107/6023

244 88ST

2 4 4

8 S T

244-6023

KANDY DISTRICT WATER SUPPLY
AND
SANITATION PROJECT
PHASE I

STUDY ON BACTERIOLOGICAL CONTAMINATION IN HAND PUMP WELLS

SEPTEMBER , 1988

SOIL AND WATER LTD

R1-30-09/56
R Aapola/ph
23 09.1988

KANDY DISTRICT WATER SUPPLY AND SANITATION PROJECT

STUDY ON BACTERIOLOGICAL CONTAMINATION IN HAND PUMP WELLS

Final Report

Kandy, Sri Lanka
SOIL AND WATER LTD.

CONTENTS

1. INTRODUCTION

The bacteriological analyses of a number of water samples from hand pump wells in Harispattuwa Water Supply and Sanitation Project area have indicated bacteriological contamination if interpreted according to the Sri Lanka Standards.

The scope of this study is to clarify the reasons for this alleged contamination and to find ways to prevent it.

The first issue is to study the different bacteria as reliable indicators of contamination of faecal origin and to clarify the levels of these to be acceptable. The Standards applied in Sri Lanka are based on WHO recommendations.

Specialists in microbiology have been consulted Sincere gratitude is expressed to Professor M.R.M. Pinto and Dr Mrs. Chandra Kodikara, both from the University of Peradeniya.

The means to prevent bacteriological contamination can be clarified if the indicators of contamination and the transportation systems of bacteria in the hydrogeological circulation are understood

This report was prepared by R Aapola and M Taka of the Hydrogeological Department of Kandy District Water Supply and Sanitation Project, P O Box 84, Kandy, Sri Lanka (Tel 08-22052/32408)

Inquiries and comments are welcome.

Matti Taka
Hydrogeologist

Roger Aapola
Hydrogeologist

2. BACTERIA AND CONTAMINATION

2.1 Indicator Bacteria

It is calculated that bacteria constitute over 30% of the total wet volume of faeces and counts of 10^{10} anaerobes and 10^{8} aerobes per gram wet weight of faeces are recorded. Counts of intestinal bacteria can, therefore, be used to give a very sensitive test of the extent of faecal pollution of water.

Bacteriological tests for the detection of faecal pollution of water have been developed using non-pathogenic groups of bacteria. These bacteria should occur numerous in faeces, but not in other materials and should be counted by means of simple, reliable tests. The bacteria should also be more resistant than pathogens to physical and chemical inactivating agents and unable to grow in conditions outside the intestine.

The organisms which have been found to fulfil most of these criteria, at least in temperate climates, are the coliform, faecal coliform (or Escherichia coli, or E.coli), faecal streptococcus and clostridium perfringens groups

In hot climates problems arise because of physiological changes in the organisms which alter the selectivity of the tests and enable at least some organisims to grow outside the intestine

The coliform groups (or total coli) includes organisms classified in genera Escherichia, Citrobacter, Klebsiella and Enterobacter. Because several of these species are regularly found in unpolluted soils and water, the standard test (at 35°C) for these organisms cannot be said to indicate specific faecal pollution. It is reported frequently that coliform numbers in water can increase quite significantly, especially

in warm polluted waters. Coliform regrowth conditions are expected to occur regularly in polluted tropical waters where temperatures exceed 20°C. It is not established whether pathogenic organisms such as Salmonella typhi will regrow under the same conditions.

The faecal coliform test (at 44°C) is more specific indicator of pollution. Escherichia coli is considered exclusively faecal and constitutes over 90% of the coliform flora of the human intestine. It is generally distinguished from other coliforms on the basis of its growth at 44°C on media normally used for total coliform determination. However, in tropical waters there are many more coliforms which can grow at 44°C. The sanitary significance of these organisms has not yet been established. There have also been reports on regrowth of E.Coli associated with rottening vegetation at elevated temperatures. The faecal coliform test must still be taken as the most sensitive and specific indicator of faecal pollution available at present.

Faecal streptococci are occasionally used as indicator organisms, especially where confirmation of dubious E.Coli results is required. They have also been recommended for the examination of tropical waters. Although the organisms show little tendency to regrow, their rapid death rate in temperatures greater than 20°C seems to diminish their value as indicators in tropical waters.

2.2 The Sri Lankan Standards

The Sri Lankan Standards refer total Coli and E.Coli to be the indicators for bacteriological requirements of drinking water. These requirements are according to WHO recommendations. The bacteriological requirements for small community wells are:

1 None of the samples examined shall contain more than 20 coliforms per 100 ml at 35°C on repeated examination.
2. No sample shall contain E.coli per 100 ml at 44°C.

Two alternative methods are given for determination. However, these may give different results in untreated ground water Tests at the projects laboratory and at the University of Peradeniya show that if the water sample is uncontaminated both methods give the same result. If the sample is contaminated the two determination methods give different results in both directions.

These standard determinations are not very selective as explained above and other bacteria than those of faecal origin may be traced, especially in tropical conditions. These things are still poorly studied and known.

The co-operation with the University of Peradeniya is in progress.

2.3 Bacteria And Chemical Composition Of Ground Water

Human and animal wastes contain nitrogen compounds, mainly ammonia (NH_4) which under oxidizing conditions will be oxidezed into nitrite (NO_2) and further to nitrate (NO_3). At least part of it can be removed by plants in the top soil. In latrines, deeper water pits and other such anaerobic places, a major part of nitrogen compounds remain and flow with the ground water stream and will not be removed. It is to be mentioned that nitrogen compounds travel longer distance as high concentrations than the coliform bacteria can be traced.

In areas where natural nitrate concentrations in ground water are low, and where agricultural fertilizers are not used, an increase in nitrate concentration may indicate faecal contamination.

In the project area the nitrate concentrations are, almost without exceptions, very low. No correlation between total coli or E coli and nitrate is found It might indicate a) that the bacteria get more or less straight to the well or b) that these bacteria are not of faecal

origin or c) that the contamination comes from the ground surface and the nitrogen compounds are removed.

2.4 Transportation Of Bacteria In Ground

Unsaturated Zone:

Filtration of bacteria at the infiltration surface appears to be the main mechanism limiting their movement through soil. Further the grain size distribution in the unsaturated zone is an important factor for the bacteria removal, this being more effective in fine grained soils. The mechanism of this is complicated including bacteriological activities, absorption, filtration, etc. and is not discussed in details in this connection

The most common material in the unsaturated zone in Kandy District is insitu weathered rock with high clay content. This is also nearly ideal material to avoid effluents from latrine pits (Fig 1).

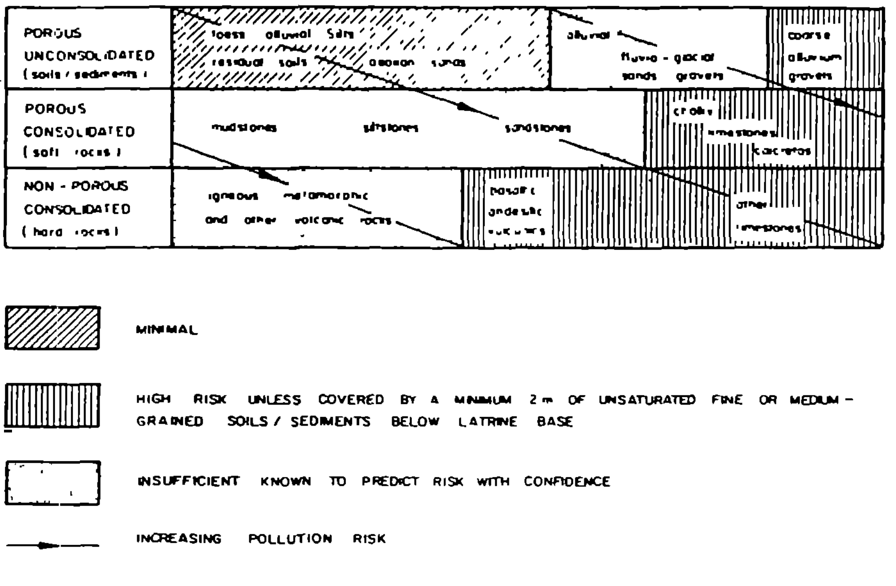


Fig. 1 Classification of soils and rocks in an array of relative pollution (Lewis et al , 1982, p 60)

Saturated Zone.

As the bacteria reach the ground water they are easily transported long distances. Their survival time under these conditions is poorly known and depends largely on temperature. There are some studies made on the survival time which gives different results, but it is likely to exceed eight days (The German Standards suggest that bacteria die within 50 days).

One study (McFeters et al., 1974 in Feachem et al., 1987, p.43) on comparative survival rates of pure cultures of various pathogens and indicator species in membrane chambers suspended in a stable well water supply indicates the following T_{50} values (time for 50% of the population to die):

	Hours
Shigella flexneri	26.8
Shigella sonnei	24.8
Shigella dysenteriae	22.4
Enterococci	22.0
Coliform bacteria	17.0
Salmonella enderitidis	16.0
Vibrio cholera	7.2
Sa. typhi	6.0

These experiments were conducted at 9.5° - 12.5°C in water with little or no organic material present. These tests refer to considerably colder temperatures than met in Sri Lanka.

The flow velocity of the ground water is a difficult thing to measure and depends on a number of hydrogeological parameters. As no aquifers are uniform and homogenous and the gradients vary it is not possible to give any general recommended distance in the flow direction from a latrine to a well.

The ground water movements in fissured crystalline bedrock can be fast and take place in direction difficult to predict. Thereby

bacteriological contamination may take place at a considerable distance from the source of contamination.

In latrine pits different types of clogging, mechanical, biological and chemical take place. Consequently as a latrine has been in use for a period (say three months) hardly any effluents from the latrine are likely if the filling of the pit is not heavy or no larger quantities of surface water are entering it. Also the grain size distribution affect the effluent, but the prevailing conditions in Kandy District are nearly ideal to avoid the effluent.

3. INVESTIGATIONS

3.1 Occurence Of Indicator Bacteria In Ground Water

An investigation in Harispattuwa concerning hand pump wells, not handed over on 23.11.1987, was carried out (Fig. 2 and 3). The study covered a total of 388 hand dug wells of which 26.5% (103 nos.) did not fulfil the bacteriological standards. Fig. 2 shows that there is no correlation between total coli and E.coli amounts in these wells. Fig. 3 shows that only 13 4% of the wells are contaminated with E.coli. Of these wells with E coli, 48% have less than 10 nos. E.coli per 100 ml. In the studied literature it is often suggested that the total coli is not an indicator for faecal contamination and that less than 10 E.coli/100 ml is so good water in tropical conditions that it can be supplied without treatment.

The bacteriological contamination in wells in Udunuwara was studied. It covered 39 nos. of shallow wells and 38 nos. of deep wells constructed by HWSSP and 24 nos. of shallow wells and 46 nos. of deep wells constructed by KDWSSP. The results according to sampling on 30.08.1988 are.

	HWSSP	KDWSSP
Shallow Wells	n=39	n=24
Total coli nos.	10 (25 6%)	7 (22.6%)
E.coli nos.	7 (17.9%)	4 (13.9%)
Amount of E coli per 100 ml	2,4,8,12,14,22,28	2,2,6,8
Deep Wells	n=38	n=46
Total coli nos	6 (15.8%)	8 (17.4%)
E coli nos.	3 (7 9%)	2 (4.3%)
Amount of E coli per 100 ml	2,2,4	2,4

Fig. 2

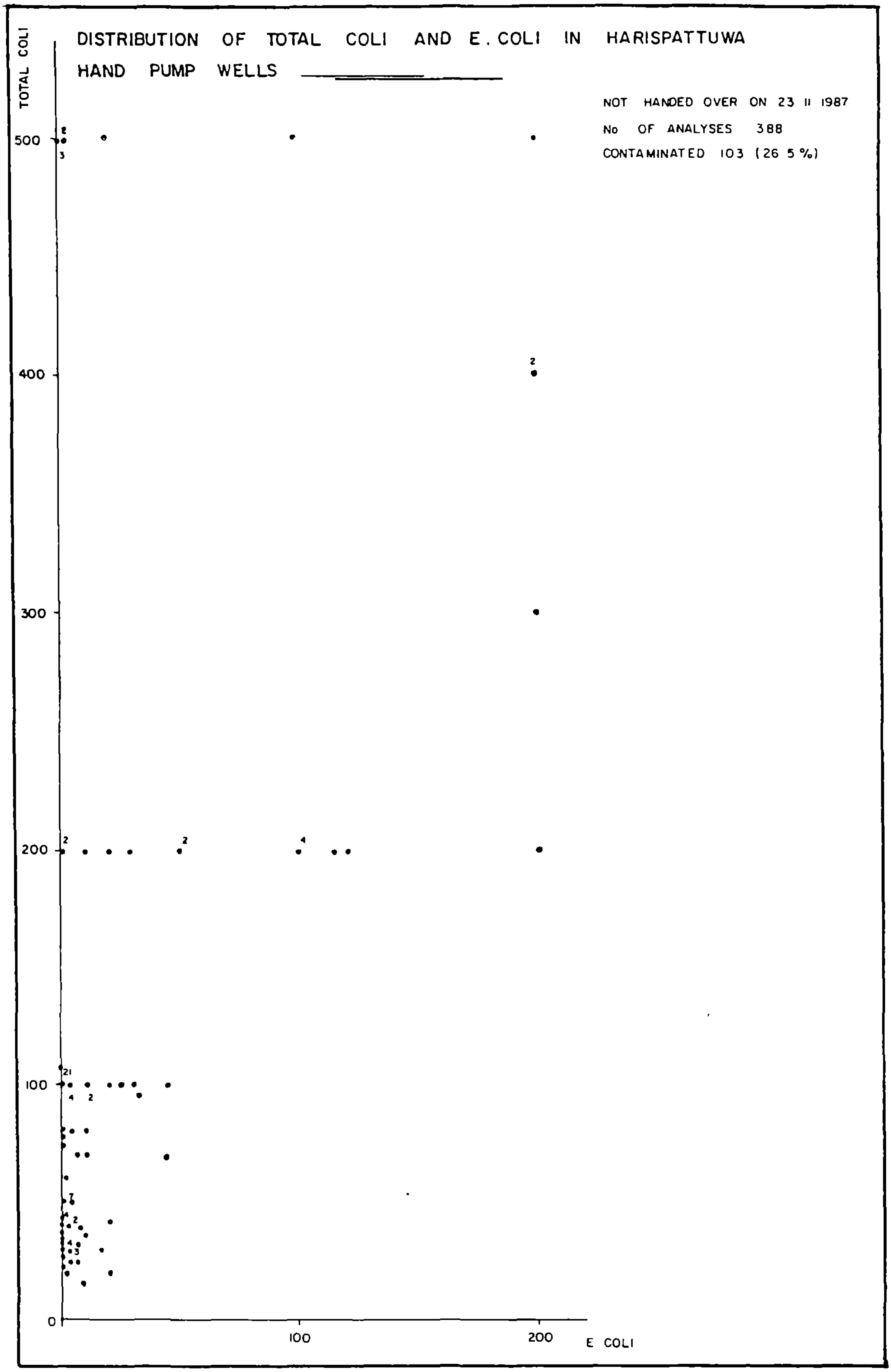
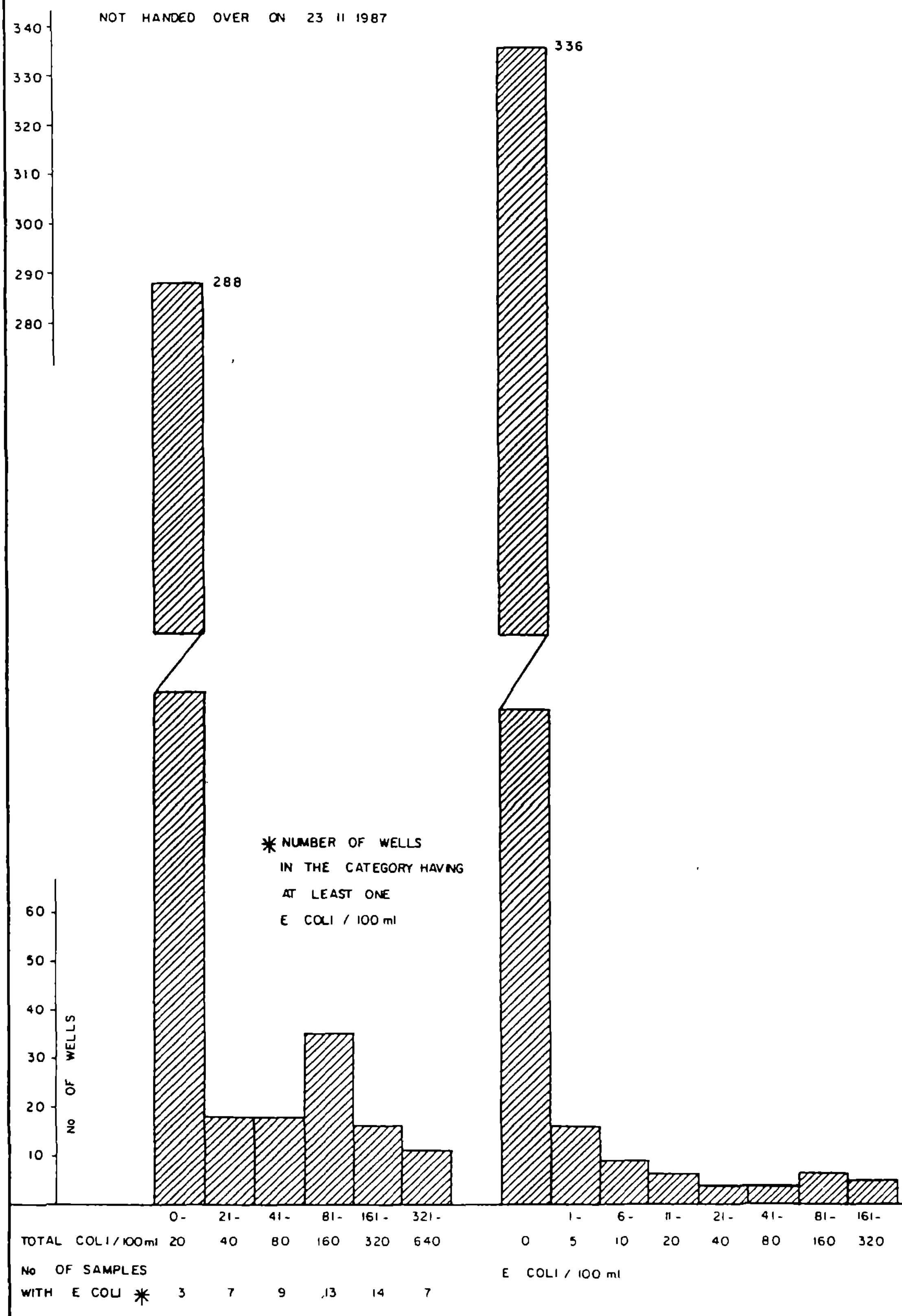

DISTRIBUTION OF TOTAL COLI AND E. COLI IN HARISPATTUWA HAND PUMP WELLS
NOT HANDED OVER ON 23 11 1987
No OF ANALYSES 388
CONTAMINATED 103 (26 5 %)
TOTAL COLI
500
400
300
200
100
0
100
200
E COLI

Fig. 3

HISTOGRAMS FOR NUMBER OF TOTAL COLI AND E. COLI IN HARISPATTUWA HAND PUMP WELLS



These figures show that the quality of water according to E.coli has improved. In HWSSP shallow wells 7 nos. of wells with E.coli was met and in KDWSSP only 4 nos. of wells with E.coli. No wells in KDWSSP have more than 10 E.coli per 100 ml. Concerning the deep wells the results are even better. Out of 46 only 2' KDWSSP wells have E.coli and the amounts are under 5 E.coli per 100 ml. According to the studied literature these results are considered good and should be supplied without treatment.

This study also clarifies that deep wells are less contaminated than shallow wells.

A comparison of the bacteriological quality of traditional and shallow wells was made (Table 1.). This comparison shows that the shallow wells are far safer than traditional wells.

Correlation between construction depth of shallow wells and total coli or E.coli was studied. No correlation in either case was seen. Wells with more than 100 total coli per 100 ml are constructed to depths of 4 to 9 m and wells with more than 20 E.coli per 100 ml are constructed to depths of 4 to 9 m. The average depth of Harispattuwa improved work wells is 6.4 m and the construction depths varies from 4 to 10.3 m.

Correlation between total coli and nitrates was also studied. No correlation was found. Later correlation between E.coli and nitrates was studied and no correlation was found. Positive correlation would indicate aquifer contamination of faecal origin

Harispattuwa improvement work wells were constructed by HWSSP and by two private contractors. In order to check the contamination due to poor well construction, the frequency of contaminated wells were counted contractorwise. No clear concentration to any of them was noticed.

Table 1.

J.P. Padmasiri
Chemist
18.05.1988

Comparison Of The Bacteriological Quality Of Traditional And Shallow Wells

Date Of Sampling	Location	Well Number	Total Coli	E.coli
04.12.1987	Udunuwara	4001-UN	200	14
		Open well	200	100
15.12.1987	Udunuwara	4002-UN	80	20
		Open well	200	64
15.12.1987	Udunuwara	4004-UN	nil	nil
		Open well	60	24
15.12.1987	Udunuwara	4005-UN	nil	nil
		Open well	500	100
22.02.1988	Katugastota	422	nil	nil
		Open well	500	100
22.02.1988	Katugastota	4896	100	50
		Open well	TNTC	TNTC
22.02.1988	Katugastota	562	20	nil
		Open well	100	70
25.02.1988	Pujapitiya	309	10	02
		Open well	TNTC	200
25.02.1988	Pujapitiya	4828	62	nil
		Open well	200	24
25.02.1988	Pujapitiya	335	20	nil
		Open well	TNTC	20

All these traditional wells are in close proximity to the protected hand dug wells

* TNTC Too numerous to count

No very clear areal concentrations of contamination were observed in Harispattuwa. The highest percentage was met in Arambekade (44% of 34 wells) and lowest in Arambepola (9% of 22 wells) The number of observations is too low to make statistical decisions.

To investigate if surface water can intrude the wells a tracer test was made. Two hand pump wells with cracks on the aprons were selected and two other hand pump wells, all in Harispattuwa. The selected well nos. with cracks are 4807 and 650 The other well nos. are 4 and 652. Dissolved table salt (NaCl) was used as a tracer. The salt was poured on the apron of those wells with cracks and around the well on the others. The electric conductivity was expected to rise if there is any intrusion to the wells.

The conductivity was measured before pouring out the salt solution and a couple of times daily for 4 to 9 days. No traces of salt was found. The conductivity was fluctuating from day to day, and more due to rain fall. After rain the conductivity was lower (well nos. 650 and 652). This could indicate that although the salt was not traced in the wells the rain water can also enter the wells as surface water. The salt can be clogged in the unsaturated zone of the soil (Fig. 1). The conductivity variations are so sudden and large that there cannot be such variations in the aquifer and are, therefore, considered as indication of surface water intrusion to the well.

The survival rate of indicator bacteria was studied by analysing same sample twice. The other analysis was made after 24 hours. The literature suggests that the die off (T_{50}) for coliform bacteria is 17 hours (See chapter 2.4 for survival times of pathogens.). The test made correlates with it Table 2 shows the figures of the test.

Storage of drinking water for about 24 hours could be one way to produce safe water by simple means.

Table 2

J.P. Padmasiri
Chemist

Bacteriological Water Quality Checks In Storage

The water samples brought to the laboratory were inoculated and incubated for 24 hours at 44°C. The balance samples retained in the bottles at room temperature for further 24 hours and the test repeated

The results obtained of the samples kept in storage for 24 hours shows low count in E coli.

Well No.	E.coli	E.coli (after 24 hrs storage)
632	12	nil
282	04	nil
78	16	06
4715	14	02
75	500	128
2023-KU	120	82

E coli tends to die off in storage

Another test was made to check if the water gets contaminated after taken from the well. The results from this test are in Table 3. It is very clear that the water gets contaminated, usually by hands touching the water when pouring in or from the pot or can. The sample collected from house 1 in test site 1, Weligalla is not more contaminated than well water. The water was collected from a water cooler with a tap. The water in the cooler is prevented from later contamination because it is a closed system. The water had been stored for 96 hours

Table 3

J.P Padmasiri
Chemist

Bacteriological Survey Of Wells And Its House Holds In Udunuwara Area Carried Out On 17.08.1988

This survey is carried out to check the contamination levels of water in the households in Udunuwara area The hand pump wells selected were free from bacteria, water is carried to households using aluminium pots From these pots water transferred to other utensils such as jugs, tumblers, cans, etc. Most of the householders interviewed were not boiling water for drinking purposes

	Samples Collected From	Storage Time In Hours	T.Coliform per 100 ml 35°C	E coli per 100 ml 44°C
1	Pethiyagoda - UN 6/36	-	nil	nil
	House 1 - aluminium pot	2-3	06	nil
	2 - glass tumbler	2	26	08
	3 - water can	1	60	nil
	4 - jug	1	80	nil
2	Weligalla - UN 7/4	-	nil	nil
	House 1 - aluminium pot	2-3	34	nil
	2 - aluminium pot	27	200	nil
3	Weligalla - 1016-UN	-	02	nil
	House 1 - water cooler tap	96	02	nil
	2 - aluminium pot	2	08	02
	3 - aluminium pot	14	14	nil

Samples for chemical and bacteriological analyses were earlier collected from newly constructed wells by KDWSSP during test pumping. It has been discovered that the results of the bacteriological analysis are not representative and give high numbers of indicator bacteria This is due to human contact with the water and the inner parts of the

well before proper chlorination. Therefore, it is proposed that the samples for bacteriological tests should be collected after 1 to 2 months after installation of the pump, when the well has reached stable conditions. During this procedure the results have become better and more reliable.

3.2 Construcion Of Hand Pump Wells

Possible construction defects and shortcomings were studied by field checkings. No direct construction errors were found. In a few cases the concrete cylinders have settled a little and, therefore, the aprons are cracked. In other cases the soil around the well has settled and because of that cracks on aprons have appeared. This has already been prevented by constructing the apron to the well after a few weeks, so that the soil will settle before construction.

It is suggested that a hand dug well should be protected from surface water by an imperveous apron and impervious concrete cylinders to a depth of 3 m. A test is proposed with about 15 to 20 wells. Tar or bitumen is to be applied on the outside of 4 to 5 uppermost concrete cylinders to make them impervious.

The apron slab and the well cover is regarded as impervious enough as there is no water pressure on them and the amount of contaminated water on them is very small and it is running very rapidly away from them It is to be mentioned that although the apron of well no. UN-7/4 (Udunuwara) is badly cracked, possibly due to settling of the surrounding soil the water is completely free from coliforms It has not been studied whether any other not contaminated well has cracked aprons.

If the tar or bitumen prevents surface water to enter wells this method is suggested to be used during construction of new shallow wells

It is shown that deep wells provide safer water than shallow wells. Therefore, more effort has been taken to construct deep wells as possible. A new hand transportable drilling rig is to be provided for the Project for the amount of shallow well constructions to be decreased.

3.3 Reasons For Contamination

Many possible reasons for contamination of wells are noticed. Most shallow wells are located in or very near orchards. These gardens are often fertilized with cattle manure. Cattle is also frequently grazing in the vicinity of the wells.

Some of the shallow wells are situated by paddy fields. These fields are often fertilized with urea. This should effect the level of nitrogen compounds, but it has not been indicated in water analyses.

Near the wells there are often heaps of decaying fruits and leaves. As mentioned earlier in this text, both total coli and E.coli is expected to be found with rotting vegetation at elevated temperatures.

People have a habit to wash themselves on the apron if there is not any bathing well nearby, also being a considerable pollution risk for the wells. Although the apron and the well cover are impervious the contaminated water is not led far away from the well by the outlet drain.

Sometimes the well is situated in the middle of a village, which can create problems to the well due to high risk of contamination by wastewater, domestic animal dung, etc.

Some of these contamination risks can be avoided by informing the people of the risks. It is very obvious in some cases that people do not know about these risks. In some cases, in Harispattuwa, there are

cattle shelters within a few metres from the well and even high heaps of dung by the well.

During field investigations it was also checked if the vicinity of latrines can be the reason for contamination. No correlation between contamination and the distance to latrines or open water pits was observed. No wells constructed within a distance of 15 m from a latrine were observed. The distance of 15 m around a well should be kept free from pollution.

4. CONCLUSIONS

- The presently used non pathogenic coliform bacteria to indicate faecal contamination are not necessarily reliable in Sri Lanka. These indicator bacteria tend to regrow at elevated temperature and they occur also in rottening vegetation. As indicator E.coli is more reliable than total coli.

- No correlation has been noticed in this study between amount of total coli and E.coli.

- The standards are understood to be too strict for tropical conditions because of the capacity of coliforms for regrowth outside human influence.

- No correlation between suspected contaminated wells and the possible contamination sources such as latrines and traditional water pits has been noticed.

- Pit latrines and other faecal originating contamination are expected to discharge nitrogen compounds. No sign of this has been indicated in wells.

- No correlation between the depths of hand dug wells and possible faecal contamination has been discovered.

- The amount of indicator bacteria in drilled wells is less than in dug wells, but the difference is not remarkable according to E.coli analyses.

- The water quality of protected hand dug wells is clearly better than that of traditional wells

- No direct construction defects were discovered.

- The bacteriological analyses from dug wells have been made too early after construction. This has given too high contamination figures.

- The soil in the project area is nearly ideal for preventing contamination from latrine pits.

- Contamination is not clearly concentraded in any certain area.

- E.coli tends to die off in storage. Storaging may be a simple method of preparing safe drinking water.

- Household water tends to get contaminated after collection from the well This is due to human contact with the water, dirty hands, etc.

- There seems to be a great need for basic research into the suitability of the various tests, suitable indicator bacteria and for sound epidemiological studies to establish realistic standards, which can be applied in tropical areas. The project proposes that the Competent Authorities seek donor co-operation to initiate these most likely very extensive studies.

5. RECOMMENDATIONS

- The presently used indicator bacteria, especially total coli, is not to be taken alone as an evidence of faecal contamination in the tropics.

- Reviewing of the Sri Lankan Standards should be done accordingly.

- The bacteriological water analysis of dug wells should be done after 1-2 months from chlorination and installation of the pump.

- Drilled wells are preferred where selection between dug well and drilled well is possible.

- It is necessary to give people more information about how to prevent contamination of drinking water.

- A distance of about 15 m around a well should be kept free from pollution sources.

- Surface water should be prevented from entering the wells by constructing ditches where it is possible. Tests could be made with impervious concrete cylinders in the upper part of the wells.

- The outlet drain from the apron should be at least 3 m where possible.

- The apron should be clearly inclined to keep it dry and free from contaminated water.

- Study programme with Peradeniya University should be continued to do more specific determinations of the bacteria.

Studied Literature

- Abebe, L.S., 1986.
  Hygienic Water Quality: Its Relation to Health and the Testing Aspects in Tropical Conditions. Tampere University of Technology, Dept of Civil Engineering in Co-operation with FINNIDA, a postgraduate course n:0 28, Tampere, Finland, 94 pp.

- Feachem, R., McGarry, M. and Mara, D.(editors) 1987.
  Water, Wastes and Health in Hot Climates. English Language Book Society and John Wiley & Sons, Chichester, U.K. 399 pp.

- Geldreich, E E., Bordner, R.M., Huff, C.B., Clark, H.F. and Kabler, P.W., 1962.
  Type Distribution of Coliform Bacteria in the Faeces of Warm-Blooded Animals. Journal WPCF, vol. 34, No. 3, pp 295-301, U.S.A.

- Huotarinen, H., 1988.
  Status Report on Balance Hand Pump Wells in Harispattuwa, KDWSSP, Kandy, Sri Lanka, 10 pp.

- Huotarinen, H. and Taka, M. 1988.
  Report on Survey of Bacteriological Contamination in Harispattuwa and Udunuwara Hand Pump Wells, KDWSSP, Kandy, Sri Lanka, 4 pp

- Lahti, K., 1986
  Kaivovesien Mikrobiologiset Maaritykset ja Tulosten Tulkinta (The Microbiological Determination of Well Waters and Interpretation of Results), a memorandum National Board of Medicine, Helsinki, 4 pp.

- Lewis, J W , Foster, S.S.D. and Drasar, B.S., 1982.
  The Risk of Groundwater Pollution by On-site Sanitation in Developing Countries, A Literature Review, 1982. International Reference Centre for Wastes Disposal, Duebendorf, Switzerland, 79 pp.

- Padmasiri, J.P., 1988.
Report on the Bacteriological Examination of New Hand Dug Wells and Borehole Wells in Udunuwara KDWSSP, Kandy, Sri Lanka, 2 pp.

- Padmasiri, J.P , 1988.
Bacteriological Survey of Open Wells in the Project Area, KDWSSP, Kandy, Sri Lanka, 2 pp.

- Padmasiri, J.P., 1988.
Bacteriological Censes of the Hand Pump Wells in KDWSSP - First Quarter 1988, Kandy, Sri Lanka, 2 pp.

- Standridge, J H and Sonzogni, W.C., 1988.
Evaluating Modifications to the MF Total Coliform Method for Drinking Waters with High Non-coliform Backgrounds. Journal AWWA, Research and Technology, June, 90 & 91 pp., U.S.A.

- Taka, M. and Aapola, R., 1988.
Study on Bacteriological Contamination and its Prevention in Hand Pump Wells in HWSSP Area, Interim Report, KDWSSP, Kandy, Sri Lanka, 7 pp.

- Taka, M., 1987
Preliminary Report on the Bacteriologically Contaminated Wells in Harispattuwa, KDWSS, Kandy, Sri Lanka, 6 pp.