

A STUDY ON THE DRINKING WATER QUALITY OF LOW YIELDING BOREHOLE WELLS IN NORTH-WEST OF KANDY DISTRICT

by

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Abstract

Hydrogeological investigations were carried out to provide high quality groundwater for the people living in rural areas by the Kandy District Water Supply and Sanitation Project, being part of the development co-operation between Finland and Sri Lanka.

Deep boreholes were constructed by drilling at the selected sites and hand pumps were installed for the low yielding wells after evaluating quantity. Water samples were collected to find the quality of water sources from 152 borehole wells in the Galagedara AGA division, north-west of Kandy district.

Out of 152 wells, 474 water samples were tested. Eighty percent of the water samples conformed to WHO/SLS of drinking water. It was found that the deep groundwater from the fractured crystalline rocks gets contaminated (due to construction and installation errors) by bacteria and therefore boiling is necessary before drinking. Thirteen percent of wells had a high iron content. The excess iron contents could be removed by utilizing FINNIDA filter units. The quality of water in the study area of the Wet Zone is much better than the Dry Zone deep well water for drinking purposes.

1.0 Introduction

1.1 General

Water is perhaps the most basic resource. It is an extremely scarce and hence a most valuable resource in many parts of the world. Because of this the period from 1981-1990 was declared as the International Decade for Water Supply and Sanitation. Sri Lanka was able to launch out on several water supply and sanitation projects. The donor of one such project is the Finnish International Development Agency (FINNIDA) with the object of providing safe drinking water and sanitation in the Kandy district.

The deep well concept was introduced to Sri Lanka in 1978 and a number of foreign organisations have started to tap deep groundwater resources in crystalline rocks. Under

this programme SUNNITTELUKESKUS OY - PLANCENTRE LIMITED executed a water supply project (being part of the development co-operation between Finland and Sri Lanka) in the area of Harispattuwa electorate in Kandy district. The project works and its future programmes were undertaken by SOIL AND WATER LIMITED, Finland, in 1987. The project involves planning and designing of water supply for the total area of Kandy district. The project supervision for Finland was done by FINNIDA and it was named as "Kandy District Water Supply and Sanitation Project (KDWSSP)". Hydrogeological investigations are being carried out by this project for locating groundwater resources and determination of their properties for the realization of water supply in the area belonging to the Kandy district.

1.2 Objectives

The purpose of the groundwater investigation was to find high quality groundwater for the total population of the project area. The objective of this paper is to highlight the deep groundwater quality variation of different low yielding, borehole wells in the areas coming under Galagedara electorate, and its effect on people living in the study area, north-west of Kandy District.

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2.0 The Project

According to the project plan of the Kandy District Water Supply and Sanitation Project, the area of Kandy district has been divided into Assistant Government Agent (AGA) divisions, to carry out water resources studies including identification of communities, their requirements and areas to be implemented.

Galagedara AGA division which is situated north-west of the Kandy district in the central hills of Sri Lanka is one priority area belonging to the project. The elevation varies between 250 and 1020 meters above mean sea level. Geographically it is north west of the Kandy district. It is adjoining Harispattuwa and Yatinuwara AGA divisions and is also bounded by the Kurunegala and Kegalle districts. The main roads that run through the area are Kandy-Rambukkana and Kandy-Kurunegala (Fig. 1). The size of the area is about 120 square kilometers. Mean monthly temperature variation in Kandy lies between 23° and 26° C. The mean annual rainfall in the Kandy district ranges from 1940mm to 5520 mm (PLAN CENTRE LTD. REPORT, 1986). The population of Galagedara AGA division is estimated to be 64,000 (SOIL & WATER LTD, 1989).

The water supply of the area was based mainly on an open dug well which normally supplied an adequate amount of water but where the quality of water is poor. The poor water quality was caused by the wells being unprotected and partly because the water of the well was used for different purposes near the well itself. This was used for domestic purposes as well as for sanitation and for washing laundry which were done beside the well. A survey carried out on the quality of groundwater in unprotected traditional wells indicated that about 94% of wells do not conform to WHO standards of drinking water. (Padmasiri et. al. 1992). In addition these open dug wells run dry during droughts. Therefore hydrogeological investigations were carried out to obtain an adequate amount of high quality groundwater in the densely populated areas within the division.

The number of wells needed for the villagers in each Grama Sevaka Niladari area were decided by the committee appointed from the consumers. Locations to be drilled were selected according to the hydrogeological conditions of the area. After feasibility investigations a deep borehole was constructed by drilling at the selected suitable location, or otherwise the location was recommended for a large diameter dug well where accessibility was poor. Each well was tested to evaluate the quantity and quality of the water source.

The deep wells have been categorised into hand pump borehole wells and production borehole wells. Hand

pumps were installed for the low yielding wells (generally the well yield is above 4 liters per minute) and electric water pumps were installed for production wells (very high yields above 200 l/min) for distribution of water through a distribution network; after pumping to a storage tank. Boreholes of 115-200mm diameter and in the range of 15-100m depth were drilled in this area.

3.0 General Geomorphology, Geology and Hydrogeology of the Area

The area is hilly, characterised by narrow and steep valleys. Most of valleys are large and generally parallel to NW direction, which is the normal direction of Rambukkan Oya. The peak height in the west area is around 250 MSL and in the east commonly around 550-650 MSL. The highest peak is on the southern boundary being 1020 MSL.

The major rock types in this area are biotite gneiss, hornblende biotite gneiss, migmatite, charnockitic gneiss and quartzite. All these rocks are Precambrian crystalline and geologically belong to the Highland Series of Sri Lanka. There are a few bands of pink feldspar granitic gneiss.

Structurally the areas consists of two anticlines and a syncline and the anticlines plunge towards the north-west. The general trend of the all rock types is NW-SE. Quartzite is the only highly fractured rock. Joints in other rocks are of the tightly closed type. A few open joints which are filled by other materials can be seen at the ground surface. There is a major fault lying to the west of the area.

In situ weathered materials are the overburden in the hilly areas, and the valleys are filled by transported materials from clay to gravel with a few large boulders. The general thickness of the weathered overburdens varies up to 20m. But in fracture zones where the rock underneath is quartzite, the overburden thickness may be higher than the general and the thickest overburden has been recorded as 36m above quartzite rock.

The valleys are very deep, narrow and their slopes are very steep. The steep slopes do not create proper aquifers and the groundwater table fluctuations are large. Therefore percolation is low and most of the precipitation runs off as surface flow. The overburden in the valleys in the valleys is generally thick. Suitable locations for drilling are selected by means of the directions of rock fractures (joints, faults and weak zones) and the thickness of overburdens. Comparatively low success rates (low yields) of drilled wells in the studied area indicate that locating a suitable place in the fractured zone for a borehole well is also difficult.

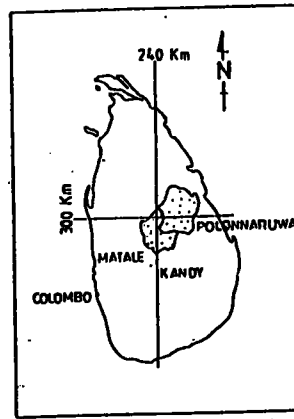
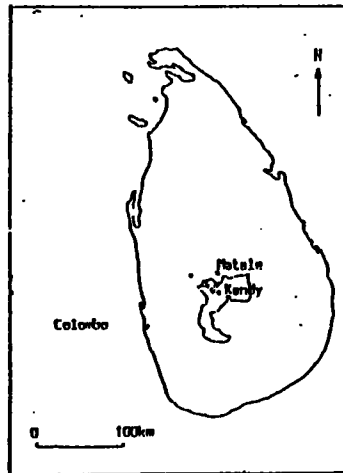


Fig.1 The project area

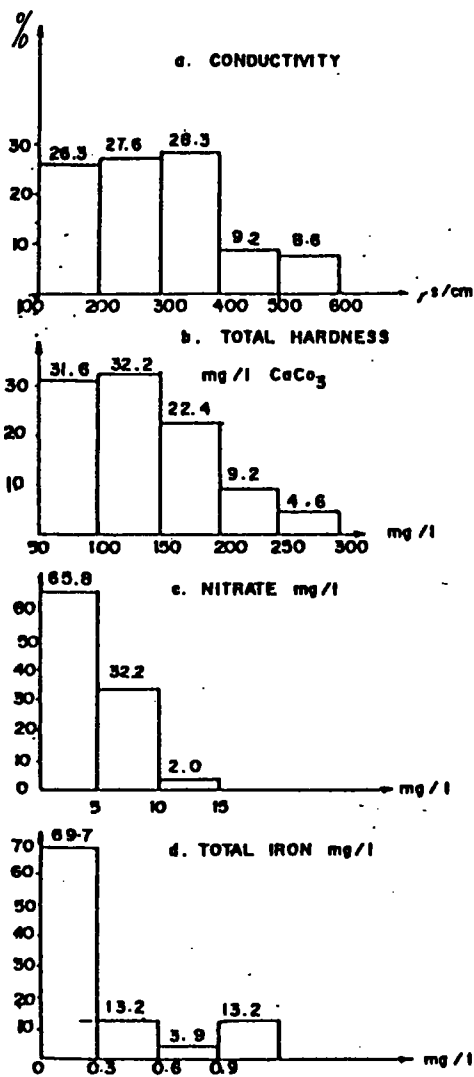


FIG -2 CHARACTERISTICS OF BOREHOLE HPWS

Table 1 Range of the Chemical Parameters in Bore Holes in Galagedra and Safe Limits for Drinking Purpose

Parameter mg/l	Range of Parameter		Safe Limits	
	Min	Max	WHO 1983	SLS 1983
Conductivity $\mu\text{s/cm}$	50	585	2000	3500
Hardness	40	285	500	600
Nitrate	1.0	15	45	45
Iron	0.10	7.5	0.30	1.0
Ammonium	0.01	0.05	-	0.06
Chloride	3.00	40	250	1200
Fluoride	0.10	0.80	1.5	1.5
Sulphate	10.00	295	400	400
Manganese	0.10	2.0	0.10	0.5
Phosphate	0.03	1.0	-	2.0

Table 2 Yield of Boreholes HPW

Flushing Yield l/mt	No of B.H. Wells	%
4	41	32.8
5-20	34	27.2
21-50	29	23.2
51-100	11	8.8
101-200	07	5.6
201-300	03	2.4

Table 3 Summary of the Total Coliform and Faecal Coliform Densities in Borehole Hand Pump Wells.

Density Range per 100 ml	Total Coliforms		Faecal Coliform	
	No. of Samples	%	No of Samples	%
0	347	71.0	435	91.8
1-10	74	15.1	33	7.0
11-100	54	11.0	06	1.2
101-500	14	2.9	-	-

Table 4 Bacteriological Quality of Bore Holes HPWs

No of Samples	TC } <1 per 100 ml FC }		TC<10 } per 100 ml FC<1 }		Conforming to WHO Standards	
	No of Samples	%	No of Samples	%	No of Samples	%
474	379	80.0	36	7.6	415	87.6

4.0 Methodology

Water samples were collected from 152 borehole wells which were constructed in the Galagedara AGA division.

The samples were collected in cleaned acid washed plastic bottles and transported to the laboratory in a cool box. These sampling bottles were rinsed with water to be sampled before the final collection for analysis. These samples were analysed within 24 hours after sampling.

In ascertaining the water quality of hand pump wells, DR/2000 HACH programmable spectrophotometer was utilised along with pH and conductivity meters.

The samples were collected after preliminary pumping of the residual water in the pipe and sterilization of the mouth of the outlet by flame for the bacteriological examination. The water was collected in sterile glass bottles and transported in cool boxes. The samples were then subjected to culturing within two hours of sampling. All the samples were tested for total coliforms and faecal coliforms by membrane filter (MF) method using MILLEPORE materials and media.

The results of the chemical and bacteriological analysis were compared with the Sri Lankan Standards and WHO limits. The variation of chemical parameters were interpreted using bar charts (Fig. 2).

5.0 Results and Discussion

Conductivity, total hardness, nitrate, total iron, ammonia, chloride, fluoride, sulphate, manganese and phosphate were measured to find the inorganic quality of borehole well water. Table 1 shows the range of the parameters and safe limits. Table 2 gives the yield of boreholes with hand pumps. Tables 3 and 4 show the summary of the total coliform and faecal coliform densities and bacteriological quality of borehole wells.

Table 5 shows some similar analysis of groundwater from borehole wells in Matale and Polonnaruwa districts which belong partly to the Intermediate Zone and Dry Zone of Sri Lanka. These results can be used for comparative study with the present results which belong to the Wet Zone of the country.

Excessive concentration of fluorides is found in many deep wells in the Dry Zone, notably in the Anuradhapura and Polonnaruwa districts. The fluoride concentrations in many of these deep wells exceeds 1.5 mg/litre and pose a health hazard to the consumers (Dissanayake, 1989). Most of the tube wells drilled in Matale and Polonnaruwa districts show higher fluoride concentration than 1.5 mg/litre (Christensen and Dharmagunawardena, 1986).

The fluoride level in borehole wells in the study area varies between 0.10 and 0.80 mg/litre, and shows that its effect to human health is not dangerous. Table 1 indicates that the fluoride level in deep wells constructed in Galagedara AGA division is within the permissible level of WHO.

The conductivity measured was below the maximum desirable level of 750 $\mu\text{mhos/cm}$ as defined in the Sri Lankan Standards of 1983. About 46.1% were in the conductivity range of 300-600 $\mu\text{mhos/cm}$ and 53.9% are below 300 $\mu\text{mhos/cm}$ as indicated by Fig. 2a. The range of conductivity in Matale and Polonnaruwa districts lies in between 250-1000 $\mu\text{mhos/cm}$ and indicates more ion concentration in Dry Zone wells than the wells in the study area in the Wet Zone.

The maximum desirable level for total hardness is 250 mg/l and the maximum permissible level is 600 mg/l. 95.4 percent was in the total hardness range of 50-250 mg/l as CaCO_3 for drilled wells, and therefore it can be categorised as either soft or moderately hard water as described by TODD(1980). None of these wells had hardness concentration exceeding 600 mg/l (Fig. 2b). About 42-45% of borehole well waters in Matale and Polonnaruwa districts are very hard and the remaining are moderately hard to hard water (Table 5).

The maximum permissible level is 44 mg/l as NO_3 according to the Sri Lankan Standards (SLS) 1983. All wells had nitrate concentration within the safety limits and only 2.0 percent was in the nitrate range of 10-15 mg/l as NO_3 (Fig. 2c).

The iron taste in water from a borehole well may originate either from the natural iron content in groundwater or from corrosion of metallic pump parts. Iron concentration in Matale and Polonnaruwa districts is below 0.3 mg/l (about 80%) and only in 6% of the samples it exceeds 1.0 mg/l. But in the studied area about 69.7% is below 0.3 mg/l and therefore comparatively the iron content in these deep wells is higher than in Dry Zone waters.

The main constraint of the hand pump borehole wells is the presence of high iron content (13.2% above 0.9 mg/l). If the water is aerated, dissolved iron (Fe^{++}) is oxidised to insoluble iron (Fe^{+++}) and precipitates as Ferric Oxyhydroxides. This aeration and retention time of water in the filter has been adopted in designing the filter units for the removal of iron (Fig. 2d).

69.7% of the wells of the conform in the range of 0.3 mg/l as Fe, which is the maximum desirable level for FE in Sri Lankan and WHO standards (Fig. 2d). There are 13.2% drilled wells exceeding 0.9 mg/l as Fe. The quality of water in these wells has been improved utilizing FINNIDA filter units (PADMASIRI & ATTANAYAKE, 1991). The new

FINNIDA square type filter unit (Fig. 3) has been designed to avoid these problems. The special features are simplicity of design and possibility of construction in situ. Handling during maintenance is easy, thus achieving village level operational and maintenance (VLOM) status. In addition the construction cost was low (Rs.1,600/-US\$40). FINNIDA square type low cost filter units were constructed at some of the hand pump well locations. Frequent maintenance of these filter units is essential. It is also necessary to train the beneficiaries to maintain the filter units. The beneficiaries themselves are able to identify when to clean and maintain the filter unit because the high iron content gives a yellowish brown colour and a bad taste to the water.

In addition to filtering rate is slow when porosity of the charcoal is reduced. Once the filter unit is blocked, water splashes out from the inlet of the hand pump. Table 6 gives further details about the FINNIDA type filter units. Maximum permissible level of iron is 1.00 mg/l according to Sri Lankan Standards of Drinking Water (SLS 614 Part 1, 1983). Above these levels the quality of water is poor due to unpleasant tastes and yellowish brown colour and therefore recognition is easy.

After initial installation of the filter unit, the first two cycles of cleaning were handled with consumer participation. Thereby beneficiaries were trained to clean the filters by themselves. Hand pump wells installed with FINNIDA filter units have been monitored to determine the effectiveness and efficiency in reducing iron concentration.

The consumers are trained to do the cleaning of the filter units from time to time. Cleaning required in the filter units depends on the iron content of hand pump wells. The cleaning interval is varied between 3 weeks and 3 months, and the time required for cleaning the unit is 30-45 minutes. Details of FINNIDA type filter units for iron removal have been given by Padmasiri and Attanayake (1991).

The chloride content of the wells tested in the range of 10-40 mg/l. The chloride content of these wells were very much below the maximum allowable limit of 400 mg/l. In the case of SO₄ content, the tested well were in the range of 10-80 mg/l as SO₄. However there were two wells where the SO₄ contents were 280 and 295 mg/l. The other parameters such as ammonia, phosphate and manganese have been carried out and found to be very low and not harmful (Table 1).

It is evident from the results in Table 3 that the increase in bacteriological densities were much less in drilled wells. The Faecal Coliform density range of 11-100 per 100 ml,

was present in only 1.2% and about 92% of drilled wells show absence of Faecal Coliform densities ().

Finally, the overall inorganic chemical quality of water of the drilled hand pump wells has been good except for the presence of iron in 13.2 percent of the wells. The water quality of those well could be improved using iron removal plants (PADMASIRI & ATTANAYAKE, 1991). However, only 87.6% of drilled well water samples conformed to WHO standards of bacteriological quality (Table 4). This indicates that deep groundwater from the fractured crystalline rocks gets contaminated (due to construction and installation errors) by bacteria and therefore boiling is necessary before drinking.

33% of the borehole wells had a flushing yield of 4 liters/mnt (Table 2). This amount of water is sufficient for 20 households. The high yield wells of more than 200 l/min were limited to 3 wells in this studied area. Hence a piped water supply scheme was not feasible in this area.

6.0 Conclusion

Production borehole wells of yield more than 200 liters/minute were limited to three wells. Hence a piped water supply scheme is not feasible. This may be due to the unfavourable geological structures of the area.

Iron content in this deep groundwater are comparatively higher than the deep water of Dry Zone wells in Sri Lanka. This problem can be eliminated using FINNIDA square type filter units. 13.2% of the wells had high a iron content of more than 0.9 mg/l. All these were utilised by construction of FINNIDA filter units. The filtered water so obtained conformed to Sri Lankan Standards of drinking water. All other elements tested were within or below the WHO safe limits and of no harm to the human health. Out of the 152 borehole hand pump wells, 474 water samples were tested. 88% of the water samples conformed to WHO/SLS of drinking water. Comparatively the quality of water in this study area is very much better than the deep well water in the Dry Zone.

The deep groundwater from the fractured crystalline rocks may be contaminated due to construction and installation errors by bacteria and therefore boiling is necessary before drinking.

7.0 Acknowledgement

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Table 5: Summary of values of chemical parameters in ground water from different rock types

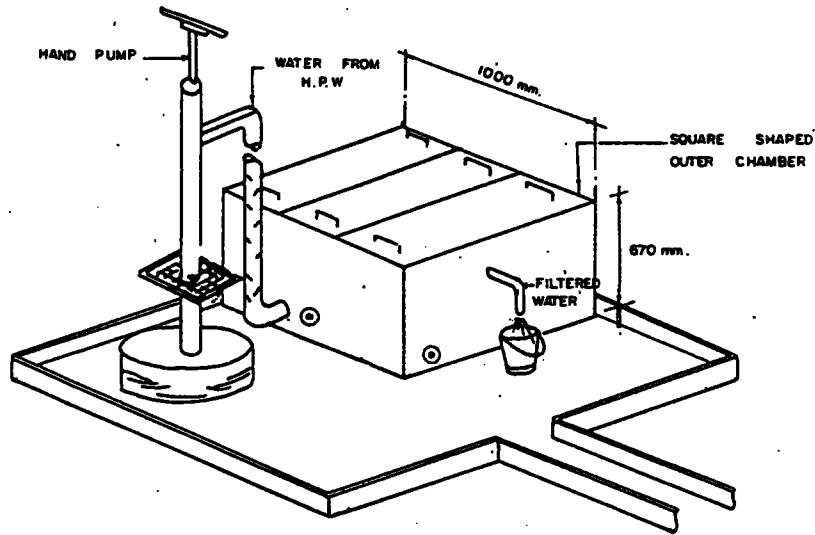
	CONDUCTIVITY		pH		FLUORIDE		TOTAL HARDNESS		TOTAL
	micro-mhos/cm				mg/l				IRON
	Range	Shape	Range	Shape	Range >1.5	>2.0	Range		<0.3 mg/l
					mg/l	mg/l			
Biotite Gneiss	250-1000	W	6.5-7.0	W	0.0-2.5	19%	9%	Moderately hard very hard	80%
Calc Gneiss	200-1000	W	6.5-7.0	W	0.0-2.0	10%	0%	42% ver hard	78%
Charnockites and Charnockitic Gneiss	250-1000	W	6.5-7.0	N	0.0-2.5	36%	20%	44% very hard	80%
Granulites and Granulitic Gneisses	250-1000	W	6.5-7.0	W	0.0-2.0	8%	0%	Moderately hard	58%
Quartzites	250-500	N	5.5-7.0	W	0.0-0.5	0%	0%	Soft to moderately hard	95%
Crystalline Limestone	500-750	N	6.5-7.0	N	0.0-0.5	0%	0%	44% very hard	98%

RANGE : Typical interval including the major part of data (at least 80%)

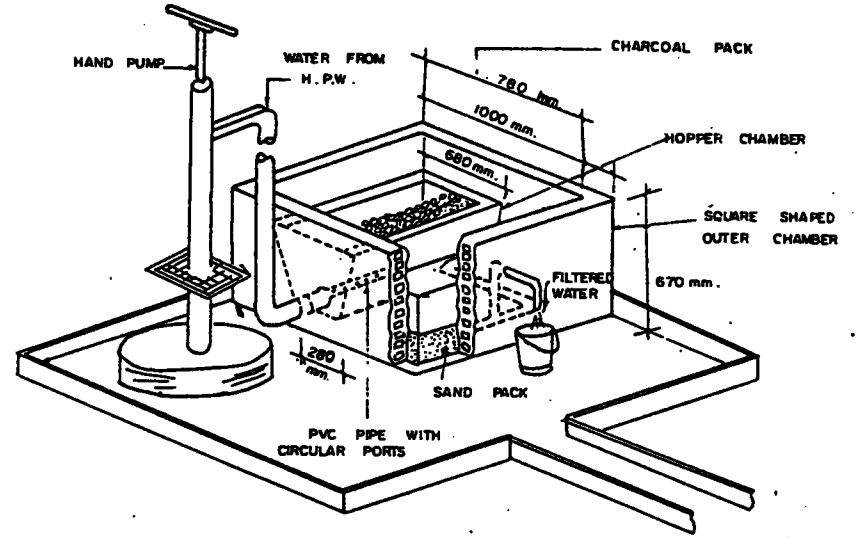
SHAPE : Appearance of frequency distribution histogram (W = 'wide', N = 'narrow')

Table 6. Comparison of Iron Reduction Filter Units.

	FINNIDA Circular Type	FINNIDA Square Type
Easiness in transportation	Needs to be transported as the pre-cast unit which is very difficult in handling. Weighs about 900kg.	Can be transported to the site as materials and could be insitu constructed
Requirements of space for installation	1.1 m ²	1.2 m ²
Effective filter area	0.80 m ²	1.2 m ²
Moulds and special facilities for production	Requires a mould and pre-cast yard for production	Only a simple shuttering is required and could be insitu cast
Initial cost	Rs. 2,400/-	Rs. 1,600/-
Easiness in cover slabs for maintenance	Very heavy as the cover slab weighs 350kg and needs about 04 people for handling	Each segment of cover slab weighs about 50kg. 02 persons can handle
Percentage iron reduction	In the range of 75%	In the range of 92%
Easiness in maintenance at village level	Easy	Very easy
Maintenance cost excluding labour per annum	Rs. 100/-	Rs. 100/-



IRON / MANGANESE REDUCTION PLANT
FINNIDA SQUARE TYPE



FINNIDA SQUARE TYPE FILTER
CONSTRUCTION COST - Rs. 1600/- US \$ 40

Fig. 3 Iron/Manganese reduction plant - FINNIDA square type.

8.0 References

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