis. They were analyzed within 12 hours in case of the bacterial parameter and within 24 hours for the physical parameters. T.D.S was analyzed subsequently, taking minimum required time.

The membrane filter technique was adopted for the estimation of fecal coliforms. Definite volume of the sample as such, or suitably diluted, was filtered under suction through sterile membrane filters. The colony-forming units collected on the filters, placed on M-FC (Membrane Fecal Coliform) broth, were incubated at 44.5° C with + 0.2 accuracy for 24 hours. Developed blue colonies were counted. They are reported as count/100 ml, indicative of the number of colony-forming units originally present in the water sample.

pH and conductivity were measured using pH meter and conductivity meter respectively, permitting direct reading with accuracy. T.D.S. was estimated gravimetrically by evaporating on a water bath a known volume of the sample in a previously weighed evaporating bowl and then finding out the weight of the residue left over.

2.3 Presentation of Data

The analytical data was presented in forms to permit an overall comparative glance of the data and other relevant factors. For easy reference a copy of the form is given in page 7. Out of the ten items of the form, items 1 and 2 are for the identification of the well. Items 3 - 9 are the variable factors which have influence on the 10th item (water quality).

Each item in the data sheet gives varying information. Among these, the applicable one is suitably marked and the inapplicable left blank. For example, if water of a well is used for drinking, the box under 'Drinking' will have a check (✓). If used only for domestic purposes, the said check will be below the box labelled 'Domestic only'. The number of members using the water will be shown under 'BY' in the box for 'Members'. Supposing the number so given is 8 and the check is under drinking, then the component can be read as 'Water used for drinking by 8 members'.

If any of the information under any component is not distinct or comparisons are insignificant, all items will bear the mark. The last item under component 5 is an example of this. If the geographical slope is not distinct, the 'UP' and 'DOWN' will be checked.

1. IDENTIFICATION NO.	M		

ZONE	
SOUTH	
CENTRAL	
NORTH	

2. LOCATION

Panchayat	Ward	House No.	Name of Owner

3. WATER USED FOR

Drinking	Domestic only	By
		Members

4. NATURE OF THE WELL

Open	
Hand Pipe	

Availability of Water	
Round the year	For part of the year

Private	
Public	
Depth M	

5. PROTECTION

From Surface Flows

Covered with	
Roof	Net

Up	Down
Slope of Pit	

6. USER BEHAVIOUR

	Bathing	Washing	Cattle Washing
Within 5 Meters			
Within 10 Meters			

7. DISTANCE OF WELL FROM

Pit	Cattle Shed
M	M

8. TYPE OF LATRINE

SEU	
OTHERS	

Leach Pit	
Septic Tank	

Load factor	Members
Using since	19

9. SOIL TYPE

Laterite	Clay	Sand	Silt Sand

10. WATER QUALITY DETERMINATION

No.	pH	Conductivity ms^{-M}	•T.D.S mg/1.	Fecal Coliform Count / 100 ml
1.				
2.				
3.				
4.				

3. OBSERVATIONS

The fecal coliform count in all the 144 open wells is above the limit prescribed by the Bureau of Indian Standards for drinking water. There was no significant difference between the 133 open wells with latrine pits nearby and the 11 open wells without nearby pits. Among the 6 closed wells with hand pumps monitored, 5 had nil (zero) fecal coliform count for all the four samples. The one well out of this 6 that failed was physically damaged permitting water or dirt to come from outside. Three of these four high-quality closed wells have SEU latrine pits between 5 and 7 meters distance and one has a pit at 10.7 meters. The sanitary condition around these wells bears no distinction from any average well monitored. The significant factor appearing through out in every well with fecal coliform contamination is its open character.

Although the investigation was carried out on existing wells selected for this purpose at random, the factors with a potential influence on water quality (such as soil type, presence of latrine pit and cattle shed, depth of pit) were haphazardly related. This is to say that there is no significant pattern in the data that enables identification of specific factors responsible for specific levels of pollution.

4. DISCUSSION AND INTERPRETATION

Based on the above observations on the poor quality of water in the open wells, the study aimed at assessing the contribution, if any, of factors having potential influence on water quality. For this purpose all the wells were classified into 4 quality classes (A, B, C and D) with respect to the coliform content in them. These classes were then analyzed with reference to certain characteristics (distance from latrine pit, type of soil and so on).

As none of the wells had the drinking water quality prescribed by the Bureau of Indian Standards, and in the absence of any other standard criteria for the qualitative classification of drinking water based on quality aspects including fecal coliform count, an independent approach is adopted for the classification so as to get a reasonable number of wells in each class for a statistical evaluation. The criteria adopted for the classification are listed below:

Class A. All open wells which have shown the fecal coliform count in the range of 0 to 100 per 100 ml for all four observations are put in Class A.

Class B. All open wells which have shown a fecal coliform count above 100 per 100 ml in only 50% or less of the observations (that is, 1 or 2 samples out of four) are put in Class B.

Class C. All open wells which have shown the fecal coliform count above 100 per 100 ml in more than 50% of the observations are put in Class C.

Class D. All open wells which have always shown fecal coliform count of 300 or more per 100 ml are put in Class D.

Class A and Class B may further be combined and referred to as a 'Low Pollution Class' for statistical comparison. Similarly the Classes C and D are often referred to as the 'High Pollution Class' in this text.

Table 2 shows the distribution of the wells in the four quality classes. Out of the 103 wells with SEU pits in the vicinity only 17 quality for class A, 20 for class B, 48 for class C and 18 go into class D. In the case of the 30 wells with other types (not SEU) of latrine pits, 9 qualify for class A, 7 for class B, and 9 for class C, while class D has 5 of them.

Of the 11 wells with no latrine pit in the vicinity five are in class A while three each of the remaining 9 maintains the class B and C status. None are in class D.

Table - 2

Distribution of open wells in the 4 quality classes

Quality classes	No.of open wells		
	With SEU pits	With Other pits	Without pits
A	17	9	5
B	20	7	3
C	48	9	3
D	18	5	-

As a general approach, the interpretation is undertaken by examining the relevant data about the wells in relation to the class status. Table 3 shows the distribution of the 4 quality classes in different soil types. Under each soil type, the wells are also categorized according to their

distance from a latrine pit, into three groups, less than 5 meters, 5 to 10 m, and more than 10 m distance from a latrine pit.

Table - 3

Distribution of open wells in the four quality classes, in different soil types and in relation to distance of latrine pit

	No.of wells	Laterite Dist.of pit(M) <5	Laterite 5-10	Laterite >10	Sand Dist.of pit(M) <5	Sand 5-10	Sand >10	Clay Dist.of pit(M) <5	Clay 5-10	Clay >10	Sandy Clay Dist.of pit(M) <5	Sandy Clay 5-10	Sandy Clay >10
A	26	1	5	6	0	0	1	0	0	2	1	3	7
B	27	0	3	7	1	2	1	0	2	2	0	3	6
C	57	3	6	22	1	1	2	0	3	4	1	4	10
D	23	0	3	6	2	2	3	0	3	1	0	3	1

These quality classes are examined without reference to the distinction between SEU and other types of latrines. A separate discussion follows for SEU latrines located near wells.

4.1 Pit distance-soil type relation

Distance of the well from latrine pit can be a very important factor contributing to pollution. However, the distance should be considered in association with soil type. Therefore all the open wells with pit relation are projected in table-4 to permit a statistical view of their distance from latrine pits according to soil type.

Table - 4

Distribution of open wells in different soil types in relation to pit distance

Soil Type	Pit distance groups in meters (m) <5m	5-10 m	>10m	Total in each
Laterite	4	17	41	62
Sand	4	4	7	15
Clay	-	8	9	17
Sandy Clay	2	13	24	39

As the most prominent soil type in this study is laterite, the discussion is focussed first on the wells in this type of soil. Table 5 presents the distribution of open wells in laterite soil in relation to pit distance. Out of the 62 laterite wells with pit relations monitored, 41 had latrine pits more than 10m from the well; 17 had pits at 5 to 10m distance; 4 at a distance of less than 5m. With respect to the quality classes, out of this total of 62 wells only 12 qualify for class A. Among this 12, six are more than 10m distance from a pit, 5 at 5-10 m distance and one is less than 5 m distance.

Table - 5

Distribution of class A open wells in laterite soil with respect pit distance

No.of wells	Pit distance groups in meters (m)		
	<5m	5-10 m	> 10 m
No. monitored	4	17	41
No.in Class A	1	5	6

The proportion of class A wells which are less than 5 m, 5-10 m and more than 10 m away from latrine pits is 25%, 29% and 14% respectively. As the pit distance increases from less than 5 m to 5-10 m, there is a slight increase in the percentage of class A wells, but the trend disappears as the pit distance increases to more than 10 m.

Looking at the scenario in sandy clay in Table 6 it can be seen that out of 11 class A wells in the total 39, seven are more than 10 m from the latrine pit, three at 5-10 m distance and only one at below 5 m distance.

Table - 6

Distribution of class A open wells in sandy clay soil with respect to pit distance

No. of wells	Pit distance groups in meters (m)		
	<5 m	5 - 10 m	>10 m
No.monitored	2	13	24
No.in Class - A	1	3	7

In table 5 and table 6 the distance of the pit from well is not significantly related to water quality. To examine the possibility of cross pollution from latrine pits further, factors would need to be investigated such as slope of ground water table and sub-soil water velocity and direction.

4.2 Depth, soil type, pit-distance combination

For open wells, the depth of the well and soil type are inter-related and the leach pit can be a factor influencing water quality. Therefore an examination of this combination was thought essential. In this perspective, the data presented in table 7 should be examined.

The table groups the wells in each soil type into three different depth groups--where the depth of the well is below 5 m, 5-10 m and above 10 m. These depth groups are further categorized according to their distance from latrine pits.

Table - 7

Distribution of wells in relation to depth and distance from pit

	No.of wells								
	Depth ≤ 5m Pit distance (m)			Depth 5-10 m Pit distance (M)			Depth ≥ 10 m Pit distance (m)		
Soil type	<5m	5-10 m	>10m	<5m	5-10m	>10m	<5m	5-10m	>10m
Laterite	-	5	10	3	8	24	1	4	7
Sand	3	2	7	1	2	-	-	-	-
Clay	-	8	8	-	-	1	-	-	-
Sandy Clay	-	10	23	2	3	1	-	-	-

Table 8 shows the distribution of the different quality classes of open wells in relation to soil type, and depth of well, and distance of pits from the wells. It can be seen that among the wells in laterite, the 5 - 10 m category contains the maximum number of 10 class A wells. Analyzing the data further by pit distance, three out of 8 wells in class A are situated at 5 to 10 meters from a latrine pit. In the category of greater than 10 m pit distance, only 2 out of 24 could qualify for class A. Here, it may be argued that increasing the pit distance alone in the same soil type and depth group could not protect wells from pollution.

Table - 8

Distribution of the four quality classes of open wells in relation to soil type, depth and distance of pits from wells

Quality Class	Soil type	No.of wells in different depth groups Depth in meters)								
		Depth <5m			Depth 5-10m			Depth >10m		
		Dist.from pit			Dist.from pit			Dist.from pit		
		<5m	5-10m	>10m	<5m	5-10m	>10m	<5m	5-10m	>10m
	Laterite	-	1	2	1	3	2	-	1	2
A	Sand	-	-	1	-	-	-	-	-	-
	Clay	-	-	2	-	-	-	-	-	-
	Sandy Clay	-	3	7	1	-	-	-	-	-
	Laterite	-	1	1	-	1	5	-	1	1
	Sand	-	-	1	-	2	-	-	-	-
B	Clay	-	2	1	-	-	1	-	-	-
	Sandy clay	-	2	6	-	1	-	-	-	-
	Laterite	-	2	4	1	2	16	1	2	3
	Sand	1	1	2	-	-	-	-	-	-
C	Clay	-	3	4	-	-	-	-	-	-
	Sandy clay	-	2	9	1	1	2	-	-	-
	Laterite	-	1	3	-	2	2	-	-	-
	Sand	1	1	3	1	-	-	-	-	1
D	Clay	-	3	1	-	-	-	-	-	-
	Sandy clay	-	3	1	-	-	-	-	-	-

Now a look at the wells in sandy clay (Table 8) shows that out of 39 wells, 11 are in class A and 10 of these are less than 5 meters deep. Seven of these 10 wells are located more than 10 meter from latrine pits. Thus 7 out of 23 wells located in sandy soil were more than 10 meters from latrine pit and were in class A. Out of the 10 class A wells less than 5 meters deep in sandy soil three were located 5 - 10 m from a latrine pit. Considering the variable, the pit distance, its role in the pollution status of open wells, remains doubtful.

If by another approach, the wells in the 'Low Pollution' group (A + B) and the wells in 'High Pollution' (C + D) group are compared, the maximum number of wells in the lower pollution class are found in laterite (in the 5-10 m depth group) and sandy clay soil types (in the below 5 m depth group). Percentage-wise, sandy clay scores high with 51% of wells of below 5m depth in the 'Low Pollution' class while laterite has 43% of wells of the 5-10m depth category in the class. Once again, the data does not show a significant relationship among the quality of well water, depth of well, type of soil and distance from well to the leach pit.

Discussion of laterite and sandy clay wells above have covered 101 open wells in the total of 133. As no significant trend is noticed in the other two soil types, discussion on them is not attempted.

4.3 Cattle-shed combination

Among the 133 open wells with nearby latrine pits 32 have a cattle shed in the vicinity. Only 4 wells out of these 32 have qualified for class A which *prima facie* shows that just the presence of a cattle shed in the vicinity can be a source for fecal contamination of open wells. For a close examination, distribution of these wells according to the distance from cattle shed and latrine pit is shown in table 9.

Table - 9

Distribution of wells into the low and high pollution classes relative to their distance from cattle sheds and latrine pits

No.of wells	Distance between cattle shed and well: <5 m			5-10 m			> 10 m		
	Dist.of well to pit			Dist.of well to pit			Dist.of well to pit		
	< 5	5-10	>10	5	5-10	>10	<5	5-10	>10
With cattle shed	-	5	5	-	2	8	-	3	9
Low Pollution Class (A+B)	-	1	-	-	-	5	-	-	4
High Pollution Class (C+D)	-	4	5	-	2	3	-	3	5

The 'Low Pollution Class' has 10 wells, only one of which is less than 5 meters from the cattle shed.

It is observed that 9 of the 10 low pollution class wells have the same distance from the latrine pits but differing distances from the cattle sheds. While 5 of them have the shed at a distance of 5-10m, four have sheds at a distance of above 10 m. The data does not give any indication that distance of cattle shed alone is a determining factor for pollution of open wells.

The 'High Pollution Class' has 22 wells, 5 in the group of within 5 m from a cattle shed and another five with cattle sheds more than 10 m away. This again does not help to establish the role of the cattle shed distance variable in the pollution of open wells.

4.4 Effect of Slope

The wells have been examined according to their slope from latrine pits. Here the micro slope of the ground alone is considered and not the ground water slope.

Table - 10

Distribution of the wells of the 4 quality classes with respect to their slope from pit

Quality Classes	Downward Slope	Upward Slope	Level
A	5	-	21
B	2	2	23
C	4	2	51
D	1	1	21

Out of the 12 wells at downward slope from the latrine pit, 5 are in the quality class A, while out of the 5 wells at upward slope of pit none are in class A. The observations are seemingly in contradiction to scientific hypothesis. This may be due to the absence of data on other influencing factors (such as flow of ground water) and hence further discussion on this aspect is not attempted.

4.5 Load Factor

Load factor is defined as the number of members using a latrine. The wells are classified into two groups: those with latrine pits with up to (and including) 5 member load factor and those related to latrine pits of more than 5 member load factor. Within these two groups the 4 quality classes are distributed according to their distances from pits in table 11. Here, only the wells located near SEU latrines are considered because only these latrines have uniformity in type construction.

Table - 11

Wells with SEU pits in relation to load factor
(No. of persons using the latrine) under varying pit distances.

Quality Classes	Load Factor (No. of persons using the latrine					
	Up to 5 members Pit distance in meters			Above 5 members Pit distance in meters		
	<5	5-10	>10	<5	5-10	>10
A	-	3	4	1	3	6
B	1	3	6	-	1	9
C	1	5	10	2	6	15
D	1	2	7	1	4	3

In both the load factor groups more wells are at above 10 m pit distance. In group with u to 5 member load factor, out of the 36 wells located more than 10 m from a pit, only 4 are in class A while 7 are in class D. In this case, if the low pollution class and high pollution class are considered the ratio is 10:26. In the case of the above 5 member load group this ratio is 15:18.

Comparing wells at a distance of 10 meters from a latrine pit having two different load factors (of up to 5 members and more than 5 members), while the above 5 member load factor group has 18% of class A wells, the up to 5 member load factor group has only 11% of class A wells. On the same pit distance consideration, while 72% of the wells of up to 5 member load factor group is in high pollution class, only 54% of the above 5 member load factor group are in the high pollution class.

It can be stated from the present study that in the case of water quality of open wells, the influence of latrine pit load does not show any trend upon which conclusions can be made.

4.6 Chemical quality aspects

With respect to the chemical quality of water also some of the wells are found to show objectionable trends. As per the Bureau of Indian standards specification for drinking water, a pH range of 6.5 to 8.5 is prescribed. In this sample, 117 wells have gone below the lower range but none has crossed the upper range of 8.5. The lowering of pH to the acidic side in majority of wells may perhaps be due to some geological peculiarities of the terrain. This interesting aspect

needs further detailed studies to pinpoint the exact source of acidity in the well water. Only two wells have shown a low value of below 4.5 and none has shown values higher than 8.5, the range for natural waters.

With respect conductivity, 5-10 ms-m being the value for natural waters it can be stated that 34 out of 150 wells have shown the value above the natural range. The Bureau of Indian Standards however did not prescribe any limit for this parameter.

With regard to T.D.S. (total dissolved solids) content, the results reveal that 23 wells have shown T.D.S. content above the limit prescribed by B.I.S. for drinking water. Out of these, 14 wells have shown the value of above 1000 mg/1 (12 in Anjengo of the South zone and 2 in Edathurithy of central zone). The highest value found was 3660 mg/l in a well in Edathurithy.

The areas with high T.D.S. content is appear to be close to estuarine systems and hence may be attributed to the natural phenomenon of seasonal saline intrusion.

4.7 SEU Latrines

The general scenario described above is also applicable to wells with SEU latrines in the vicinity. A closer look at the relevant data in table 12 and 13 demonstrates this point.

The Table 12 shows the class distribution of the wells while table 13 gives the distribution of the low pollution classes (A&B) in relation to type of soil and pit distance.

Table - 12

Distribution of wells at a measured distance from SEU pits in the four quality classes

Quality class	No.of wells
A	17
B	20
C	48
D	18

Table - 13

Distribution of wells in low pollution classes (A & B) located near SEU latrine pits

No.of wells	Soil Type											
	Laterite			Sand			Clay			Sand Clay		
	Dist. of pit(m)			Dist.of pit(m)			Dist.of pit(m)			Dist. of pit(m)		
	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10
Total monitored	3	12	38	4	4	4	-	4	7	1	7	16
No.in Class A	0	4	5	0	0	0	-	0	1	1	2	4
No.in Class B	0	1	7	1	2	1	-	1	2	0	1	4

Among the 103 open wells with SEU-pit relation, 17 have qualified for class A, and 20 for class B. Soil of type distribution for class A are 9 in laterite, 1 in clay and 7 in sandy clay. Among the 9 class A laterite wells, 5 are more than 10 m distance from a pit and 4 are 5-10 m distance from a pit. The 5 above are in a group of 38 wells which are all more than 10 m from a latrine pit. The 4 are in a group of 12 wells at 5 to 10 m from a pit. This implies that increasing the distance to the latrine pit alone does not seem to contribute to the quality of water in open wells.

The 20 class B wells do not demand any special comment except that while none of the sandy wells are in class A. 4/12 of them qualify for class B. They are also of varying pit distances. None of these wells have cattle sheds nearby.

For 'high pollution class' of the SEU-pit-related wells also, a close examination reveals nothing for a convincing comment. All the 66 of this class have a haphazard distribution with respect to water quality and the other variables. Table 14 shows that SEU wells arranged by soil type, in groups of less than 5m, 5-10 m and more than 10m distance from a pit.

Table - 14

Distribution of open wells in High Pollution Classes (C & D) located near SEU latrine pits

	Soil Type											
	Laterite Dist. of pit (m)			Sand Dist.of pit (m)			Clay Dist.of pit(m)			Sandy Clay Dist. of pit (m)		
Depth	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10
<5m	1	3	5	2	2	3	-	6	4	-	2	6
5-10m	1	2	17	1	-	-	-	-	-	-	2	2
>10m	1	2	4	-	-	-	-	-	-	-	-	-

Out of these 66 wells in classes C and D, 36 are in laterite and among them, 26 are at above 10m distance from pit, and 17 of these 26 are in the 5-10m depth range. This implies that neither sufficient distance from pit nor the reasonable depth of wells helped them to maintain water quality with respect to fecal pollution.

Table 15 shows the distribution of the wells with both SEU pit and cattle shed relations from among the 'high pollution' Class discussed above. These wells are arranged by the respective soil types and by distance from latrine pits.

Table - 15

Distribution of SEU pit & Cattle shed related wells of High Pollution class according to the distances from pit and cattle shed in the respective soil types.

Cattleshed distance Group(m)	Laterite			Sand			Clay			Sandy Clay		
	Dist.of pit(m)			Dist.of pit(m)			Dist.of pit(m)			Dist.of pit(m)		
	<5	5-10	>10	<5	5-10	>10	5	5-10	>10	<5	5-10	>10
<5m	-	1	2	-	-	-	-	1	-	-	2	-
5-10m	-	1	1	-	-	-	-	-	-	-	1	1
>10m	-	2	3	-	-	1	-	-	1	-	-	-

The largest number of wells with cattle sheds nearby are found in laterite soil. Out of the total 10, six have latrine pits at more than 10m distance. For half of these, the cattle sheds are also at above 10m distance. Four of the 10 wells in laterite have pits at 5-10 m distance and 2 of the these 4 have cattle sheds at above 10m distance, providing no useful insight on the effect of this combination on ground water quality.

4.8 Protected wells

In many cases steps had been taken to protect the open wells either during construction or afterwards. Of the 144 open wells, 91 (63%) were improved with nets, specially constructed aprons, separate buckets. To examine how successful these measures might have been, a comparison is shown in the table below of the protected wells versus and unprotected wells for the low and high pollution classes. For reasons which can not be explained, if the small size of the sample or other factors, a greater proportion of the 'unprotected' wells were in the low pollution class. From this may be inferred, however, that the actions undertaken for protecting wells does not have the desired result.

Table 16

'Protected' and 'unprotected' wells by pollution class

	No. of 'protected' wells	Total no. of wells in the class
low pollution class	27	61
high pollution class	64	83

4.9 Hand pumps

As mentioned earlier, the most important of the observations is on the quality of water in covered wells with hand pumps. All the five wells of this type are in sandy clay with the latrine pits at 5 to 7.5 meters distance. In the four observations, all of them except one, had no fecal coliforms implying the resistance of soil to leachate transportation of fecal coliforms. The one that failed is physically damaged. All the chemical parameters except pH are well within the range for natural waters and the BIS range for drinking water. In the case of pH, only two of these wells have shown the value within the BIS range for drinking water. In no case, is the higher limit exceeded. The lowest value found is 4.7. All these wells belong to the Edathurithy area of Central region.

4.10 The quality of wells with no latrine pits in the vicinity

The failure of the eleven wells with no latrine pit in the vicinity to retain the specified drinking water quality standard with respect to coliforms is indicative of the general quality of well water. As has been established by the observations, the open character of the wells seems responsible for the pollution. Out of these 11 wells, nine are in laterite and two in sandy clay. Out of these 9, eight belong to the Kulakkada area of Kollam zone. Socially and culturally, this area is typical of rural Kerala. The area is not too congested and the thrust of external factors is minimum. All the eight wells are in individual domestic compounds. Only one has cattle shed relation of 3 m distance. But for many people in the area open defecation is the most usual mode of personal waste disposal, which is more than enough reason for fecal contamination of open wells. The other laterite well of this group is a public well in Mala and by the side of a public road.

The laterite wells except one at Kulakkada come under the low pollution class (A-5 + B-3). The other one is in the C class. Out of the two sandy clay wells of this group, one is a public well in Edathuruthy - while the other is at Anjengo. Both of them are in the depth group of below 5 m and in the quality Class C.

The study in general indicates that with the existing sanitary conditions, cultural habits and social behaviour of the people of the area studied, it is not possible to keep open wells free of fecal coliforms. Only with appropriate measures to improve quality can well water be a safe source of drinking water.

5. CONCLUSIONS

1. Water in none of the open wells investigated is of drinking water quality standard as prescribed by the Bureau of Indian Standards.

2 The open character of the wells and the conventional maintenance habits are found to be responsible for fecal pollution in them.

3. Pit latrines with average family load factor (5 members) at a distance of 5 meter from wells are found to make no contribution to the pollution of well water.

4. Water analyzed from covered wells with hand pumps as close as 5 meters to the SEU latrine were found to contain no fecal coliforms.

5. There is need for a systematic study of the effect of load accumulation in pits on well water quality.

6. There should be a regular system of monitoring the quality of water since habits of poor maintenance always overtake programmes for disinfection and protection of wells resulting in water quality deterioration.

7. The present study was fairly rapid, focussing on existing wells selected at random. A detailed study has to be conducted on the effects of leachates from latrine pits in different soil types at definite increments of distance and time.

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