RURAL SANITATION

RESEARCH AT
CENTRAL PUBLIC HEALTH ENGINEERING RESEARCH INSTITUTE
NAGPUR, INDIA

REPORT BY

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C O N T E N T S

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by

Prof. S.J. Arceivala
Director
Central Public Health
Engineering Research Institute
Nagpur, INDIA

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INTRODUCTION

Nearly 75 % of the Indian population lives in villages. They depend mostly on open dug-wells for their water supply. Rural water supply is, therefore, of prime interest for a country like India. Surveys carried out by the CPHERI, Nagpur, and others have invariably shown that open dug-wells are highly polluted. It is no wonder that the death rate for enteric diseases in India is approximately 360 per 100,000. The back-log of water supply schemes to be undertaken is so enormous and the rate of population growth is so rapid (doubling every 25 to 30 years) that it is a moot point whether the backlog will ever be wiped out.

Research in rural water supply is strongly supported by the Government both at the Centre and at the State levels and also forms an important activity of the CPHERI, Nagpur, a national laboratory under the Council of Scientific & Industrial Research, India. Some aspects of the work done by CPHERI are described below :

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RURAL WATER QUALITY SURVEYS

(a) Bacteriological Quality of Open Dug-wells :

Bacteriological quality surveys of well waters in India have always presented a sorry tale. Generally, these are open dug-wells, grossly polluted, as can be seen from the following table based on some surveys carried out by CPHERI :

TABLE I

Well Water Surveys

Indicator Organisms	Percentage of wells showing MPN values of bacteria per 100 ml							
	Delhi and surroundings				Bhopal and surroundings			
	Wells examined - 300				Wells examined - 50			
MPN/100 ml	0	1 to 20	>21	Max. value recorded	0	1 to 20	>21	Max. value recorded
Coliforms	4%	3%	93%	2,40,000	4%	0%	96%	2,40,000
Enterococci	6%	0%	94%	93,000	6%	24%	70%	40,000

(b) Quality of Well Waters Fitted with hand-pumps :

A similar study carried out by CPHERI, of covered wells fitted with hand-pumps at Delhi shows a somewhat better picture,

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though not satisfactory (See Table II). Unfortunately, only about 10 % of the wells in and around Delhi are fitted with hand-pumps :

TABLE II

Hand-pumps Survey

Indicator Organisms	Percentage of hand-pumps showing MPN values of bacteria/100 ml							
	Delhi City				Rural Delhi			
	Hand pumps examined - 97				Hand pumps examined - 20			
MPN/100 ml	0	1 to 10	1 to 20	> 100	0	1 to 10	1 to 20	> 100
Coliforms	37%	15%	21%	27%	25%	-	30%	5%
Enterococci	44%	16%	25%	15%	40%	-	25%	0%
Faecal coliforms	67%	12%	17%	4%	Not available			

(c) Quality of River Supplies :

A large number of villages located on the banks of perennial rivers take their water supplies directly from the rivers which are also often grossly polluted. A survey of the Jamuna river carried out by CPHERI between Delhi and Agra shows the following picture which is again highly unsatisfactory

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(See Table III). It is interesting to see how the quality of water deteriorates progressively as the river flows from one city to the next.

TABLE III

Quality of Jamuna River Water Consumed Untreated by Villagers

	Delhi	Okhla	Mathura	Agra
BOD, 5 days, 20°C mg/l	2	5	9	12
Cl, mg/l	18	46	111	140
SO_4, mg/l	29	44	110	112
Nitrates as N mg/l	0.8	1.3	2.1	3.8
Coliform MPN/100 ml	150	24,000	84,000	240,000
Enterococci MPN/100 ml	21	1500	46,000	150,000

Guinea worms have been reported from a large number of rural wells all over India and Bilharziasis from 2 States in India. In some areas, such as Calcutta and its environs, there is the added problem of iron-bacteria (Crenothrix, etc. with its attendant complaints of choking, colour and taste.

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(d) Chemical Quality :

There are hundreds of villages where waters are consumed which fail to meet accepted Standards for drinking waters, such as for fluorides, nitrates, iron & manganese, total dissolved solids, heavy metals, etc. etc.

There is no data available on the epidemiological status of such villages, nor on the physiological effects caused in the population from continued consumption of such waters. A pilot study has been planned by CPHERI in one of the States of India.

(e) Physical Condition of Rural Wells :

In a typical survey conducted in the rural areas surrounding Delhi, over 600 wells were inspected of which only 10.8 % could be described as " sanitary " wells, the rest being in an unsatisfactory condition :

Wells without hand-pumps	...	90 %
Wells without drainage	...	85 %
Wells without cover	...	91 %
Wells without parapet	...	48 %
Wells without lining	...	47 %
Wells without surrounding platform	...	30 %

Improved designs of hand-pumps and better guidance for construction of sanitary wells are being given by the Ministry of Health, Government of India, and the State Health Departments but the problems are too enormous to be solved in a few years.

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PVC PIPES FOR RURAL WATER SUPPLY

Based on a report by a German investigator*, a doubt was expressed that if plastic pipes are used for water supplies, the bacteria contained in the water may multiply using the substances leached out from the pipe for their nutrition. The Health authorities and the Indian Standards Institution, thereupon, requested CPHERI to conduct detailed experiments to establish the following :

i) Do a larger number of bacteria adhere to the internal surfaces of plastic pipes in comparison with the conventionally used galvanised & cast iron pipes ?

ii) Will chlorination, as practised usually, be capable of disinfecting the water flowing in a plastic pipe as effectively as in a galvanised pipe ?

iii) Will the organisms present in water either passing through or stagnant in a plastic pipe, be likely to multiply more than in the case of galvanised or cast iron pipes ?

Extensive studies carried out by CPHERI on PVC, high-density & low-density polyethylene pipes vis-a-vis galvanised and cast iron pipes under identical conditions showed that there was no significant difference between the plastic and the conventional pipes as far as the above three questions were concerned.

The Indian Standards Institution and the Ministry of Health have cleared the plastic pipes for use in cold water transmission. Rural installations are also coming up.

CPHERI is presently preparing a brochure giving recommendations on installation of plastic piping in the field and in buildings.

Ref : (i) Zimmermann W. - Stantehygiene, Vol. 7 pg. 266, 1956

(ii) Suitability of Plastic Pipes for Conveying Drinking Water - Environmental Health, Vol. 10, pg. 68, 1968

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DEFLUORIDATION

Several States in India have the problem of fluorosis due to excessive amounts of fluorides in their groundwaters ranging from 2 to 12 ppm as F^- and even higher. CPHERI has taken up this problem for study and development of a suitable medium for selective removal of fluorides in a unit which can be operated by semi-skilled personnel.

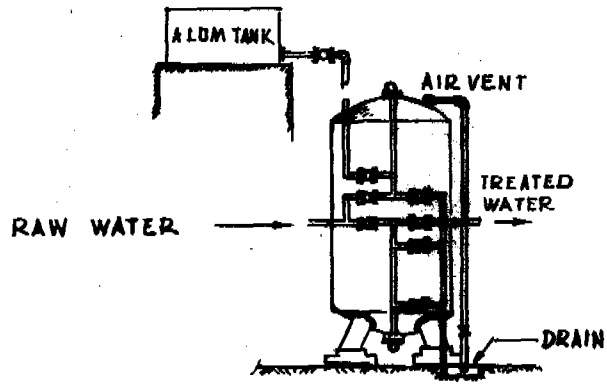

Diagram shows a pressure-filter type installation in which the special medium called " DEFLUORON-2 " is placed to a depth of 0.9 m.

DEFLUORON-2 is a synthetic, carbonaceous sulphonated material in granular form having a removal capacity of 620 mg of F^-/Kg of medium (224 grains/cft). Alum solution is used for regeneration.

The medium has been tested in two pilot plants set up last year and has proved to be very satisfactory and simple to operate. Cost of operation depends upon the concentration of F^- in the raw water and ranges from Re. 1/- to Rs. 2/- ($ 0.14 to 0.27) per 5,000 litres.

A home-defluoridator suitable for family use in rural areas has also been developed by the Institute.

Ref : " Defluoron-2 " - A new Medium for Reduction of Fluorides in Water Supplies ", Environmental Health, Vol. 11, p. 108, April 1969

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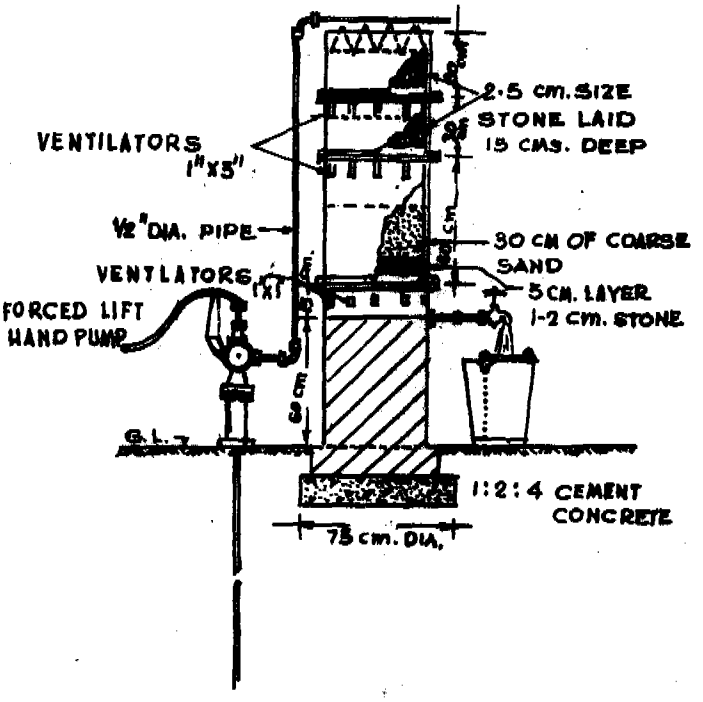
IRON & MANGANESE REMOVAL

The removal of iron and manganese from small water supplies particularly from individual or community wells in rural areas poses a problem which CPHERI is trying to solve by the development of a hand-operated unit suitable for the type of waters generally met in the north-eastern parts of India.



The iron removal unit developed by CPHERI comprises of four dismantleable cylinders placed one above the other as shown in the diagram. The top two cylindrical vessels each contain 15 cm layers of 2 to 5 cm assorted stones. The third cylinder contains a 5 cm layer of 1 to 2 cm stones and 30 cm of coarse sand. The bottom cylinder is a collection trough to which is attached a 1.2 cm tap through which the iron-free water is collected in a bucket. Ventilator holes for aeration are provided in-between the cylinders.

The raw water containing iron is sprayed over the gravel in the top cylinder and trickles down. The gravel gradually gets coated with oxides of iron which helps in the oxidation of iron.

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A portion of the precipitate is retained on the gravel. Although the gravel needs no washing, the sand requires washing once in every month. This can be done by removing the sand into a bucket and washing it manually to free it from sediment.

A unit of 1'-6" dia would be capable of handling 180 litres or 40 galls/hr. The estimated cost of the unit constructed from cement pipes is Rs. 250- ($ 33 approx.) exclusive of the hand-pump.

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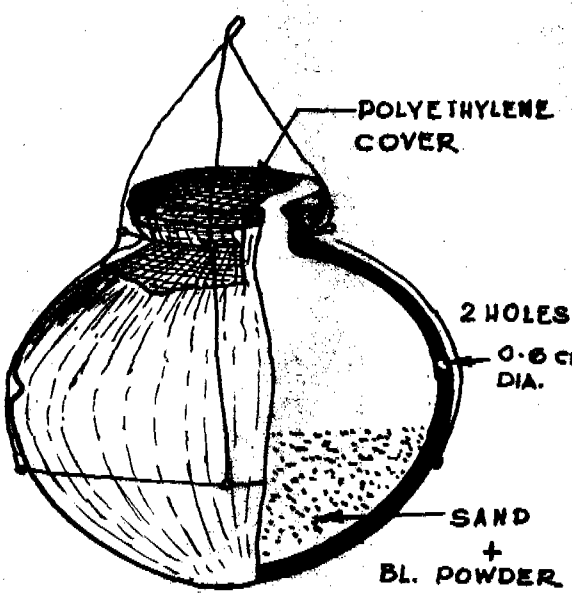
DISINFECTION TECHNIQUES FOR SMALL WATER SUPPLIES

Various disinfection techniques for small community water supplies were studied by CPHERI in order to assess their performance with open dug-wells as well as piped water supplies. Some of the known techniques were tried, a few were modified and few entirely new methods were developed. The disinfectant used in each case was bleaching powder. Other disinfectants were not used as they may not be readily available in all developing countries and were also not included in the scope of the present study.

The various methods were found to have their pros and cons, which have been summarised below for ready reference :

SINGLE POT WITH HOLES IN MIDDLE



One unit will chlorinate wells of 9000 to 13000 litres contents and having a withdrawal rate of 900 to 1300 litres/day (i.e., serving 40 - 60 people per day). Unit is filled with 1 $\frac{1}{2}$ Kg of bleaching powder mixed with 3 Kg of coarse sand (2 mm and above) covered and suspended 1 meter below water level. Needs replenishing every week.

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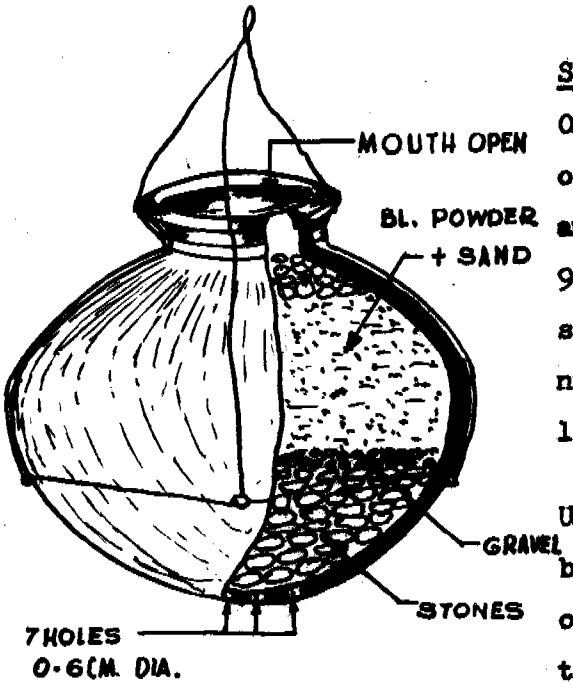
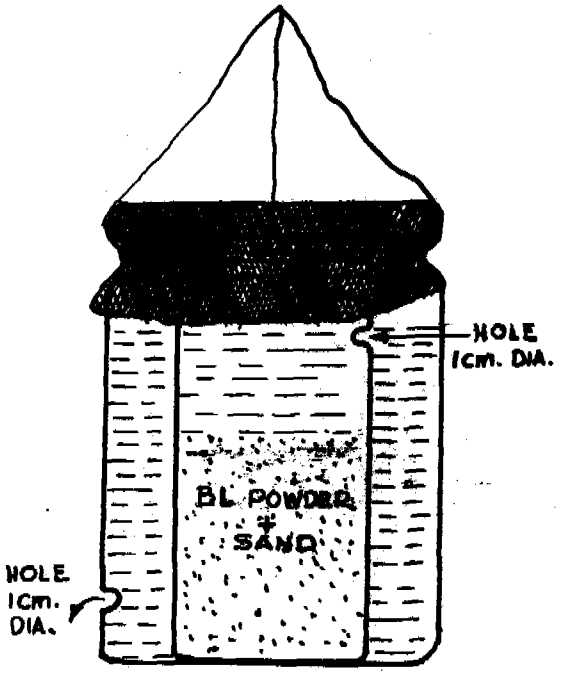


SINGLE POT WITH HOLES AT BOTTOM

One unit will chlorinate wells of 9000 to 13000 litres contents and having a withdrawal rate of 900 to 1300 litres per day (i.e., serving 40-60 people/day). More number of units may be used for larger wells.

Unit is filled with 1 $\frac{1}{2}$ Kg of bleaching powder mixed with 3 Kg of coarse sand as before but with the addition of 75 gm of sodium hexametaphosphate. It is then packed with gravel upto the top and suspended 1 meter below water level. Needs replenishing of chemicals every 2 weeks.



DOUBLE POT WITH A HOLE IN EACH POT

One unit will chlorinate wells of 3600 to 4500 litres contents and having a withdrawal rate of 360 to 450 litres per day (i.e., serving 15-20 people per day).

The inner pot is filled with 1 Kg of bleaching powder with 2 Kg of coarse sand (2 mm and above) and placed inside the outer pot. The mouth is loosely covered and the unit lowered as before. Needs replenishing every 3 weeks. Ideal for individual household wells.

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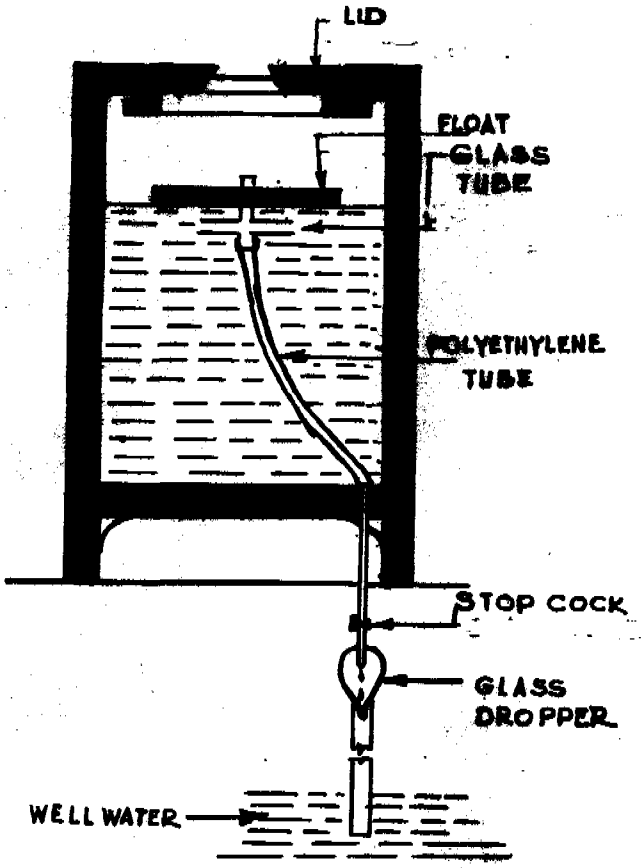
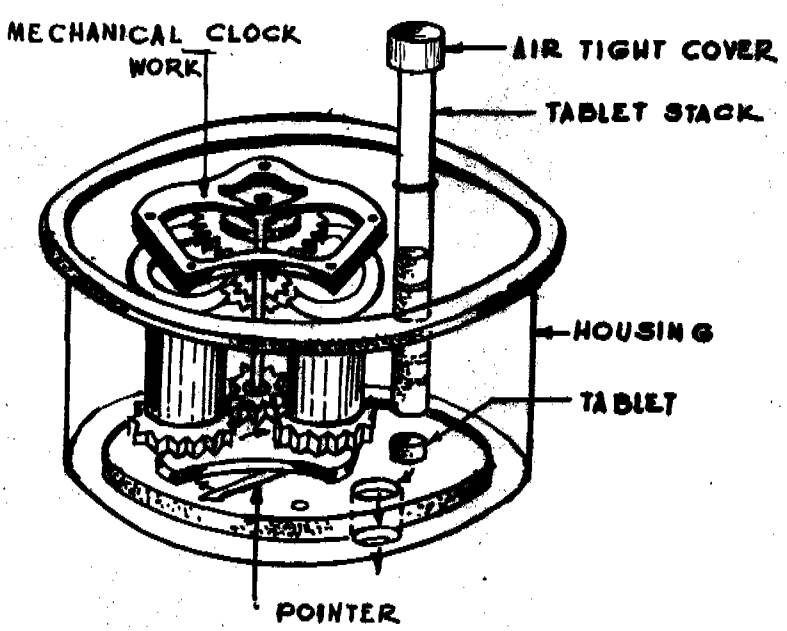
DRIP CHLORINATOR



It can be used to disinfect either open dug wells or covered wells, which contain 20,000 to 60,000 litres with a daily withdrawal of 2000 to 6000 litres. (i.e., serving 80 to 240 persons) The unit needs refilling after 2 to 5 days depending on the consumption. 1 % solution of bleaching powder is used. Drip rate may need adjustment once a day.

CHLORINE AND IODINE TABLET DISPENSER



This device uses a mechanical or electrical clockwork mechanism for dropping stacked tablets, one at a time, into the well through a hole, at each revolution. Its initial cost is about Rs. 100 - 200 ($ 14 to 28) per unit and appears to be more suitable for household wells in suburban areas, where electricity is available and tablets can be purchased.

Not recommended for villages due to possible pilferage.

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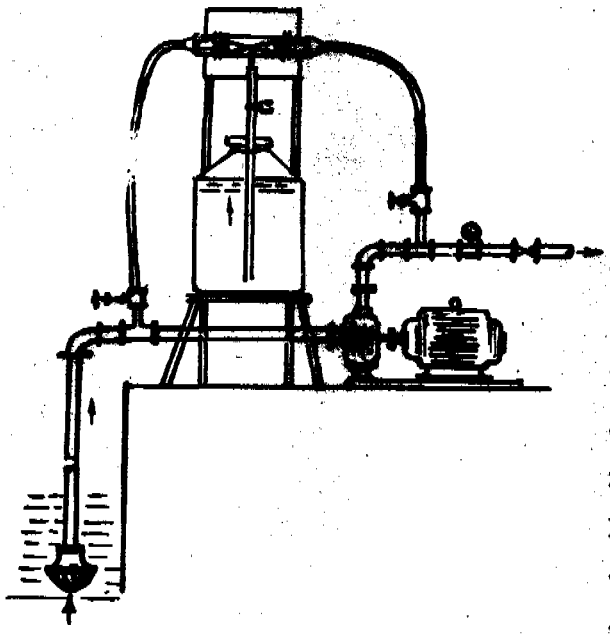
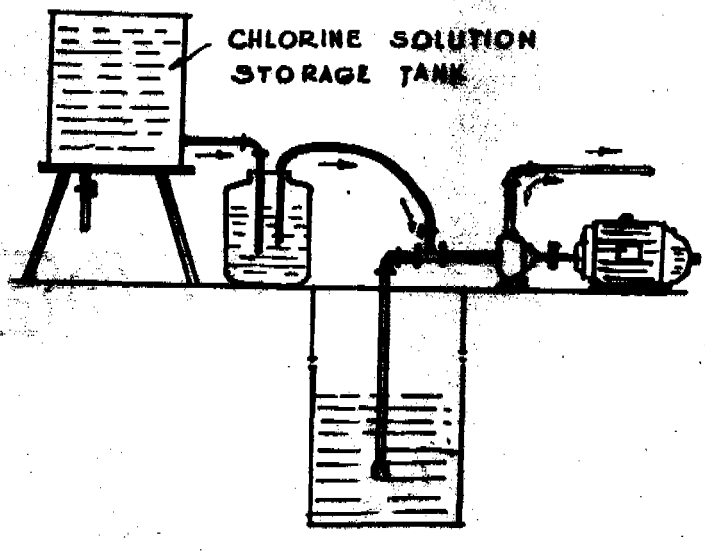


VENTURI AND EJECTOR-TYPE CHLORINATORS

These chlorinators which are available commercially and sometimes used with piped water supplies were found to be unsatisfactory owing to rapid chokage by $CaCO_3$ deposits at throats. Hence not recommended. Costs are also high ranging from Rs. 800/- to Rs. 1000/- per unit ($ 106 to 140)

DIRECT-FEED TYPE CHLORINATOR



A simple method of disinfection for piped supplies is to feed bleaching powder solution directly in the suction line of the centrifugal pump used for drawing water. The dose is adjusted by using a pinch-cock on the feed containing 1% solution in enough quantity to last 1 day and yet leave a surplus to prevent air from entering the suction side. This method requires no special gadgets and has been found satisfactory in operation.

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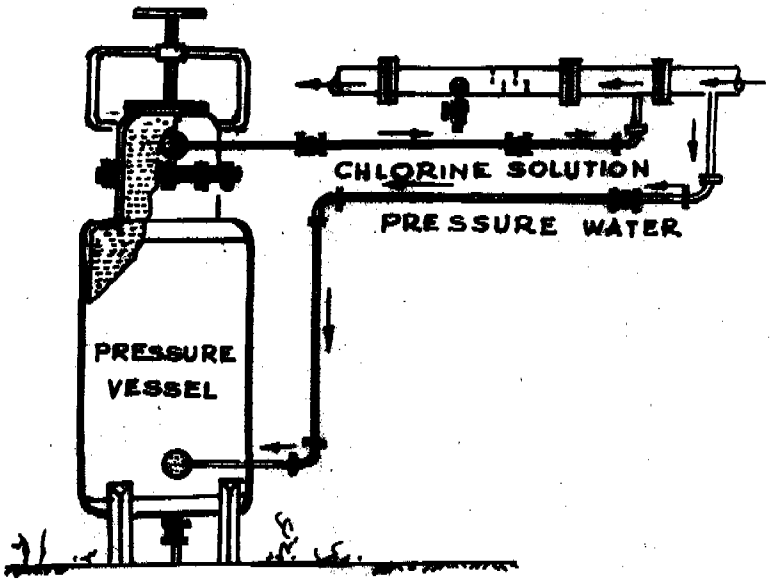
DIFFERENTIAL PRESSURE TYPE CHLORINATOR



This type of chlorinator is commercially available for use with piped water supplies. A solution containing bleaching powder and soda ash in the proportion of 5 : 1 is filled in a rubber bag (housed in a metal container) from which it is gradually squeezed out in proportion to the differential pressure across an orifice plate. The rate is adjusted by a needle valve. This type of chlorinator though expensive, Rs. 1500 - 3000 ($ 200 to 400) is widely used and found to be quite satisfactory except for the need to replace the rubber bag, costing about Rs. 200/- ($ 28) every 4 to 6 months.

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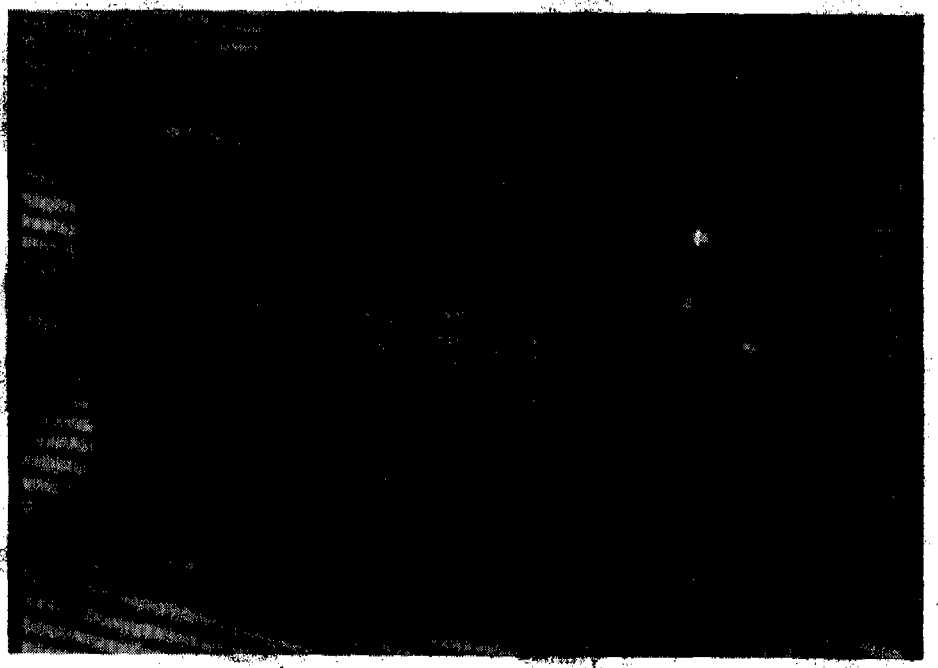
RESIDUAL CHLORINE DETECTION KIT

CPHERI has fabricated a simple chloroscope from indigenously available materials to enable detection of residual chlorine concentrations. The unit costs about Rs. 15/-($ 2) against Rs. 150/- to Rs. 200/- ($ 20 to 28) for a standard kit available in the Indian market.



Permanent colours corresponding to the standard colours obtained by the use of orthotolidine for different concentrations of chlorine are fixed in gelatin, sandwiched between two glass cover-slips and fitted into a plastic box. Such colour discs developed by CPHERI have been found to be perfectly stable over a period of 2 years now and are under further observation.

DOUBLE-ACTION TABLETS

There are many occasions when one has to depend on surface waters which are both polluted and highly turbid. The disinfection tablets currently available in the market are capable of disinfecting but not removing the turbidity. The object of these double-action tablets developed by CPHERI, Nagpur, is to remove the suspended matter and to disinfect simultaneously.

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The tablets are made from alum, bleaching powder, sodium bicarbonate and talc mixed in appropriate proportions.

Each 1000 mg tablet is sufficient to treat about 2 gallons of water containing upto 500 ppm turbidity. The treated water will contain about 2 mg/l residual chlorine. The effectiveness of these tablets is independent of the pH and alkalinity of natural waters.

Several tablets have been prepared and tested on a laboratory scale. Field testing is now in progress.

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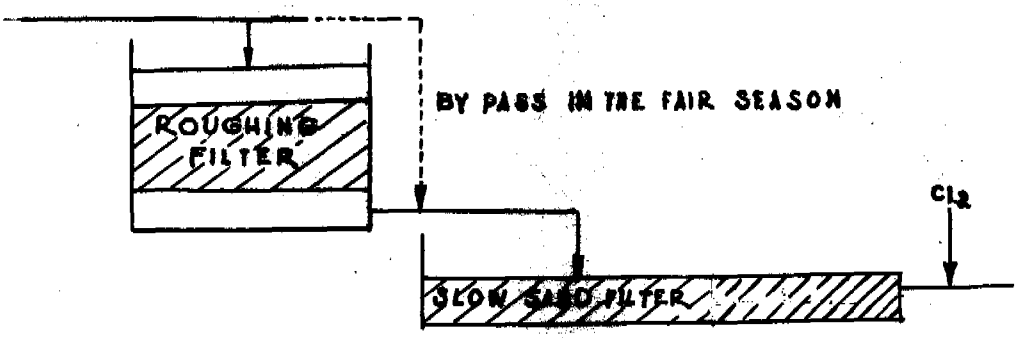
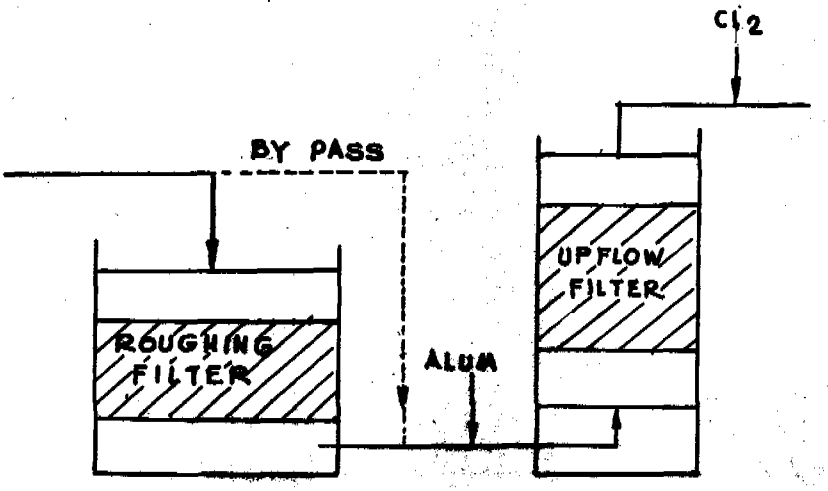
WATER FILTRATION

For many rural water supplies particularly ground water supplies, the only form of treatment given to the water is chlorination. At times, for surface waters, treatment for turbidity removal is necessary. A study made by CPHERI of existing treatment plants, large and small, has shown that the weakest link lies in the operation of the chemical dosing and coagulation units. Although a filter with all its valves may look more complicated to operate, our observation has been that it is actually better operated than the pre-treatment units where chemical dosing is involved.

Based on the work done by CPHERI on different types of filters, the following solutions are now being inspected further for use in rural areas :





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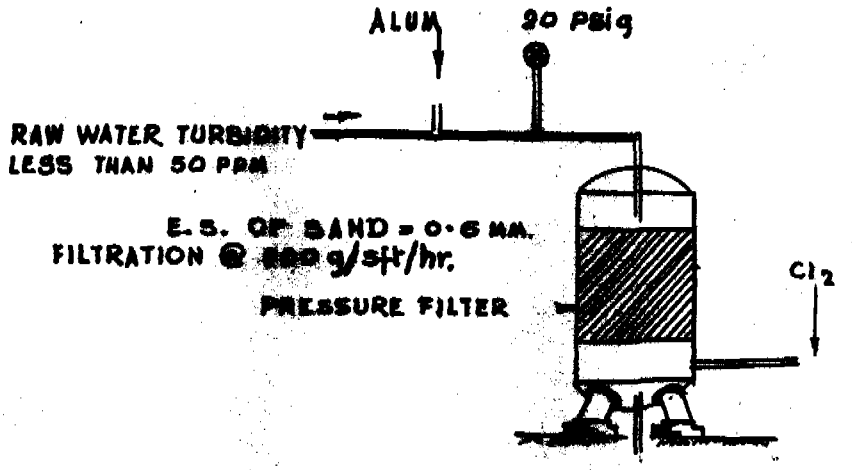

TABLE IV

Tentative Basis of Design

Population	Supply	Roughing Filter at the rate of 12 $m^3/m^2/hr$	Slow Sand Filter at the rate of 0.3 $m^3/m^2/hr$	Upflow Filter at the rate of 9 $m^3/m^2/hr$
2000	100 litres per capita per day in 8 hours	1.45m x 1.45m	9.2m x 9.2m	1.7m x 1.7m
5000		2.3m x 2.3m	14.5m x 14.5m	2.6m x 2.6m

CPHERI has also undertaken a testing programme for local sands and coals in order to encourage greater use of local materials available at a given site and avoid transportation costs. The use of standardised and/or pre-cast components is being explored.

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EVAPORATION CONTROL IN VILLAGE WATER TANK

The general principles of evaporation control in large reservoirs can also be applied to the village water tank which often varies from 1 to 10 acres in water-spread and tends to dry up in the summertime in arid zones.

Cetyl alcohol or hexadecanol has been used thus far in India but its use has not been possible to extend owing to difficulties in importation of the chemical. A sister-laboratory of CPHERI is exploring the possibility of manufacturing this or another similar chemical in India.

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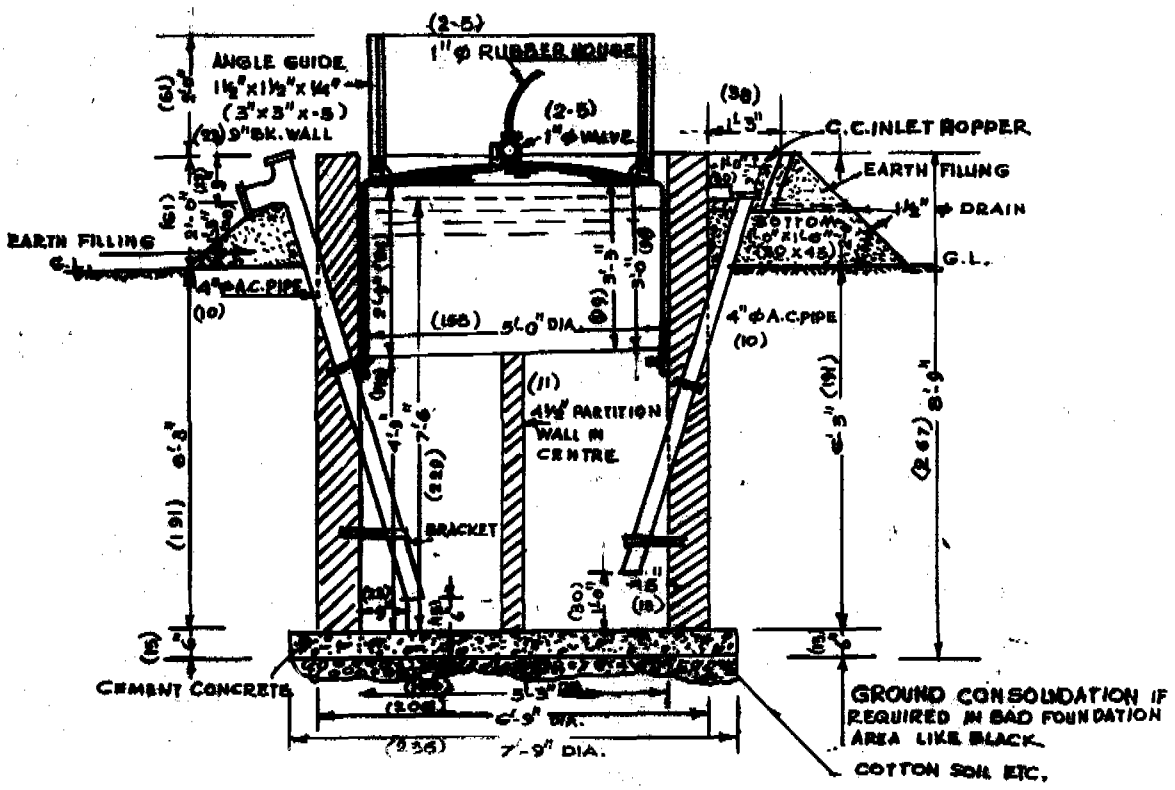
NIGHT-SOIL DIGESTION & GOBAR (COW-DUNG) GAS PLANTS

To avoid indiscriminate dumping of night-soil and its unhygienic handling on farms in the raw condition, CPHERI has been working on night-soil and cow-dung digesters. Digestion would give inoffensive sludge, undiminished in its fertilizer value, and gas which may be profitably used in the rural areas not served with electricity.



The characteristics of night-soil are somewhat different from those of the cow-dung (Table V) . Cow-dung is poorer in nitrogen and phosphorous compared to night-soil. Also the destruction of volatile matter and the gas produced per unit weight of volatile solids added to the digester are both lesser

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for cow-dung than for night-soil :

TABLE V

Characteristics	Night-soil	Cow-dung
Moisture content of raw material, percentage	85 - 90	74 - 82
Total solids, percentage ...	10 - 15	18 - 26
Volatile solids as a % of total solids	80 - 88	70 - 80
Total nitrogen as N, % on dry basis	3.0 - 5.0	1.4 - 1.8
Total phosphorous as P_2O_5, % on dry basis	2.5 - 4.4	1.1 - 2.0
Potassium as K_2O, % on dry basis	0.7 - 1.9	0.8 - 1.2

NOTE : The nitrogen, phosphorous and potassium values in digested material are found to be almost the same as for the raw material shown above, both for night-soil as well as cow-dung.

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Digesters for night-soil or cow-dung can be designed under Indian conditions on the following design criteria developed by CPHERI :

TABLE VI

Digester Design Criteria	Night-soil	Cow-dung
Total solids contribution, average Kg/head/day ...	0.08	2.85
Volatile solids, Kg/head/day	0.067	2.14
Digester loading, Kg of volatile solids per cu.m./day ...	1.6	3.0
Detention time, days ...	25 - 30	25
Solids concentration of slurry as fed to digester (%) ...	5	9.5
% volatile solids destroyed in digestion ...	45 - 55	16 - 22
Gas expected, cu.m./Kg of V.S.added	0.5	0.2
cu.m./head/day	0.034	0.43
Methane content (%)	60 - 70	55 - 65
Calorific value of digester gas		
BTU/cft	624	580
K. Cal/cum.	5558	5130
Approx. H.P. generated per 1000 persons or 1000 cattle	2.0*	36 *

* Assuming that 25 % of the theoretical calorific value can be converted into H.P.

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Several units have been constructed in India and are working satisfactorily. Cow-dung units can be set up preferrably where several animals are housed together as in a rural farm or dairy. Current work at CPHERI shows that a mixture of night-soil and cow-dung digested together would be better than either one alone.

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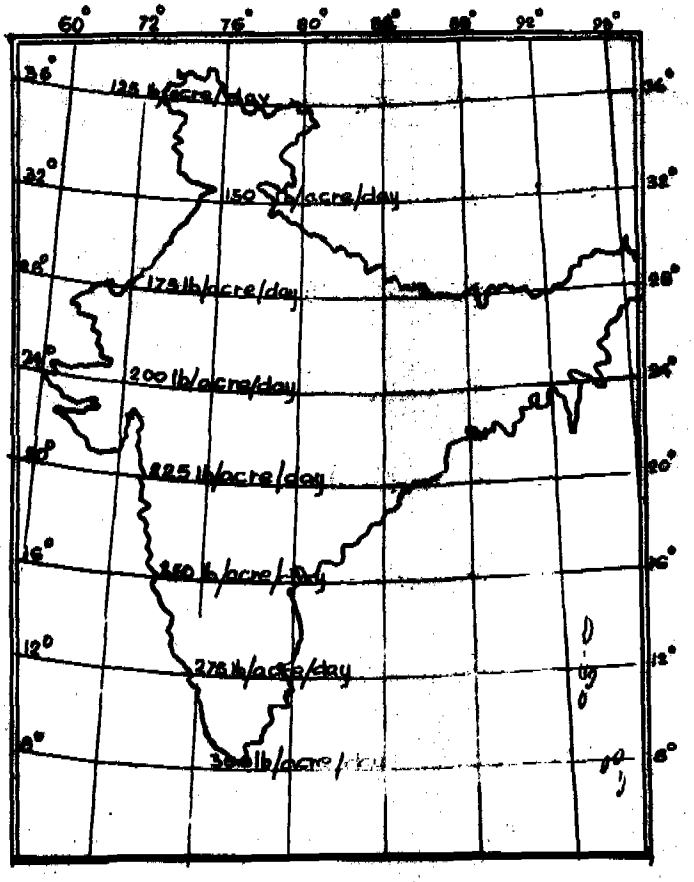
WASTE STABILISATION PONDS

There are several suburban and some rural communities that are sewered. Many new industrial housing estates and townships are coming up all over India with proper water supply and sewerage systems. Waste stabilisation ponds are ideal for such communities.



Note : 1 lb/acre/day corresponds to 1.12 Kg/hectare/day.

Design criteria for waste stabilisation ponds under Indian climatic conditions have been developed by CPHERI which has done extensive work in this field.

Pond loadings are related to latitudes as shown in the diagram. They are such that with the usually adopted depths of 1.2 to 1.5 meters, sufficient detention time will be obtained (average 10 - 12 days) keeping in view the prevailing temperatures in in that location. This simplification does not apply to ponds at high altitudes or under other conditions requiring special design.

It is interesting to find as a result of long term studies at Nagpur on a pond treating 0.5 mgd of city sewage, that pathogens

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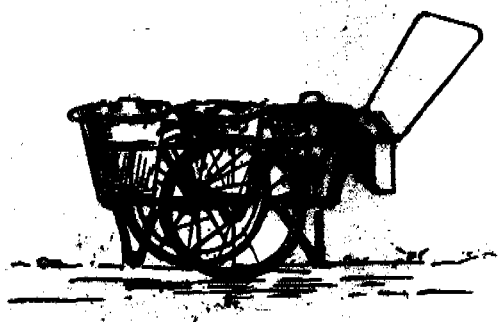
like Salmonella, helminthic eggs and amoebic cysts are removed completely unlike in the conventional treatment processes.

Cost studies made at CPHERI have shown that under Indian conditions, the stabilisation pond is the cheapest out of all methods of sewage treatment (taking all capital & running costs into account) as long as land is available at less than Rs. 55,000/- ($ 7000 approx.) per acre. A manual on the " Design, Construction & Operation of Waste Stabilisation Ponds in India " is under printing.

Further work is in progress at CPHERI, Nagpur, on (i) fish-culture, (ii) algae harvesting and (iii) various aspects of sewage farming.

NIGHT-SOIL CONVEYANCE

Many towns in India are unsewered and even some of the bigger cities are only partially sewered. Night-soil has, therefore, to be conveyed manually from the houses to the disposal sites.



WHEEL BARROW

In order to provide the scavengers with a convenient device for carrying the night-soil (without having to carry it as a head-load), CPHERI has prepared type-designs incorporating a set of 2 or 3 buckets mounted on a wheel-barrow along with necessary tools to prevent direct contact with night-soil.

A larger unit (200 litres capacity) which is cycle-mounted has also been developed by CPHERI. The Ministry of Home Affairs, Government of India, encourages Municipalities to adopt such methods

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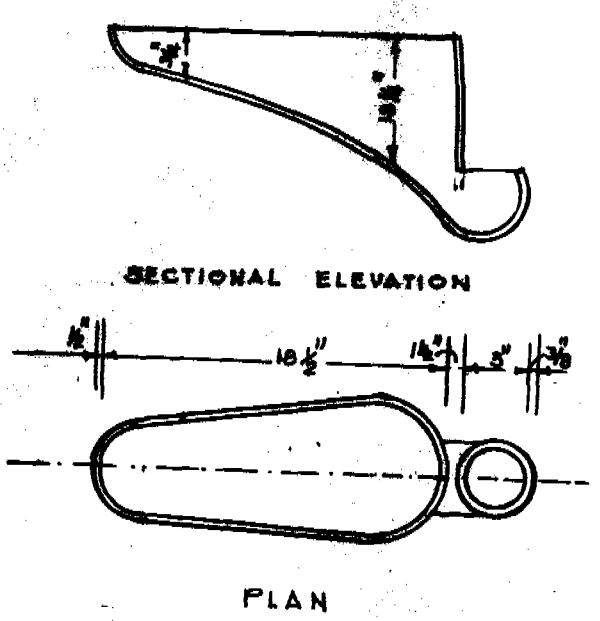
by subsidising 75 % of the initial cost of the night-soil conveyors, protective clothing and footwear.

RURAL LATRINE



Several workers have developed designs for rural latrines. Alongside, is a water-seal type latrine pan recommended by CPHERI. Nearly 6000 such units have been supplied to-date.

Unfortunately, some of the villagers avoid using these units and prefer to continue using the wide open fields to which they have been accustomed all their lives.

DRAINAGE OF SULLAGE WATERS

In the absence of an underground or surface drainage system in the villages, the sullage water from hutments flows over the pathways, or stagnates in shallow areas which breed mosquitoes and other insects.

A soak-pit is recommended in this situation. The village apathy is the snag in the non-acceptance of this simple measure. A soak-pit 4' x 4' x 4' with graded boulders and an attached solids-trap has been found adequate for a family of six.

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" ADOPTION " OF A TYPICAL VILLAGE BY CPHERI AT NAGPUR

A typical village of about 700 people and located within a few miles of the Institute at Nagpur has been " adopted " and is being helped in the provision of various types of sanitary installations. This helps to establish a rapport between the scientists and the villagers and gives the former an opportunity to apply their knowledge to the actual conditions prevailing in the village. This project also enables CPHERI to find out the " acceptance " by the villagers of the sanitary units developed by the Institute.

When the village wells were disinfected by a device developed by the Institute, there was a lot of resistance on the part of the villagers to drink chlorinated waters. However, some educated villagers did come forward and drank this chlorinated water gladly.

From this experience it became clear that effective health education given to the villagers will go a long way in improving rural health.

RURAL SANITATION DEMONSTRATION AREA AT CPHERI, NAGPUR

A rural sanitation workshop has been set up to fabricate sanitary-ware such as latrine pans, urinals, wash-basins, drip-chlorinators for wells, and devices for ventilation, kitchen and washing places, etc.

Full scale units of a rural house, model well, soak-pit, cattle shed and refuse-composting are being installed for demonstration to health educators, sanitary inspectors, government officials, village " patils ", " panchayat " members and social workers.

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