COMMUNITY WATER SUPPLY

AND

WASTE DISPOSAL

VOL : ONE

(Community Water Supply)

CENTRAL PUBLIC HEALTH ENGINEERING RESEARCH INSTITUTE

NAGPUR-3 (INDIA)

Community Water Supply and Waste Disposal

Proceedings of the Symposium
held at CPHERI
Nagpur-3

December 19-21, 1966

VOL. ONE

(Community Water Supply)

CENTRAL PUBLIC HEALTH ENGINEERING RESEARCH INSTITUTE
NEHRU MARG, NAGPUR - 3 (INDIA)

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FOREWORD

A symposium on ''Community Water Supply and Waste Disposal'' was held by the Central Public Health Engineering Research Institute, Nagpur during December 19 to 21, 1966 at Nagpur.

The symposium was inaugurated by Dr. V. B. Kolte, Vice-Chancellor, Nagpur University, Nagpur after the welcome address by Shri R. S. Mehta, Director of the Institute. Prof. S. J. Arceivala of V. J. T. I., Bombay delivered the key-note address. Over 200 delegates representing State Governments, Local Bodies, Research and Educational Institutes attended the symposium and took active part in the discussions.

The subjects dealt with included: (a) Community Water Supply; and (b) Community Waste Disposal. The chairmen for the five technical sessions were Dr. B. V. Bhoota, Shri P. C. Bose, Shri U. J. Bhatt, Prof. S. J. Arceivala and Col. (Dr) R. R. Rao. In all, 33 papers were presented during the symposium.

The proceedings of the symposium are published in two volumes. The first volume deals with community water supply while the second deals with community waste disposal. It is hoped that the information presented in these two volumes will be of immense use to all the workers connected with the problem of community water supply and waste disposal. Supply of wholesome and pure water to the small communities is of prime importance in our country. So is the problem of disposal of domestic sewage and other wastes. It is presumed that the information provided in this booklet will be useful to research workers, practising engineers, engineers employed in educational institutions and departments connected with public health engineering.

Due to unavoidable circumstances the proceeding could not brought out early and we sincerely hope that the readers would bear with in this regard.

We extend our heart felt thanks to all those whose efforts, individually and collectively, have made the Symposium a great success.

C. A. SASTRY
Convener, Symposium

SESSION CHAIRMEN

Session I :

DR. B. V. BHOOTA

Session II :

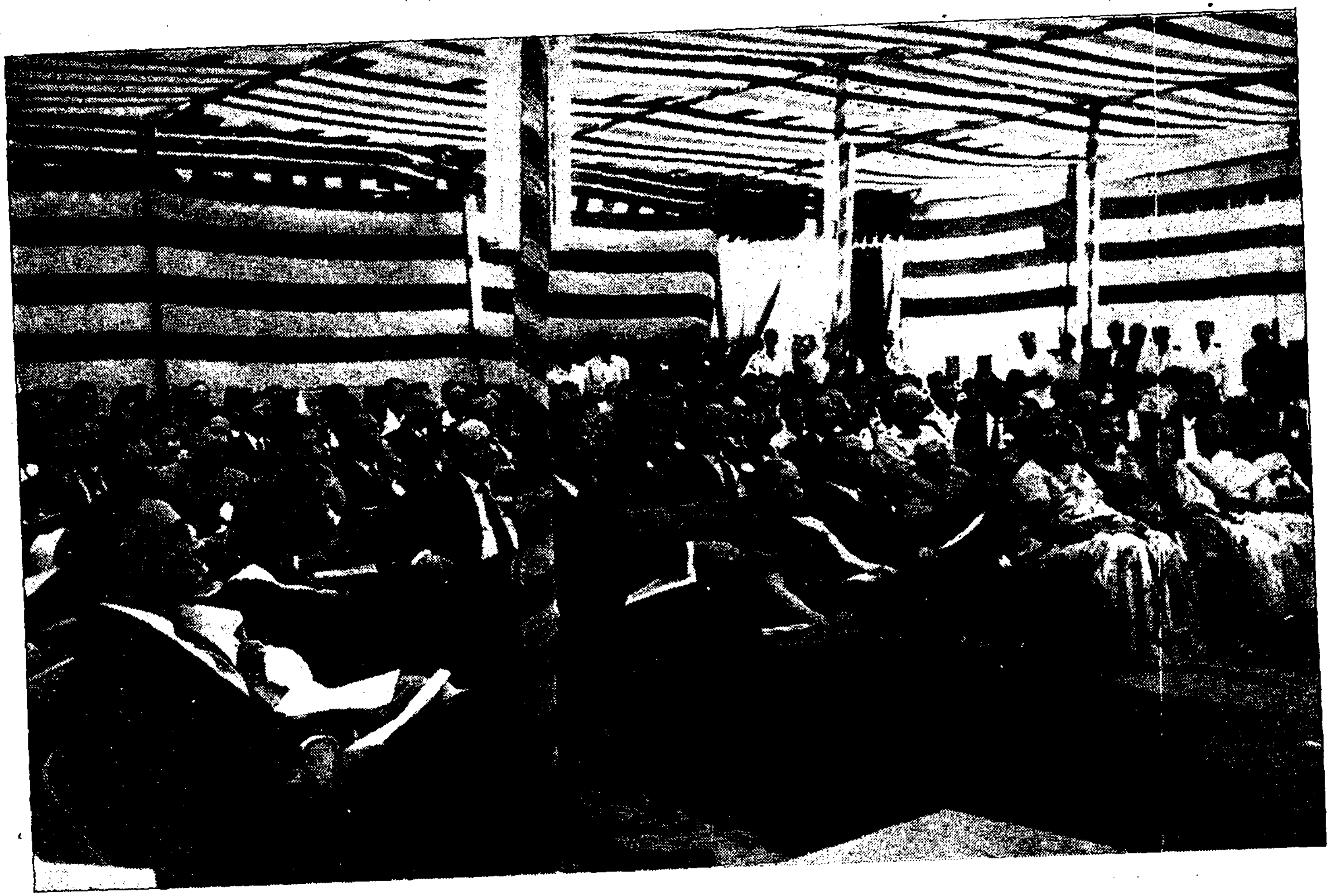
SHRI P. C. BOSE

Session III :

SHRI U. J. BHATT

CONTENT

Session—III



A view of Technical Session of the Symposium

Welcome Address

By

Shri R. S. Mehta, Director, CPHERI, Nagpur

Mr. Vice Chancellor, Participants to the Symposium, Ladies and Gentlemen,

It is my great pleasure to welcome you all on behalf of the CPHERI and myself to this Symposium on Community Water Supply and Waste Disposal.

We are indeed fortunate in having with us the Vice-Chancellor of the Nagpur University, Dr. Kolte, to inaugurate our symposium. Research and teaching should always go hand in hand and it has always been the policy of the Council of Scientific and Industrial Research to exchange our scientists from research institutions with the university teachers and **vice versa**. You are aware, Sir, that we are collaborating with the Visvesvaraya Regional College of Engineering, Nagpur, in organising the post-graduate course in public health engineering along with the UNESCO. Our premises, our well equipped laboratories, our library and specialised personnel in several disciplines are placed at their disposal. Besides this, we have scholars working for their doctorate degrees in our laboratory under our guidance and the University of Nagpur as well as many more Universities have accepted some of us as post-graduate guides.

We have also organised training courses for chemists and bacteriologists in the specialised field of water and waste water treatment. Every year we organise a refresher course for engineers who are engaged in the field of water supplies. One such course has just been completed and was attended by about 15 engineers from all over the country. These engineers are also participating in this symposium.

We have in our midst today, a large number of students from several post-graduate institutions giving courses in public health engineering along with their professors and I welcome them all to our symposium.

This symposium is a meeting ground of engineers and scientists of several disciplines engaged in the specialised field and gives us an opportunity of discussing the latest advances and new techniques. It is indeed gratifying to see the response to our invitation and I am very happy to welcome the participants who have come from very long distances.

The subject for discussion in this symposium will be "Community Water Supply and Waste Disposal" and I should like to say a few words on this important subject.

From times immemorial, the great need of a community was its water supply, and a high value has been set upon an abundant and pure water source. Centres of population and culture sprang up in ancient times around those points where the water was readily available and great expenditures were made to transport it to places where it was not naturally plentiful.

Community Water Supply has become a critical factor in public health and economic development in most parts of the world, particularly in the developing countries.

An aggregation of houses which by virtue of their proximity, if economically served with a water supply system, is called "Community Water Supply". This definition is applicable to rural as well as to urban areas. It presupposes safe and adequate amount of water. The main purpose for assuring safe and protected water supply to the communities is to ensure that they get this amenity into their houses, if possible, or at least in the neighbourhood so that the water would be easily available and would result into reduction in water-borne diseases. Cholera, Typhoid, Dysenteries and Diohrreas have been completely eradicated in the developed countries by concerted effort of many years and this has to be done in India in the shortest possible time.

Vital statistics of mortality and morbidity are not adequately maintained in our country and this does not enable us to bring the glaring facts and the advantages of protected water supplies to the communities. From the figures available in the developing countries and the last few years' experience in our country, there is not the slightest doubt that enteric diseases can be almost completely eradicated with protected water supplies. The World Health Organisation publication on "Urban Water Supply-Conditions and Needs in 75 Developing Countries" gives a true picture of the conditions in urban towns in such developing countries and the magnitude of the problem, this part of the world, has to face in future. The water supplies have to be simple, cheap and installed rapidly without sacrificing the reliability and safety.

The urbanisation and industrialization of several areas in the developing countries has made it into a global issue. In India, with a population of 440 million, and with some 80 million people living in the urban communities and 360 million in the rural areas, the problem of supplying water is stupendous. There is a large backlog of many years and the population explosion at the rate of about 2.5 to 3.5 per cent per annum, with the rapid urbanisation and industrialisation, has created problems which need adequate financial support. Unless a bold policy is adopted and proper priorities given, we shall face a crisis unknown in the history.

In India, it has been reported that 33.9 per cent of the urban water supplies are satisfactory, 26.3 per cent inadequate and 39.9 per cent do not get water supply at all. On the rural side, the percentage of people who have been supplied with protected water supplies are not correctly known and most of these supplies are entirely unprotected. Even after 20 years of Independence, a large majority of the population in the rural areas goes without safe water supplies and no means of disposal of wastes.

The following figures give the distribution of the population in communities of different sizes for both urban and rural population :

TABLE 'A'—URBAN WATER SUPPLY

POPULATION GROUP	NO. OF TOWNS
Over 100,000 each	113
Between 50,000—100,000	137
Between 20,000—50,000	487
Less than 20,000 each	1,714

TABLE 'B'—RURAL WATER SUPPLY

Population Group	No. of Villages	% of Total	Total Population in thousands	%
Less than 500	380,019	68.0	78,348	26
500 — 1000	104,268	18.6	72,921	24.2
1000 — 2000	51,769	9.3	71,156	23.5
2000 — 5000	20,508	3.6	59,109	19.5
5000 — 10000	3,101	0.5	20,754	6.8
	559,665	100	302,288	100

Almost all the major towns in India with a population of more than 100,000 people are getting water supplies that are intermittent, though some of these supplies are properly treated and disinfected. The pressures, however, are not always adequate and continuous, and this is a health hazard as there is a possibility of the water quality deteriorating in the distribution system. Due to this and the high temperature conditions in the summer months, the residual chlorine is not always found at the tap. This category comes within the 33.9 per cent of the urban water supplies that are stated to be "satisfactory". Calcutta, Bombay, Madras, Delhi, Ahmedabad, Kanpur, Nagpur, etc. come under this category and it is well known to us that in all these towns the population has increased tremendously along with the industries and the supplies are intermittent and grossly inadequate. In smaller towns and cities conditions are much worse as the supplies are intermittent and mostly inadequate.

The problem in the rural areas is far from satisfactory. Most of the villages depend on well water supplies, though some attempt has been made to improve the wells and make it into sanitary wells. Some efforts have also been made to provide hand pumps. Where the supplies are from underground sources, the quality of water is not very unsatisfactory but where the supplies are from open dug wells, the quality invariably deteriorates in certain seasons. Disinfection of rural wells has yet to be systematically organised. There are regions in this country where the water is highly brackish or contains large amount of iron or large amount of fluorides. Such waters are not satisfactory from the health standards.

The authorities are well aware of the dangers of dug wells even though they are partially protected. The bucket and rope is not an approved method of drawing and carrying water and the health hazards involved are also too well known. Hand pumps have been installed in many areas but the maintenance has not been generally satisfactory.

Efforts are being made to develop scientific methods of disinfection of wells which would be acceptable to the rural population and which would be economical. Methods for removing the brackishness of waters, iron and fluorides are also being developed. But the multiple agencies responsible for the development of rural water supplies make this problem very complicated. Work is being done on solar distillation and desalinisation, but the cost of production is still very high and more intensive research is needed in bringing down the cost.

On the water treatment side, lot of progress has been made in the last few years. Today, we are in a position to manufacture all the equipment needed for water treatment in our country, but the prices of such equipment are too high for smaller communities. By more economical designs of flocculation and clarification equipment and by non-conventional designs of rapid filters and disinfection, many more communities would be able to avail of this amenity. Cheaper and more suitable coagulants could be used if the qualities of the waters are correctly evaluated.

Regarding the ground water supplies, we have carried out very little work. It is necessary to have a detailed Ground Water Map of our country. Such supplies are very much more economical as they do away with the treatment of water. Some work is being done to improve the strainers for the tubewells but very much more remains yet to be done.

Coming to the problem of water resources, we have to recognise the fact that majority of our rivers are non-perennial. We have storage reservoirs which are not properly protected. The seasonal rainfalls in our country make the water resources problem very critical, especially in the summer months, when the demand of water is at its maximum. We have in India some large perennial rivers but a major part of their waters is committed to irrigation requirements; with the result that the towns situated downstream get little or no water at all. This is true of the areas served by important rivers like the Ganga, Yamuna, Godavari, Krishna and Kaveri, etc. The water from the main river is diverted into the irrigation canals especially during the summer months with the result that the water supplies go dry in the towns situated downstream. Many instances can be quoted such as Delhi, Agra, Kanpur, etc.

There are areas where there is very scanty rainfall as in Rajasthan and some parts of Gujarat, Kutch, Maharashtra, etc. where critical situations develop every time the rainfall is not adequate and the people have to sometimes migrate to other places with their kith and kin with a great economic loss to them. Alternate sources of water have to be investigated for such semi-arid regions.

The problem of water resources and water pollution cannot be separated. With the phenomenal increase in the population and the rapid trends towards urbanisation and industrialisation and the consequent concentration of population, the problem of water pollution has become very critical. Streams which were clean and carrying good water are today highly polluted. The untreated domestic wastes—sewage and storm water—flow into the rivers as well as the concentrated discharges from factories carrying a high BOD and suspended solids. This makes the problem of water treatment very much more complicated and expensive. Very few towns in our country have underground sewerage system and sewage treatment plants. Even in the towns with underground sewerage, the disposal of the sewage is mostly on sewage farms or into the nearest stream. The Municipal Corporations and Municipalities have meagre resources and have not given any priority to the waste water treatment. Cheaper and yet efficient method of waste water treatment is available and should be popularised. All the communities that are sewered must treat their effluents upto a specified standard and then discharge it into streams. For small communities Oxidation Ponds and Oxidation Ditches are good solutions and should be popularised. We have also to consider the utilisation of sewage effluents for irrigation and the by-products from the treatment of sewage, sludge and industrial wastes. Treated sewage can be profitably used for growing more crops. The utilisation of gases from decomposition of sludge, utilisation of dried sludge as a fertilizer and soil conditioner and many more by-products from the waste water treatment plants can be utilised and would result into substantial revenues. Composting of domestic refuse along with the sewage sludge and digestion of night-soil would also give some returns and provide hygienic disposal. The temperature and sunshine conditions in our country are more favourable for waste disposal and this should be scientifically harnessed.

Many of these subjects will be discussed in the symposium during the three days as can be seen from the Abstracts of Papers which are made available to you.

In the end, I would like to state that this problem of 'Community Water Supply and Waste Disposal' needs to be given a very high priority. These schemes may not show immediate returns but would indirectly pay rich dividends by ensuring better health of the community and by the general happiness it will bring to mankind.

May I request now the Vice Chancellor, Dr. V. B. Kolte to inaugurate the symposium.

Inaugural Address

By

Dr. V. B. Kolte,
Vice-Chancellor, Nagpur University, Nagpur

Shri Mehta, Ladies and Gentlemen,

Being in the academic line for the past 30 years, it had been a great pleasure for me to see new educational and research institutions coming up in and around Nagpur. I have been watching with great interest, the coming up and growth of a National Institute on Public Health Engineering in Nagpur. It is gratifying to know that the Institute is doing immensely good work on different aspects of water supply and waste disposal, and this work will be useful not only to the area around Nagpur but to the whole country at large. I was very happy to hear that the work carried out by the Institute on Oxidation Pond treatment of sewage and on industrial waste treatment has brought good name to the Institute.

It is my proud privilege to be here amongst you to inaugurate this very important symposium on Community Water Supply and Waste Disposal. This subject is of immense interest not only to the Engineers and Scientists but also to the common man. As you are all aware India is a country of villages and 80-85 per cent of our population lives in them as small communities. The Father of our Nation, Gandhiji had rightly pointed out that India lives in villages. Our country cannot march forward in individual prosperity if the villages are not uplifted from their present position. Unless diseases are eradicated from the village population, the overall progress of our country will be hampered.

Water supply and sanitary measures are essential requisites of the community life of a civilised country. The purity of water for human use finds mention even in the **Rigveda.** Civilization through the ages has been in quest for pure water. Emperors and Administrators attached special importance for provision of good water for their citizens. That, water can act as a vehicle for the transmission of disease, was rediscovered by the scientific world in recent centuries. In our homes whether in the city or in the village water is essential for cleanliness and health. Every activity of man involves some use of water. Water is of course absolutely essential to life—not only to human life but to all life, both animals and plants. Indeed, it is a part of life itself, since the protoplasm of most of living cells contains about 80 per cent water and any substantial reduction in this percentage is disastrous. Most of the biochemical reactions that occur in the metabolism and growth of living cells involve water and all of them take place in water. Water has often been referred to as the 'universal solvent.' Yet, man's assessment of the value of water is very low until he finds himself without it, as rightly mentioned by Lord Byron and Don Juan "Till taught by pain man really knows not what good water's worth."

It is scarcely necessary to detail the relation of water supply to public health. Water is of primary importance in the transmission of intestinal diseases like Cholera, Typhoid and Dysentery. The lack of abundant water of good quality for bathing and cleansing is normally related to the prevalence of worm infestations, skin infestations and probably Trachoma. Any experienced doctor, from his own knowledge may give many examples of the relationship of bad water to bad health, to high morbidity and mortality rates, and to loss of productive working time

In addition to these, it is well known that water supply is an economic asset to a community. A good water supply increases propriety values, encourages the construction of higher valued buildings, attracts profitable industries and thereby improves individual prosperity of the community. In view of these, it is absolutely necessary that we should devise ways and means of providing safe water supply to our communities at large. The overall picture at the moment in the country regarding supply of water and its quality is extremely depressing. Most of the villagers still depend upon time old tanks, ponds and wells for all their water supply needs and where no such sources exist, the villagers have to trek for miles in search of drinking water. It is well known that in many regions of our country, a major part of the day is spent by our womenfolk in transporting water for domestic consumption. If we want to improve the situation, we should make an all out and integrated effort to solve this vast problem of supplying our rural population with safe and clean water.

The vastness of the area can be understood by looking at the census figures in 1961 according to which there are about 360 million of our countrymen living in 55,970 villages forming roughly 81 per cent of the country's total population. The technical, administrative, financial, procedural and maintenance problems of a programme to encompass the entire rural area are a challenge to effective planning.

Some of the methods, equipment and basic design factors developed by Western countries are not readily applicable under conditions available in our country. We should make efforts to evolve simple and easy systems of water treatment and distribution and of preservation of water resources which are inexpensive to construct and simple to operate and maintain. To this end, there is an urgent need for research and development and for a realistic reappraisal of the fundamental basis of engineering design. I am happy to know that the symposium is being conducted with this in view and that it gives an opportunity to the engineers, scientists and public health administrators to come together and discuss ways and means of solving these problems.

In addition to the supply of clean and safe water, it will be necessary to safeguard the health of the community by providing all homes (whether in villages or in cities) with some sort of sanitary means of sewage disposal. Many communicable (human) diseases can be spread from person to person through contact with human excrements or through the medium of animals, flies and insects which carry the disease—causing microorganisms. Improper waste disposal systems will also cause pollution of drinking water supply and thus spread disease. The best method of sewage disposal would of course be by means of underground water carriage system which terminates in a sewage treatment plant. But this will be too expensive for small communities. There is a need for evolving simple and economic methods of sewage disposal from individual homes. I am glad to know that some papers in this symposium are devoted to this subject. The findings reported therein will be very useful to the country at large.

In problems connected with community waste disposal, the disposal of night-soil finds a very important place. Many of our cities and towns and almost all of our villages are not provided with underground water carriage system. They are only served by a sort of dry conservancy system which poses the problem of hygienic disposal of night-soil. Large amount of work on this aspect has been done in countries like Japan, China and Korea. In India, very little work is done on the hygienic means of carrying night-soil as well as its disposal. I hope, the learned delegates who are attending the symposium will keep this in their view and try to discuss out the problems involved in this.

Last but not least in importance in the overall community disposal programme is the disposal of garbage and refuse. Careless handling of garbage, as is done in most of our villages, towns or cities, attracts rats and other rodents and provides breeding spaces for flies and sometimes mosquitoes. In some of the cities, garbage is collected at regular intervals and hauled away to a disposal plant. Such facilities are not existing in small communities. Most of the public health authorities seem to feel that the problem of garbage collection and disposal in smaller communities is one of individual family to workout. But if the garbage can be collected in a systematic way and composted, it will go a long way in solving the problem of food scarcity. I am happy to know that some papers are being presented on this aspect also.

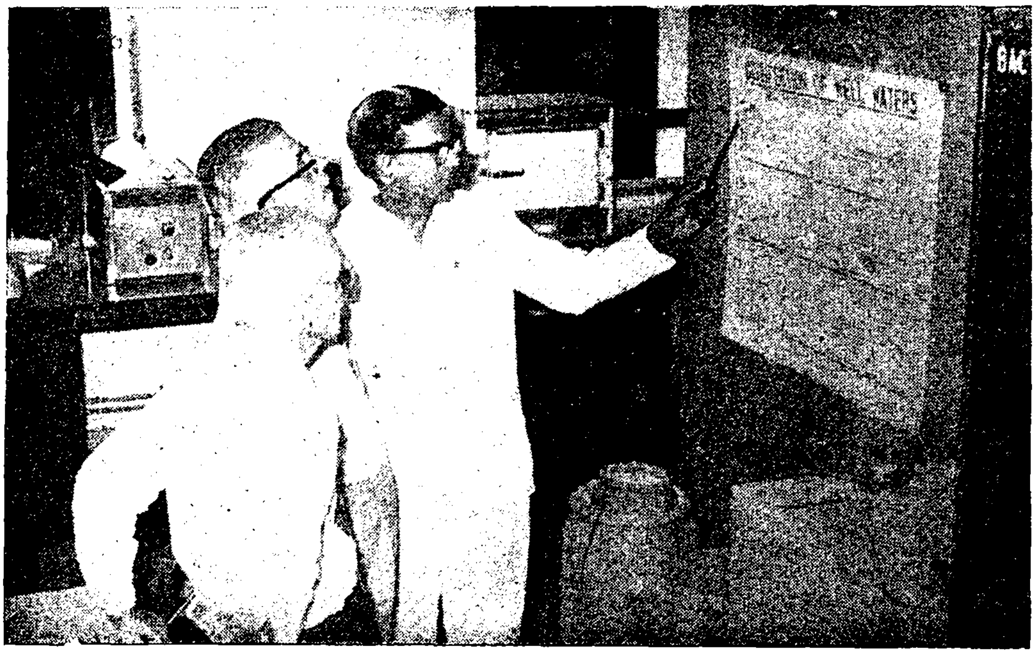
In view of our determined efforts for industrialization and improvement of standards of living of the population, we will have to increase the supply of protected and piped water and extend this facility to smaller communities. This can be done by a two-pronged attack; (1) by maintaining our rivers and streams clean or by resorting to new resources like ground water resources; and (2) by evolving simple and economic methods of water supply.

Taking into consideration the huge financial requirements for the construction of community water supplies required to meet the speedily growing communities, I suggest that the designers of community water supplies should make the fullest possible use of the locally produced items. The use of substitute materials does not necessarily impair the usefulness of the system. Concrete or asbestos cement pipe for example can usually be substituted for cast iron pipes. Plastic pipes can be used extensively in small systems. Increased use of substitute materials will encourage local manufacturer. I also suggest that all public water supply schemes should be managed and operated in accordance with sound principles of business administration. There is a need to correct the concept that water, like air, is free and should be provided without charge. This concept seems to exist throughout India and particularly in rural areas. This situation must be corrected by education and clear explanations of the fundamental economics involved. Water in nature is free but its collection, purification and distribution under pressure in individual homes cost money and must be paid for. I also feel that in view of serious shortages of public health or sanitary engineers or water works operators and technicians, and skilled workers, there should be training programmes, preferably by Institutes like the Central Public Health Engineering Research Institute in collaboration with Universities and other Institutions. In this connection, I am happy to say that the Central Public Health Engineering Research Institute is already collaborating with the Visvesvaraya Regional College of Engineering of Nagpur in conducting post-graduate courses in Public Health Engineering leading to M.E. and Ph.D. degrees. There is also a need to intensify the research activities with a view to devising and developing systems of water treatment and distribution which are inexpensive to construct and simple to operate and mantain. I don't think I need to emphasise the importance of the symposium any further.

I am extremely happy to be amongst people who are dedicated to science and engineering related to community water supply and waste disposal. I am sure, the information that the delegates are going to present at this symposium will be of immense value to the Nation. I am inded very glad to inaugurate this symposium.

Dr. V. B. Kolte, Vice-Chancellor, Nagpur University who inaugurated the Symposium going round the exhibition alongwith Shri R. S. Mehta

Visitors in the Exhibition



Key-Note Speech

by

Prof. S. J. Arceivala
V.J.T.I., Bombay

THE CHAIRMAN, THE DIRECTOR, DISTINGUISHED GUESTS, MY COLLEAGUES, LADIES & GENTLEMEN :

I am grateful and happy to be here this morning—grateful that the Central Public Health Engineering Research Institute has asked me to deliver the Keynote address this year, and happy that we are having another Conference of this magnitude, once again, this year.

At the outset, I am sure, you will join me in expressing our sincere appreciation and gratitude to the CPHERI which has been taking great pains every year to organise a Symposium for us. In fact, I am sure, the whole Public Health Engineering profession is thankful to them for giving us this steady diet of a Symposium a year which like the proverbial "apple a day" has been helping to keep us professionally healthy!

Progress in 13 years :

Many of my Senior colleagues will bear me out if I were to say that Public Health Engineering in India was in a latent or lag phase until as late as 1953, except for a few brilliant flashes here and there in the country. Then in 1953 the Delhi Seminar organised with WHO's assistance can be recalled as a glorious landmark from which time onwards Public Health Engineering has continued to grow rapidly at a geometric rate of growth. With the starting of the Central Public Health Engineering Organisation in 1955 and of the Central Public Health Engineering Research Institute in 1959 other important landmarks of progress were established.

Many will recall that only thirteen years ago it was difficult to get even two or three Papers published in a year. Today we receive so many that we have to review them and refuse some. Today we have over 500 well-qualified persons who have undergone specialised training in Public Health Engineering at post-graduate level. In the next five years we will spend more money on Public Health Engineering projects than what we have spent in all the preceding hundred years put together.

The future belongs to......

If this can happen in just thirteen years, we could perhaps ask the question, what will happen in the next thirteen years? I do not profess to be a fortune-teller. I only believe that the future belongs to those who prepare for it. To prepare effectively we must be able to judge what the modern trends are, to find the direction in which this profession is drifting. It will, therefore, not be out of place to use this occasion to assess the modern trends in Public Health Engineering.

To my mind, the biggest change that has taken place in our profession is that the "rule of thumb" era is rapidly yielding to rationality, innovation and design for economy. The old time-honoured assumptions are being challenged and new answers have to be found in keeping with the technological advances of the times. The new trends as I see them can be grouped under three headings:—

(1) Automation
(2) Optimisation
(3) Process Design.

I will now give some examples under each category to illustrate how they are setting the new trend :

Automation

This is perhaps of least immediate interest to us, but we will not be able to shut our eyes for too long. Wherever automation can help us to reduce overall costs of a system, we will have to welcome it. Besides, the higher rates of process loading make it essential to adopt a certain amount of automation for proper control of the process. With high-rate filtration, high-rate digestion, high-rate activated sludge and so on, controls are getting sophisticated. In the treatment of industrial wastes batch treatment is giving way to continuous flow methods wherever proper instrumentation is available. The latter has helped to reduce costs substantially where large flows are involved.

Some examples of instrumentation and automation are :

(1) Residual chlorine monitoring and feed-back of data to adjust chlorine doses to get the desired residual values. Similarly, pH actuated dosing control.

(2) Continuous recording turbidimeter to monitor high-rate filter turbidity and set off back-washing sequences automatically at pre-determined turbidity values.

(3) Distribution network control.

(4) Water distillation which is up and coming, will not be feasible without a high degree of automation.

(5) Closed-circuit television has made it possible to inspect sewers and other relatively inaccessible operations.

(6) In an effort to separate combined sewers in the older cities of the world, new concepts are being tried out to lay small sewers within big sewers to take advantage of the latest advances in pumping & piping. All of this will require more automation.

Optimisation :

This is a new field which Public Health Engineers in India will have to take very seriously. With the development of electronic computers, it has now become possible to subject complicated problems to a mathematical analysis so as to obtain the optimum solution—the maximum benefit at the minimum overall cost. This is also referred to as "Operations Research" of "Systems Analysis". Some notable examples are—

1. The design of optimum networks for distribution systems, not just solving by Hardy-cross method but getting the cheapest overall solution to a given problem.
2. Optimisation of treatment units so that overall treatment costs are least.
3. The study of river systems which supply water as well as receive waste waters from several communities, so as to ensure optimum use and re-use of water.

This is a new tool in the hands of the Public Health Engineers and there can be no excuse whatsoever for not using it. Electronic computers are already available to us in India in the larger cities and Universities. We have only to learn how to use them. This is one thing in which after learning we could immediately find application for it. Once we see how this technique helps to save money, usage will become widespread. With this view in mind I am very happy to report that from the last month we have just started a course at my V.J.T. Institute on "Operations Research and Computer Programming", specially designed for Public Health Engineers. It is an optional subject offered under our post-graduate programme and has evinced considerable interest among the Staff and students alike.

Process Design :

Great strides are being taken in developing new processes and refining and rationalising the existing processes, and we in India cannot afford to be left behind. .One thing is apparent, the initiative seems to be passing from the traditional Civil Engineers to the Chemical Engineers.

I will give some examples from the field of sewage and industrial waste treatment in which I have considerable interest.

1. New concepts have been developed for separation of solids, drawing heavily on the experience of chemical and metallurgical Engineers. The hydraulic engineers approach of controlling velocities has not been enough in all situations and has been replaced or supplemented by the Chemical Engineer's approach of centrifugal action, flotation etc.
2. The use of plastic medium in tricking filters.
3. Complete-mixing activating sludge.
4. Extended aeration which shows great promise in India.

5. High-rate digestion with re-circulation of digesting sludge to give increased solids retention time.

6. Zimmermann Process for wet oxidation of sludge.

7. Ultra-filtration membrane using reverse Osmosis process for purification of sewage.

In the years to come, there will be less and less of Civil Engineering structures, and more and more of process mechanisation to give compact, high-rate plants. This is best illustrated by the Zimmermann process and the ultra-filtration membrane process where one could well ask: 'Where is there any Civil engineering in this?' The traditional Civil Engineer who is perhaps most often only acquainted with pumps and mixers will have to widen his horizons to take in these newer developments.

Education & Research in the future:

What I have given above are only a few pointers to the future and we will have to gear our whole planning particularly of education and research, to meet the needs of the future. Both these aspects, namely education and research are dear to me, and it is my humble submission that we must re-orientate them more fully to meet the rapidly changing trends, so that we do not lag behind the world any more in our field.

The question is: how are we going to re-orientate our educational programmes to achieve these laudable objectives? To this the answer is perhaps that we must educate better the educators themselves. Given all the usual physical facilities we soon find that in the final analysis it is the STAFF that matters. The same is true for research institutions, and I am sure that no one is more keenly aware of this fact than our Director, Shri R. S. Mehta himself.

Teaching of Public Health Engineering at post-graduate level is quite different from teaching it at under-graduate level. The need for a heterogenous faculty to cover all the major facets of Public Health Engineering has to be appreciated and new institutions would do well not to rush in without considering all the difficulties involved in organising a strong faculty.

Research in Universities:

To attract the best teachers and sustain their continued interest it is very necessary to remember that teaching work needs to be supplemented by research and consultation work. Adequate pay scales, although helpful, do not always ensure that the best talent will be attracted. Man does not live by bread alone. He needs a challenging environment. And we must not fail the young men who come into the teaching profession.

For this purpose, we must have an imaginative research programme. Give more generous allocation of funds for sponsored research in Universities on a continuing basis from all national agencies interested in Public Health Engineering programmes.

Here I would like to mention that the CPHERI, a very good organisation as it is, would yet greatly benefit if it were to harness the resources available in the Universities, to get more research work done. Particularly in those Universities where post-graduate courses are running, there exists a trained group of staff and students, with considerable enthusiasm who would like to be partners with CPHERI in its research activities and whose aspirations must not be overlooked. Suitable research problems could be framed out to them by the CPHERI at little or no cost. Such an arrangement would be of great benefit to all concerned and foster a healthy spirit of family kinderedship among all the research workers in our field. We are after all so few, we must pool our resources together.

Freedom to participate in useful consultation work helps to expose the teacher to "live" problems and improve his perspective since there is always a considerable gap between theory and practice. It is gratifying to note that this is being increasingly allowed and encouraged in many institutions and the Education Commission has also endorsed it.

Interesting work for the interested :

Considering the fact that we in India already produce a large number of Public Health Engineers with post-graduate training, second in numbers only to the United States, it behoves us to find out how they are faring in practice. Upon my own initiative I have asked them questions on a number of occasions and have come to the sorry conclusion that many of them have developed a sense of frustration. Many of our post-graduates feel that interesting opportunities have not come their way in keeping with their educational attainments.

Many of these highly trained engineers feel that they are designing only simple, rural water supply schemes, laying pipes, building pump-houses and sumps and checking residual chlorine' which any ordinary Civil Engineer could have done. Some feel that M.E.'s are being used to do the work of B.E.'s and B.E.'s to do the work of diploma holders.

This is perhaps because the most interesting part of a Public Health Engineering specialist's duties namely, the designing of water and sewage treatment plants, is generally not being done by our practising engineers but by only a few contracting firms. The reversal of this trend will put more life in the young, highly trained Public Health Engineers of our country. They will find a renewal of interest in their specialised subject. They will go back to the libraries and refer journals. They will be absorbed in a very rewarding experience. The ability to design water, sewage and industrial waste treatment processes is what marks a Public Health Engineer as something distinct from the traditional Civil Engineer.

Innovation in designs :

If we learn to design our treatment plants instead of asking the tenderers to design them, we will incidentally reap a rich harvest of new ideas and innovations. Designs furnished by contractors although technically sound, have perforce to remain conventional in most cases. Contractors are unfortunately in such a position that they find it difficult to put across new ideas or use any design criteria which is not time-honoured. How can we accelerate the pace of development in this field unless we change this practice?

Education and practice :

One cannot help reflecting with a slight sense of fear, that merely changing our educational curriculum to include new subjects like "Operations research and Computer programming" will only add to the frustrations of our young engineers unless they find encouragement to use their newly acquired knowledge and techniques. Education and practice have to go hand in hand. Our Universities and I.I.T.'s are quite capable of giving a highly sophisticated product, well trained in all the latest techniques. The question is whether the Public Health Engineering profession is ready for this kind of engineer. It will be a pitiable waste of human resources if we are not.

Education and research :

Education and research have great similarities. Both are in the pursuit of knowledge. Both have their ultimate goal in improvement of professional practice. It is in the fitness of things that some of our best brains are today engaged in research work. But we are yet only beginning to learn the *MODUS OPERANDI* of this type of work. In some instances we are doing not research but only investigational work. In some cases we are repeating what has been done elsewhere. We have yet to make our mark in this field and I have no doubt that in course of time we will make our mark and place India on the World map for Public Health Engineering research.

To bring that day closer, it is my humble suggestion that we must take into account the modern trends which I outlined earlier. If we are to attract world attention as the Russians did after launching their Sputnik, we, Public Health Engineers, will have to launch our "Sputnik" so to speak. This we cannot do by going on the beaten path. We must harness new tools like computers and develop new processes with an entirely new approach. This will not be easy, but someday, it will be extremely rewarding, giving us renewed confidence in our abilities.

In this great task I would like to assure that my service will always be available in any required capacity, at any time.

With these words I would like to conclude, thanking you all for giving me a patient hearing, and also thanking the organisers for giving me this opportunity today to speak before you and share these thoughts, on the occasion of this very useful Symposium. I wish them the fullest measure of success, and hope and pray that there will be many more such Symposia in future.

Session—1

Dr. B. V. Bhoota, Chairman and Shri R. S. Mehta

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Community Water Supplies

With Special Reference to Uttar Pradesh

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No one knows just how or when the miracle of life first happened, but scientists agree that life began in the waters of an ancient sea. Without water, life cannot continue. The first civilization grew in the river valleys—the Nile, the Tigris and Euphrates, the Indus and the Ganges. Search for safe drinking water continued over the ages. The earliest method of artificial water supply in ancient times was from wells, a mention of which has been made in *Rig Veda* which dates from 4000 years B.C. and Sushrita Sanhita, a Sanskrit Medical lore dated 2000 B.C., wherein it has been mentioned that "it is good to keep water in copper vessels, expose it to sunlight and filter it through charcoal."

Nature has given us abundant water supply in the forms of rivers, streams, springs, lakes and ground water reservoirs. The water falls upon the earth in the form of rain. It runs its life giving course and then it is drawn back into the air soon to fall again. This is the water cycle. Water which has fallen as rain is partly taken up by vegetation, partly by earth, partly by surface streams and lakes and finally the overflow reaches the ocean. About one fifth of the atmospheric moisture which falls as rain is evaporated directly from the ocean surfaces. The remaining four fifths come from the other bodies of water, vegetation and the earth. The water is often referred to as the "Universal Solvent" because of its tendency to dissolve all things with which it comes in contact viz. gases as it falls through air, minerals as it percolates through the earth materials as ground water etc. The quality of natural waters depends on its content of impurities. Chemical analysis reveals the quality and quantity to the extent that dissolved minerals, gases affect it and make it suitable or otherwise for human consumption. The important facts are generally obtained with the determination of (i) pH value (ii) free carbon dioxide (iii) hydrogen sulphide (iv) phenolpthalein alkalinity (v) methyl orange alkalinity (vi) total hardness (vii) chlorides and (viii) total iron. For specific water, determination of dissolved oxygen, toxic and harmful compounds like lead, arsenic, zinc, copper, fluorides and iodides etc. may be necessary to find out what treatment or addition of specific compounds are necessary to render the water fit for human consumption.

The primary function of a water supply is to promote health, which as per earlier notion meant "absence of disease". However in 1945, the World Health Organisaion has given a far more reaching and positive definition. "Health is a status of optimal, mental, physical and social well being." From this standpoint a water supply has to respond to much higher standards. On this basis the community should demand water not only exempt from illness causing effects, but also an attractive water from physical standpoint, clear, non-coloured, reasonably cool, palatable and not too hard.

The bacteriological quality is most important in relation to health. Water borne diseases can be divided into three separate classifications. Firstly those diseases caused by inanimate matter in solution or suspension such as vegetable extracts from marshy or peaty soil in catchment areas, finely divided clay in suspension, high salt content, etc. Hardness can also cause troublesome side effects. Fluorine in water can cause dental upsets in children. While water passing through lead pipe may cause lead poisioning as was observed in the epidemic caused in Sheffield in England in 1887. The second classification of water borne diseases is that in which some vector is present in water which indirectly passes disease to men. *Schistosomiasis* (bilharzia) transmitted through fresh water snails falls in this category. Recent studies have explored the possibility that virus diseases may be water borne due to discharge of human faces in water. The viruses of the adenoidal-pharyngeal-conjunctival (APC) group described by Rowe and Huebner and responsible for upper respiratory disease and conjunctivities are also excreated in the faeces. Both poliomylitis and coxsackie virus can be isolated readily from urban sewage. These serve to focus attention on the significance of polluted water as a possible vehicle for the transmission of enteric virus diseases. The third and by far the most important group of water borne diseases are caused by the presence of microorganisms in water. Into this group falls cholera, typhoid, am-oebic and bacillary forms of dysentery. It is this group of diseases which causes much of the preventable sickness throughout India as was observed this year due to excessive drought in different parts of India, depletion of natural water resources and consequent heavy pollution load transmitted to these waters and due to inadequate treatment by nature or by man received by these waters before they were used by human beings. These are transmitted to water by the discharge of sewage into receiving waters and are easily preventable by filtration, chlorination and by other methods of sterilisation.

Thus, even though water is available in plenty in nature its harnessing, treatment to bring it to drinking water supply standard, conveyance to community and equitable distribution to all with adequate safety, pressure and quantity at all times are not easily achieved and cost of such installations, test and maintenance amounts to considerable sum for a community to afford. In the actual stage of technical development, the highest standards of quality can be assured by a complete series of following lines of defence.

(a) Detailed hydrological, hygronamic and geological survey and investigation for the determination of source.

(b) Purity of source,

(c) Pre-treatment to assure constant quality of the water before filtration,

(d) Filtration,

(e) Sterilisation,

(f) Permanent technical, chemical and bacteriological control.

In view of the need for co-ordinating limited resources in finance, materials and manpower and for relating community water supply to the broader aspects of water resources development and conservation, it is recommended by the WHO Regional Committee for South East Asia in September, 1962, that, in general, community water supply programme should be developed on a national basis and their organisational structures should allow for integration or co-ordination of the functions of planning, financing, engineering, management and supervision of the health aspects of water supply. A systematic effort should be made to accumulate and record fundamental data of : water resources available or needed for community water supply now and in future, the existence and nature of water supply systems, amount of water used and required now and in future, cost of construction and operation of water supplied and the quality of water served to the public. The collection, tabulation, analysis and publication of such data should be the function of a central authority or agency.

Considering the limited economic and technical resources generally available in this region, it is recommended that a consistent co-ordinated programme for research and development be undertaken by the Government, Institutions and Universities leading towards the development of materials, methods and system of water treatment, distribution and management which are inexpensive to construct and simple to operate and maintain. The WHO should stimulate and co-ordinate such research and development by all appropriate means at its disposal. A step towards this recommendation has been taken with the establishment of Central Public Health Engineering Research Institute at Nagpur with its field units in various states of this country. Provincial Research and Action Institute, Lucknow (PRAI), is also doing commendable work in the field of rural water supply and sanitation. The All India Institute of Hygiene and Public Health, Calcutta is also conducting a number of field studies for septic tanks, rural water supply with dug wells, hand pumps, tubewell strainers, etc. The Roorkee University has opened a Water Development Section. Other Universities are also contributing towards some form of research or the other on public health engineering subjects.

Having examined the basic need of Sanitary Water Supply for a community and its direct relation to health, let us now examine the growth and development of water supply systems in this country. As per statistics collected by South East Asia Region of WHO in September, 1962 only 11 per cent of India's population (438 millions in 1960-61) have community water supply as against 16 per cent in Indonesia, 13 per cent in Ceylon. Out of 1750 community water supply systems in India, only 200 or 11 per cent have complete treatment plants, 500 communities are supplied with chlorinated water only and 1050 communities are supplied with ground water or untreated surface water. This excludes 3245 villages in 9 states where piped water supply had been provided. Between 1958 and 1962, 3 independent agencies viz. the Panel on National Water Supply and Sanitation under the building project team of the Planning Commission, a three man team of Public Health Engineering Consultants sponsored by the USAID and the National Water Supply and Sanitation Committee set up by the Union Ministry of Health made a comprehensive review of the situation in the country in the field of water supply and sanitation. The following figures convey a rough idea of the situation.

The urban population of India according to 1961 census was roughly 79 millions distributed over 2,451 towns. Out of these the number of towns which have a water supply system, either in operation or under implementation was: (a) All the 113 towns which have a population of 1 lakh and above (total population 36 millions), (b) 109 out of 137 towns (total population 9 millions) each with a population of half to 1 lakh, (c) 253 out of 487 towns (total population 15 millions) in the population range of 20,000 to 50,000, (d) About 200 out of 1,714 towns (total population 15 millions) in the population range of 20,000 and below. Even most of the towns having a water supply system are undoubtedly in need of considerable improvements and expansion. In Uttar Pradesh, by the end of March 1964, 111 water-works in urban areas were commissioned and 29 new water-works and for 38 numbers reorganisation and extension programmes for water supply of the previous years were in progress. The total number of water-works by the end of Third Five Year Plan is 140.

Prior to independence, the progress in the field of urban water supply was slow and spasmodic depending on the need of the alien rulers. Water Supply in rural areas was more or less unknown. With the advent of popular ministries in post independence period, an intensive programme to meet the challenge of water supply, particularly in the rural areas in Bengal, Madras, Bombay and the old Mysore State was started. In the post war development era, the Bhor Committee came into being and for the first time pinpointed attention to the importance of safe water supply. They assumed importance in the National Development Plans. The Environmental Hygiene Committee (1948-49) appointed by the Union Government was the first agency of its type charged with an overall assessment of the country-wide problems in the entire field of Environmental Hygiene. The Committee made notable recommendations in this field and urged for greater activity in this direction. They recommended specially for a comprehensive plan to provide water supply and sanitation facilities for 90 per cent of the population within a span of 40 years. No concerted measures were taken to implement their recommendations. Some states started their First Five Year Plan (1951-56) but they soon came up against formidable obstacles in the way of raising the finances for such schemes, building up of the Public Health Engineering Organisations and in the procurement of proprietary materials needed for such schemes.

In 1954 Union Health Ministry announced their National Water Supply and Sanitation Programme as part of Health Schemes and made specific provision to assist sanitation schemes with loans for urban water supply schemes and 50 per cent grant for rural water supply schemes. Subsequently, State Government extended the facilities of grant for water supply scheme for rural town areas and N.A.C.'s, 75 per cent grant-in-aid is being given to encourage these small local bodies to go in for wholesome drinking water supply schemes by taking only 25 per cent loan on the usual terms of 30 years payment at a rate of 6¼ per cent interest. For hill and scarcity rural areas, State Government is now giving 100 per cent grant-in-aid and even these poverty stricken areas have now been exempted from giving any contribution by way of *Shramdan* or otherwise for which a 10-25 per cent limit was fixed in the earlier stages.

In the First Plan period, a total provision of Rs. 12 crores for Urban Schemes and Rs. 6 crores for Rural Schemes to cover activities during last 18 months of the Plan period was made by National Water Supply & Sanitation Programme. The State Governments channelise their water supply projects to Union Health Ministry for aproval and allotment of funds under National Water Supply & Sanitation Programme. In all 252 urban water supply and sanitation schemes for a total estimated cost of Rs. 45 crores and 133 rural water supply and sanitation schemes for a total estimated cost of Rs. 13.5 crores were generally approved for inclusion in the Plan. Actual expenditure in First Plan period was of the order of Rs. 10 crores for Urban Water Supply and Sanitation and Rs. 5.5 crores on rural schemes. Under community development programme, total expenditure was about Rs. 4.5 crores incurred on health schemes including water supply taken up by blocks & about 1,07,000 sanitary wells were constructed. Expenditure under Local Development Programme was Rs. 7.2 crores. About 29,650 wells were constructed or renovated. During Second Five Year Plan some 208 Urban Schemes at an estimated cost of Rs. 27.9 crores and 214 rural schemes of an estimated cost of Rs. 5.48 crores were added. Total expenditure in the Second Five Year Plan under National Water Supply & Sanitation Programme was about Rs. 42 crores on Urban Water Supply and about Rs. 18 crores on Rural Schemes. Under community development programme in Second Five Year Plan Rs. 11.5 crores and under Local Development Works Programme Rs. 13 crores were spent covering construction or renovation of 4,53,000 and 1,02,500 wells respectively. In addition to this Rs. 3 crores were spent under welfare of Backward Classes Programme where some 20,000 wells were constructed or renovated.

During Third Five Year Plan, Rs. 89 crores for Urban Water Supply and Sanitation Schemes and Rs. 67 crores for Rural Water Supply and Sanitation Schemes were provided under National Water Supply & Sanitation Programme (Rs. 16 crores), Local Development Programme (Rs. 35 crores), Community Development Programme (Rs. 12 to 13 crores) and Welfare of Backward Class Programme (Rs. 3 to 4 crores).

The Third Public Health Engineers Conference held in October 1958 estimated that the total magnitude of the urban water supply and sanitation schemes awaiting accomplishment would be of the order of Rs. 900 crores based on rough approximation of the population in urban areas and rough per capita cost on water supply and sewerage undertakings based on past experience in the states. For rural water supply and sanitation, the figure worked out was Rs. 600 crores.

Let us now examine the specific problems concerning water supply for the State of Uttar Pradesh. It is a large State covering an area of 1,13,654 sq miles with a total population of 7,37,46,401, as per 1961 census. Present population is nearing 80 millions. The rural population of the State constitutes 87 per cent living in 1,12,624 villages. Total number of Blocks covering the state is 875. The State can be divided into 3 main groups as far as water supply problems are concerned. These are the sub-himalayan hill areas in the North covering the border districts, the Tehri and Pauri Garhwal districts, the Kumaun Region of Nainital. Almora and the Siwalik ranges covering Dehradun and Sharanpur. The Tarai and Bhabar Estates at the foot hills of these areas have also to be considered in this category. In these hill areas few water supply schemes have been provided and scarcity conditions exist there. Then comes the great Indo-Gangetic alluvium plains and lastly the sub-mountainous rocky region of Vindhyachal ranges in the South stretching from Jhansi via Banda, Allahabad to Mirzapur Districts. For the northern hilly areas, water supply can mostly be drawn from natural springs, gaderas or hill streams or canals or rivers. In Tarai and Bhaba areas, deep tubewells have been successful in some areas. The Indo-Gangetic plain is rich in ground water supplies, which can be obtained by comparatively shallow boring upto 200 meters or so. Some Corporation towns like Lucknow, Allahabad, Kanpur and Agra etc. draw their water supply from perennial rivers like Gomti, Ganges, Jamuna, etc. In the Sub-mountainous region of Vindhachal impounded reservoirs, bundis or lakes are the source of water supply as in Jhansi, Mirzapur, etc. These are scarcity areas particularly in the interior portion where deep wells are difficult to be dug, no perennial rivers are there and villagers mostly collect water in shallow ponds or bundis during rains, which they consume in summer. The water gets highly contaminated and unfit for human consumption. Drawing water from deep wells is a problem. Besides the water gets depleted in summer. The acute scarcity areas cover 9 districts viz. Dehradun. Saharanpur, Tehri Garhwal, Mirzapur, Jhansi, Nainital, Almora, Pauri Garhwal and Banda, having 118 blocks and 20,676 villages in it. having a population of about 52.34 lakhs (1961) (Designed population will be 78.51 lakhs).

The preliminary assessment to provide drinking water supply in all the rural areas of the State brings the cost of Rs. 253 crores. The nine scarcity districts mentioned above will require Rs. 32.75 crores to provide water supply in rural areas, the annual maintenance cost of which has been worked out as Rs. 63.20 lakhs.

The districts lying along river Jamuna are also termed as scarcity districts because ground water in this terrain is brackish and mostly unfit for human consumption. Districts of Agra and Mathura come under this group. Sweet water is obtained in a very limited belt. There are no suitable rivers which can provide water supply to all areas. Very deep tubewell could not be tried due to non-availability of proper boring equipment besides cost will be prohibitive for the small communities to bear. Infiltration galleries too did not prove effective or adequate.

During the post independent period there existed a small Public Health Engineering Organisation in the State. With the introduction of State First Five Year Plan in the post independent period the activities of the organisation were expanded and with the establishment of National Water Supply and Sanitation Programme under Union Ministry of Health in 1954, the State Public Health Organisation, which later came to be known as LSGED, was expanded rapidly. It has now 29 divisions divided under five circles with a Chief Engineer at top. Out of these 29 divisions, there are 3 project divisions and 2 survey and investigation divisions sponsored by the Government of India, Ministry of Health. In the pre-independence period only 27 waterworks were constructed, all in urban towns. By the end of Third Plan 140 waterworks were completed in the urban sector. This means that more than 1/3rd of the total towns in the State have been covered with piped water supply. In the rural sector under National Water Supply & Sanitation Programme, Water Supply Schemes at a total cost of Rs. 1.49 crores were undertaken in 1,465 villages under First Five Year Plan by the LSGED and Irrigation Deptt. The progress was slow due to inadequacy of organisation and lack of local response to raise contribution by way of cash or *shramdan:* During the Second Five Year Plan a sum of Rs. 36 crores was spent under National Water Supply & Sanitation Programme for Rural Water Supply and Sanitation Schemes. During Third Five Year Plan, a provision of Rs. 6.87 crores has been made for Rural Water Supply Schemes under the National Water Supply & Sanitation Programme. Bulk of the work under Rural Water Supply Schemes has been included under the Community Development Programme in which about 2 lakh wells and hand pumps are to be installed at an estimated cost of nearly Rs. 4.42 crores. Rs 2 crores worth of work will be got executed by LSGED. In this State Rural Water Supply Schemes have been entrusted to the agencies other than Public Health Engineering Department like block agencies, Irrigation Department, etc. The Chief Engineer, LSGED, has stated that "it has been felt that at times multiplicity of the agencies working in the field and their division, ways of thinking and implementation of the Rural Water Supply Schemes without observing certain pattern practice and standard, have resulted in failures of such schemes. It is difficult to suggest type designs or design criteria or standards as for urban towns for rural areas throughout the State as these schemes are to be framed keeping in view topographical, climatical and socio-economic conditions of the people which differ from area to area." As such discretion of experienced Public Health Engineer becomes necessary.

In 1963 Government of India desired to collect the statistics in respect of the water supply problems in the scarcity and difficult areas of the state. One Survey and Investigation Division was created in January 1963, to work out the problems in 9 acute scarcity districts mentioned earlier. The Second Survey and Investigation Division came into existence in January 1964, when 9 more scarcity districts viz. Uttarkashi, Chamoli, Agra, Mathura, Hamirpur, Jalaun, Varanasi and Allahabad were covered. These divisions are collecting information regarding names of villages suffering from scarcity of drinking water, their population, the nature of existing sources both qualitative and quantitive, epidemeological statistics, proposals for augmenting or providing safe drinking water both in adequate quantity and of minimum hygenic quantity and their financial cost, both capital and maintenance, etc. On the basis of these investigations it is gathered that there are 33,140 villages in 18 scarcity districts of the State out of which water is to be provided on priority basis to 13,917 villages. There are 14,090 villages in the non-scarcity area of the State which also require urgent attention and same priority as the scarcity districts. Approximate population desired to be covered under priority schemes is about 5.433 crores out of 7 crores rural population. The proposal for water supply in respect of these villages will cater for an ultimate population in 30 years of about 82 lakhs in the scarcity and 1.5 crores in the non-scarcity districts. The total cost of water in these 18 districts for the scarcity hit villages (13,197 villages) comes to Rs. 56.70 crores. For difficult and backward villages in non-scarcity districts the cost comes to Rs. 50.06 crores. The maintenance cost for the above schemes for these 18 scarcity districts and the difficult backward villages in the non-scarcity districts comes to Rs. 1.45 crores and Rs. 1.60 crores respectively. The Plan allocations for Fourth Five Year Plan are not known as yet. But as the figures suggest the problem of providing safe water supply even in these priority schemes is formidable, and unless considerable plan outlay is made available to the State in this connection hardly any headway to solve the problem can be made. So far plan allocations made hardly touched the fringe of the problem. There has been consistent demand from Divisional Planning Committee Forum and the Panch Sammelans of the scarcity hit areas of the State for greater plan allocations for this most important aspect of the Plan for quicker implementation of detailed schemes already framed for these areas and for the State Government Department viz. LSGED to take over maintenance of these schemes since the Antarim Zilla Parishad (AZP) or the Gram Pradhans, the beneficiary, are not in a position financially or technically to maintain these water supply schemes even though the Antarim Zilla Parishad passed resolutions while accepting Government Grant for Rural Water Supply Schemes to take over and maintain these schemes by the respective Gram Pradhans and that necessary funds will be raised for the same. It is felt that maintenance of these costly undertakings requiring technical experience, skill and knowledge should be entrusted to LSGED and that maintenance funds be raised as a cess to land revenue by the revenue staff and the amount be placed with the LSGED to raise necessary organisation, tools and plant and other necessary equipment to maintain the system in perfect working order. It will be able to keep necessary hydrological records of the sources and shall keep control over quality of water supply throughout the year. Education of the people for proper utilisation of water, prevention of waste, water conservation etc., will also be possible through this agency.

Inspite of the general consciousness of health and life giving properity of water and inspite of strong recommendations of Bhor Commitee, Environmental Sanitation Committee, Public Health Engineering Conferences, National Water Supply and Sanitation Committee etc. the progress on the implementation of water supply schemes through five year plan allocations remained much too slow. The formidable obstacle is the finances. The local bodies have neither the resources nor the capacity to finance large loans from Government. Due to political set up, they are not readily agreeable to impose water tax and even if they do, the realisation of the tax from public remains mostly in arrears and most of the costly water supply undertakings are going to ruins due to improper finances, inadequate maintenance etc. Only in a few cases the undertakings run on profit. The back log of interest on Government loan accumulates and Government can not sanction further loan assistance to such defaulting Boards. Government cannot undertake all such Water Supply Schemes out of its own resources because of limitation of capital and resources available to it and because of other high priority projects like defence, food production, minor and medium irrigation schemes, industry, road communication and power.

One of the recommendations made by Fourth Conference of Public Health Engineers held in Delhi in November, 1960, was the setting up of Regional Water and Sewerage Board. The Seminar on Financing and Management of Water and Sewerage Works convened by the Ministry of Health, Government of India at Delhi from April 24-30, 1964, recommended that a Statutory Water and Drainage Board should be set up at each State level with regional boards if and to the extent necessary within the State to provide water and sewerage service and to collect revenues to meet such services, to raise the capital needed to provide the facilities and to exercise all other corporate powers necessary to act on behalf of the constituent local bodies within its jurisdiction. It can float loans as Municipal Corporation, Bombay did. This procedure is common practice in many parts of the world. For some times to come Central and State Government should act as borrowing agents on behalf of Statutory Boards. It was recommended that Govt. of India should appoint a high level committee with representatives from the Union Ministry of Health, the Union Ministry of Finance, the Planning Commission, a Mayor of a Corporation, a Chairman of a Municipality, a Municipal Commissioner, a Public Health Engineer and a lawyer assisted by consultants as necessary to draft model enactment for setting up Statutory Water & Drainage Boards, defining their power and duties and recommending appropriate methods of funds raising. It may be constituted on the lines of State Electricity Board or Metropolitan Water Board, London, constituted under the provisions of the Metropolis Water Act, 1902. The Statutory Water and Drainage Board may obtain loans from International and bilateral agencies such as the World Bank and International Development Agencies (IDA) and USAID and the conditions be fulfilled before such loans are granted. UNSF be requested to assist by supply of equipments, transport vehicles and specialist services to provide water supply facilities in different areas and to carry out detailed investigations for the purpose. The Government of West Bengal is preparing a legislature for the creation of a Metropolitan Water & Sewerage Board for greater Calcutta area to deal with problems of water supply and sewage in this region which will cover an area of 300 sq miles.

One of the main functions of the Statutory Water and Sewerage Board should be to initiate research in the field of public health engineering in the State, to make extensive explorations of possible sources of water supply to determine region by exploratory borings where ground water supply will be copious and wholesome, possibilities or recharging the ground water artificially or otherwise, area where infiltration galleries will serve the purpose, etc. They should adopt legislative measures to conserve and protect streams and lakes and impounded reservoirs against possible pollution, etc. They should evolve drinking water standards for specific regions depending on its socio-economic position, availability of cheap water sources, habits and epidemeological conditions of the region and other technical considerations. Research to find out cheap methods of tapping sources of conveyance of water, pumping, treatment, etc. with available local materials as far as possible should be continued. The per capita supply needed for a specific region to meet normal human industrial and fire demand should be worked out and design criteria for water supply for specific regions be worked out. As aptly pointed out by Shri N. V. Modak in one of his speeches that "Research in Public Health Engineering is a team work requiring close cooperation of not only public health engineers, but electrical, mechanical, electronic and chemical engineers, scientists trained in algology, mycology and plant pathology, microbiology, limnology, bacteriology, physics, botany, chemistry and biochemistry, biophysics, statistics, medicine, geology, anthropology, sociology and meteorology and also other health specialist. The research must proceed to solution of the environmental problems created by our complex society."

Let me conclude the paper with the observation that adequate wholesome water supply is an index of a community's civilisation, growth and development and a growing community has to give highest priority for expenditious implementation of drinking water supply schemes. Civil Defence measures have to be adopted to protect public water supplies from being interfered with or contaminated by saboteures or enemy agents during escalation of hostilities like the one India witnessed during Chinese and Pakistani aggressions. Steps to store underground water with protective steps against radiological contaminations by fall out or otherwise detection of radiological contamination, protection of water supplies against biological warfare by establishing network of personnel and facilities for emergency, sampling and laboratory examination of suspected B.W. materials and toxins, decontamination by boiling or chemicals should be undertaken in every emergency. Technical personnel charged with the responsibility for safety of water supply should be trained to detect and identify all hazardous chemicals expected to create problems during emergey such as Cyanogen bromide, Hydrocyanic acid etc. Conservation of water during emergency will be necessary. This can be done by reducing per capita supply during peak demand period, restricting water use of certain periods during the day, posting police on watering points and curtailing industrial uses. Drinking water standards may be relaxed to the extent that it causes no serious health problem. For very turbid water large dose of chlorine or iodine will be required to maintain minimum residual. Water containing a minimum of 5 mg/lit. of free chlorine at 30 min. contact time may be considered bacteriologically safe—when biological warfare is suspected or else a residual of 2 mg/lit. at 30 min. contact is adequate. Portable water treatment equipments, chlorinators and quick coupling light weight pipe at a number of locations in the country be stockpiled. Army units may have mobile or field water treatment equipments. These equipments for a 10 mile unit are—

(1) 10 Miles light weight 8 in. diam. steel pipe with couplings, fittings valves, etc.

(2) Two portable Diatomite 100 gpm purification unit.

(3) One mobile, 300 lb per 24 hr. capacity chlorinator.

(4) Five 1500 gpm centrifugal pumps. single stage, gasoline—engine driven, skid and/or wheel mounted, 100 psi discharge—15 ft suction lift.

(5) Two 100 gpm pump—centrifugal, single stage, gasoline-engine driven, skid mounted 130 ft dynamic head.

(6) 4 tanks—Nylon, Rubber Coated 3000 gal each.

(7) Two 40 kw generator set, portable gasoline driven, skid mounted— alternate current and few small mobile generator of 15 kw and 10 kw capacities.

For quick bacteriological examination of water during emergency for quality control membrane filter technique is considered more rapid than MPN (most probable number) coliform tests. Another coliform measuring technique utilising carbon—14 labelled lactose is being evaluated and preliminary studies indicate as little as 2 to 4 hr is required. But such tests may not be possible for small improvised water supplies during evacuation, etc. when chlorine residual test alone will have to be relied upon. The water board at State level has to collect information for emergency water sources in the community in consultation with Municipal Department, PWD, Water Resources Commission, Health Department, State Geological Survey, Exploratory Tubewell Organisations, etc. Annual Stream gauging reports, water quality division and Ground water divisions of Geological Survey Department should be of assistance. When collecting information on existing water treatment facilities special consideration be given for emergency use of (i) flexibility of plant to operate inspite of certain break downs, (ii) raw and finished water storage capacity and (iii) adequacy of replacement equipment and parts personnel should be trained to operate water treatment equipments etc. for emergency besides the water-works operators. Universities, technical societies, engineering firms and trade unions can lend such men for emergency training. Civil defence concepts should be introduced into normal design and maintenance of water supplies and distribution system. It has been stated that Civil Defence is "a way of life". The truthfulness of this statement is becoming more apparent each passing year. The horizon at this time holds no promise to the cessation of world conditions which necessitate Civil Defence. When large scale water supply undertakings are being considered for the country, it would behove us to integrate these concepts into our normal pattern of life so that a state of readiness can be obtained and maintained.

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DISCUSSION

Shri R. S. Mehta, Director, CPHERI, Nagpur: Do the water supplies pay for itself? Some idea of cost of schemes and the rate charged per 1000 gals may be given.

Shri H. P. Ghose (Author): Yes. All water supply schemes are so framed that these, if run properly, should pay for itself even after meeting loan and sinking fund charges. Some existing water works are not paying themselves due to poor maintenance, non-realisation of water tax and for not providing metered connections resulting in wastage and improper low rates provided for per rule ratings, etc.

The cost of schemes for tube well water supply in urban towns vary from Rs. 30 to 40 per capita. The usual rates charged per 1,000 gal comes to about one rupee.

Shri R. S. Mehta: How far has metering of supplies helped since your manufacture of meters in large numbers? Have you been able to maintain the meters in small towns?

Shri H. P. Ghose: With metering introduced for public water supplies, wastage has been greatly controlled. Some fully metered water works are self supporting. Old water works are also being processed to convert all connections into metered ones. The process is slow but gradual. The Precision Instrument Factory at Lucknow offers for services of three mechanics to repair meters supplied by them. Meters sent to the factory are also repaired. Defective parts are freely replaced.

Shri R. S. Mehta: How is water works department connected with problems of water pollution of alluvial river areas where water is grossly polluted.

Shri H. P. Ghose: The large water works, obtaining surface water supply from alluvial rivers, maintain well equipped laboratories at places like Allahabad, Agra and Kanpur. For specific problems of pollution, they refer their problems to research institutions like CPHERI. Pollution surveys are also being carried out to find out how river pollution can be prevented.

Shri R. P. Mishra, CPHERI, Nagpur: You have mentioned that the main aim of your rural water supply programme is to give adequate and wholesome water supply. What specific measures do you propose to adopt to supply water that is bacteriologically pure in rural areas?

Shri H. P. Ghose: All-sources that are tapped for rural water supply are adequately tested chemically as well as bacteriologically before adoption. Mostly spring water or tube wells are adopted as sources for rural areas. These waters are generally found wholesome and free from bacterial contamination. Provision of chlorinated water by the use of bleaching powder solution is invariably made to safeguard such water against subsequent bacterial pollution. Periodical examination of water is recommended to maintain reasonably good standard of drinking water even for rural communities.

Dr. N. U. Rao, CPHERI, Nagpur: During a state of emergency that exists during armed conflict with our enemies what sort of preventive and remedial measures would you take to safeguard the water quality? It is obvious that more chlorination does not help.

Shri H. P. Ghosh: I have fully dealt with the preventive measures that should be taken during escalation of hostilities to safeguard public water supplies against radiological, biological contamination in my paper. I need not repeat the same.

A residual dose of 5 mg/lit free chlorine shall take care of biological contamination with 30 min. contact time. It may not be adequate for virus infection. Quick detection of contamination by membrane filter technique may be useful. Another coliform measuring technique utilising carbon—14 labelled lactose is being developed and may bring out results in 2 to 4 hours.

Shri B. S. Mahantannayar, Banglore: Has the State Public Health Engineering Organisation solved the problems of treatment of underground hard waters?

Shri H. P. Ghose: Very hard water has not been encountered in the water works so far established in the State and the question of providing softening plants did not arise.

Shri B. S. Mahantannayar: Were there areas affected by water-borne diseases? Did the Government receive assistance from WHO or UNESCO? If so, how much?

Shri H. P. Ghose: Yes. Pilot schemes of water supply in rural sector under UNICEF/WHO aid program has been undertaken in scarcity hit areas and areas affected by water-borne diseases in Dehradun and Saharanpur Districts (Dharana), in Motadhak circle under Tehri districts in Eastern districts of U.P., etc. Some of these schemes have been successfully completed. One hundred and forty one villages with a total population of 54,000 will be benefited. The total cost of schemes works out to Rs. 43.35 lakhs against which materials worth Rs. 6.802 lakhs have been supplied by UNICEF/WHO aid as free gift. The UNICEF aided schemes in Bara Banhic, Meerut and Gorakhpur blocks work out to Rs. 6,95,000/- against which materials worth Rs. 3,74,000 have been given as free gift by the said aid programme.

Shri B. S. Mahantannayar: Did the organisation solve the problem of getting small size pipe of 3, 4, 6 inches size and the high power pump-sets? What is the prescribed time limit for completion of project and what is the period of completion of a rural scheme?

Shri H. P. Ghose: Mostly A.C. pressure pipes of 3, 4 and 6 inches sizes were arranged and there have been no difficulties. For hilly tracks, G.I. and M.S. pipes have been procured. Normal size 5 to 15 hp pumps could be procured in India from indigenous manufacturers like Jyoti, Thomston's etc. without much difficulty. The period of completion of rural scheme is usually 1 to 2 years.

Shri U. J. Bhatt, Baroda: I wish to know how many urban water supplies, drawing water from alluvium rivers, have intake works with infiltration galleries? Have you tried tapping water on Rhine system by perforated pipes? My recent experience has demonstrated that whenever the groundwater conditions are favourable, this is the cheapest and quickest method.

Shri H. P. Ghose: So far no infiltration galleries with the system suggested by you has been tried in the alluvium rivers of Uttar Pradesh. We are drawing water directly from the river supply by conventional intake towers with pumping arrangements.

Shri D. L. Mathur, Udaipur: What is the pattern of rural water supply? Are all the systems piped completely.

Shri H. P. Ghose: Pattern varies in rural areas. In hills, mostly water supply is given from springs. The water is collected in a collecting chamber and it is partially treated through roughing filters and chlorinated. Water is supplied to the houses from the storage tanks designed for half day capacity in rural areas.

For plains, small tube wells or infiltration galleries or sanitary dug wells are provided for water supply. Water is stored in centrally situated storage tanks and distributed to different groups of villages through pipes after chlorination. Tank type or pillar type stand-posts are provided with arrangements to drain off waste water to natural drains or fields.

All water supplies are piped fully.

Shri D. L. Mathur: What is the cost per capita? How is brackish water treated?

Shri H. P. Ghose: Cost per capita for rural water supplies varies depending upon source, nature of population, distance of distribution system and groups of villages. etc. In plains, with tube well as source of supply for compact group of villages, it works out to Rs. 23.5 or so per capita. For hilly areas, it may vary from Rs. 60 to 120 per capita.

No demineralisation plant has been put up so far in this state for highly brackish water. Such acute problem has not yet been met with.

Shri J. M. Dave, CPHERI, Nagpur: With so many water treatment plants, do you have any standard methods of design, so that maintenance etc. are economical?

Shri H. P. Ghose: Yes. Standard design criteria for urban and rural water supply schemes, have been evolved for the state of Uttar Pradesh and all schemes are now being prepared on the basis of the criteria with such modifications as become necessary due to topographical, geological and socio-economic conditions of a particular place. Efforts to keep maintenance cost at the most economical level are being made in each scheme.

Shri N. M. Basu, Durgapur: When so many schemes have been prepared for water supply, why no provision was made for harnessing the water resource?

Shri H. P. Ghose: The question is not clear. For every water supply scheme, whether for rural or urban scheme, proper and most economical sources of water supplies that will ensure adequate water supply throughout the design period, have been harnessed. Every available water source, viz. surface water or ground water, available close at hand, and which can be economically harnessed with least amount of treatment necessary have been tapped.

Geological and hydrological surveys to determine ground water resources even in the rocky parts of Vindhya range stretching from Jhansi to Mirzapur on the southern region of the State are proposed to be undertaken soon with the help of rock drilling diamond rigs to be made available by UNICEF/WHO to meet the challenge of water supply in the drought affected areas. The investigations of sources have also been started for scarcity hit areas of the State.

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Community Water Supply in Durg District

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It is very unfortunate that our villages inhabitated by more than 80 percent of the country's population have remained neglected for years in the field of water supply and sanitation. Majority of rural communities depend upon the surface water sources-rivers, nallahs, ditches, tanks and canals—for their domestic water supply. These sources are subject to pollution and are responsible for spread of water-borne diseases. With the rapid urbanization and industrialisation taking place in our country the chances of pollution of the surface water sources are even more. Under the changed circumstances the Government and local bodies have now realised that proper rural water supply and sanitation is necessary for improving the national health.

Schemes have been prepared and beginning has since been made but there may be considerable difficulty in executing the schemes for all rural areas because of the prohibitive cost of treatment and lack of public health education in our country as a whole.

The position of rural water supply in Durg District is as deplorable as in any other rural area of our country. Durg is one of the important districts of Madhya Pradesh. It occupies an area of 7498 sq miles and includes six municipal towns, the beautiful township of Bhilai and 4267 villages. The total population of the district is 19 lakhs, 86 per cent of which is distributed in the rural areas.

Broad cut lines

The State Government has launched a programme for improving the water supply position in the rural areas, through the agencies of block development organisations and Gram Panchayats. According to this scheme a village with population upto 500 is provided with a tube well, operated by hand pump, on condition that 25 per cent of the expenses should be met with by the people.

More tube wells are provided where the population exceeds 500 and in places where the population is above 2000 piped-water facility is given on the same condition. In tribal villages, however, the entire expenses are borne by the Government.

Unfortunately the above scheme has not been very popular among the people. This will be clear from the fact that only 2 per cent of the rural communities have availed of the facility so far. One need not go deep to discover the probable reasons for poor response. The first is, obviously lack of public health education, secondly, their deplorable financial condition, the third one is due to a technical difficulty which arises whenever the hand pump goes out of order and finally, it is believed, availability of alternate source of water supply howsoever contaminated it might be. An important point, here, is that even 2 per cent people who have accepted the Government scheme does not seem to be due to their desire for good quality and adequate quantity from the tube well but because of the fact that they had no other easily available source. Such villages where there is acute shortage of water have been listed as *PROBLEM VILLAGES* and their number is 285,460 which have been provided with tube wells.

Brief Description of the Facility Provided

As mentioned above there are 46 villages that have been provided with tube wells, with hand pumps. The actual average cost of a tube well system is about Rs. 5000 depending upon the hydro-geological strata the cost of executing the scheme differs. In some places it has been possible to get ample discharge at a depth of 40 ft whereas in certain others adequate water is not available even after boring 250 ft. In these villages 3-4 in. diam G.I. casing pipe has been used.

In 16 villages, with population 2000 and above, piped water supply, through bore-wells, has been given. The Management is done by the local bodies. For the present private house connections have not been given. Instead, public stand posts have been provided. Only two schemes in the rural areas and one in urban area are described below:—

BEMETARA

This is a Tahsil head quarters under Durg district having a population of 4934. A tube well has been dug at a depth of 202 ft 6 in. diam G.I. casing pipe acts as a suction for a 5 hp electric-driven pump which lifts the water to an elevated tank of 5000 gallons capacity. Murum, yellow earth, reddish soft stone and lime stone strata have been found during drilling operation. Average discharge per hour is 1700 gal. The scheme has cost Rs. 50,000.

The quality of water available from the above tube well is acceptable for domestic use as may be seen in Table I. A remarkable point regarding this water is that coliform organisms are absent from 100 ml portion.

DHAMDA

This is another semi-urban village in Durg district. Its population is 4264. An yield of 1860 gal/hr is available from the tube well, 202 ft deep, 6 in. diam G.I. casing pipe acting as suction for a 5 hp vertical electric-driven pump. Here also the pump lifts the water to an over head tank of 3000 gallons capacity. The cost of the scheme is Rs. 53,000. Analysis of this water may be seen at Table I. Presence of *E. coli* to the extent of 10/100 ml necessitates the provisions for disinfection.

The only urban area (of Durg district) where drinking water is supplied through a system of tube wells is the Khursipara labour-colony owned and managed by Bhilai Steel

Plant. In all, there are 13 bore wells, all 200 ft deep with 6 in. diam G.I. casing pipe to supply water to a population of over 15000 souls. Lime stone stratum stretches for a depth of 121-133 ft in these wells. The average discharge of the well is 1600 gal/hr. Water Supply is given through elevated steel tanks, each of 50,000 gallons capacity. All the residential accommodations are provided with sanitary fittings. Apart from these a few public stand posts are also provided.

The water supplied to the consumers from the tube wells is of the prescribed quality. This may be seen in Table I.

As already mentioned the tube well water supply scheme has, till now, covered only 2 per cent communities. The position regarding 98 per cent rural population is rather alarming. The communities living on the banks of rivers, nallahs and canals draw their entire water requirements from these sources all the year round. Quite a number of villages depend on tanks and ponds for their domestic water supply. Thus over 65 per cent of the rural population of Durg district utilises the surface water sources. The rivers that flow through the district are the Sheonath, the Kharun, the Tandula, the Kharkhara, the Hanf and the Surhi, all of which are subject to pollution and great fluctuations in chemical and bacteriological quality throughout the year. The villagers drink the water, in its natural form, and most of them fall victim to a number of water-borne diseases. Fortunately none of these rivers receives industrial wastes of toxic nature otherwise the situation would be more serious.

The tanks and ponds (another surface water source) that meet the de-

TABLE I

Characteristics	Results obtained from tube well		
	BEMETARA	DHAMDA	KHURSIPARA (BHILAI)
pH value	7.1	7.3	7.3
Alkalinity Total as $CaCO_3$ (mg/lit)	290	198	201
Free CO_2 (mg/lit)	0.3	2.0	10
Hardness Total as $CaCO_3$ (mg/lit)	280	200	144
O.C.P. (mg/lit)	nil	0.3	0.4
Chloride as Cl^- (mg/lit)	22	102	11
Nitrate (mg/lit)	3.0	1.2	0.15
Iron (mg/lit)	nil	0.1	0.3
MPN Index (Coliform Bacteria in 100 ml portion)	nil	10	2

mand of quite a number of villages are also, very often, contaminated. It is a shocking fact, that in a few places the same tank serves the purpose for both cattle and human beings. The result is, obviously, disastrous in such cases. Due to lack of Public Health education and poverty people are reluctant to accept the tube well water supply scheme. Analysis of water samples of a few surface water sources is given in Table II.

Open wells, both shallow and deep, depending upon the hydrogeological strata available at a particular place, form the source of water supply to one-third of the rural population of Durg district. Only a very few villages have got open wells with sanitary protection which too is not adequate. In most cases hardly any thought has been given in selecting the location of the well. Quite a number of them are located at low levels, either near the manure pits or near stagnant water ditches, thus increasing the chance of pollution by seapage. The top of the wells is almost always kept at ground level because of which the drain water and other rubbish matter find access into the well and affect the quality of water, apart from causing accidents to children and the cattle.

Occasional disinfection of wells by potassium permangnate (which is an obsolete method) or by bleaching powder hardly helps in improving the quality of drinking water. Moreover this work being done by the village level workers, deputed by the local bodies, is not satisfactory as the dose given is, invariably incorrect either excess or far below the requirement.

"Cartridge methods of disinfection" has been carried out in a few places of the district and satisfactory results obtained, as may be seen in Table IV. Cartridge is a hollow unglazed cylindrical earthen vessel with narrow mouth. This can be prepared locally by pottors making use of porous clay, of any dimensions required. For disinfecting small water supplies, particularly open wells, a cartridge of internal dimensions 9 x 4 in. diam. with 1 in. or a little more diam. opening has been found to be convenient. This can hold about 2.7 lb of bleaching powder. To charge the cartridge, bleaching powder of known available chlorine content is filled and well packed and moistened with a little water. The mouth is, then, tightly closed by a rubber cork. It is then immersed in a vessel containing water which completely covers it. Cartridge is kept in the water until the active chlorine begins to percolate through its porous walls, by diffusion. This takes from 22 to 36 hr depending on the porosity of the walls. It is equally convenient to directly immerse the cartridge into the body of water to be disinfected. Before disinfecting a particular supply it is necessary to know the following (a) Chlorine demand of the water to be sterilized, (b) Rate of flow per hour and total daily consumption.

If these figures are known, it can be found out as to how many days months charge will last for a particular source.

Method of Disinfection

In case of open wells the charged cartridge is immersed into the water with its neck securely fastened to a

TABLE II

S. No.	Characteristics	SOURCES: Rivers and Nallahs — Sheonath River: Rainy season	Sheonath River: Dry weather	Kharkhara: Rainy season	Kharkhara: Dry weather	Phulgaon nallah: Rainy season	Phulgaon nallah: Dry weather	Tanks, Ponds & Ditches — Ahiwara Tank	Deorjhal village pond.	Ditch located in Nandini Mines area.
1.	Turbidity	100—2000	15—50	100—1500	10—40	500—1500	20—100	10—45	100—230	5
2.	pH value	7.0-7.4	7.6-7.8	7.2-7.6	7.8-7.9	7.3	7.4	7.0-7.6	7.8	7.4
3.	Total Alkalinity as $CaCO_3$ (mg/lit)	75-85	90-130	155-165	—	—	—	51	118	153
4.	Chloride Cl^- (mg/lit)	7.0	8.0	2.5	2.5	2.0	2.2	5.0	7.0	9.0
5.	O.C.P. (mg/lit)	2.8	1.9	—	—	—	4.5	2.7	9.8	2.1
6.	MPN Index (Coliform bacteria in 100 ml portion)	250—1800+	250	350—1800	900	250—1800+	350	60—250	1800	160

TABLE III—QUALITY OF WATER COLLECTED FROM OPEN WELLS OF DIFERRENT PLACES

S. No.	Characterstics	SOURCES (OPEN WELLS)				
		Sambalpur (Lohara block)	Andi village (Lohara block)	Jamul village A.C.C.	Khamdih village (Saja block)	Kohaka village (Durg block)
1.	pH value	6.6	6.6	7.9	7.2	8.4
2.	Alkalinity total as $CaCO_3$ (mg/lit)	50	121	135	338	30
3.	Hardness Total as $CaCO_3$ (mg/lit)	53	323	138	82	200
4.	Chloride as Cl^- (mg/lit)	5	122	14	235	175
5.	Nitrate (mg/lit)	0.35	0.55	—	—	1.8
6.	MPN Index (B-coli in 100 ml of portion)	900	1600	17	35	1800+

wooden plank placed across the well. Chlorine gas begins to escape into the water by diffusion as described above and disinfectes it. The process continues until all the active available chlorine from the charge is exahausted. In case residual chlorine, by orthotoulidine test, is found to be excess of the requirement, the cartridge can be lifted a little above the water so that chlorine gas will percolate only from the portion immersed. Once the active chlorine is exahausted, the same cartridge, after cleaning, can be re-charged. This method has been tried only in a few places and has been found to be cheap and dependable for community water supplies. The details may be seen in Table IV.

Details about the cartridge and the charge it holds

1. Internal dimensions 9 in. (h) x 4 in. (diam), 1 in. diam Opening of mouth.
2. Quantity of charge hold—2.7 lb.
3. Available active chlorine from the bleaching powder—25%.
4. Total quantity of chlorine available from the charge) 0. 675 lb (305.8 gm)
5. Cost of cartridge—Rs. 2.00
6. Cost of bleaching powder Rs. 0.75 per lb (Retail price).

TABLE IV—DETAILS REGARDING DISINFECTION OF WELL WATER BY CARTRIDGE METHOD

S. No.	Place where disinfection carried out	Chlorine demand of water (mg/lit)	Yield of water per day in litres	Residual chlorine maintained (mg/lit)	Consumption of chlorine per day in gm.	MPN index (in 100 ml portion)		No. of days the Cartridge actually lasted
						Before chlorination	After chlorination	
1.	Open pacca well at Rly. colony of Maroda Rly. Station near Bhilai.	0.6	5,000	0.1	3.5	90	nil	72 days
2.	Pandhar dalli well located at Rajhara Iron Ore Mines of Bhilai Steel Plant.	0.2	45,000	0.1	18.0	16	nil	15 days
3.	Open well at village Khamdih under Saja block.	0.5	4 000	0.1	2.4	35	nil	90 days

The total cost of cartridge, its charge, orthotoulidine solution and the rope works out to Rs. 5.50 only.

Suggestions

From the foregoing description we get a dismal picture of water supply position in rural areas of the Durg District. Quantity is not a serious problem but the quality of the water consumed by the rural communities is a real cause of concern. We have to make earnest efforts to improve the situation. Water from any source can be rendered safe and potable by proper treatment. The difficulty is that all the known methods of purification of water are costly from practical point of view as the financial resources of the local bodies operating in the rural areas are very poor. The following suggestions are, therefore, offered:—

(i) Every community/village with population of 500 and below should be provided with an open well with all the sanitary protections and the top, elevated above the ground level with adequate cement mortar plaster. In case of deep wells, periodical disinfection with either bleaching powder solution or chlorine water (made available by the Government or local bodies through the village level workers) is, generally; the only treatment required. In shallow wells, however, continuous disinfection by "Cartridge method" may be carried out. This arrangement is not only satisfactory but also cheaper. Tube wells, with hand pump, is much more costlier than the open well. The hand pump very often goes out of order and causes lot of inconvenience to the consumers The protected open wells can be provided by the Government alone without asking the consumers to share any part of expenditure and yet spending lesser amount than in the case of tube well. The people, otherwise compelled to drink untreated river or tank water, will draw their drinking water supply from the well alone.

(ii) For all the bigger communities with population of 2000 and above piped water supply should be made available. Cost of the scheme for such places can be borne by the Government and the consumers, as is being done at present. For piped-water supply bore well system should be preferred as the water from deep borewells is, almost always free from bacterial contamination. Provision of pump and elevated tank facilitates satisfactory water supply. Where surface water is the only available source the minimum desirable treatment is disinfection, preferably, by cartridge system. This can be conveniently done if the source is a tank. Difficulty arises in case of rivers and nallahs water from which is highly turbid and contaminated, particularly during rainy season. In such cases purification, consisting of settling and disinfection, is a most, whatever may be, the cost of treatment.

(iii) For the success and popularity of the protected water supply scheme, as suggested above, it is necessary to explain our people the importance of "HEALTH & HYGIENE". A number of enthusiatic public health workers and educators have to move among the masses and convince them that by developing clean habits, they can improve their living and working conditions.

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DISCUSSION

Shri M. V. Rao, Nagpur: What is the life of the effective chlorine in cartridges? Is it possible to use the same cartridge again and again after refilling?

Shri A. R. Tiwari (Author): The life of chlorine in a cartridge will depend upon the quality and quantity of the charge and the pores on the pot. However, we have observed that a cartridge rendered ineffective due to blockage of pores still contains some chlorine in the charge.

It is not possible, in practice, to re-use earthen cartridges because of the pores completely sealed off.

Shri M. V. Rao, Nagpur: Don't you think that the chlorine content is increased considerably because the cartridge is immersed in water?

Shri A. R. Tiwari: The rise in chlorine content in a source where cartridge has been immersed will occur only during the slack hours. However, if the rise is considerable, as noticed by O.T. test, the cartridge can be lifted a little above the surface of the water so that the chlorine gas will escape into the water only from the portion immersed.

Shri A. S. Hariharan, Madras: Is the bleaching powder mixed with sand or pebble in your method of chlorination? If so, what is the size of the material used?

Shri A. R. Tiwari: We have not used either sand or pebble with the bleaching powder.

Dr. N. U. Rao, CPHERI, Nagpur: In our experience, the fine pores of the earthen pots always got choked in a day or two due to calcium carbonate. I am interested to know whether the authors noticed any such blockage of pores.

Shri A. R. Tiwari: The cartridges used by us were made of clay and sand. We have observed that at least during the first week, after immersing the cartridge in the water, blockage of pores does not occur. Thereafter, the pores appear to be gradually sealed but not to the extent of completely preventing the release of active chlorine. It will be seen at Table IV of our paper that a cartridge has lasted for 72 days. The residual chlorine could be detected only upto 50th day. After that, although no residual was detectable the water remained free from the *B. coli* and this means that the active chlorine continued to escape from the cartridge and was just sufficient to satisfy the chlorine demand of water.

Shri N. M. Parhad, CPHERI, Nagpur: Cartridge method is extremely satisfactory for small water supply. How did you control the chlorine content of water? How many days did it work?

Shri A. R. Tiwari: Based on the rate of flow and chlorine demand of water to be disinfected we may select such a cartridge which, when filled with the charge and immersed in the water, may constantly give a free residual chlorine to the extent of 0.1—0.15 mg/lit. In case it goes beyond this, we can lift the cartridge a little above the surface. Normally this is not necessary as after a week or so the pores start getting choked up and the release of chlorine is restricted. Although a cartridge can disinfect a well for as many as ninety days, it is better, if a size just to last for a fortnight is selected.

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Rural Water Supply Programme in Madhya Pradesh

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Madhya Pradesh is the largest state of the union, having an area of 171,217 sq mile and a total population of 3,23,72,408 (1961 Census) spread over 43 districts. The total number of revenue villages is 75,510 having a population of 2,77,45,174 as per 1961 Census. Thus nearly 86 per cent of the total population lives in rural areas, where there is no arrangement of safe and protected water supply, besides there is acute scarcity of water in summer when the open wells go dry and the people meet their requirement from nearby ponds and tanks which are most unhygenic and highly polluted and this ends into out break of water borne diseases year after year.

The preliminary survey indicates that there are nearly 5000 villages scattered all over the state where there is no source of drinking water, what to say of a safe water supply. While top priority was fixed for the drinking water supply schemes, inspite of country's difficult economic situation which called for a cut in all development schemes, our problem has been, how to provide an adequate arrangement of water supply in as small a cost as possible and in as short a period as possible for all these villages.

For convenience of working we divided the number of villages into two categories: (a) Bigger villages with population over 1000, and (b) Small villages with population less than 1000.

Amongst these villages also priority was given to those villages where there was acute water scarcity particularly in summer.

All these schemes were based on the principle of cash contribution by the beneficiaries to the extent of 25 per cent of the cost. For bigger villages a piped water supply scheme was designed, which provided for tube well as a source, deep well pump, reservoir, and a net work of distribution pipe lines and street type public water stand post, at a cost of Rs. 40,000 approximately. For small villages it was planned to provide a tube well with hand pump for every 200 people, or at least two such tube wells per village, at a cost of Rs. 8,000 per village.

This arrangement worked alright where tube wells were successful in a sense that small tube wells worked by hand pump yielded 200 to 300 gph or tube wells for bigger villages yielded 1500 to 2000 gph, so that at least 5 to 10 gpd/cap could be made available, and the cost involved was reasonable.

Madhya Pradesh comprises of vast areas, which have not been surveyed geologically, nor any data for geological interpretation was available. While the tube wells helped to solve the water scarcity problem and to provide safe water supply to communities they also provided material for geological interpretations, but the greatest problem was where these tubewells were failure in a sense that the yield was very poor or these were almost dry tube wells. In such cases we attempted for alternative sources, and in quite a number of cases we have been able to tap the supply from rivers, nallas which are not perenial by providing suitable storage dams. The cost of such a scheme is fairly high and besides the maintenance cost also becomes high, and since we have planned our schemes on the principle of 25 per cent contribution from beneficiaries, we had to experience paucity of funds for execution. A suggestion was made that the complete scheme be executed at Government cost, but our experience with these schemes show that unless these are financed by the local bodies the feeling of ownership is lacking and the people do not get interested in execution of the scheme and ultimately do not want to take advantage after its completion. On these grounds participation of the community towards the cost of the scheme was made compulsory and therefore only those villages which experienced acute scarcity of water in summer came forward readily for execution of the schemes.

From the experience in execution of the schemes stated above, following design criteria has been adopted.

(i) Since census record for many years is not available, the designed population is estimated at 50 per cent over the latest census figures, (ii) Quantity of water supply is designed at 5 to 10 gpd/cap, (iii) 16 hours pumping is provided for electric driven pumps and 8 hr for diesel driven pumps. Only one pumping unit is provided, (iv) Capacity of reservoir is kept at 15 per cent of the designed supply, (v) The distribution system is designed for 8 hr supply, providing 2 gpm at each stand post tap, (vi) For small schemes one source of supply e.g. hand pump is provided for 200 souls. (vii) Soakage pits are provided on every public water stand post.

As per the existing policy all the complet works are handed over to local bodies for maintenance.

Maintenance of water supply scheme has not been much of a problem where there was acute water scarcity, but with the rest some times the Gram Panchayat or local body does not come forward to take over and run the scheme. This gives a great set back to the popularization of natural water supply programme in rural areas. Besides since only one pumping unit is provided eliminating the provision of a stand bye, it becomes very difficult to keep the supply in running order after it has worked for 4 to 5 years. On account of difficult position of funds as stated in earlier paras it has not been possible to provide a stand bye arrangement. Also repairs for the pumping units which have worked for 4 to 5 years involve heavy expenditure which is beyond the capacity of the local bodies. In our state, we have been providing free technical help to the local bodies who have been bearing the cost of the material required for repairs etc.

This arrangment is not at all satisfactory and many times the schemes have faced a shut down which has had a dampering effect on the progress of these schemes. It is impossible to operate these small scattered water works under a central control. The only correct method would be to leave it for maintenance with the local body. It may be stated that during the last 3 plans a number of pumps for agriculture purposes were installed and the consumers who derive advantage out of this have been attending to maintenance and upkeep of the same. The drinking water supply schemes can also be managed by local bodies successfully if the similar incentive as that of the agriculturist is created with local body.

The non-availability of spares particularly for deep well pumps has also been a cause of great set back.

It would be a great help in the programme if the manufactures of the pumps could provide arrangement for service and spares in the regions where there has been demand, through agents or through departmental stores. Generally the interest of the manufacturer is limited to the sales. They do not care for the service and the spares required for the same. If the manufacturers attend to the service perhaps problem of maintenance would be solved to a great extent.

DISCUSSION

(Paper presented by: Dr. G. J. Mohanrao)

Prof. Chandrasekhar, Manipal: Has the location of the tube wells been fixed arbitrarily or any study of the aquifer has been made? Has the yield in the deep wells been checked periodically? If so, how and how often? Have there been any fluctuations and if so, how have they been accounted for? Is the pump removed and cleaned periodically? If so, at what frequency?

Shri R. A. Khanna (Author) : The State of M.P. comprises of vast areas which have not been surveyed geologically. Whenever possible, Geological Survey Department was consulted. Now, of course, after a trial of tube wells in various areas we have selected sites for tube wells at most convenient places from consumer's point of view. The water in tube wells in M.P. is stuck in crevices in rock and successful tube wells have been drilled even in places where geologists have no hope.

There has been no method of checking yield of tube wells after completion of the same. The design of the pumping equipment is based on the yield obtained in dry summer. Blank casing pipe is inserted for at least 30 ft from the top ground level. It may be stated here that these tube wells are generally 150-200 ft deep and yield at 1,000 to 1,500 gph is considered adequate for the villages between population range of 1,000 to 3,000.

There is no regular aquifier water available from the crevices in the rock.

As it stands today, the pump is removed and cleaned only after it goes out of order. The completed schemes are handed over to the local body for maintenance as it is not possible to operate these various schemes situated at different places under central control. It was suggested in the paper that if the manufacturers provide facility for service and spares the local body could perhaps go in for regular check ups.

Shri P. Balakrishna Rao, Roorkee: Regarding cost details of the scheme, it is not practicable to pay for 25 percent of the total cost. So, what is the next alternative?

If the mechanical equipment goes out of order in 4 to 5 years then what is the use of giving something which is totally lost in 5 years.

Shri R. A. Khanna: As was mentioned in the paper our experience was that wherever there was scarcity of water, villagers readily come forward with contribution. We have a system of relaxation of the quantum of contribution to 10 or 5 per cent for poor and deserving cases. Full relaxation was however not advocated as that had an adverse effect towards the feeling of ownership.

We have to provide adequate and safe water supply to the community. Tube wells help in giving a source that was safe but to draw water from tube wells mechanical equipment would be required. The period of 4 to 5 years would be trouble free run; after which the maintenance problem starts. This would also happen in case of urban water supply schemes. As was suggested in the paper, by proper maintenance service and facility and availability of spare parts the system would be continuous. The investment on the system is never lost. There will be tremendous gain to the community by use of hygiene and safe water.

Shri C. L. Toshniwal, Roorkee: At 3 percent per year the rate of growth of rural population; the design population of 150 percent would be reached within about 16 years. Would this period be long to be taken as design period?

Shri R. A. Khanna: The growth of population would put pressure on urban areas and industrial zones by migrations. so that designed population for rural areas at 150 percent would be reached not earlier than 20 to 25 years by which time we may augment the works starting with the augmentation of source. The task before us is great and therefore, a balance has to be reached between the present investment and future requirement. This has been suggested by CPHEO.

Shri D. L. Mathur, Udaipur: Maintenance of Turbine pumps in highly mineralised waters when the shaft of the turbine pump gets corroded or goes off, is difficult. What is the remedy?

Shri R. A. Khanna: The stainless steel shaft and prelubricated tanks appear to be a remedy. Of course, we did not have suoh a problem since there is not much variation in the water level.

Dr. G. J. Mohanrao, CPHERI, Nagpur: When water is supplied after full scale treatment it has to be paid for.

Shri R. S. Mehta, CPHERI, Nagpur: We have very little information about ground water investigations like tube wells etc. It is high-time for us to collect information on this aspect. New water supplies which have come up in Sudan, Ethopia are all paying for the treated water. Water supply scheme should be self supporting proposition.

Dr. B. V. Bhoota, Bombay: India has made tremendous progress in steel sector and such Engineering equipments are being exported. When such is the case, maintenance of mechanical parts cannot be a problem.

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Development of Community Water Supply

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Much has been said already about community water supply; yet, with the ever-growing need to improve conditions throughout the world and the increasing importance which developed and developing countries alike attach to the evolvement of this activity, it is expected that this subject will continue to remain an important topic for discussion for many years to come.

Concerted action on a world-wide basis originated in 1959, when a report on a comprehensive study of WHO's programme in Environmental health was presented to the World Health Assembly (1). As a result, the World Health Assembly approved a priority programme and authorized the Director-General to establish a Special Account for the improvement of community water supply on a global basis (2). This followed by the technical discussions held during the Seventeenth World Health Assembly in 1964 (3) and action by WHO as well as by bilateral and multilateral agencies, has given considerable impetus to the development of programmes in this field.

From time immemorial, large cities have been concerned with their water supplies, and through the ages man has devoted much time and effort to developing skilled methods in order to ensure the supply of water—for domestic uses, as a start. Man has migrated thousands of miles to slake his thirst; he has also fought over water, as evidenced by the well-known story of Sennacherib of Assyria, who avenged himself on Babylon by throwing polluted material and debris in the city's canals.

The most ancient method of obtaining a water supply other than from springs and rivers is undoubtedly through the digging of wells. Historians mention famous wells in ancient Greece, in Persia and in India. The digging of wells was also accompanied by the installation of facilities for rain-water storage and distribution. Improvements on these early water supply installations were made by the construction of infiltration galleries in Athens some 2000 years ago.

Later, when it was found that the supply of water to the important cities of antiquity through wells and rain water cisterns was quantitatively inadequate, spring sources offered a practical solution to the Greeks and to the Romans, and water from these sources was conveyed from far distances in aqueducts, which are to this day an object of admiration. At the same time, underground reservoirs in Egypt and in India were constructed to serve irrigation purposes.

The Middle Ages witnessed the destruction of the Roman Empire and of the aqueducts of Athens and Rome. As a matter of course the whole subject of water supply was neglected. Water continued to be provided in the more important cities, but only very scantly; in many instances, the supplies entirely ceased. The use of grossly polluted water became then a common occurrence—a situation which undoubtedly accounted for the ever-remembered ravages of water-borne diseases of that era. General improvement to this state of affairs had to await the end of the Sixteenth Century, when special attention was focussed on sanitary matters. Few aqueducts were, however, built, and spring water sources continued to be the main source of supply to serve big cities in Europe and the Americas.

No appreciable progress in public water supply was made in the Eighteenth Century. However, it should be mentioned that the introduction of power-operated pumps at that time gave considerable impetus to the construction of modern waterworks, developed in the following century. Then rapid growth began and numerous water works were constructed the world over.

Calcutta was the first city in India to have a modern water supply installation; this system was constructed in 1870.

The most interesting and valuable phase of development in the field of water supply is undoubtedly the improvement of the quality of supplies. Water purification was practised in China and in India thousands of years ago. That impure water is the cause of outbreaks of different diseases was also recognized by the Romans who constructed their aqueducts beyond the reach of pollution. However, modern water treatment operations were introduced in the Nineteenth Century and the installation in England of the first slow sand filter in the early eighteen hundred is the starting point of the rapid development which followed in Europe and in the USA. Disease prevention became then well established, so was the role of the engineer in this field of activity.

Looking into the evolutive process of community water supply, one may observe that, up to the late Eighteenth Century, most of the largest cities were able to draw water from relatively safe sources. An ample supply was also available to satisfy man's limited demands. However, as more and more water was made available to meet the increasing needs, man soon learned to waste water—a situation which further deteriorated because of population growth, the development of industries and the increasing impact of urbanization. Never before has there been so much effort to overcome these difficulties as is now being made; yet the gap between the present needs and today's water supply conditions is alarmingly widening.

The magnitude of this problem was defined in a report made by the Director General to the Seventeenth World Health Assembly (4). This report was mainly based on the findings of a study carried out by WHO in 1963, in 75 selected countries of the world. It was found that out of a total of 320 million people, "only about 30 per cent of the urban population in these countries, and certainly less than 10 per cent of the total population, is supplied with piped water in the home. The report further reads: In the 75 selected developing countries studies, the population is expanding at an annual rate of 2.4 per cent, i.e., almost 40 per cent faster than the world population as a whole."

The status of urban water supply (as of 1962) in South-Central Asia* was as follows: 14 per cent of the urban population, i.e., 12 per cent of the total population was supplied from house connections and 20 per cent from public outlets, leaving 66 per cent of the urban population, i.e., 48 per cent of the total population, not served. No survey was carried out in the rural areas, but one may presume that the situation in these areas is much worse. It is also estimated that the rate of water supply construction for the next fifteen years will need to be about eight times the present rate throughout the South-East Asia Region** as a whole, in order to provide 80 per cent of the population with piped water.

Admittedly, water supply to urban communities has received and is receiving—increasing attention and support in most of the developing countries, where it is quite often necessary to bring water from hundreds of miles to the cities. Existing schemes are being enlarged and improved; numerous new schemes are being implemented. However, it is a well established and disturbing fact that the construction and improvement of water supplies are not keeping pace with the growth of the population.

In addition to appraising community water supply in the developing countries and focussing on the need for rapidly improving the existing conditions in these countries, the report of the Director General listed a number of steps that are essential in the promotion of community water supply programmes. All of these steps need not be listed here again, but the following, it is felt, are prerequisites:

i) *Formation of a national policy on community water supply.*

This is the basic requirement. Indeed, today, in spite of all the aggravating conditions arising out of industrialization, population growth, etc., not only the resources but the scientific and technical means for solving current problems of community water supply are available and can be utilized. What is urgently needed in many countries is the promotion of a national policy in which water supply is incorporated in the general programme for economic and social development. National programmes and their organizational structures will, among other things, generate public interest, stimulate initiative on the part of communities and attract financial support.

* South-Central Asia Region is defined as comprising the following countries: Afghanistan, Ceylon, India, Nepal and Pakistan.

** South-East Asia Region which includes Afghanistan, Burma, Ceylon, India, Indonesia, the Maldive Islands, Mongolia, Nepal and Thailand. Mongolia, which joined WHO more recently, was not included in the survey.

Of this need, the countries in the South-East Asia Region are fully aware. India took the lead, when, in 1954, the Indian Government initiated India's national water supply and sanitation programme and allocated substantial funds for its implementation.

ii) *Organization of a water Authority*

The creation, under appropriate legislation, of a Central Authority to deal with all problems related to community water supply is a modern trend and was first suggested in 1961 by a team of WHO consultants. This Authority should promote co-ordinated action, assure sound technical and financial control and give momentum to those programmes that are so urgently needed in many developing areas, where more than one government agency has responsibilities regarding water supply.

The structure and functions of such an Authority will vary from one country to another, but, as recommended by the WHO consultants, it will be so constituted that it will be:

"—an efficient engineering and management unit;

"—a financially sound business operation;

"—a responsible governmental and political agency;

"—a good neighbour and co-operating associate for all the local governments of the metropolitan area."

The West Bengal Government in India, with the assistance of WHO, acting as the Executing Agency under a Special Fund project established the Calcutta Metropolitan Water and Sanitation Authority, following these general lines. It is expected that this Authority will enter into active operation in the not too distant future. With the developments that are now under way in some of the other countries of the South-East Asia Region, it is hoped that similar activities will be undertaken by the governments in these countries.

iii) *Preparation and technical planning of community water supply programmes.*

There are many examples of water schemes having been implemented to serve moderate size cities which so far amount to no more than a hodge-podge of small inadequate schemes because the projects have not been soundly planned. Too often a supply for a community is from a source the capacity and potability of which have at no time been investigated. These small schemes are short-lived and expensive and often contribute to making unsafe water more readily available to larger groups of people. Community water supply programmes need careful preparation and technical planning. Once the basic information is available, the second phase of development should be the preparation of a Master Plan, which is an engineering and economic study and sets out a programme designed to proceed in stages that are adapted to the conditions of the country concerned.

Careful technical planning of community water supply programmes calls for a large number of qualified and experienced personnel at all technical levels. Shortages of such personnel impose severe restrictions on the rate of new water construction and the practice of satisfactory operation and management of completed schemes.

The most significant cause of world-wide deficiencies in community water supply schemes is the huge financial outlay required for construction. Apart from the initial capital investment necessary, there are the recurrent and cumbersome operational and maintenance costs. Therefore, despite increasing awareness of the fact that community water supply is a basic factor in economic development, government are still unable to face up to the costs which will necessarily be entailed if improvement in this field is to be of any significance. It is hoped that the Asian Development Bank will provide an additional source of financial assistance for the development of community water supply in the South-East Asia Region.

Many sources of assistance to water supply programmes are available today from international organizations, regional or bilateral agencies and private institutions. International sources within the United Nations system include the United Nation's Special Fund, the Expanded Programme of Technical Assistance, the World Health Organization, the International Bank for Reconstruction and Development, the International Development Association, and UNICEF.

WHO is in a position to assist governments in preparing requests for obtaining assistance from international financing agencies for community water supply programmes.

Summary

Down through the ages, communities have been concerned with their water supplies. There has been steady improvement of water supply to cities, and the most interesting and valuable phase of the development is the quality of the water supplies. However, a large proportion of the population of the world today is not adequately supplied with water. Everywhere in the world water is connected with troubles due to population growth, and development of industries and the increasing impact of urbanization. The magnitude of the problem with regard to the gap between present and future water needs and today's water supply conditions has been studied and defined by WHO, and appreciable efforts have been made by many of the developing countries; yet the rate of construction of new schemes is not keeping pace with today's needs in the world. In defining the problem, WHO also made a number of recommendations, which were embodied in a report made by the Director-General to the Seventeenth World Health Assembly.

International assistance to water supply programmes is available, and WHO can assist even in the stage of preparing requests and schemes.

References

1. *Official Records of WHO No. 95, Annex 14.*

2. *Resolution WHA 12. 4B, Handbook of Resolutions and Decisions of World Health Assembly and the Executive Board.*

3. A/7/Technical Discussions/6 Rev. 1.

4. *Official Records of WHO No. 135, Annex 10.*

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Water Supply to Small Communities from Tube Wells in the Calcutta Metropolitan District

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The Calcutta Metropolitan District is spread over an area of four hundred square miles on either side of the Hooghly river and include the four districts—Howrah and Hooghly on the right bank and 24-Parganas and the Kalyani Division of Nadia District on the left bank (Fig. 1).

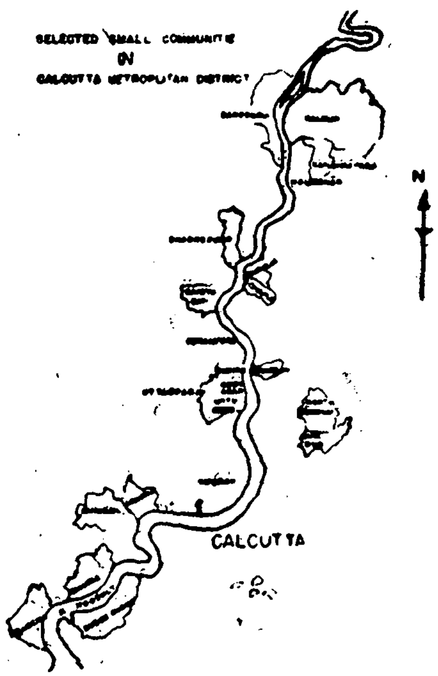

Fig. 1

There are thirty three municipal towns with a total population of 5.5 millions in this area. Small communities, as enunciated, with population of 50,000 and less constitute an appreciable portion as is evident from the particulars given below:

District	No. of small communities	Percent of the total population
Hooghly	13	70
Howrah	13	24
24-Parganas	22	24
Nadia (Kalyani only)	2	—

These small communities are mostly urban and industrial. Although the river Hooghly is in close proximity to them water supply to these communities is derived from tube wells. The following reasons may be attributed for tapping ground water for drinking and other domestic purposes from tube wells.

(i) Soil conditions are most favourable for sinking tube wells.

(ii) The water is bacteriologically safe and can be supplied directly to the consumer even without chlorination.

(iii) The chemical quality of the ground water in most of the localities conforms to the prescribed standards and generally does not require pre-treatment, if sunk in proper strata.

(iv) Other factors include low initial capital outlay and recurring costs.

Notwithstanding the variations in chemical quality, ground water has been exploited to the maximum extent in the entire region and also in other districts in the state of West Bengal.

The strata in the entire region is underlain by wide spread and thick alluvial deposits comprising a succession of clays, clays with kankar, peaty intercalations, sandy to silty clays and fine to coarse sand the thickness of which varies from place to place. The ground water occurs in very thick zone of saturation from within a few feet below ground level to a depth yet unknown. The water table at the top levels is very shallow and is considered to be polluted (Cronin *et al*, 1960). But the water in the deeper zones is in a confined state as it is overlained by layers of clay. This water rises within 10 to 20 ft below the surface in the tube wells tapping the confined aquifers. The data, hitherto available, indicate that the average yield from a 8 in. diam tube well usually ranges from 20,000 to 40,000 gph. The depth of the tube wells vary from 200 ft to about 750 ft and the chemical quality is highly variable. Results of test borings carried out at greater depths upto 2100 ft by the Exploratory Tube Wells Organization and the State Government in some selected sites in the area indicates that at greater depths the yield of water increases but there is considerable deterioration in chemical quality as shown in Table II. In view of this and the high costs involved, the idea of sinking deep tube wells have more or less been abandoned. Already in this region a very large number of tube wells have been sunk for community water supply. The chemical quality of water derived from these areas shows a considerable variation irrespective of their locations, depth and output. Wells situated even within a short distance from each other show a marked variation in chemical and bacteriological quality.

Materials and Methods

A comparative study of the water quality from different tube wells in this region is described. The engineering data pertaining to depth, diameter, length of strainer used and yield of water have been collected from the authorities concerned and are given in Table I (a) and VI (a). Chemical and Bacteriological analysis data available from both the records of the same source and of the laboratory have been used for the purpose of this paper. The analysis data on total solids, total hardness (as $CaCO_3$), Chlorides (as Cl) and iron content only have been used (Table I (b) and VI (b)): Results of bacteriological examination are given in Table III.

TABLE I (a)—ENGINEERING DATA OF TUBE WELLS IN SOME SMALL COMMUNITIES OF CALCUTTA METROPOLITAN DISTRICT

Description	(Location)	Population (1961)	Dia-meter (in.)	Depth (ft.)	Length of strainer (ft.)	Yield gph	gpd
RIGHT BANK							
Bansbaria (M)							
	No. 1.	45,463	6	369	72	17,350	12
	No. 2.		6	394	72	20,280	
	No. 3.		6	388	99	27,200	
Bhadreshwar (M)							
	No. 1.	35,489	6	372	65	14,900	12
	No. 2.		4	380	—	10,250	
Champadani (M)							
	No. 1.	42,129	6	395	105	29,000	20
Rishra (M)							
	No. 1.	38,535	6	368	73	20,850	20
	No. 2.		6	410	90	24,200	
	No. 3.		6	410	87	24,200	
Konnagar (M)							
	No. 1.	29,443	6	399	81	22,700	21
	No. 2.		6	380	81	22,400	
Kotrang (M)		31,031	8	379	100	33,780	—
LEFT BANK							
Kalyani (M)		10 000					40
Halisahar (M)							
	No. 1.	50,000	6	421	104	33,780	20.2
	No. 2.		6	420	105	25,500	
	No. 3.		6	333	103	—	—
	No. 4.		6	350	105	22,400	—
Garulia (M)		29,041					15.6
Khardah (M)		28,362					
North Dum-Dum (M)							
	No. 1.	38,140	6	386	106	30,000	
	No. 2.		8	403	106	30,000	
Dum-Dum (M)		20,041	6	398	101	45,000	
Budge Budge (M) (including Batanagar)		39,824					11.2

(M) = Municipal Town

TABLE I (b)—CHEMICAL DATA OF TUBE WELLS WATER IN SOME SMALL COMMUNITIES OF CALCUTTA METROPOLITAN DISTRICT

Description (Location)	CHEMICAL ANALYSIS			
	Total Solids (mg/lit)	Hardness (mg/lit)	Chloride as Cl (mg/lit)	Iron (Fe) (mg/lit)
RIGHT BANK				
Bansbaria (M)				
No. 1.	—	200.0	130.0	0.5
No. 2.	—	160.0	—	Traces
No. 3.	—	80.0	70.0	5.0
Bhadreshwar (M)				
No. 1.	440.0	250.0	—	Traces
No. 2.	400.0	250.0	—	Traces
Champadani (M)	460.0	290.0	37.0	Nil.
Rishra (M)				
No. 1.	53.0	33.0	9.2	0.05
No. 2.	56.0	33.8	8.0	0.04
No. 3.	54.0	33.0	8.2	—
Konnagar (M)				
No. 1.	—	280.0	160.0	3.2
No. 2.	1494.0	654.0	456.0	0.9
Kotrang (M)	—	325.0	344.0	1.6
LEFT BANK				
Kalyani (M)	—	—	—	—
Halisahar (M)				
No. 1.	—	260.0	—	0.6
No. 2.	—	300.0	—	Traces
No. 3.	—	310.0	—	Traces
No. 4.	—	—	—	—
Garulia (M)	—	—	—	—
Khardah (M)	—	—	—	—
North Dum Dum (M)				
No. 1.	1,100	490.0	250.0	—
No. 2.	1,100	575.0	260.0	Traces
Dum Dum (M)	800.0	V. Hard	475.0	1.2
Budge Budge (including Batanagar)	—	—	—	—

(M) = Municipal Town

TABLE II—VARIATIONS IN CHEMICAL QUALITY AT DIFFERENT DEPTHS

Location	Depth (ft.)	Total Solids (mg/lit)	Total Hardness (mg/lit)	Chloride as Cl (mg/lit)	Iron (Fe) (mg/lit)
I. D. H. Belliaghata	140 — 450	1306.0	298.0	316.0	2.1
	471 — 550	1320.0	164.0	354.0	0.95
	699 — 872	—	398.0	440.0	1.4
	900 — 987	—	592.0	598.0	1.6
E. T. O. Municipal Market : (HOWRAH) :	200 — 370	1240.0	210.0	300.0	2.0
	425 — 570	1420.0	340.0	399.0	Traces
	570 — 615	1400.0	200.0	290.0	4.4
	700 — 730	1980.0	270.0	292.0	4.8
Doodwallah Park (HOWRAH)	124 — 195	3600.0	340.0	570.0	25.0
	204 — 339	3120.0	230.0	630.0	17.0
	339 — 524	4470.0	320.0	620.0	35.0

TABLE III—BACTERIOLOGICAL EXAMINATION REPORT

S. No.	Name of the Tube Well	Standard Plate Count 37°C—24 Hrs	Coliform per 100 ml MPN	Strepto-cocci per 100 ml MPN	Iron Bacteria
1.	Natabarpal Road, Howrah	7	0	—	Absent
		$4.2x10^8$	210	9	Present
2.	Narasingha Dutta Road, Howrah	$1.5x10^3$	0	—	Absent
		$2.2x10^3$	4	—	Present
		60	3	—	Present
3.	Doodvala Park, Howrah	$7.8x10^2$	23	—	Present
		32	0	—	Present
		41	0	0	Present
4.	Panchanantala, Howrah	$2.2x10^2$	0	—	Absent
		40	0	0	Present
		12	0	0	Present
5.	Bharpara, Howrah	$2.6x10^2$	0	—	Absent
6.	College Ghat Road, Howrah	$2.6x10^2$	0	—	Present
		28	0	—	Present
7.	Salkia Reservoir No. 1, Howrah	170	0	—	Absent
		15	0	0	Absent
8.	E.T.O. Market Area, Howrah	$3.6x10^2$	0	—	Absent
		2.9x10	7	0	Present
9.	Belilose Park, Howrah	60	0	—	Absent
		31	4	—	Present
		44	4	0	Present
10.	Sradhananda Park Howrah	42	0	—	Absent
		15	0	0	Absent
11.	Naskarpara Road, Howrah	48	0	—	Absent
		24	0	0	Present
12.	Bandhaghat, Howrah	$2.9x10^2$	93	—	Absent
13.	Howrah General Hospital Tube well No. 1	$7.2x10^2$	0	—	Present
		$3.9x10^2$	0	—	Present
14.	Howrah General Hospital, Tube Well No. 2	23	0	—	Present
		16	0	—	Present
		$1.6x10^8$	2400	—	Present
15.	B. E. College, Sibpur No. 1	$9.6x10^8$	0	—	Absent
	" " No. 2	28	0	—	Absent
		$1.1x10^8$	0	—	Absent

TABLE III—(continued)

S. No.	Name of the Tube Well		Standard Plate Count 37°C—24 Hrs	Coliform per 100 ml MPN	Strepto-cocci per 100 ml MPN	Iron Bacteria
16.	Hind Motors	T. W. No. 1	2.4×10^2	[illegible]	—	Absent
	Uttarpara	,, 2	1.9×10^2	0	—	Absent
		,, 3	1.0×10^4	4	—	Present
		,, 4	96	0	—	Present
17.	Poddar Park, Jadavpur		41	0	0	—
18.	T. B. Hospital,	T. W. No. 1	33	0	0	—
	Jadavpur	, 2	82	9	0	—
		,, 3	7.2×10^2	93	15	—
19.	Regent Estate, Jadavpur		4.3×10^2	43	9	—
20.	Ganguli Bagan,	T,W. No. 1	7.6×10^2	460	43	—
	Jadavpur	,, 2	24	0	0	—

TABLE IV—CLASSIFICATION OF THE TUBE WELLS FROM CHEMICAL QUALITY

	No. of Wells under study	QUALITY GRADING		
		Grade-I	Grade-II	Grade-III
Small Community Wells				
RIGHT BANKS				
Howrah General Hospital	2	—	—	2
Howrah (Big Community Wells)	12	—	4	8
B.E. College, Shibpur.	3	2	1	—
Hind Motors, Uttarpara.	18	4	3	11
Kotrung.	1	—	1	—
Konnagar.	2	2	—	—
Rishra.	3	3	—	—
Champadani.	1	1	—	—
Badreshwar.	2	2	—	—
Bansberia.	3	3	—	—
LEFT BANK				
Halisahar.	4	4	—	—
North Dum Dum	2	2	—	—
Dum Dum	1	—	1	—
Jadavpur	7	3	—	4
	61	26	10	25

TABLE V—VARIATIONS IN CHEMICAL QUALITIES OF TUBE WELL WATERS IN HOWRAH

Location	Total Solids (mg/lit)	Total Hardness (mg/lit)	Chlorides (as Cl) (mg/lit)	Total Iron (mg/lit)
Natabarpal Rd. Howrah	3304.0	580.0	870.0	0.04
	2796.0	894.0	780.0	1.60
	—	—	741.0	0.138
Narsingha Dutta Road, Howrah	2338.4	700.0	203.0	1.4
	1968.0	564.0	955.5	5.5
	1976.0	651.0	735.0	0.6
Doodhwala Park	—	—	275.5	0.136
	2346.0	840.5	817.0	2.1
	1550.0	714.0	—	5.0
Panchanantala	787.0	400.0	200.0	0.0
	810.0	426.0	193.5	0.6
	784.0	454.0	213.12	0.16
Bharpara	2364.5	472.0	—	8.5
College Ghat Rd.	3932.0	1084.0	815.0	2.7
	3372.0	1170.09	1225.0	2.7
Salkia Reservoir No. I.	1692.0	577.2	530.0	0.5
	1612.0	658.0	288.0	0.46
E.T.O. Market area	1620.0	639.0	530.0	0.2
	2050.0	722.0	520.0	0.2
Bellilose park	920.0	499.0	235.0	0.64
	810.0	336.0	367.0	0.84
	884.0	486.84	184.32	0.74
Sradhananda Park	880.0	365.1	154.00	Traces
	882.0	400.0	359.04	0.1
Naskarpara Rd.	1278.0	592.8	186.5	0.6
	1284.0	656.0	362.8	0.24
Bandhagat	2212.0	857.8	510.0	1.8

TABLE VI (a)—TABLE SHOWING ENGINEERING DATA FOR TUBE WELLS

Descriptions	Population	No. of Tube Wells surveyed.	Depth (ft.)	Diameter (in.)	Yield
Howrah General Hospital	—	2	350—460	4	8000-10,000
B.E. College, Shibpur	—	3	200—740	3—6	3000-14,000
Hind Motor, Uttarpara	10,000	18	—	4—6	4000-8000
Poddar Park	2,000	2	700—750	8	12000 gph.
T.B. Hospital	1,200	3	285—300	2½—6	1500-12,000
Regent Estate	1,000	1	500—0	4	5000
Ganguli Bagan	4,000	2	300—0	6	6000

Experimental

(A) CHEMICAL QUALITY

1. The pH of these tube well waters generally ranges from 6.7 to 7.7.

2. The water contains a fairly high amount of dissolved carbon dioxide.

3. The sulphate content of waters is very low ranging from traces to 57.0 mg/lit.

4. The total alkalinity and total hardness are very high. The hardness is present mainly in the form of carbonate hardness and wherever high non-carbonate hardness is encountered it is present mostly in the form of chlorides of Calcium and Magnesium.

5. The Calcium and Magnesium content in the tube wells are also very high.

TABLE VI (b)—TABLE SHOWING CHEMICAL DATA FOR TUBE WELLS

Descriptions	Total Solids (mg/lit)	Total Hardness (mg/lit)	Chloride (as Cl) (mg/lit)	Iron (Fe) (mg/lit)
1. Howrah General Hospital				
No. 1.	29670	12140	1281.0	1.6
	3109.0	1173.0	1302.0	0.8
No. 2.	1243.0	624.0	533.0	1.2
	1257.0	599.0	406.0	0.2
	1398.0	588.0	377.0	Traces
2. B.E. College, Shibpur				
No. 1.	790.0	392.0	42.0	0.2
	3372.0	1170.9	1225	2.7
No. 2.	766.0	373.0	39.0	0.24
No. 3.	1442.0	391.0	387.0	0.5
3. Hind Motors, Uttarpara				
No. 1.	1276.0	579.0	376.0	0.04
No. 2.	1532.0	728.0	535.0	0.54
No. 3.	794.0	466.0	165.0	0.30
No. 4.	794.0	461.0	165.0	0.60
No. 5.	744.0	451.0	173.0	0.14
No. 6.	1760.0	818.0	682.0	0.56
No. 7.	1784.0	495.0	624.0	1.6
No. 8.	2032.0	820.0	643.0	0.12
No. 9.	1508.0	707.0	530.0	0.14
No. 10.	1656.0	786.0	572.0	0.7
No. 11.	1858.0	823.0	643.0	2.4
No. 12.	1536.0	713.0	596.0	0.02
No. 13.	1750.0	747.0	677.0	0.4
No. 14.	1736.0	747.0	643.0	1.16
No. 15.	1720.0	747.0	534.0	0.06
No. 16.	850.0	444.0	211.0	0.06
No. 17.	330.0	284.0	24.0	0.04
No. 18.	1074.0	488.0	326.0	1.40
4. (a). Poddar Park				
No. 1.	840.0	175.0	172.0	0.32
4. (b). T.B. Hospital				
No. 1.	1396.0	444.0	534.0	4.6
No. 2.	760.0	212.0	142.0	0.18
No. 3.	1928.0	653.0	730.0	1.8
5. Regent Estate				
No. 1.	698.0	335.0	152.0	0.26
6. Ganguli Bagan				
No. 1.	2436.0	869.0	857.0	0.22
No. 2.	1892.0	722.0	612.0	0.44

6. None of the waters examined so far shows the presence of **fluorides.**

7. The chloride content in the waters is generally higher than the prescribed limits for drinking water but in the tube wells located in Serampore (Hooghly district) and above in close proximity to the river, have a low chloride content. Below Serampore the general trend of chloride content is that it increases with depth. No definite correlation, however, between the two can be drawn.

8. The iron content shows wide variations ranging from traces to a maximum of 8.5 mg/lit. Generally the tube wells in Howrah-Salkia area and Jadavpore have a higher iron content than in other locations. No special treatment for iron removal at the pumphead is given and the water from such wells as supplied to the consumer remains turbid.

From the point of view of the chemical quality the water from tube wells under survey, may be classified into the following three grades.

Grade I : In this grade are grouped the tube wells having low dissolved solids, total hardness, chlorides and iron content and are close to the maximum acceptable and well within maximum permissible concentrations.

Grade II : Waters from these groups are within the maximum permissible concentrations.

Grade III: Waters from this group mostly exceed the maximum permissible limits for drinking water.

Sixtyone tube wells are included in the survey out of which 47 tube wells are situated on the right bank and 21 on the left bank and their classification from quality point of view are shown in Table IV. It will be seen from the Table that 26 wells fall under grade I, 10 wells under grade II and 25 wells under grade III.

(B) BACTERIAL QUALITY

The tube well waters in most of the localities are free from Coliform bacteria and the water is supplied to the community as such without chlorination. In a few wells, however, presence of Coliform organisms was observed in the samples collected from the distribution system in the near vicinity of the pump house of the tube wells. Most of the wells showed presence of Crenothrix only while in a few wells both Crenotrix and Leptothrix have been isolated. It was observed that where Iron bacteria have been isolated breakdown in the wells due to rusting away and clogging of pipes by filamentous growth of the Iron bacteria has been reported. But here also no correlation could be found between the presence of Iron bacteria and the content of iron in the well waters.

Discussions

The large scale exploitation of the ground water sources of the tube wells in the Calcutta Metropolitan District has been very indiscriminate and without proper scientific assessment of the water quality obtainable. In several tube wells there is evidence of positive deterioration in the quality of the water with the passage of time. It is believed that near Calcutta local rainfall may replenish the water in the shallow aquifers while the deeper aquifers may be recharged from the Ganges-Bhramaputra systems (Cronin, op. cit). But from the laboratory analysis data on repeat samples from same tube wells taken at different intervals of time do not indicate evidence of such replenishment (as is evident from Table V). There is however certain amount of uncertainty about chemical quality. In the area south of Serampore chemical quality of tube well waters varies erratically (both laterally and vertically), there being a marked variation in quality within a very short distance. This is very well exemplified from the chemical quality of the tube well waters in the premises of Hindusthan Motors near Uttarpara. Here, within an area of about four hundred acres 18 tube wells of 4 inches diameter have been sunk for water supply to a small community consisting of 10,000 inhabitants and for the factory. The water derived from the wells show appreciable variations not only in the yield but also in the chemical quality. The quality of water from 11 out of 18 tube wells is very poor. Four wells have yielded water of good quality. In such situations it would be advantageous to pump waters from different tube wells to a centralised service reservoir so that water with varying chemical constituents could be blended together before it is delivered to the consumer. The quality of the blended water may conform to the prescribed limits for drinking water and may not require any pretreatment for removal of iron and hardness.

Conclusions

(a) The water derived from tube wells serving small communities in the Calcutta Metropolitan Districts is of variable quality and in most cases exceeds the limits prescribed for drinking water.

(b) Tube wells situated in Serampore and above yielded water of good quality and below Serampore the quality is highly erratic. Almost all the wells in Howrah-Salkia are of poor quality.

(c) There is no definite correlation between the depth of the wells and the chemical constituents, such as chlorides and iron etc.

(d) Wherever Iron bacteria have been isolated the breakdown in the water supply due to clogging of pipes and incrustation by the filamentous growth of Iron bacteria is very common.

Acknowledgements

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DISCUSSION

Prof. V. Chandrasekhar, Manipal: Test borings to greater depths extending upto 2,100 ft below ground level have not yielded water of good quality. Has the water been analysed? How has it been bad in quality? How is the clogging of pipes overcome? What are the filamentous growth eliminated?

Shri S. Rajagopalan, (Author): Test borings have been carried in several locations in and around greater Calcutta under the joint auspices of the Public Health Engineering Directorate of West Bengal, the Exploratory Tube wells Organisation of the Union Government and the Geological Survey of India. Borings were carried out upto 2,000 ft or so and complete analysis of the water derived at every 100 ft depth and that of the stratum (lithological studies) have been done. The general trend was that beyond 8,00 ft or so, there was an increase in chlorides, hardness, dissolved solids and iron.

Clogging of pipes due to growth of filamentous bacteria were overcome by periodical cleaning of the particular section of the pipe and flushing the mains with bleaching powder solution.

Shri B. K. Lonsane, CPHERI, Nagpur: In addition to iron bacteria, some slime producing bacteria are also responsible for clogging of the pipes. I would like to know whether the authors have bacteriologically examined the material. Which of the organisms were responsible for the clogging ? If so, what are the results ?

Shri S. Rajagopalan: The isolation of iron bacteria and their identification reported in this paper are made from the water samples collected from tube wells. We have not so far examined the pipe clogging material for organisms other than iron bacteria as this aspect of the problem is outside the scope of the survey presented in the paper. However, we would examine such growths, if any, in the pipes of the distribution system. The authors are thankful to you for the suggestion.

Shri N. M. Parhad, CPHERI, Nagpur: Was the iron bacteria estimation done quantitatively or qualitatively? How was it done quantitatively? What was the medium employed for the identification of the iron bacteria? What was the type of iron bacteria predominant in the findings?

Shri S. Rajagopalan: Iron bacteria have been isolated from a large number of samples of tube well waters. Qualitative analysis only was done. No methods have so far been reported in the literature regarding quantitative enumeration of iron bacteria. They are filamentous type and hence counts are not easy.

The medium used is Duchou and Miller's, as given in the 12th Edition of Standard Methods

Regarding the type of iron bacteria, generally *Crenothrix* have been identified in the samples of tube well waters, but in far well samples, both *Cremothrix* and *heptothrix* have been seen.

Shri S. D. Gomkale, Bhavnagar : Reference was made regarding permissible limit of chloride contents in water. WHO has given a limit of 500 to 1,000, mg/lit for TDS for drinking water. All the methods for conversion of saline water to conventional water should give a product with TDS of less than 500. Some methods like electrodialysis removes salts in proportion to original concentration. Thus, if this method gives a product of less than 500 mg/lit. which is permissible it is quite likely that concentration of some iron exceed permissible limit. I want to know the permissible concentration of common iron in drinking water.

Shri S. Rajagopalan : The tolerance limits of dissolved solids in drinking water will be found in the 2nd edition of the WHO Publication, "International Standards for Drinking Water", Drinking Water Standards of U.S. P.H.S. and the I.C.M.R. Standards. The maximum acceptable and permissible limits of some of the dissolved solids are as follows :

		Max. acceptable concentration	Max. permissible concentration
1.	Total solids	500 mg/lit	1,500 mg/lit
2.	Colour	5 units	50 units
3.	Chlorides	200 mg/lit	600 mg/lit
4.	Sulphate	200 ,,	400 ,,
5.	Calcium	75 ,,	200 ,,
6.	Magnesium	50 ,,	150 ,,
7.	Iron	0.3 ,,	1.0 ,,
8.	Mn	0.1 ,,	0.5 ,,
9.	Cu	1.0 ,,	1.5 ,,

Shri N. V. Ramamohan Rao, Hyderabad : I want to know whether fluoride is completely absent in all the waters tested and please let me know whether these waters contain sodium bicarbonate giving rise to any excessive alkalinity.

Shri S. Rajagopalan : Fluorides were completely absent in all the waters tested so far. The alkalinity of the water is due to calcium and magnesium present in the water as bicarbonate. In as much as the chloride content is also very high, it may be inferred that all the sodium in the water is likely to be present as NaCl. In none of the samples examined so far, the alkalinity ever exceeded the hardness but the hardness is in excess of alkalinity.

Shri R. P. Mishra, CPHERI, Nagpur : It has been mentioned that the water from the tube wells is bacteriologically safe. Could you please support the statement by giving the average coliform counts, E. Coli I count and faecal streptococci count of the waters derived from these tube wells or shall we take it that all tube well waters always showed 'nil' coliform and faecal streptococci count per 100 ml.

Shri S. Rajagopalan : Please refer to the original paper wherein it is stated that tube well waters in most of the localities were free from coliform bacteria. But in few cases, presence of coliform and streptococci were observed, specially so when the samples were collected from the distribution system. For further details, Table III of the paper may please be referred to.

Shri A. S. Hariharan, Madras : India has now its standards of water quality. The ICMR constituted an expert committee and they have prescribed standards of water quality which has been published as a manual. The standards have been prescribed for the various ions under the permissive and excessive limits. The limits for toxic substances have been laid as absolute. The bacteriological requirements have also been given.

Shri S. Rajagopalan : This is only a statement supplementary to the discussion on the various standards that have been developed such as the WHO and American PHS.

Shri J. M. Dave, CPHERI, Nagpur : What is the static water level in the Hooghly basin and what relationship does it have with acceptable water quality ?

Shri S. Rajagopalan : The static level of water varies from 10 ft to say 35 ft in the region.

No correlation can be drawn between the static water level and the acceptable water quality since the chemical quality of the water derived from a tube well depends on the depth at which water is tapped. At greater depths in some areas the water quality has been reported to be poor.

Shri P. C. Bose, Calcutta: In Calcutta, ten wells were drilled upto a depth of 2,000 feet. The water quality deteriorated as the depth increased. There was an increase of calcium and iron content and hence the growth of iron bacteria took place in these waters. As we go away from the river bank, the quality of the water improves. In the Central Calcutta, it is more brackish.

Since the supply of water has been started from the tube wells, the cholera incidence has gone down considerably.

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Community Water Supplies in France

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Rural regions deserve all encouragement for the establishment of proper civilized conditions. Water supplies form an integral part of the rural development. The rural regions of France, in many respects, resemble those of India and it is profitable to know about their community water supply systems.

Administrative Organisation

The main cell of the organization is a "Commune" in which 100 to a few thousand habitants live. Normally the area occupied by these people ranges from 10 km^2 to 50 km^2 but on average 15 km^2. Some are very small in which a few hundreds of people live but sometimes there may be many people in a small area. Historically these were lordly estates which were taken away by the people's Government after the revolution.

The communes are situated sometimes very near to each other or isolated. There are 38,000 communes in France of which 1000 are cities and towns and the remaining 37,000 are very small and they comprise the rural communities.

The communes are administered by a Municipal Council. The Municipality is at liberty to decide about its equipment, modernization, food and water supplies etc. in its own departments of its province. The province is governed by a Prefect who is a representative of the Government. The prefect will decide about the communities public security and difficulties but with reasonable management.

As the communities are small and they are many times situated nearer to each other for realisation of certain projects and for the execution of some services they are grouped into "Syndicat Intercommunal" i. e. Intercommunal Syndicates. These function normally on the same rules of a commune and their objective is to exploit the reserves of water, electricity, creation of an hospital, sports grounds, swimming pools etc. To guard the interests of the proprieters of the private properties there is an Association called "Association Syndicale Fonciere". There are "Cooperatives" whose functions are mainly connected with commerce, service conditions etc.

These groups of committees-communes, syndicat Intercommunal and Association Syndicale Fonciere—plan their activities together and elaborate their projects with a technical person of their choice.

Rules for Subsidization

The Government accords permission and aid only to such projects only if they fulfil the following conditions: The project (a) must be well conceived in the interests of the collectivety of people and for the general promotion of the communities, (b) should have an honest and judicious claim, (c) the credits should be well employed and (d) the realization must be correct confirming to the project.

The main control for accomplishing these projects rests with the Ministere de l' Interieur for big cities and towns. The rural communities (37,000 of 38,000), having 50 per cent of the total population of France, are under the Agriculture Ministry.

The theory of subsidization favours mainly for: (i) difficult equipment which can not be available for the rural areas and (ii) the medium sized projects which should have the following technical aspects: the interests of the collective people should be satisfied, in the general interest there should be coordination, avoidance of double-employment and wastage or squandering of funds, and the plan should be collective.

The services of the technical persons of the Genie Rural are utilized for all the collective communities but not alone for one particular collective community. The technicians of the commune of the Genie Rural work together for the realization of the project.

Water Supplies and Planification

From 1943, one inventory was maintained for all the rural communities wherein data on the water resource availability, population, diverse activities of the population (small industries, dairies etc.), and the needs of the public were collected. The geological survey for the underground water, the surface waters analyses and other points of interest were also investigated. From these inventories the general programme for the water supplies was established for the rural areas so as to: (a) hoard water collectively from various small water sources (b) to group the communities without leaving any one of them, as far as possible, and (c) to assure needs of all the people. This resulted in: (i) one principal water source for some communities grouped together (ii) one secondary water source for very small groups, (iii) for individual 'communes' which are very far (such 'communes' occupy 1/15th of the total "Communes" of the 25 departments of the Ginie rural).

The programmes are chalked out in such a way so that there may not be any loop-holes, and acceptable under the collective economy. Liaisons are established between the communes, and the security of continuous water supplies at the point of consumption is assured.

Naturally this work is very important and the Government of France had instituted a plan for the modernisation of the Equipment in all the communes. France is now in its 5th plan period and for the social uplift the water supplies had formed the primary objective which is followed by the sewage and other waste treatment programmes.

Social Revenue

The social evolution has the one main object of planification of economy so that there will be hundred per cent justification in the revenue. It is difficult to count the revenue in terms of money but the plantification had reduced many epidemics, and the general health and life of the people has increased and mortality rate decreased. As per calculations one m^3 of potable water costs 0.80 to 1 NF when compared to lifting of water charges from wells etc. which costs about 6.50 NF.

For increasing the hygiene of the animals also good water is necessary and every year France is spending 800 to 900 million Francs towards this end. It may take another 13 to 15 years to achieve an ideal goal in this direction.

Water charges

For potable water-supplies different formulas exist for water charges. The collective commune will decide about the rates depending on their expenditure etc. and it is difficult to generalise.

The industrial establishments, which take water from the collective communes, purchase water according to a rate based on the personnel involved, energy and other charges or on collective payment or on payment for the installation.

Management of the Water-works

The collective community employs a technical employee who runs and supervises the water-works, fixes the price of the water etc. But the direct administration is in the hands of the local communities of "Communes" which are affliated to the syndicat Intercommunal. These local committees check the prices and handle other industrial demands concerned.

Subterranean Water

The subterranean water sources have been thoroughly investigated and in many parts of France the superficial water-table as well as the deep water tables are exploited after finding out its suitability for drinking. In the case of the latter the geological conditions sometimes produce water with pressure (carbonic acid) and sometimes without pressure. A typical installation of pump-house where the subterranean water forms the water source could be seen in Fig. 1. In many instances the subterranean water is chemically and bacteriologically pure and hence without treatment it is used for potable water-supplies. During the last few years Morocco was benefitted by French Experts' advice on its subterranean resources.

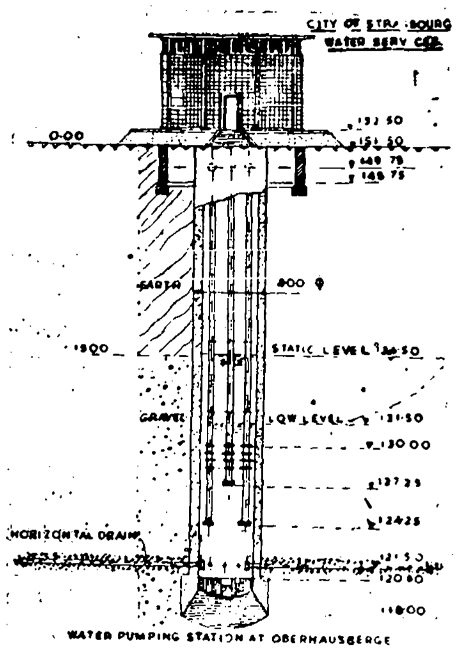

Fig. 1

Collective Public Works and Equipment

The public works department is subjected to the special rules of the Government and is responsible to the public works committee of the Government or to a collective union of public nature like Syndicate of the communes. Public works department is responsible for report of the project, its construction, management and supporting of the works like water-carrier system, transport etc. Under the Public Works department's guidance and administration many private industrial Corporations or Societies (connected with the waterworks construction etc.) carry out the projects. All the machinery and equipment necessary for Public Works purposes is used collectively.

Participation of Private Societies

The setting up of water purification stations is the source of considerable activity in France. Most often the contractor participates closely in the planning of a scheme and assumes responsibility for the choice of methods as well as for their putting into effect. The individual plants tend to reveal traits characteristic to them. The main component parts of a plant are designed and built by the very same contracting firm specifically to meet the requirements of the overall installation of which they are to form a part. This in turn made it possible to arrive at simple and elegant solutions notably in the field of hydraulic regulators, mud bed decanters and automation devices, Degremonts' decanter pulsator and Aquazur, telemecanique equipments, Detecture combine Triphone T 64 of the compagnie Francaise des conduites d'eau, ozonizres etc. France produces most of the raw-materials such as pipes, motors and pumps, water meters electironic Instruments, Chemicals for sterilization of water etc. that are necessary for the water-supply systems. Societe des Fonderies de pont-a-Mousson, La telemecanique. Etts., Vincent Freres Haguenau, Societe Rateau, Societe Nouvelle de Sondage" Rateau, Societe Nouvelle de Sondage "Bonn Esperance", CEM (Cie Electromechanique compagnie des Faux et l'ozone) are some of the well-known manufacturers of some of these equipments.

Appendices A to D will show some examples of community water supplies of different population sizes. These indicate existance of very good co-operation and organizational capacity amongst the communes which live harmoniously with each other The water-supply of the Saone-turdine is an excellent and typical example.

APPENDIX 'A'

Sydicat Intercommunal d' Abduction d' Eau de l' Echel Superieur

TIEFFEN BACH (Bas-Rhin, France)

Comparative Table (1958—1965)

Consumption of water per year (m^3)	1575	10893	15469	26151	29076	29178	32907	29879
Electrical energy consumed per year (kwh)	5139	12049	19531	23381	23844	31045	37328	33178
Population served (habitants)	450	450	1100	1100	—	—	—	—
Number of house connections provided (maison)	105	116	292	296	301	308	—	312
Year	1958	1959	1960	1961	1962	1963	1964	1965

Water charges per head works out to 0.20 N.F.

APPENDIX 'B'

ALIMENTATION EN EAU POTABLE

des coteaux et du Haut-Plateau Vosgien de la region Nord-Ouest de Colmar a-partir de la nappe phréatique de la plaine

CONSOMMATIONS

Communes	Daily water consumption Maximum m^3	Minimum m^3	Yearly
Sigolsheim	100	90	32.850
Ammerschwihr	250	225	82.125
Katzenthal	63	55	20.075
Niedermorschwihr	88	70	22.550
Trois-Epis	307	145	52.439
Labaroche	244	70	25.754
6850 habitants	1052	655	235.793

APPENDIX 'C'

RESERVOIR AND WATER-TREATMENT STATION FOR RIBEAUVILLE

—Population

Actual: 4.700 habitants

Basis for the project: 5.000 habitants

Existing old reservoir has a capacity of 500 m^3

Source of water—stream water

—New reservoir:

Capacity : 1.000 m^3

Height of water d' eau : 2,60 m^3

—Reserve total

2x500 m^3 = 1.000 m^3

1x1000m^3 = 1.000 m^3

Total = 2.000 m^3

reserve for daily consumption: **1.500 m^3**

general reserve : **500 m^3**

APPENDIX 'D'

ASSOCIATION INTERCOMMUNAL AND INTERSYNDICALE FOR THE DISTRIBUTION OF WATER SAONE-TURDINE

Name of the Communities	Number of communities	Total water demand per day
—Syndicat de la REGION de TARARE	14 communes	2.300 m^3/day
—Syndicat du VAL d'AZERGUES	25 ,,	1.700 m^3/day
—Syndicat du CANTON du BOIS d'OINGT	9 ,,	700 m^3/day
—Syndicat de la BREVENNE	3 ,,	600 m^3/day
—Syndicat d'ANSE et REGION	4 ,,	500 m^3/day
—Ville de TARARE	1 ,,	2.000 m^3/day
—Commune de l'ARBRESLE	1 ,,	600 m^3/day
—Commune du BOIS d' OINGT	1 ,,	200 m^3/day
—Commune de CHESSY	1 ,,	200 m^3/day
TOTAL:	59 ,,	8,800 m^3/day

Total population served —48,000

The under-ground water present in the Alluvial belt of SAONE in the plains of Amberieuy—D' Azergues and the water present in dam of Turdine form the water resources.

DISCUSSION

Shri U. J. Bhatt, Baroda: I am happy that the author has shown on the screen the water intake at River Rhine. I would like to mention here that the public health engineers can come and see such a system consisting of 2 wells for a water supply of the Refinery Project. I have the honour to introduce this for the first time in India. This is the cheapest and quickest method. The cost of 20 mgd plant is Rs. 45 lakhs. The time taken for one well was six months and for the second well it was five months. The complete well system will cost Rs. 68 lakhs and time of completion will be 28 months.

Prof. C. H. Khadilkar, Baroda: Hon. Minister of Public Health declared open before the sub-committee of Parliament that estimated cost of supplying potable water to villages and semi urban towns is about 1,400 crores while she was able to get only 325 crores for the Fourth Plan period. This is only one fifth of the requirements and as such we might be touching the fringe of the problem. The information I have from a developed country in the continent showed that the water supply schems are at present executed at a cost of about one fifth of the estimate of our similar Indian projects. They were able to achieve this cost level on account of the approach adopted by that country in getting the design of such projects. The Government of that country declared thirty years ago that they have accepted the responsibility of getting safe water to drink to each and every individual of the community, and that no work in the country should be carried out by outside agency. It must be done by the local people with the talent and material available in the country. The Government requested a Professor of Public Health Engineering of a University to work out a filtration plant for water treatment. He was allowed to incur the expenditure without any limitation. He ordered for units of different filtration plants from all the nations who are fabricating such units. He handed over the plants to his post-graduate students for operational study and the students and his associates built up a new unit incorporating the best from different units set up in the University campus.

A paper was presented before a meeting of engineering associates of the country and was submitted to the Government for consideration. The Government approved the suggestion and asked the public health engineering division to fabricate and instal such a pilot unit with the component elements manufactured in the country. They told me with a sense of satisfaction and pride that they were able to set up a pilot plant within three months or so. All the works are now being executed under the direction and supervision of the Government departments instituted for this purpose.

We must have such an approach if we mean to solve the problem of community water supplies. We have Universities and the Public Health Engineering Research Institute. We must do something to activate our efforts. Some shock treatment may have to be given. I am optimistic and hope something more in that direction.

Shri T. Durairaj, New Delhi: Recent assessment has shown that about one thousand crores of rupees are needed for the entire sanitation facilities. It is impossible to provide such a huge amount in the budget. The local bodies should be able to look into their water supply schemes. Regional sewage and water boards should be set up and a radical orientation in the approach has to be done. Most economical schemes have to be given and the planning has to be very effective.

Dr. B. V. Bhoota, (Chairman): I thank all the speakers for their interesting papers. I wish to say that all our ideas should be passed through the scene of economy and to stress the importance of water pollution control.

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Screen Wells Improve the Yield of Community Water Supplies

J. N. RAMASWAMY
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A portion of the rain that falls on the ground percolates through it and fills the interstices of the sub-soil. Such a sub-soil holding water is called an aquifer and is regarded as a natural storage reservoir from which water may be withdrawn. The water thus stored underneath the ground is termed as "Ground Water".

Ground water that is available for community water supplies is most commonly found in a strata of gravel and sand as water bearing sand formations provide the largest reservoirs of ground water in this country and elsewhere. They are the sources of water for many communities. Sand aquifers offer several inherent advantages over consolidated rock aquifers. They are more uniform in their ability to yield water and they play a significant role in removing the impurities including bacteria from the water that flows through them.

The most common way of exploiting the underground water source is by the construction of wells. Infiltration galleries and radial collector wells are also in common use but a system of vertical wells designed to provide a large water supplies by induced infiltration has a number of advantages over them. The vertical wells are easier and cheaper to construct and to maintain and the initial investment is therefore much less.

The grading or size analysis is one of the important characteristics of sand that we need to know in order to design and construct a well properly in a water bearing sand formation. This analysis shows the distribution of grain sizes and this is used in the selection of the proper size of the slot openings for the well screen to be used. Comparative analysis of the samples taken at various depths indicate what part of the formation is likely to yield the maximum quantity of water. The complete sieve analysis of a sand sample is plotted on a graph paper to provide a curve which shows at a glance how much of the material is smaller or larger than a given particle size.

Size of Screen

The length of the screen is dictated by the thickness of the water bearing formation and the level of the drawdown. The well is pumped such that the pumping water level is at or slightly above the top of the screen. The available drawdown is therefore the distance between the static water level and the top of screen. If the

Session—II

Shri P. C. Bose, Chairman (second from right) Dr. Sushila Nayar. Ex-Minister for Health & Family Planning and Shri R. S. Mehta

screen length is doubled, the maximum yield would be increased by about 70 per cent (1). Best design dictates screening the lower 1/3 to 1/2 thickness of aquifer. But if the diameter is increased, say doubled, other things being equal an increase in specific capacity of only about 10 per cent is obtained i.e. the increase in yield is not commensurate with the increase in cost (2). Hence the diameter has to be decided on the basic principle of entrance velocity of the water through the screen openings. The usual screen entrance velocity is 0.1 ft/sec. With this velocity, friction losses, rate of incrustation and rate of corrosion are minimum.

Size of Screen Opening

The selection of well screen opening is made from the sieve analysis curve. For a naturally developed well, the screen openings are usually selected at a size about equivalent to the median size of the sand, usually in the range of size which will retain 40 to 50 per cent of the material. 40 per cent retained size is chosen if the water is not corrosive and if there is no question as to the reliability of the sample. Fifty per cent retained size is chosen if the water is extremely corrosive or if there is some doubt as to the reliability of the sample or in other words, the openings are deliberately selected large enough to allow about 1/2 of the formation sand to pass through i.e. the screen openings should retain about half of sand (4). This means finer half will be removed leaving the coarser half as developed zone. To determine the correct slot opening, it is only necessary to select the point on the graph where the 40 per cent (or 50%) retained size intersects the sieve analysis curve and then determine the size from the horizontal scale.

Type of Screens

V shaped openings of the slot type widening inwardly are superior to square holes in a wire mesh or drilled holes in a pipe wall since sand grains make contact with only the 2 edges of the slot and there is far less tendency for the sand to become wedged in the two sided slot, plugging the opening. The V shape of the slot allows any sand grain that is slightly smaller than the throat of the opening to pass freely into the well without clogging. The most advanced design of well screen is recognised to be one with V slots which are continuous openings around the entire circumference of the screen.

Development of Wells

This is an operation removing the finer particles from the formation leaving an envelope of the coarser particles around the well screen. This enveloping or developed zone has much higher permeability and greater porosity than the original formation material. The yield of the well and its life are thus increased and sand free water is pumped from the well.

The fines are removed from the formation by a washing action. To be fully effective, this action must be a surging type of agitation of the water in the well. Water must be moved in and out through the screen openings to wash out all the fine particles that will pass through the screen openings and bring them into the well.

Pulling water in one direction only through the screen openings such as pumping or bailing alone may do, will remove some of the fines. But reversal of flow is essential to fully develop a well and bring it to a sand free condition and to its best efficiency.

When water moves in only one direction some of the fine sand grains will arch across or bridge the larger openings between 2 or more coarser grains. They will stay bridged in this fashion until the water movement is reversed. When the flow is reversed, the bridging is broken up, some of the particles are rearranged and the fine grains move through the voids in the formation and through the screen slot openings. Surging water in and out through the screen openings finally brings the whole zone affected by development to a "stable" condition. The coarsest material with all the fines removed is immediately against the screen. A little further away, some medium sized grains remain mixed with the coarse. Beyond that the material gradually grades back to the original water bearing formation. Under this condition, no more sand will move into the well no matter how heavily it may be pumped. Fig. 1 shows the difference in the formation.

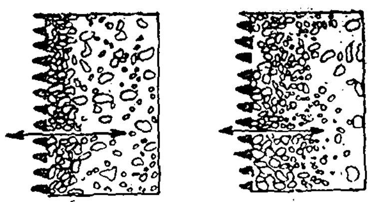


Fig. 1

Surging action can be made by any of the following methods :

i) Using up and down a surge plunger with cable tool equipment, or

ii) Forcing the water out of the screen into the aquifer by compressed air or by increasing the water head.

Location of Wells

The most desirable arrangement is to locate the wells at equal spacings on the circumference of a circle. The composite performance of a group of ordinary size wells located in a proper pattern will equal that of a single well. The equality between the battery of smaller wells and the imaginary large well will hold both with respect to total yield and drawdown. Construction of single large well will be impracticable or very costly but installing the battery of smaller wells can be readily and economically accomplished.

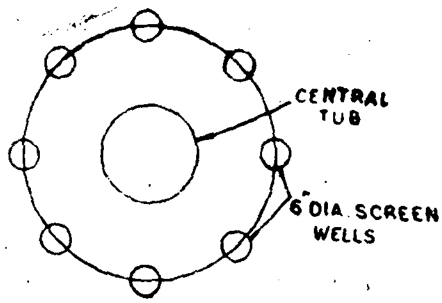
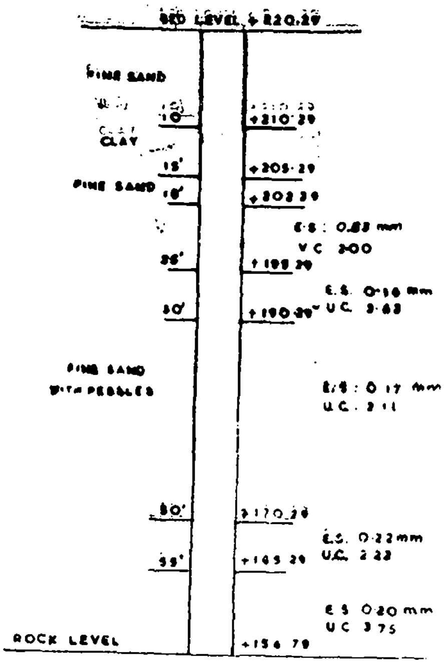


Fig 2

Description of Work Done

An existing well 12 ft diam. and 34 ft deep located in the river bed supplied about 2 lakh gallons of water per day. It was decided to increase the yield from this well. The summer water table at the river bed stands at the river bed itself. The sub-soil particulars at the well site are shown in Fig. 3

It may be seen that there is 63 ft. depth of sand at the site As the summer water table stands at the bed of the river, the entire depth of sand is saturated. The effective size of sand ranges from 6.16 mm to 0.23 mm and the uniformity coefficient ranges from 2.0 to 3.75. As the sub soil is fairly good and fully saturated, it is possible to develop good wells with suitable screen at this site.



SUBSOIL PARTICULARS

Fig. 3

Eight numbers of 6 in. screen wells were installed all round the existing 12 ft. shallow well at regular intervals in the circumference of a circle with a radius of 22'-6" as indicated in Fig. 4.

The screen wells were sunk to the full depth of the aquifer with anti-corrosive brass screens for the bottom 30 ft. depth. The strainers were provided with slot openings in the shape of V with divergence inside. The size of the slot was chosen as 0.015" to be in conformity with the median size of the sand at site and thus enabling 50 per cent of the finer sand particles to pass through the screen. Above the well screens 6 in. M. S. pipes were attached and they were stopped at a level 6 ft. below the river bed and connected on to the shallow well as shown in Fig. 4. The bottom of the shallow well was plugged with concrete and thus it could no more serve as an infiltration well

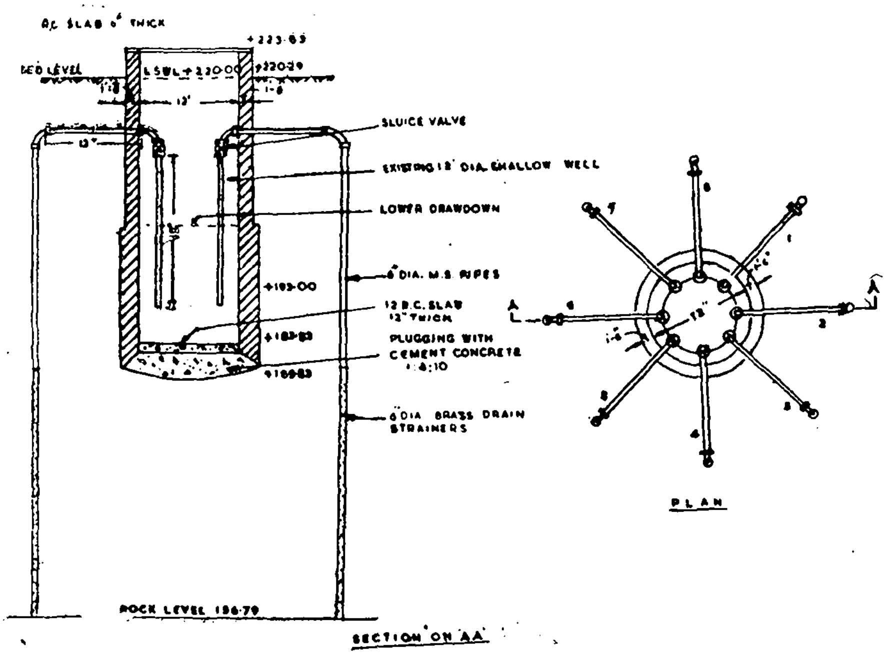


Fig. 4

but only as a collecting tub for the screen wells installed all around.

The screen wells were developed individually before they were connected on to the central tub. The developing was done by alternatively pumping in and out water and removing the accumulated sand particles which were smaller than the slot opening.

Individual pumping tests were conducted in each of the screen wells before they were connected, on to the central tub. The pumping rate was kept at 385 gpm. Different draw-downs were noticed in the different wells. The draw-down varied from 8 ft. to 15′-9″. The draw-down in different wells is tabulated as shown in Table I.

TABLE I

Screen Well No.	Draw down	Rate of pumping in gpm	Specific vertical yield in gpm
1	9′-3″	385	42
2	11′-3″	385	34
3	8′-6″	385	45
4	15′-9″	385	24
5	10′-6″	385	37
6	8′-0″	385	48
7	8′-9″	385	44
8	8′-9″	385	44

Pumping tests were conducted after all the Screen wells were connected on to the central tub. A centrifugal pump was installed over the central tub and made use of for pumping tests. The details of the pumping tests are shown in Table II.

TABLE II

Interval in min.	Depth of water level during interval in ft.	Av. depression head during interval in ft.	Qty. discharged during the interval in gal.	Qty. of water in gallons in well	Inflow of water in well during interval in gals.	Yield in gpm	Specific vert. yield in gpm per ft. depth
5	7.25	3.62	6090	5125	065	193	50.3
5	4.00	9.25	6090	2822	3268	654	70.7
5	3.00	12.75	6090	2120	3970	794	60.0
5	1.50	15.00	6090	1060	5030	1006	60.7
5	0.50	16.00	6090	353	5737	1147	71.7
5	0.33	16.41	6090	234	5856	1171	71.4
5	0.17	16.66	6090	120	5970	1194	71.7
5	0.16	16.83	6090	113	5977	1195	71.0
5	0.08	16.95	6090	56	6034	1207	71.2
5	0.04	17.02	6090	28	6062	1212	71.2
10	—	—	12180	—	—	—	—
30	—	—	36540	—	—	—	—

Note: The data in Tables I and II refer to infiltration wells in the Cauvery River bed at Trichy while the author was in charge and has been reproduced in the article subject to the approval of the Public Health Engineering Department, Madras.

A V notch with the angle of V as 90° was used for measuring the flow.

Discussion and Conclusion

From the details of the pumping tests it is noticed that the combined specific vertical yield from all the screen wells is only 71 gpm. The sum of their individual spcific vertical yield should be 318 gpm as per Table I. As against this only 71 gpm has been obtained as shown in Table II. It only shows that there was lot of interference which is due to the closeness of their location. Probably a wider circle for the location of the wells could have yielded much more water with the same number of wells and the same drawdown due to less interference between the wells.

Further, due to the limitation of the suction of centrifugal pumps, the drawdown was limited to only about 17 ft. In any water bearing strata, maximum yield can be expected if the draw down is extended upto the top of the screen which means a draw down of 35 ft. in this case which could be achieved by using a deep well pump. For this draw down, the yield that could be expected even with this close spacing would be 71 x 35= 2,485 gpm or 3.56 mgd or nearly 4 mgd. With wider spacing of wells it could be much more. As the first cost and maintenance are not much, it would be good practice to go in for such wells and to extract the maximum ground water for being supplied to the communities of medium or even big size. This arrangement can be recommended to all towns and panchayats or groups of panchayats located close to rivers where there is sufficient depth of sand saturated with water.

Reference :

1. The Johnson National Driller's Journal, July-August, (1957)
2. The Johnson National Driller's Journal, September-October (1963)
3. The Johnson National Driller's Journal, November-December (1957)
4. The Johnson National Driller's Journal, July-August (1963)

DISCUSSION

Shri B. L. Mahabal, V.J.T.I., Bombay: How the radius of 22'6" was arrived at for the circle on the circumference of which six screen wells were situated? How one goes about to decide the correct spacing of the wells?

Shri J. N. Ramaswamy, Guindy, Madras: The radius of 22'6" has been fixed arbitrarily in this case to suit the practical working conditions.

The most desirable way of locating the wells is in a circle. Under this condition the entire group of wells acts as a composite single well. Again the distance between two consecutive wells has to be decided such that there is no interference between them. To do this, preliminary investigations have to be done to decide the cone of influence etc. between the wells.

Shri U. J. Bhatt, Baroda: I would like to know the latest water supply installed by the system of screen wells. I understand that an yield of 4 mgd could be obtained by proper spacing of screen wells and proper selection of pump sets etc. I wonder whether larger water supply of 10 mgd and above can be obtained by this method rather than by radial collector system, which the author has dismissed as uneconomical. It would be worthwhile to study the relative economics as I am inclined to believe that such a system will prove economical for 5 mgd and above.

Shri J. N. Ramaswamy, Guindy, Madras: This is the only instance where the system has been tried. The yield of 4 mgd could be increased to even 10 mgd if the wells had been located at a radius greater than 22′6″. The radial collector well system is costly in that special equipment is needed to drive the wells together, with skilled workmen etc. However, comparative costs must be studied in detail before coming to a conclusion that radial wells will be cheaper for 5 mgd and above.

Shri J. M. Dave, CPHERI, Nagpur: I would like to mention that the author can improve the performance of the wells by increasing the effective head by eliminating the bend which reduces the available drawdown.

The need for eliminating 50 per cent of fine sand as referred to by the author is not a standard practice, but it might have been successful in this particular instance.

Shri J. N. Ramaswamy, Guindy, Madras: I agree that the performance will be improved if the bends are eliminated due to increased head but this could not be achieved due to practical considerations.

The need for eliminating 50 per cent of sand is to see that the aquifer is stratified with the coarsest particles being close to the screen and coarser particles further away from the screen. Under such conditions the aquifer acts as a filter and has been possible to extract water better in quantity and quality. I have seen in many of the foreign journals and books the same method and have not come across any one instance where it has been successfully adopted as per the questioner's suggestion. If he is aware of any such instance. I would be grateful if it is enlightened.

Shri L. Das, Orissa: I would like to know whether any trial boring was done across the river in a line perpendicular to the direction of river flow.

If there was proof of good width of sand aquifer it will be desirable to locate tube wells in a line across the river and the distance between tube well could be kept more than in the case reported by the author wherein the wells are located along the circumference of a circle. By adopting such a method there will be more flow into the tube wells and hence more water could be obtained. Ranney's method of collection will be costlier than the above arrangement.

Shri J. N. Ramaswamy, Guindy, Madras: Trial borings were done in and around the area. There was proof of good aquifer over a vast area of the bed.

The suggestion offered is good. It could be possible to extract more water if the wells had been located in a straight line across the river as suggested at such distances in between as not to cause interference.

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"Regulated Reservoir Operation for Augmenting Community Water Supply"*

B. B. BHALERAO
Central Public Health Engineering Research Institute, Nagpur.

Introduction

Increasing population and accelarated industrial activities necessitate the augmentation of water supplies for urban as well as rural communities. For surface water supplies one of the methods of augmentation is to alter the use of reservoirs from impounding system to regulating system. This method as adopted to a community water supply in U.K. is discussed in this paper.

(A) Existing system of supply

The Taf Fechan Water Supply Board serves a population of about 360,000 in a 185 sq. mile area of South Wales. The only source of supply is the Taf Fechan Reservoirs which have a gross maintainable yield of 22.8 mgd. Of this gross amount, an average quantity of 4.6 mgd must be supplied as compensation water to the River Taf, leaving 18.2 mgd available for supply purposes.

The major portion of the supply is fed into a low level trunk main distribution system working under a maximum potential of 980' ordinance datum. A smaller proportion—about 4 to 5 mgd is fed into two high level systems working at about 1300' ordinance datum potential.

The low level trunk main system conveys the water a distance of about 12 miles downstream of the Taf Fechan reservoir, giving bulk supplies at various points en route and terminating in a small service reservoir at a point known as Cefn Glas, Quaker's Yard, where the top water level of this service reservoir is 893' ordinance datum.

Downstream of the Cefn Glas Reservoir the water is conveyed a further 20 miles to the southern boundary of the Board's undertaking where bulk supplies are taken from the end of the main.

(B) Need to augment the supply

The total average consumption by the authorities of the Board is within about 1 mgd of the total net yield of the Board's resources.

Whilst the consumption of these authorities is not, in the main, increasing at a fast rate, the Board considered that it would be prudent to commission investigations into possi-

* Paper submitted to Delft Technological University in partial fulfilment of the requirements for Diploma in Sanitary Engineering, Delft, Netherlands.

ble new sources of supply. They authorised a start on the work in 1963 and, in early 1965, they were confirmed in their opinion of the need to obtain more water by a request from one of their constituent members for an additional supply of 4 mgd by 1970-75.

The Board have been advised by their Consultants that they should seek a new supply capable of giving at least 5 mgd and preferably 10 mgd.

(C) Possible means to augment the supplies

The Taf Fechan reservoir has a catchment area of 8,350 acres and a capacity of 3400 mg. The long term average annual runoff is 57.1" and the safe yield in a 3-dry year period 22.8 mgd of which 4.6 mgd must be provided as compensation water to the river.

The size of the reservoir is large, relative to the size of its catchment. The most economic extra yield could be obtained by building catchwaters to bring in runoff from additional catchment areas. This is not practicable, however, because adjacent upland areas to west, north and east are already reservoired by other water authorities.

The nearest unreservoired area of upland gathering ground lies some distance from the Taf Fechan valley and calculations have shown that piping the runoff from this area would only increase the yield of the Taf Fechan Reservoirs by 3 to 3½ mgd.

Attention has been turned, therefore, to the south—or downstream of—the Taf Fechan Reservoir by altering the use of the Taf Fechan Reservoir from a 'conventional' impounding scheme, to a 'regulating reservoir.' When operated in the latter fashion the reservoir would be used to regulate the flow of the river so that, at some point downstream, water would be drawn from the river in greater quantities than would be possible by drawing directly from the reservoir. Use is thereby made of the runoff from the catchment area to the river below the dam and down to the proposed abstraction point.

Since it would not be economic to abandon the present 13.7 mgd treatment works sited just below the dam, the calculations are modified to allow for these works to continue to give an output of 10 mgd, by drawing direct from the reservoir to that extent, whilst the balance of the supply is obtained from the regulated river at the proposed abstraction point.

(D) Salient features of the method

To arrive at the results we needed the following :

1) Data giving cumulative inflow in Taf Fechan Reservoir. This will indicate the potential capacity of the reservoir.

2) A frequency curve for flow duration of the river at the point of abstraction. Two curves were used for the expected driest periods (defined later) and the basic calculations are as below :

1)	Runoff from unreservoired portion of catchment down to abstraction point	x
2)	Runoff at abstraction point required to support given supply	y

3) Amount to be drawn from storage reservoir (y-x)

4) Runoff to storage reservoir z

5) Net emptying of storage reservoir (y-x)—z

The calculations should cover a period of maximum drought that can be expected. Experience in the British Isles indicates that a maximum drought may be taken as commencing with 60% rainfall year followed by 90% rainfall years. In order to obtain safe working, the reservoir is required to start to refill within 2 years i.e. in the wet period of first 90% year. The storage required to obtain yield on above method of operation must be less than or equal to the capacity of the existing reservoir. In such a case it is possible to obtain greater yield than can be at present obtained by drawing a supply direct from the service reservoir.

(E) Comparison of data with other catchments in order to eliminate errors due to observation.

This was essential since some mistakes in observations could lead to erroneous results.

(a) Data for cumulative runoff in Taf Fechan reservoir: It was not possible to obtain values for minimum cumulative runoff for periods longer than 12 months by inspection. Correlation with any well established curves with similar characteristics was necessary. The following catchment data was available.

1) Thirlmere catchment.
2) Severn catchment.
3) Brenig catchment.
4) Elan catchment.

Comparison of runoff characteristics of these catchments was made and is shown in Table VII, Fig. 2. Following conclusions can be drawn.

i) Cumulative runoff curves for Severn give much lower percentage than actually obtained at Taf Fechan. The Severn flows, however, relate to a considerable proportion of low land area.

ii) Cumulative runoff figures for Brenig are also on lower side at 12 months and 19½ months.

iii) Taf Fechan observed values do not give smooth curve, these are too high in the beginning possibly because of difficulty in surveying all the records.

iv) Thirlmere percentages which are obtained from a synthetic drought are reasonably in agreement with observed Taf Fechan values but being lower than Taf Fechan at 10/12 months. Working on this basis would be on a safer side and will eliminate observational errors possibly made in the Taf Fechan calculations. Thirlmere synthetic drought percentages were therefore taken as guide and cumulative runoff for Taf Fechan was obtained.

(b) Frequency curve for 60% and 90% year: Curves were needed showing relationship between flow in mgd. and days for which it is not exceeded. It was not possible to pick up the 60% and 90% year. Curves were needed showing relationship between flow in mgd. and days for which it is not exceeded. It was not possible to pick up the 60% and 90% years by direct inspection and use of relevant data from other catchment was necessary as a guide. Frequency curves for Windermere based on daily records were available and were made use of

Windermere flow frequency figures were converted into percentage of long average mean flow and these percentages were adopted for new catchment (Table III). The frequency curves for the new catchment were obtained by adopting 50.4 mgd. as the mean runoff for driest year (Table VI). The compensation water at the rate of 6 mgd. from catchment at the u/s was also taken into account while arriving at the frequency curves (Table VI Figs. 5 and 6).

Location of point of abstraction

The point of abstraction was to be chosen such as to fulfill the following conditions :

1) It should be sufficiently d/s from existing reservoir so as to cover a large catchment to give sufficient yield.

2) The bacteriological and chemical quality of water should be such that the water is amenable to usual treatment processes.

3) The elevation of the point should be such that pumping head is minimum.

(F) Calculations :

Rainfall runoff data for the period 1913-1950 was available for Taf Fechan reservoir catchment. By inspection, minimum runoff figures for period up to 12 consecutive months were obtained and are tabulated in Table I. From the long term average annual runoff (57.1″) and catchment area (8,350 acres) figures, (L.T.A. Runoff 10780 mg. 1 year), % of Runoff for consecutive month was also calculated (Table I).

Frequency curves

Average flow in mgd. and flow frequency as % of mean flow was also calculated and is shown in Table II. As discussed earlier, this data had to be modified to give a smooth curve thus avoiding any peaks or depressions due to observational errors. Table III shows % for 60% and 90% year for Windermere and observed values for Taf Fechan. The plot of these on graph paper shows that Taf Fechan values lie in between these two curves and hence it can be replaced by these curves to get more accurate results.

In order to select the point of abstraction on the river so as to satisfy the conditions mentioned earlier, "The Hydrographical survey of Watershed of River Taf Fechan" was taken as a guide. Table IV shows the quality of river in terms of BOD and O_2 saturation % at different points. On close inspection it was decided that point No. 9 "Above Taf Bargoed" with BOD 4.1 mg/lit. and 84% saturation with oxygen was best suited.

The area contributing runoff to this point was next obtained from Taf Fechan W/S bill 1964-55 and drawing No. 1 and is shown tabulated in Table V.

Area contributing Runoff = 16250 acres

L.T.A. Rainfall = 64″

Assuming that the losses for the catchment are same as those for Taf Fechan reservoir u/s which are 14"

L.T.A. Runoff = 50″
= 18400 mg/year = 50.4 mgd.

Adopting Windermere % and 50.4% of long average runoff as runoff for driest year, frequency curves were obtained. Compensation water from u/s catchment at the rate of 6 mgd was also taken into consideration the resulting graphs are shown in Figs. 5 and 6 and calculation in Table IV and VI.

Cumulative Runoff curves:

As discussed above, Thirlmere synthetic drought per cent were most suited for cumulative runoff curves, and hence adopted. Table VIII shows relevant calculations to give runoff for the catchment between Pontsticill and Quaker's Yard (Fig. 7).

Calculations to obtain necessary storage capacity for different abstraction rate were next carried out.

Sample Calculations. Scheme 1 (Ref: Figs. 7, 8, 9, Table XI, X, XI)
Total supply by river abstraction.

To get an abstraction of 35 mgd leaving minimum of 10 mgd in the river and abstracting in such a manner that amount of water left in river=

$$\left(10\ \text{mgd} + \frac{\text{excess above 10 mgd}}{4}\right)$$

The resulting curves of abstraction obeying above rule are shown in Figs. 8 and 9. Assuming that the first year is 60% year.

i) Release from storage in case when natural flow $= \frac{(10 + 35 + 35)}{3} =$ 56 mgd approx. (i.e. point B Fig. 8).

ii) This flow is not exceeded for 310 days. The runoff required in this period=shaded area (Fig. 8) = 15.57 in²
1 in² =500 mg ∴ Runoff required 15.57 x 500 = 7785 mg

iii) Inflow during the same period of 310 days (Fig. 7) = 4200 mg

iv) Deficit during first 300 days of 60% year (7785-4200) = **3585 mg**

v) Runoff from 310 days to 365 days > 56 mgd. No deficit. Inflow during this period (Fig. 7) = 1230 mg

vi) Deficit at end of 365 days (3585-1230) = 2355 mg
This deficit carried forward to year 2, taken as 90% rainfall year.

vii) Release from storage required for 254 days
= shaded area = 11.54 in² = 5700 mg
(11.54 x 500)

viii) Inflow from 365 to 619 (= 365 + 254) days (Fig. 7)
(10300—5430) = 4870 mg

ix) Therefore deficit 365 to 619 days (5700-4870) = **830 mg**

x) Total cumulative deficit up to 619 days (2355 + 830) = 3185 mg

xi) Inflow from 610 to 730 days (2 years) = 4000 mg
(14300-10300)

xii) Excess at end of 2 years (i.e. resvr. fills) = 815 mg

∴ **Maximum deficit = 3185 mg; period 619 days; filling starts after this period. admissible abstraction** since deficit 3185 mg < Taf Fechan storage 3400 mg

Sample Calculations Scheme 2 (Ref. Figs. 7, 10, and 11 Table XII, XIII, XIV). The total abstraction of 32 mgd. Amount of water left in the river at any time = $\left(10 \text{ mgd} + \frac{\text{excess flow above 10 mgd}}{4}\right)$

Total abstraction is obtained by withdrawing 10 mgd directly from reservoir and 22 mgd from river regulation. Assuming that first year is 60% year.

i) Flow from unreservoired area at which release from storage ceases = $10+22+\frac{22 \text{ mgd}}{3}$

= 39 mgd (Point B1 Fig. 10)

ii) This flow is not exceeded for 270 days (Fig. 10) Runoff required in this period = shaded area = 8.35 in^2 (8.35 x 500) = 4175 mg

iii) Storage required to supply 10 mgd from reservoir from storage ceases = 2700 mg

iv) Inflow during 270 days (Fig. 7) = 3400 mg

v) Net withdrawal from storage for 270 days (4175 + 2700-3400) = 4375 mg

vi) Inflow to reservoir from 270 to 365 days (Fig. 7) (5430-3400) = 2030 mg

vii) Required quantity from reservoir to supply 10 mgd (365-270) X 10 = 950 mg

viii) Net excess from 270 to 365 days (2030-950) = 1080 mg

ix) Net withdrawal from storage for first year (3475-1080) = 2395 mg

If the first year is followed by 2nd year of 90% runoff

x) Storage required for abstraction of 22 mgd for 198 days (Fig. 11) shaded area = 5.51 in^2 5.51x500 = 2755 mg

xi) Required storage to supply 10 mgd during 198 days 198 x 10 = 1980 mg

xii) Inflow to reservoir from 365 to 563 (=365+198) days (8900-5430) = 3470 mg

xiii)	Net withdrawal from storage for period 365-563 days (2755 + 1980-3470)	=	1265 mg
xiv)	Net withdrawal for 0-563 days from storage (2395 + 1265)	=	3660 mg
xv)	Inflow from 563 days to 730 days (2 years) (14300-8900)	=	5400 mg
xvi)	Amount required to supply 10 mgd during this period (730-563) x 10	=	1670 mg
xvii)	Net **addition** to storage at end of 2 yrs. (5400-3660-1670)	=	70 mg

Showing max. storage requireod 3660 mg for period up to 563 days. Reservoir Starts filling after this period.

Frequency graphs were used to give period and amount of deficit and cumulative graphs to obtain inflow during these periods. The deficit at end of a certain period indicated the amount of storage required for that period. Existing available storage at Taf Fechan Reservoir being 3400 mg abstractions demanding more storage were inadmissible. It was also ascertained that the reservoir started filling up within 2 years.

Calculations were carried out for two methods of reservoir operation.

i) Reservoir functioning as regulating reservoir.

ii) Obtaining part of the supply from river and part directly from reservoir. Thus 10 mgd was obtained from reservoir directly and emaining demand (20 22 mg respectively for 30, 32 mgd total abstraction) from river abstraction.

Calculations for both the methods are attached. Results for scheme 1 are shown in Table XI and those of scheme 2 in Table XIV.

(G) Conclusion

A comparison of results obtained by these two methods is shown in Table XV. These lead to following conclusions:

i) When fully regulated system was used it was possible to abstract 35 mgd and even 36 mgd. The relevent figures for partially regulated system were 30 and 32 mgd.

ii) In both schemes the reservoir is filled up within 2 years in case of admissible abstraction.

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TABLE I

Consecutive months	Details of Period	Runoff (in)	Runoff for the period x 100 / Long term avg. runoff 57.1″	Average daily runoff (in.)
1	Feb. 1930	0.00	0.00	0.00
2	July-August 1935	0.35	0.62	0.0058
3	May-July 1921	1.68	2.94	0.0187
4	May-August 1921	2.62	4.58	0.0218
5	May-Sept. 1940	3.99	6.98	0.0268
6	May.-Oct. 1919	6.66	11.68	0.0370
7	April-Oct. 1919	9.38	16.40	0.0446
8	April-Nov. 1919	12.56	22.00	0.0523
9	April-Dec. 1933	17.88	31.20	0.0660
10	Feb.-Nov. 1919	24.00	41.80	0.0800
11	April 1933-Feb. 1934	28.30	49.50	0.0850
12	April 1933-Mar. 1934	32.80	57.50	0.0910

Drainage area Taf Fechan = 8350 acres

Average annual Runoff = 57.1″

Avg. Runoff per annum = 10780 mg.

Figures of drainage area and Annual Runoff based on "Hepstead catchwater summary of calculations dated 1/1/65.

TABLE II

Consecutive months	days	% Runoff as in Table I	Runoff mg (% x 10780)	Avg. flow in the period mgd : mg / 30.5	Inflow in the period mg	Flow not exceeding mgd	Flow not exceeding as % of mean flow 29.6 mgd
1	30	0.00	0	0	0	1.08	3.6
2	61	0.612	66	66	2.17	5.17	17.5
3	91	2.94	317	215	8.21	7.01	23.7
4	122	4.58	494	177	5.80	7.15	24.2
5	152	6.98	753	259	8.50	12.53	42.4
6	183	11.68	1258	505	16.55	16.65	56.2
7	213	16.40	1768	510	16.75	18.25	62.0
8	244	22.00	2370	602	19.75	25.48	86.2
9	274	31.20	3320	950	31.20	35.10	118.5
10	305	41.80	4510	1190	39.00	32.95	111.0
11	335	49.50	5330	820	26.90	27.70	93.6
12	365	57.50	6200	870	28.50	28.50	96.3

Avg. days in month = 30.5

Avg. annual Runoff = 10780 mg. = 29.6 mgd

TABLE III

Months	days	Winermere Runoff 60% yr. mean flow 236 mgd		Windermere Runoff 90% yr. mean flow 236 mgd.		Taf Fechan observed and calculated mean flow 29.6 mgd	
		mgd	%	mgd	%	mgd.	%
1	30	14	5.94	25	10.6	1.08	3.6
2	61	123	9.75	38	16.1	5.19	17.5
3	91	34	14.40	56	23.7	7.01	23.7
4	122	45	18.60	78	33.0	7.15	24.2
5	152	73	30.90	107	45.4	12.53	42.4
6	183	111	47.00	140	59.3	16.65	56.2
7	213	128	54.20	173	73.3	18.25	62.0
8	244	133	56.40	224	95.0	25.48	86.2
9	274	157	66.50	286	121.0	35.10	118.5
10	305	215	91.00	—	—	32.15	111.0
11	335	308	130.50	—	—	27.70	93.6
12	365	—	—	—	—	28.50	96.3

Windermere data obtained from Windermere records of Rainfall and runoff (Fig. 1)

TABLE V—SHOWING AREA CONTRIBUTING RUNOFF UPTO THE POINT OF REFERENCE

S. No.	Catchment	Area Acres	Annual Rainfall mg inches	
1	A	3800	64	In order to obtain Runoff figure it is assumed that the losses are same as for Taf Fechan catchment i.e. 14"
2	a	810	64	
3	C	3260	64	
4	F	5330	64	
5	F(a)	1120	64	Runoff=64—14=50"
6	El.	1930	64	which is sufficiently accurate assumption in absence of any further data.

Total area 16250 acres

1" Runoff on 1000 acres=22.61x10⁶ gallons

Runoff for above catchment 16250 acres and 50" Runoff

18400 mg/year =50.40 mgd.

TABLE VI

		Windermere 60% year			Windermere 90% year		
Months	days	Flow not exceeding as % mean flow	% x 50.4 LTA Runoff mgd	Runoff+ 6 mgd compensation water from u/s	Flow not exceeding as % of mean flow	% x 50.4 LTA Runoff mgd	Runoff+6 mgd Compensation water from u/s
1	30	5.94	2,95	8.95	10.6	5.34	11.34
2	61	9.75	4.91	10.91	16.1	8.10	14.10
3	91	14.40	7.25	13.25	23.7	11.95	17.95
4	122	18.80	9.65	15.65	33.0	16.64	22.64
5	152	30.90	15.58	21.58	45.4	22.85	28.85
6	182	47.0	23.65	29.65	59.3	29.90	35.90
7	213	54,2	27.30	33.30	73.3	36.95	42.95
8	243	56.4	28.40	34.40	95.0	47.90	53.90
9	274	66.5	33.50	39.50	121.0	62.00	68.00
10	305	91.0	46.10	52.10	—	—	—
11	335	130.0	65.50	71.50	—	—	—
12	365	—	—	—	—	—	—

TABLE VII

(Ref. Fig. 2)

Period Months	Cumulative Runoff as % of Long Term average annual runoff				
	Taf Fechan	Thirlmere	Severn	Brenig	Elan
10 months	41.8	37.5	23.2	33.3	37.3
12	57.5	50.4	50.5	44.5	49.9
19½	92.0	—	71.4	79.0	—
20	—	92.3	—	—	89.60

Notes :

Taf Fechan values obtained as calculated in table 2.
Thirlmere values obtained from "North Lancashire River hydrological survey" published by H. M. Stationery office London.
Seven values from graph No.

Brenig values from paper published by W. K. Lewis—"Investigations of Rainfall Runoff and Yield on the Alwen Brenig Catchment" paper No. 6193 —Institution of Civil Engineers. October 1957

TABLE IX

S. No.	Rate of abstraction	Deficit for 60% year				Deficit 90% year preceeded by 60% year			
		area in²	mg.	period days	graph No.	Area in²	mg.	period days	graph No.
1	30 mgd.	12.42	6210	300	8	8.90	4450	600	9
2	32 mgd.	13.67	6835	305	8	9.90	4950	605	9
3	35 mgd.	15.57	7785	310	8	11.40	5700	619	9
4	36 mgd.	16.20	8100	310	8	11.90	5950	620	9

The values are obtained from the graphs. 1 in² =500 mg. on the graph for the scale adopted.

TABLE VIII—RUNOFF VALUES FOR CATCHMENT FROM PONTSTICILL TO QUAKER'S YARD BASED ON THRILMERE %

Months	Cumulative Runoff / Annual Runoff	Runoff fraction x 1078 mg mg
1	0.003	32.3
2	0.010	107.8
3	0.040	431.2
4	0.075	808.0
5	0.115	1240.0
6	0.160	1725.0
7	0.206	2220.0
8	0.258	2780.0
9	0.315	3395.0
10	0.375	4045.0
11	0.438	4730.0
12	0.504	5430.0
13	0.544	5850.0
14	0.585	6300.0
15	0.629	6770.0
16	0.675	7270.0
17	0.724	7800.0
18	0.779	8400.0
19	0.848	9150.0
20	0.923	9950.0
21	1.001	10900.0
22	1.111	11950.0
23	1.127	13150.0
24	1.329	14300.0
25	1.370	14750.0
26	1.413	15250.0
27	1.463	15800.0
28	1.519	16400.0
29	1.581	17050.0
30	1.649	17800.0
31	1.721	18550.0
32	1.806	19500.0
33	1.902	20450.0
34	2.008	21650.0
35	2.119	22850.0
36	2.233	24000.0

Thirlmere synthetic drought—North Lancashir Rivers hydrological survey Appendix Table I—H. M. Stationary Office London.

TABLE IV—SAME AS "GLAMORGAN RIVER BOARD POLLUTION AND FISHERIES HYDROGRAPHICAL SURVEY OF WATERSHED OF RIVER TAFF"

Point	temp	BOD mg/lit	% oxygen
1			
2			
3			
4			
9	8	4.1	84%

TABLE X—SCHEME 1

S. No.	period	Cumulative Runoff mg
1	235	2650 mg.
2	240	2750
3	300	3950
4	305	4050
5	310	7585
6	600	9685
7	605	9800
8	619	10300
9	620	10400

Ref: graph showing cumulative Runoff

TABLE XIII—SCHEME 2.

S.No.	period days	Cumulative Runoff mg.
1	265	3200
2	270	3400
3	553	8500
4	563	8900
5	730	14300

TABLE XI—SCHEME 1. SUMMERY OF CALCULATION SHOWING STORAGE REQUIREMENT FOR DIFFERENT ABSTRACTION.

S. No.	Abstraction mgd	storage needed mg	period of low flow days	max. time to start filling up reservoir
1	30	915	600	2 yrs.
2	32	2000	605	2 yrs.
3	35	3185	619	2 yrs.
4	36	3650	620	2 yrs.

TABLE XII—SCHEME 2.

S.No.	Rate of abstraction	Deficit							
		60% year				90% year preceeded by 60% year			
		area in²	mg.	period	graph No.	area in²	mg.	period	graph No.
1	(20 + 10)	7.15	3575	265 days	10	4.71	2355	553	11
2	(22 + 10)	8.35	4175	270 days	10	5.51	2755	563	11
3	(25 + 10)	—	—	—					

TABLE XIV—SCHEME 2.

SUMMARY OF RESULTS SHOWING STORAGE REQUIREMENT FOR DIFFERENT RATES OF ABSTRACTION.

S.No.	Rate of abstraction mgd	Storage required mg	period of low flow days	Max. time to commence filling up	Excess at end of 2 yrs mg
1	20 + 10	2960	553	2 yrs.	1070
2	22 + 10	3660	563	2 yrs.	70

TABLE XV

	Scheme 1 Total supply obtained by river regulation				Scheme 2 Supply by river regulation and from reservoir (10 mgd)			
	Total abstraction				Total abstraction			
	30	32	35	36	10+20	10+22	10+25	
storage reqd. mg.	915	2000	3185	3650	2960	3660	—	available storage capacity
period of max. deficit days.	600	605	614	620	550	563	—	at Taf Fechan reservoir 3400 mg.
Excess at end of 2 years mg.	3250	2500	815	250	1070	70	—	

EXTRACT FROM :— **TABLE XVI**

GLAMORGAN RIVER BOARD POLLUTION AND FISHERIES HYDROGRAPHICAL SURVEY OF WATERSHED OF RIVER TAFF

SR. NO.	SAMPLING POINT	TEMP °C	BOD mg/lit	SATURATION % 02
1	POINT Y CAFNAU	7	1.7	100
2	MORLAYS BROOK	7	111.6	63.5
3	BELOW MORALIS BROOK	7	62.4	76
4	BELOW BRIDGE STREET WEIR	7	28.8	85
5	ABOVE ABERCARNAID WEIR	7	21.0	56
6	BELOW ABERCARNAID WEIR	7	19.6	79
7	ABOVE TROEDYRIW S. M.	7	3.2	69
8	BELOW TROEDYRIW S. W.	7	3.3	71
9.	ABOVE TAF BARGOED	8	4.1	84
10	RIVER TAF BARGOED	8	3.2	92.5
11	BELOW TAF BARGOED	8	3.2	93.5
12	BELOW QUAKERS YARD WEIR	8	4.1	97

NOTE :—The selected point of extraction is (9) above TAF Bargoed. These points are shown in Fig.—12

TABLE—XVII

ESTIMATED DRY WEATHER FLOW OF RIVER TAFF

S.NO.	REFERENCE POINT	AREA OF GATHERING GROUND (ACRES)	ANNUAL RAINFALL (INCHES)
1	2	3	4
	T.F.W.S.B.	8,350	MEAN AVERAGE RAINFALL
	AREA A	3,800	
	CARDIFF CORPN.	10,400	
	AREA B	3,040	
1	BELOW CONFLUENCE OF TAFFS FAWR, FECHAN		
	AREA A	810	64
2	BELOW S.W.B.B. STATION		
	AREA C	3,260	64
3	BELOW NANT MARLAS		
	AREA F	5,330	64
4	TROED-Y-RHIW		
	AREA F(a)	1,120	64
5	MERTHYR VALV COLLY		
	AREA F. 1	1 930	64
	AREA E (B. TAFF)	8,550	
6	BELOW CONFL. BARGOED TAFF		
	AREA F. 1 (a)	1,500	61
	AREA D. (CYNON)	26,300	
7	BELOW CONFL. CYNON		
	AREA F 1 (b)	2,590	61
	AREA G	6,010	
8	BELOW CONFL. CLLYDACH		
	AREA F 2 (a)	1,300	60
	AREA H. (RHONDDA)	27,650	
9	BELOW CONFL. RIVER RHONDDA		
	AREA F 2 (b)	720	60
10	TREFOREST ESTATE & TINPLATE WORKS		
	AREA F 3	2,660	60
11	GENERATING STATION (UPPER BOAT)		
	AREA F 4	1,280	60
12	NANTGARW COLLY.		
	AREA F 5	5,120	60
13	TINPLATE WORKS MELIN G.		
	AREA F 6	4,800	60
14	CARDIFF DOCKS FEIDER		60

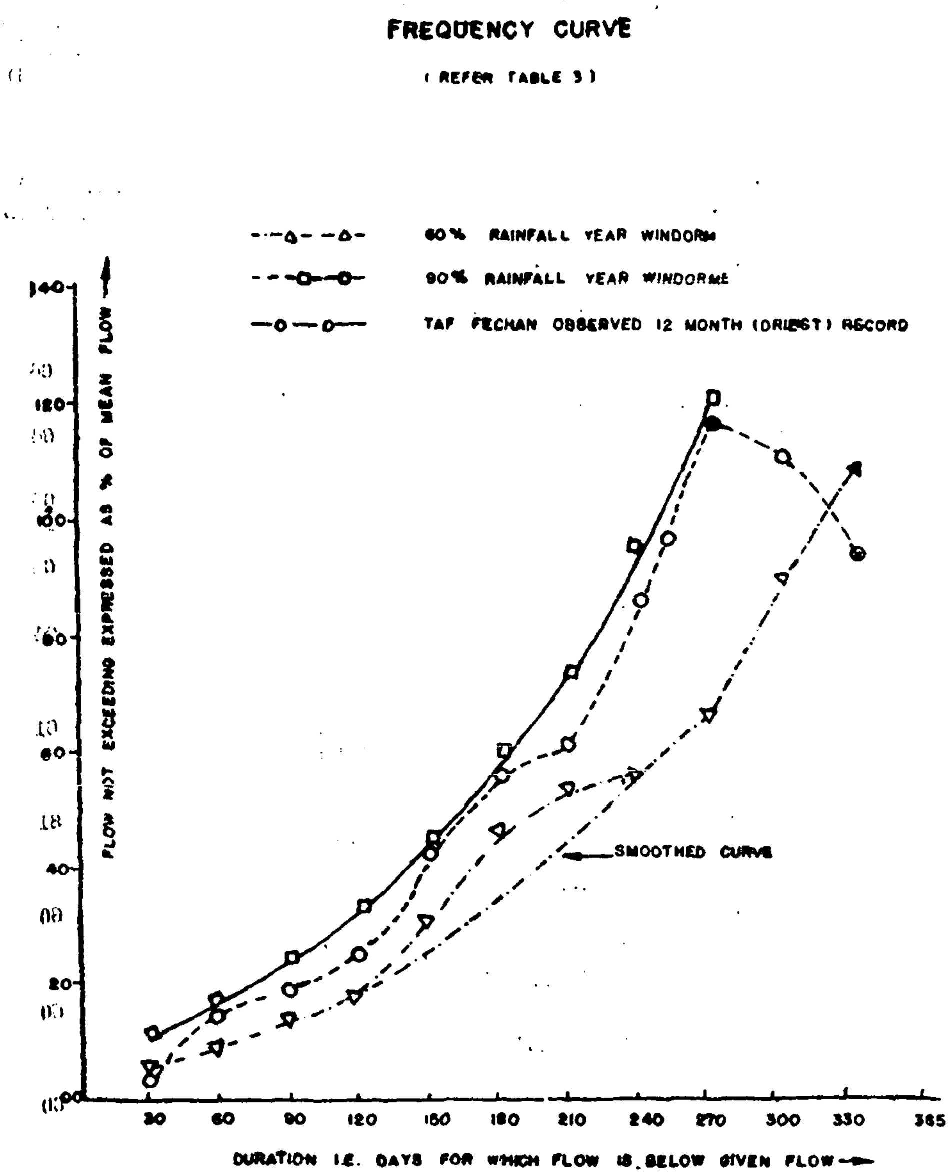

FREQUENCY CURVE
(REFER TABLE 3)
60% RAINFALL YEAR WINDORM
90% RAINFALL YEAR WINDORME
TAF FECHAN OBSERVED 12 MONTH (DRIEST) RECORD
FLOW NOT EXCEEDING EXPRESSED AS % OF MEAN FLOW
140
120
100
80
60
40
20
00
30
60
90
120
150
180
210
240
270
300
330
365
SMOOTHED CURVE
DURATION I.E. DAYS FOR WHICH FLOW IS BELOW GIVEN FLOW

Fig. 1

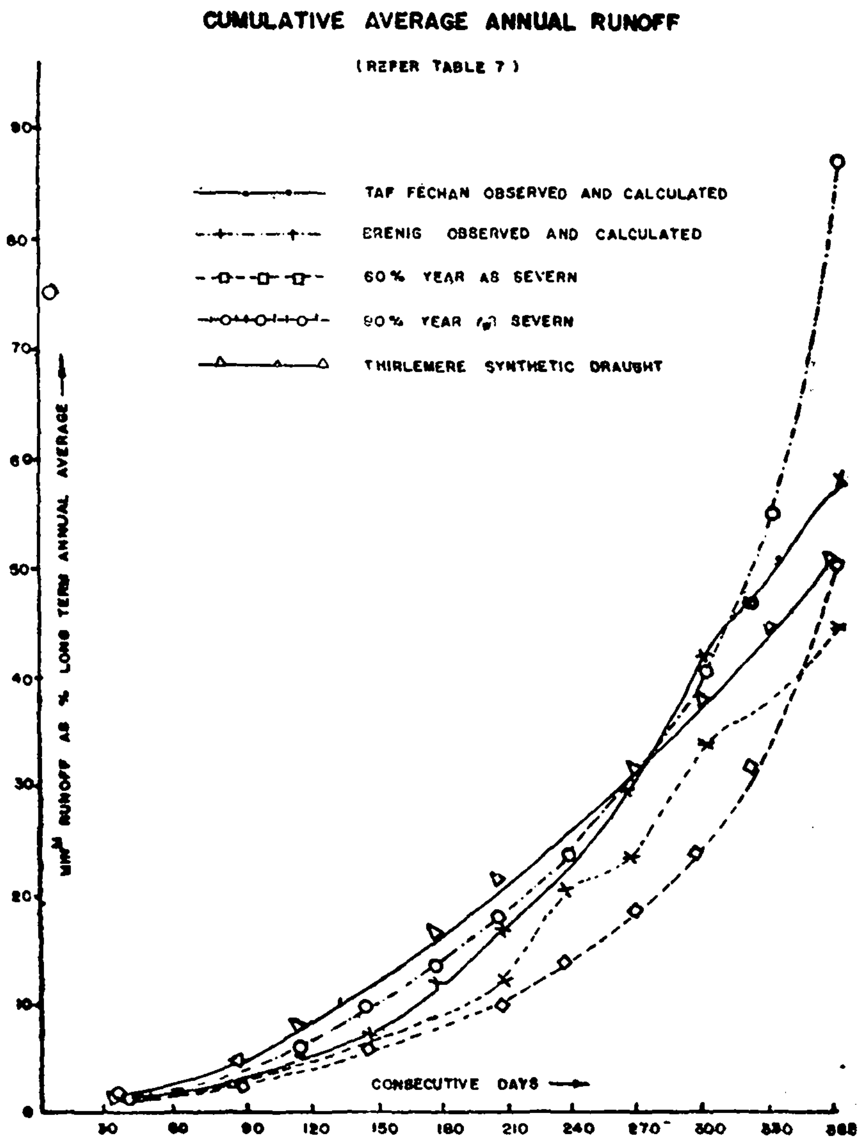

CUMULATIVE AVERAGE ANNUAL RUNOFF
(REFER TABLE 7)
TAF FECHAN OBSERVED AND CALCULATED
ERENIG OBSERVED AND CALCULATED
60% YEAR AS SEVERN
90% YEAR AS SEVERN
THIRLEMERE SYNTHETIC DRAUGHT
MINM RUNOFF AS % LONG TERM ANNUAL AVERAGE
CONSECUTIVE DAYS
0
10
20
30
40
50
60
70
80
90
30
60
90
120
150
180
210
240
270
300
330
365

Fig. 2

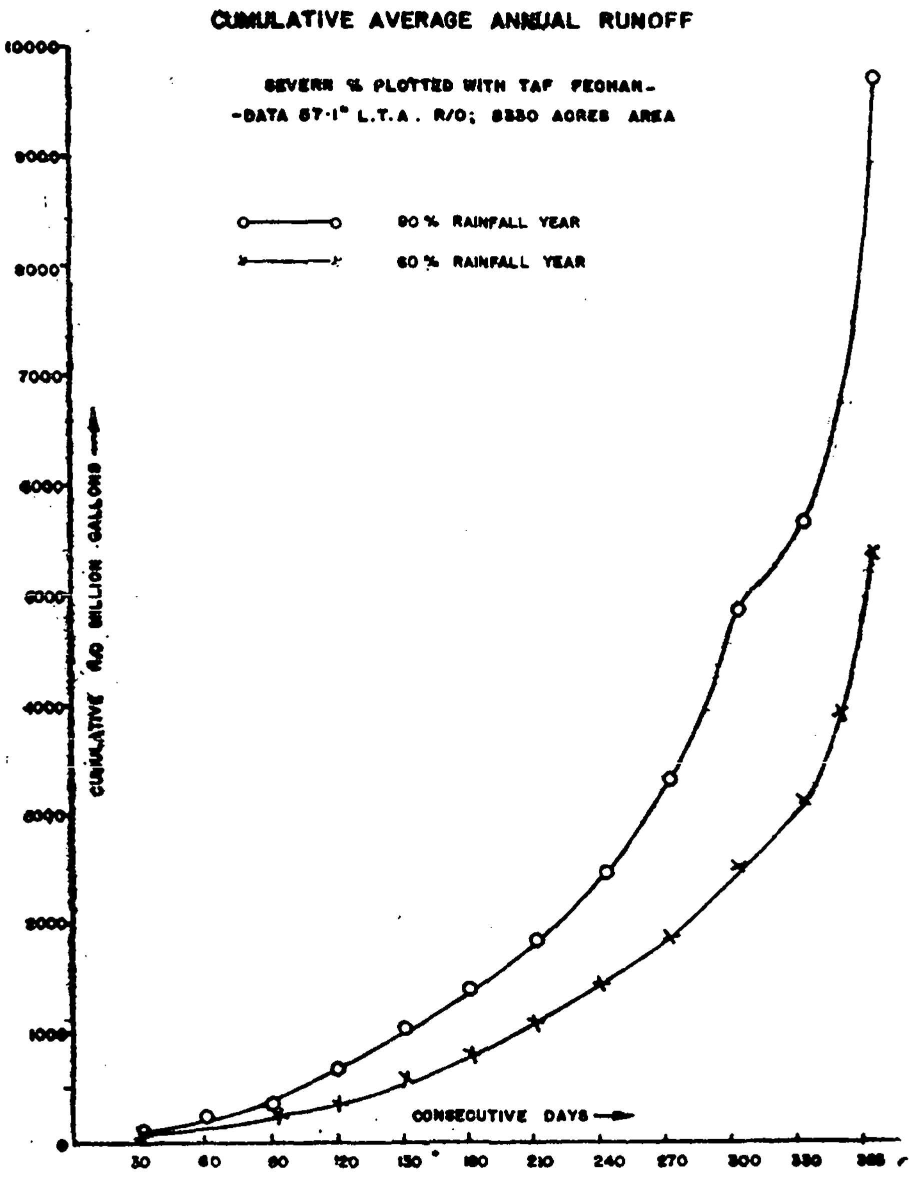

CUMULATIVE AVERAGE ANNUAL RUNOFF
90 % RAINFALL YEAR
60 % RAINFALL YEAR
CUMULATIVE R/O MILLION GALLONS
CONSECUTIVE DAYS
10000
9000
8000
7000
4000
1000
0
30
60
90
120
180
210
240
270
300
330

Fig. 3

CUMULATIVE AVERAGE ANNUAL RUNOFF

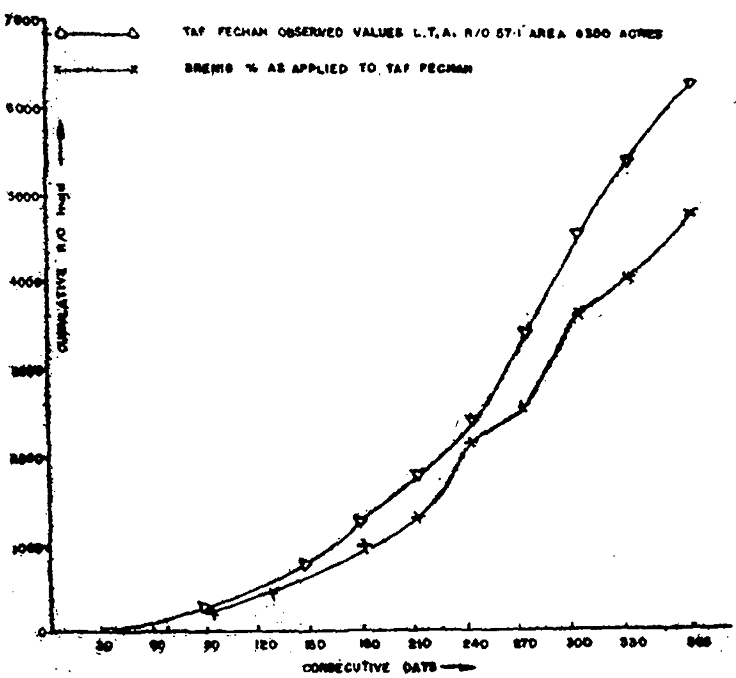
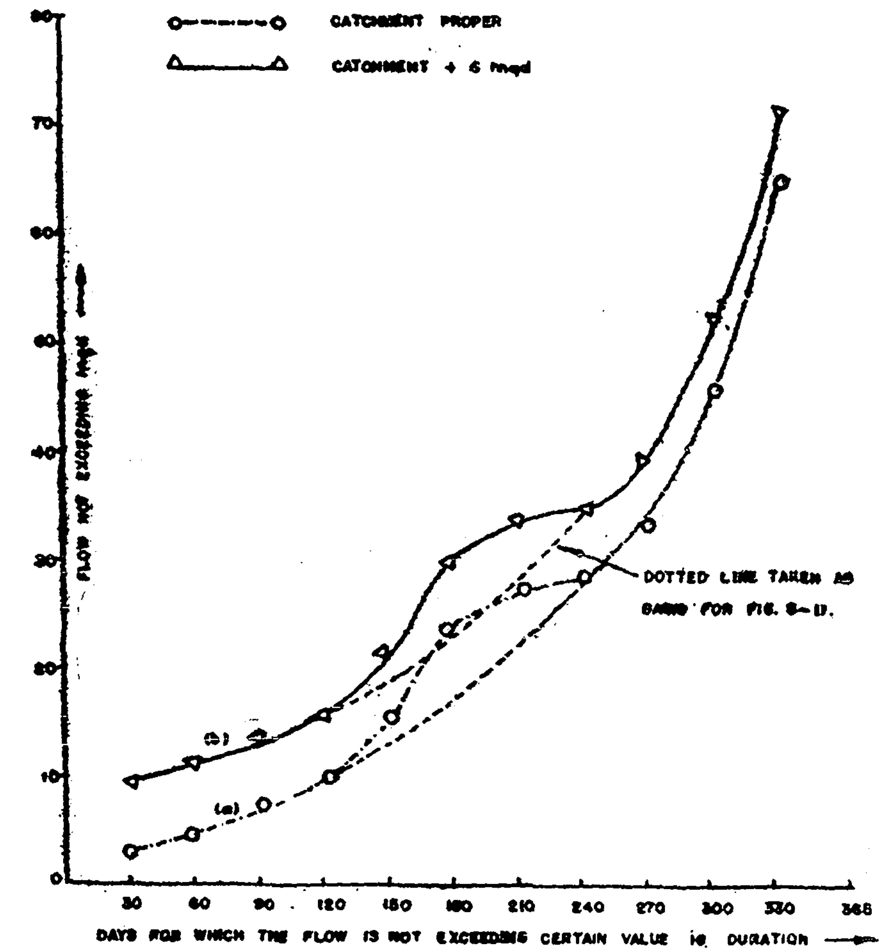


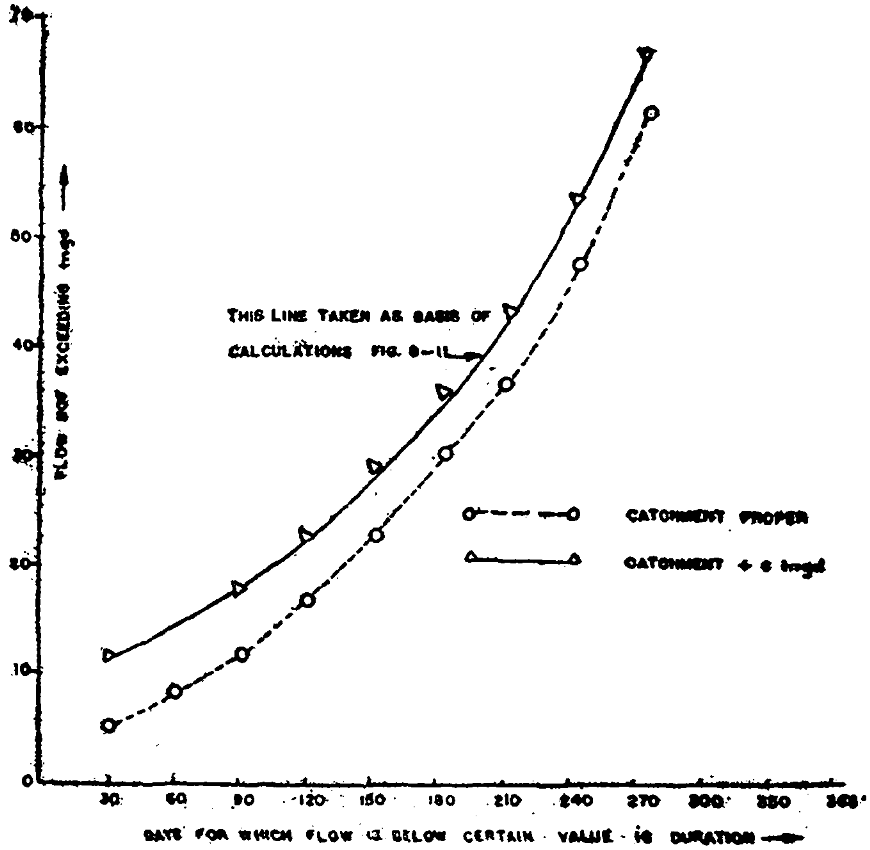
Fig. 4



Frequency Curve for 60% Rainfall Year Based on Windormere % Catchment between Pontsticill and Quaker's Yard

(Ref. Table VI)

Fig. 5



Frequency Curve for 90% Rainfall Year Based on Windormere % Catchment between Pontsticill and Quaker's Yard

(Ref. Table VI)

Fig. 6

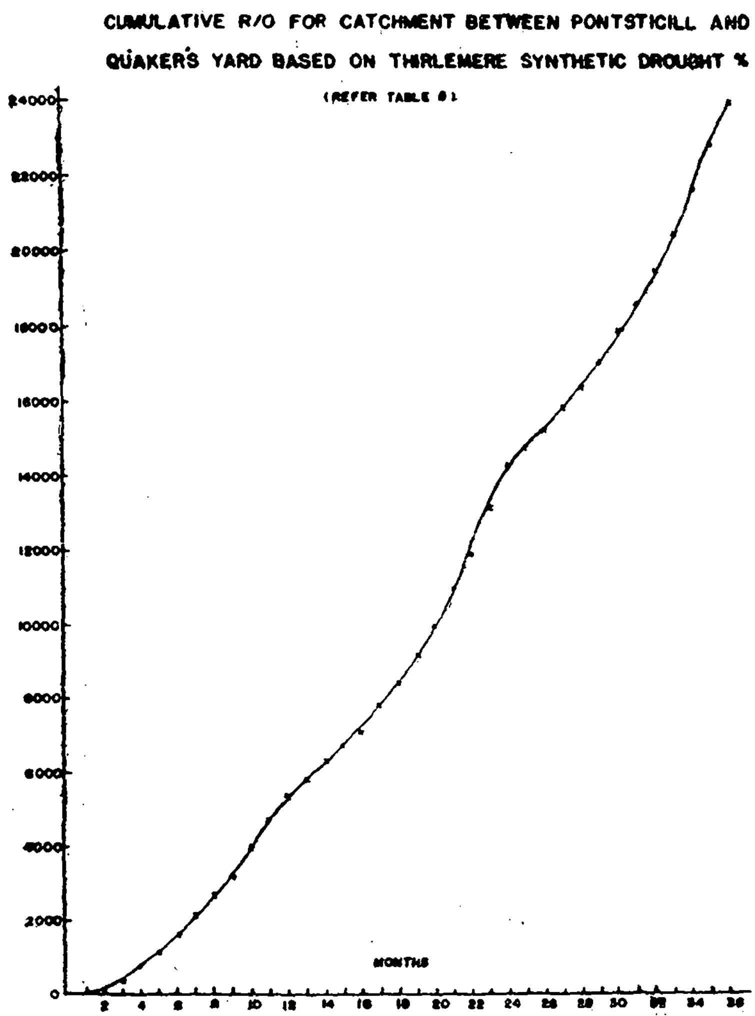

CUMULATIVE R/O FOR CATCHMENT BETWEEN PONTSTICILL AND
QUAKER'S YARD BASED ON THIRLEMERE SYNTHETIC DROUGHT %
(REFER TABLE 8)
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
MONTHS
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36

Fig. 7

FREQUENCY CURVE FOR 60 % YEAR BASIS WINDORMERE

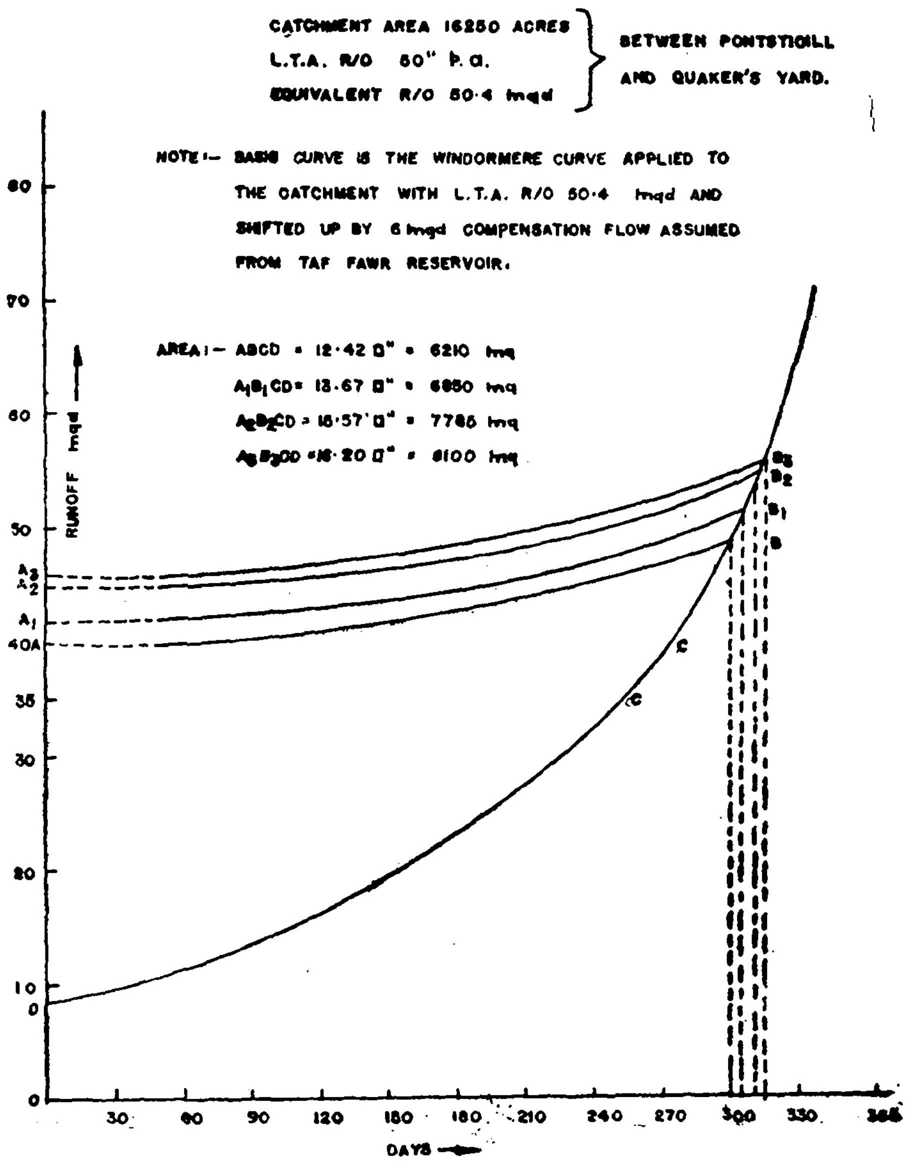
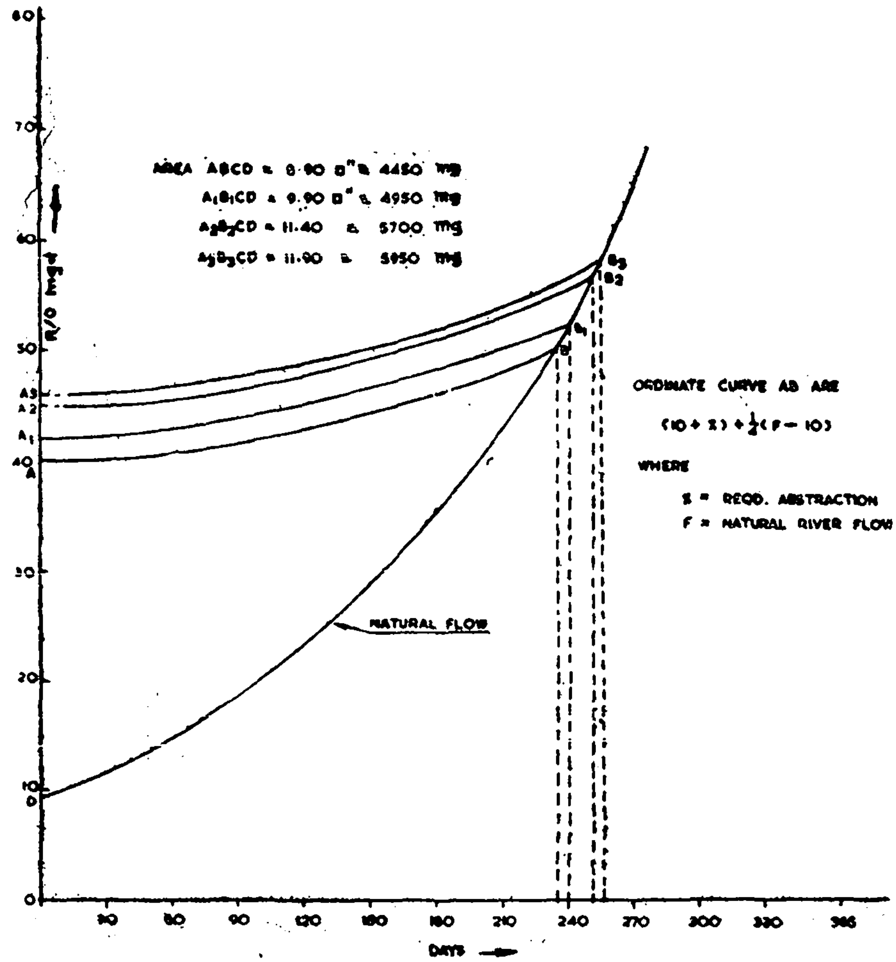


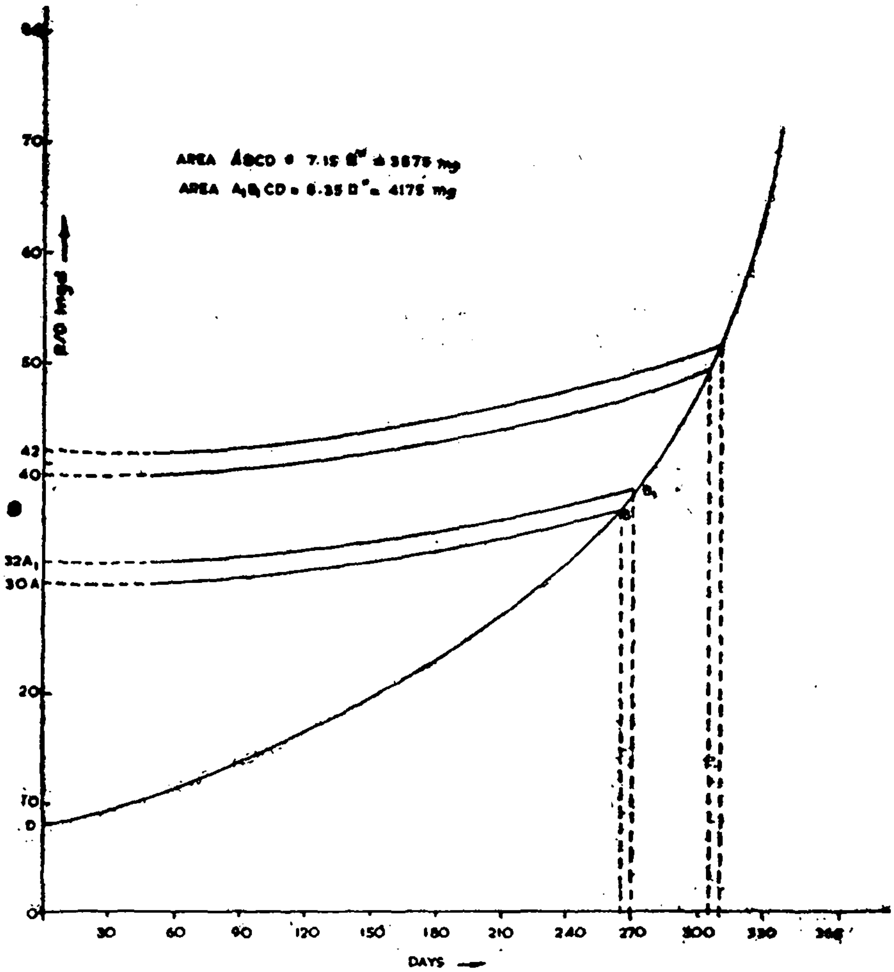
Fig. 8



Frequency Curve for 90% Year (Basis Windormere) Catchment between Pontsticill and Quaker's Yard

(See Note Fig. 8)

Fig. 9



Frequency Curve for 60% Year Abstraction by Scheme 2

(See Note Fig. 8 and 9)

Fig. 10

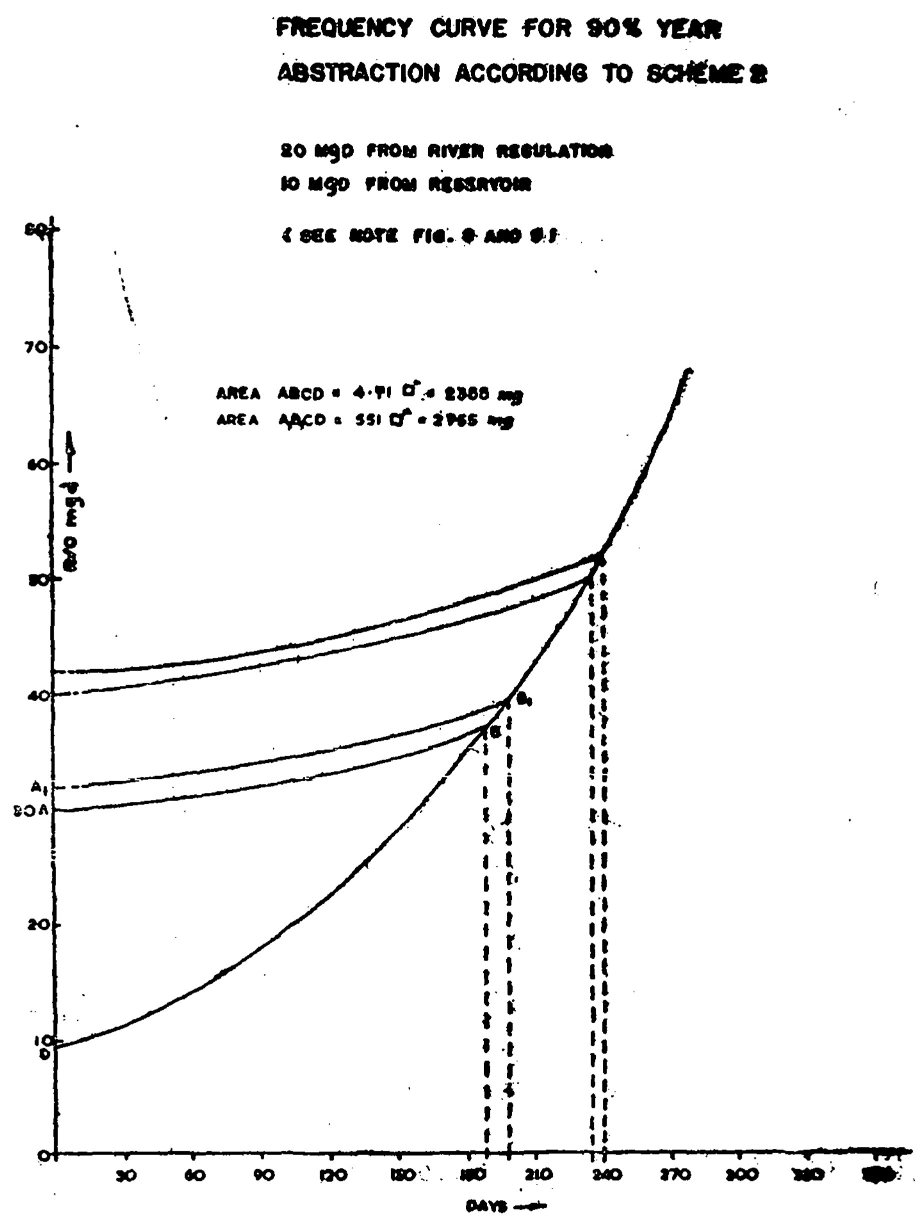

FREQUENCY CURVE FOR 90% YEAR
ABSTRACTION ACCORDING TO SCHEME 2
20 MGD FROM RIVER REGULATION
10 MGD FROM RESERVOIR
AREA ABCD = 4·71 □" = 2355 mg
70
60
50
40
20
10
0
30
60
90
120
210
240
270
300
DAYS

Fig 11

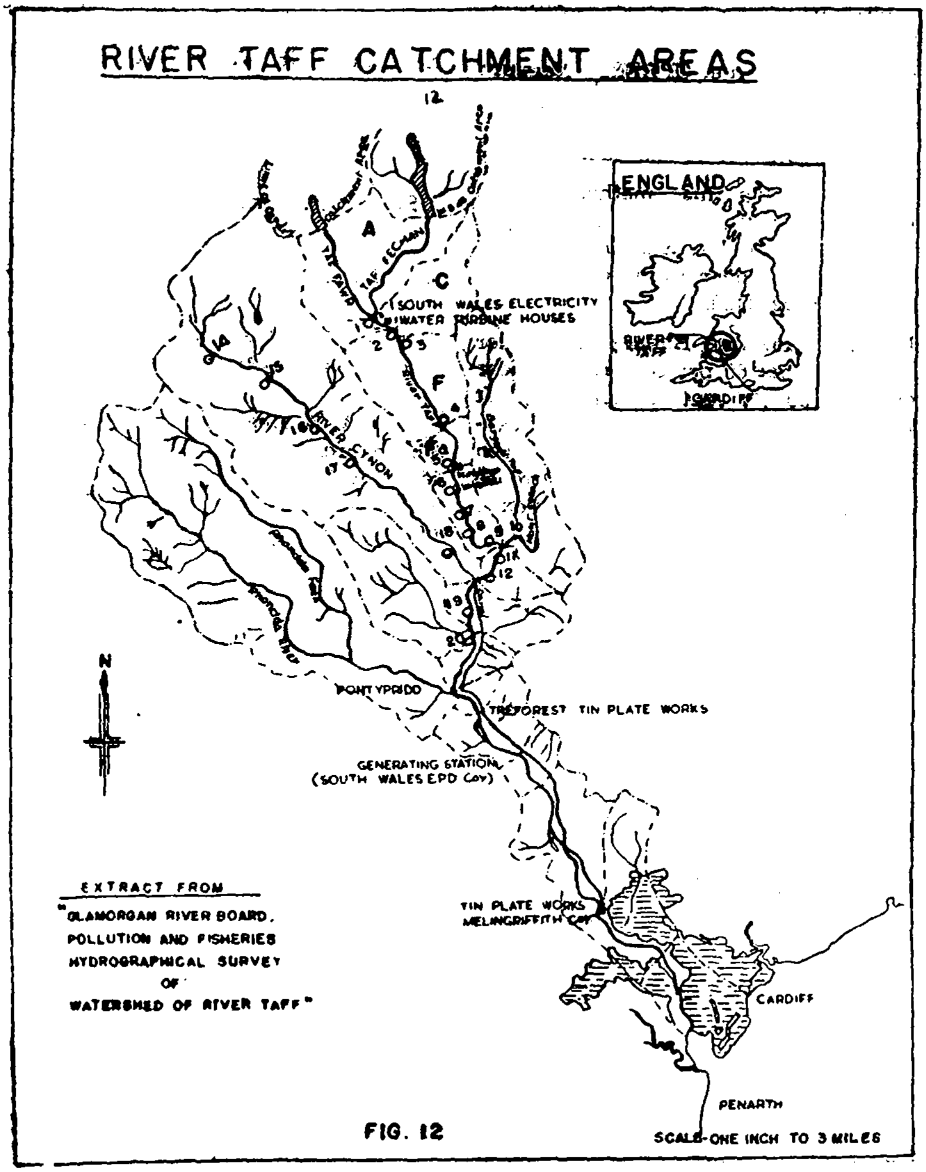

RIVER TAFF CATCHMENT AREAS
ENGLAND
CARDIFF
SOUTH WALES ELECTRICITY
WATER TURBINE HOUSES
RIVER CYNON
PONTYPRIDD
TREFOREST TIN PLATE WORKS
GENERATING STATION
(SOUTH WALES EPD Coy)
TIN PLATE WORKS
MELINGRIFFITH Coy
CARDIFF
PENARTH
EXTRACT FROM
"GLAMORGAN RIVER BOARD.
POLLUTION AND FISHERIES
HYDROGRAPHICAL SURVEY
OF
WATERSHED OF RIVER TAFF"
N
FIG. 12
SCALE-ONE INCH TO 3 MILES

Fig. 12

DISCUSSION

Shri U. J. Bhatt, Baroda : Was the stream under consideration perennial or seasonal? Would your method of abstraction apply to seasonal streams in India?

Shri B. B. Bhalerao, CPHERI, Nagpur : The stream under consideration was perennial. This fact is revealed more clearly in Fig. 7 and Table VII of the paper.

Strictly speaking this method is not useful for seasonal streams. However, in many parts of India like Kerala and Assam where we have longer rainy seasons, this method could be tried.

Shri C. B. Kharkar, Bhilai : The author has assumed that 60 per cent run off year followed by 90 per cent run off years. It would be interesting if he works out regulated reservoir system for three or even more bad years of rainfall, i.e. 60 to 50 per cent run off since such conditions exist in our country.

Shri B. B. Bhalerao, CPHERI, Nagpur : As already mentioned in the text, 60 per cent rainfall year preceeding 90 per cent rainfall years are the expected driest periods in South Wales, U.K. For Indian conditions where we have more severe driest seasons, it is worthwhile to try this method for such conditions.

Shri J. N. Ramaswamy, Madras : How was the expression $10 + \frac{F - 10}{4}$ arrived at? Is it fixed arbitrarily or based upon any mathematical calculations?

Shri B. B. Bhalerao, CPHERI, Nagpur: The expression is an arbitrary one. The idea involved is that the excess of above 10 mgd, let out in the river will take care of evaporation, seepage etc.

Proc. Symp. Community Wat. Supply & Waste Disposal
December 19-21 (1966), CPHERI, Nagpur.

Studies on the Pressure Filter Plant for Small Communities

J. M. DAVE, S. K. GADKARI, P. Y. KHANAPURKAR *and* J. M. TULI
Central Public Health Engineering Research Institute, Nagpur

Introduction

Many Indian small communities in villages, or in small industrial plants, in residential colonies or the army installations using surface water need filtration etc, for making water potable. The author has designed a small economical filter of 5 sq. ft. area to supply approximately 1,000 gph or 20,000 gal/day for a community of 2,000 persons at the rate of 10 gals per capita for drinking purposes. Also there is very little data available on design and operation of pressure filters for practical use. A suitable unit designed to meet need on experimental basis was studied for its performance as suitable treatment process, for small community and its economics.

The Filter

The filter unit is a vertical pressure filter made up of 1/8″ thick Aluminium sheets. The height is 5′-9½″ and diameter is 2′-6″. It is filled with gravel and sand to a height of 3′-2″. The sand has uniformity coefficient of 1·66 and effective size 0.6 mm. (Fig. 1). The raw water is pumped by a centrifugal pump, connected to a 3 hp. motor, through a 2″ G.I. Pipe to the filter. In order to reduce the impact of incoming water on the top layers of sand, a deflector plate is provided. The height of water above sand is nearly 2′-7½″, which provides a detention time of nearly 5 min. at the rate of 1,000 gph.

The underdrain system consists of a 2" G.I. pipe in the center to which 3/4″ diam Aluminium pipes are joined at distance of 6″ c/c. They are 5 in numbers. Out of them one is 26" long, 2 Nos are 23" long and 2 Nos are 13″ long. There are 3/8″ diam. holes at 3″ c/c on these pipes. The details of filter unit itself are given in the Fig. I (a).

To reduce the weight, the filter shell is made of Aluminium and the design pressure is limited to 25 psi. Many steel pressure filters operate well over 50 psi. But operating range of this filter is kept only 20 psi. The designed unit is intended to be mounted on a trailer with either electric or a diesel power unit to operate the pump and as such can be made into a mobile treatment unit, even for emergency purposes. The shell body though made of Aluminium is designed to take vertical and horizontal vibrations due to movement of the

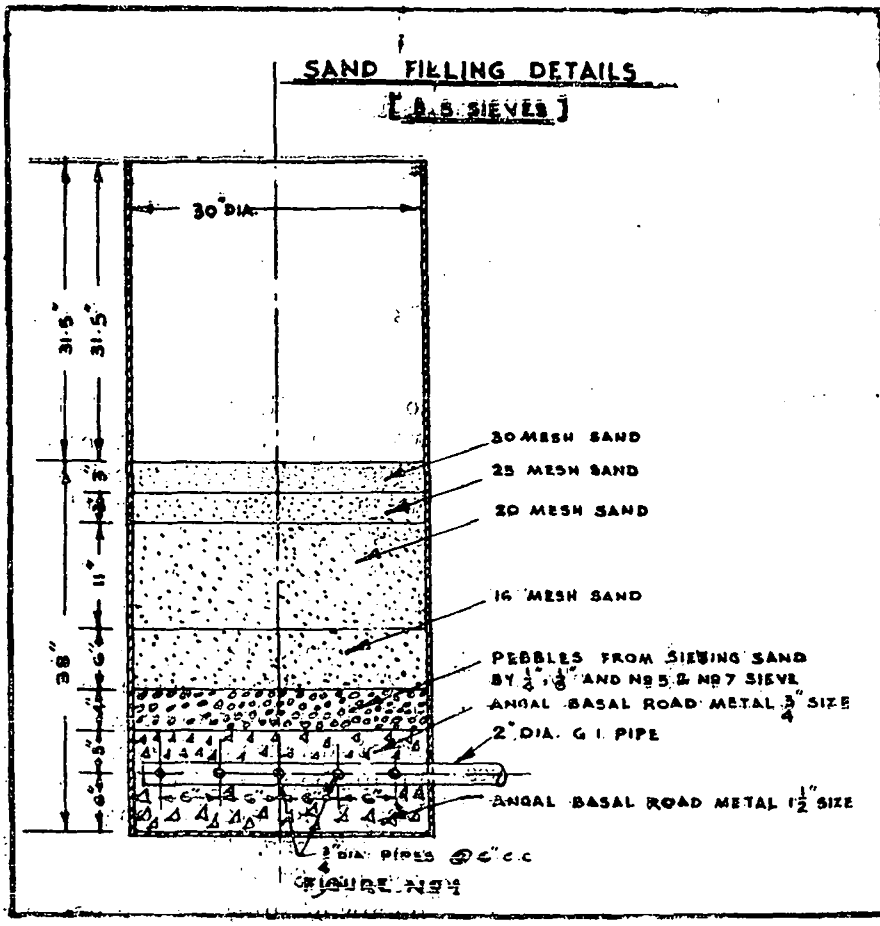


Fig. 1

trailor. The total weight of the entire assembly will be less than 2 tons. This means that the unit can be mounted on a 3 ton truck or can be hauled on the trailor by an ordinary 25 hp. agriculture tractor.

Laboratory Set-up

Due to water shortage, a closed circuit setup was used for testing the filter. In the setup there are two tanks separated by partition wall. Their sizes are 15′ x 15′ x 3′ and 15′ x 6.25′ x 3′. The bigger tank is used for creating artifical turbidities in raw water of required intensity. The small tank is used for collecting filtered water, which is used for backwashing of the filter. The smaller tank has capacity to hold nearly 1200 gals of water and excess overflows into the raw water tank over a small weir. Thus there is constant dilution of raw water by the filtered water being returned from the filter with reduction in the turbidity. To maintain certain range of turbidity, black cotton soil mixed with water is added at regular interval in fixed quantities to the wooden box placed in raw water tank, where the filtered water is returned. (Fig. 2). The range of

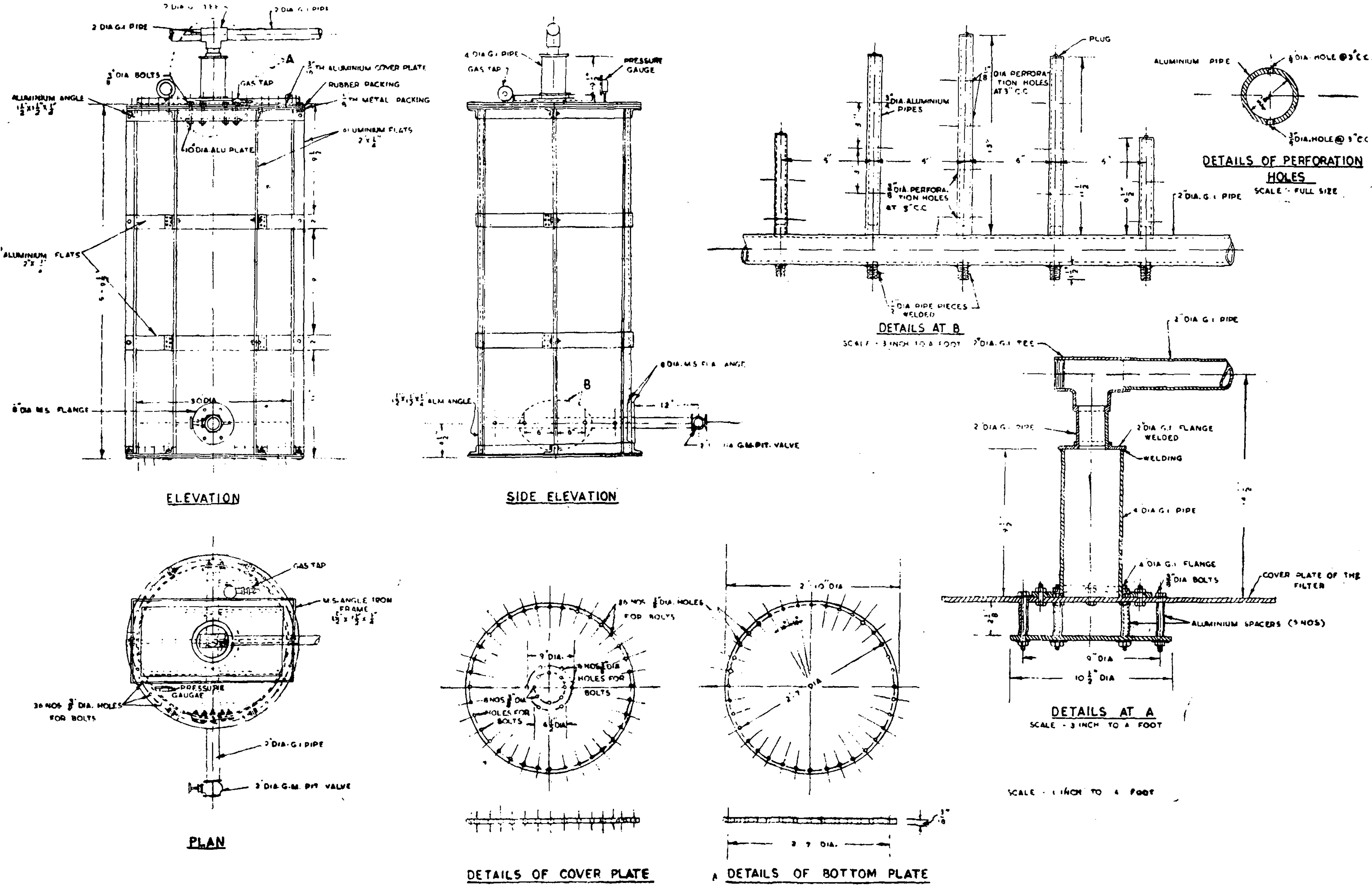

ELEVATION
SIDE ELEVATION
PLAN
DETAILS OF COVER PLATE
DETAILS OF BOTTOM PLATE
DETAILS AT B
DETAILS AT A
DETAILS OF PERFORATION HOLES
SCALE - FULL SIZE
PLUG
PRESSURE GAUGE
GAS TAP
RUBBER PACKING
WELDING
COVER PLATE OF THE FILTER
ALUMINIUM SPACERS (5 NOS)
ALUMINIUM PIPE
2" DIA. G.I. PIPE
4" DIA. G.I. PIPE

Fig. 1 (a)

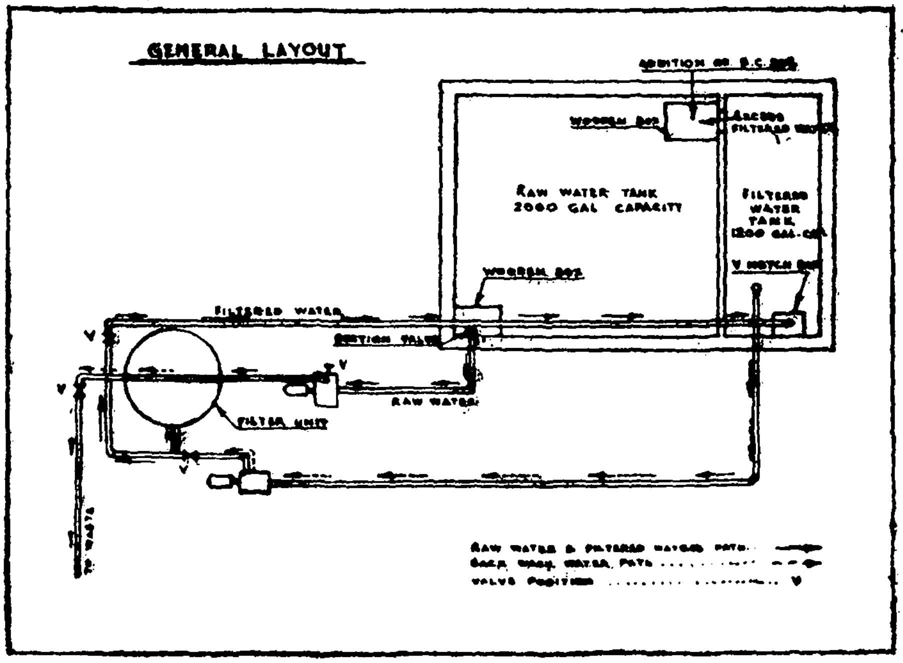


Fig. 2

raw water turbidity used in this experiment was 25 to 120 units.

The raw water suction valve is placed in a wooden box in the corner of bigger tank. The wooden box is open from top and closed from sides to a height of 1'-6". This is done to create vertical baffle in raw water tank. This prevents the easily settlable particles being sucked by the suction valve to the filter and chocking it.

The water applied to the filter was given a requisite alum dose from a jar full of 10 per cent alum solution. The dosing was controlled by measuring the volume of alum solution being fed per minute. The alum solution falling into a funnel was Introduced into the suction-foot valve of the raw water pump, by a rubber tube. It was presumed that the impeller turbulance provided complete flash mixing and no other treatment to the raw water was given. The short detention of 5 minutes in the filter will be sufficient enough to form microflocs and filter was presumed to remove it all. At the initial starting of the filter a shot dose of about 30 ml. was given to raw water for 5 to 10 min. to form the straining layer on the top of the fresh sand but this was not necessary when the filter was in use for about a week and the sand was well coated with flocs.

Test Operation

Both backwash valve and waste water valves are closed. The potash alum solution rate is adjusted and is fed just at the suction level of the suction valve by a long rubber tube. The tube is slightly inserted in the suction valve.

The raw water pump is started and the water is led to the filter. All the air in the filter is expelled from the filter through the air release valve fitted at the top of filter, by operating the raw water discharge valve and the filtered water regulating valve.

When air is completely removed the air release valve is closed and the filtered water regulating valve is fully opened. The filtered water is measured by a V notch box with 90 degrees sharp crested V notch. Then by operating only raw water pump discharge desired flow rate over V notch is maintained. Thus the test run is started by adjusting raw water discharge and maintaining the flow rate. The time of starting and the periodic pressure gauge readings are noted. The flow rate when reduced is controlled manually by increasing pressure on filter by operating raw water valve.

Samples of raw water near the suction valve and filtered water at the V notch are taken after 1/2 hr interval. The filter run is stopped when pressure reaches 20 psi. Then the filter is backwashed by operating necessary valves. The hard rate of backwash used was 20 gal/sq ft/min. The time is noted and the samples of waste water are also collected.

The filter run is stopped in the evening and it is re-started next day, without backwashing, if the filter run is not complete. The filter run is complete if the pressure reaches 20 psi value. It was observed that when filter run was interrupted for a longer period there was a pressure recovery as shown in the graphs and performance table.

When the pressure is at 10 psi value, samples of both the influent and effluent are taken in sterilized bottles for bacteriological analysis. Total bacterial count of these samples at 37°C for 48 hr were noted. And thus the percentage reduction was obtained.

For turbidity determination of influent samples the "Klett Summerson Photoelectric Colorimeter", which is standardised with Jackson Candle turbidimeter was used with the standard blue filter of wave length 420 millimicrons with 10 mm tube. For determination of the low effluent turbidities the 40 mm precision absorption cell was used instead of 10 mm tube on the same instrument. This combination was also standardised for turbidity readings with suspensions of fuller's earth and its various dilutions.

For pH determination the "Beckman Zeromatic II pH meter" was used.

Results

The results presented here are only for period of approximately four months operation and due to initial difficulty of turbidity maintenance in the raw water only limited data is included in this report. The effect of closed circuit flow did not appear to be significant except that alkalinity was reduced and the pH was changing.

The observations as tabulated in Tables I, II & III indicate that the effluent is of high grade quality showing practically 100% removal of turbidity even with variable water quality.

The pH values of the influents are in the range of 8.0 to 8.2 and the effluent values are in the range of 7.7 to 8.0.

TABLE I

RATE OF FILTRATION—2.884 gal/sq ft/ min. (850 gph)

Alum dose 15 mg/lit

S.No.	Av. Inf Turbidity units	Filter Run		Total Quantity per run in gal.	Back Wash					Av. Effluent Turbidity units	% Removal of Turbidity	pH		% Bact. Reduction
		Corrected hr. min.	Total hr. min.		Time in min.	Quantity in gal.	% B.W. Water used	Waste Water Turbidity units	Corrected B. W. Water %			Av. Inf.	Av. Eff.	
1)	43	11-13	12-12	10.370	4	402	3.88	106	4.21	*less than 0.5	100	8,13	7.98	38
2)	47	10-50	13-55	11,830	3	408	3,45	105	4.43	—do—	100	8.08	7.94	54.9
3)	60	19-25	29-15	24,012	5	441	1.83	85	2.67	—do—	100	—	—	—
4)	66	7-40	9-00	7,650	4	445	5.81	93	6.82	—do—	100	8.22	8.03	14.5
5)	95	8-52	9-20	7,953	4	402	5.05	116	5.35	—do—	100	8.12	7.96	28
6)	119	8-16	11-53	10,098	4	422	4.17	115	6.0	—do—	100	8.12	7.95	29
7)	123	9-50	11-20	9,633	4	392	4.08	91	4.68	—do—	100	8.19	8.08	29.06

*Could not be read on Klett Summerson Photoelectric Colorimeter using 40 mm precision absorption cell.

TABLLE II

RATE OF FILTRATION—3.318 gal/sq ft/min. (975 gph)

Alum dose 15 mg/lit

S.No.	Av. Inf. Turbidity units	Filter Run: Corrected hr. min.	Filter Run: Total hr. min.	Total Quantity per run in gal.	Back Wash: Time in min.	Back Wash: quantity in gal.	Back Wash: % B. W. Water used	Back Wash: Waste Water Turbidity units	Back Wash: Corrected B. W. Water %	Av. Effluent Turbidity units	% Removal of Turbidity	pH: Av. Inf.	pH: Av. Eff.	% Bact. Reduction
1)	39	3-37	3-37	3526	3	356	10.1	24	10.1	*less than 0.5	100	—	—	—
2)	42	2-20	2-35	2518	3	257	10.2	57	11.3	3.3	92	—	—	—
3)	53	4-54	5-19	5183	3	343	6.6	40	7.2	1	98.1	—	—	—
4)	60	2-25	2-25	2365	3	356	15.4	21	15.4	*less than 0.5	100	—	—	—
5)	65	2-40	2-40	2600	3	356	13.7	28	13.7	—do—	100	—	—	—
6)	76	2-45	2-45	2681	3	383	14.3	43	14.3	—do—	100	—	—	—
7)	76	3-02	3-02	2980	3	356	12.03	50	12.03	—do—	100	—	—	—
8)	86	3-15	3-15	3168	3	290	9.15	87	9.15	2.0	97.6	—	—	—
9)	91	2-55	2-55	2844	3	356	12.5	45	12.5	3.0	96.6	—	—	—
10)	114	4-08	5-03	4923	3	365	7.42	50	9.05	2.0	98.25	—	—	—

* Could not be read on Klett Summerson Photoelectric Colorimeter using 10 mm precision absorption tube.

Note:—When corrected and total runs are shown same, it means that it is a continuous run.

TABLE—III

RATE OF FILTRATION—3.74 gal/sq ft/min (1100 gph)

Alum dose 15 mg/lit

S.No.	Av. Inf. Turbidity units	Filter Run: Corrected hr. min.	Filter Run: Total hr. min.	Total Quantity per run in gal.	Back Wash: Time in min.	Back Wash: Quantity in gal.	Back Wash: % B. W. Water used	Back Wash: Waste Water Turbidity units	Back Wash: Corrected B.W. Water%	Av. Effluent Turbidity units	% Removal of Turbidity	pH: Av. Inf.	pH: Av. Eff.	% Bact. Reduction
1)	27	6-48	7-50	8616	3	312	3.62	88	4.16	less than 0.5	100	—	—	—
2)	46	8-00	8-00	8800	3	327	3.27	93	3.72	—do—	100	—	—	—
3)	46	6-04	6-04	6673	3	297	4.45	94	4.45	—do—	100	—	—	—
4)	50	6-08	6-08	6746	3¼	339	5.03	70	5.03	—do—	100	—	—	—
5)	65	4-58	5-38	6196	3	327	5.28	83	6.06	—do—	100	7.99	7.825	
6)	80	6-45	7-05	7718	4	392	5.07	74	5.26	—do—	100	8.11	7.94	15
7)	105	3-30	5-20	5866	3	343	5.85	33	9.05	—do—	100	—	—	—
8)	110	4-44	6-31	7168	4	431	6.02	86	8.26	—do—	100	8.01	7.76	—
9)	112	5-46	5-46	6343	4	418	6.6	99	6.6	—do—	100	7.91	7.73	53.4

• Could not be read on Klett Summerson Photoelectric Colorimeter using 40 mm precision absorption cell.

Note:—When corrected and total runs are shown same, it means that it is a continuous run.

Average bacterial reduction is 32.9 per cent from the reading obtained so far.

The alum dose of 15 mg/lit. applied gave very good results and was based on earlier experiments not presented here due to faulty turbidity setup. The other values tried earlier were 5 and 10 ppm but did not work satisfactorily. The value of alum for average turbidity upto 100 units should not be more than 20 mg/lit. This set up was designed for low range turbidity i.e. 25 to 120 mg/lit. only; as described earlier this type of filter without any pretreatment can handle only such waters.

The backwash water requirements range from 2 to 9 per cent for flow rates of 2.88 to 2.74 gal/sq ft/min. depending on turbidity of raw water.

The filter runs vary from 9 hr to 28 hr depending on flow rate and the turbidity level. Interrupted runs were definitely longer than the continuous ones.

The average cost of water treatment based on the above results for a medium flow of 1000 gph for the filter; as worked out are as follows:

Capital Cost

Aluminium Filter Shell	Rs. 2,580.00
Sand 15 cu ft. @ Rs. 2/- cu ft.	Rs. 30.00
Gravel 10 cu ft. @ Rs. 1/- cu ft.	Rs. 10.00
Piping lumpsum	Rs. 450.00
Raw Water Pump	Rs. 1,500.00
Backwash Water Pump	Rs. 1,500.00
Installation charges	Rs. 700.00
... ...	Rs. 6,770.00
For diesel operated engines extra cost	Rs. 2,000.00
Total	Rs. 8,770.00

Operational Cost :

1) Alum: @ 15 mg/lit. for 1.000 gph for 20 hr a day

$$=\frac{1000 \times 4.55 \times 15 \text{ gm/hr}}{1000}$$

$=68.25$ gm/hr

for 1 day (20 hr) = 1365 gm

for 30 days = 40950 gm, say 41 kg.

Rate of Alum — Rs. 300/- for 1000 kg.

The monthly Alum cost = Rs. 12.30

2) Power Consumption :

$$\text{B.H.P.} = \frac{\text{gpm (Av. pressure in psi} \times \frac{144}{62.4} + \text{Suction Lift)}}{3300 \times n}$$

$$\text{kw.} = \frac{\text{gpm} \times \text{(Av. pressure in psi} \times \frac{144}{62.4} + \text{Suction Lift)}}{3300 \times n \times 0.746}$$

Taking suction lift = 20′

n = efficiency of motor & pump = 50%

Power charges @ Rs. 0.15/kwh

Daily filter run for 20 hr.

$$\text{Power charges per day} = \frac{1000}{60 \times 3300} \times \frac{(10 \times 2.31 + 20)}{0.5 \times 0.746} \times 20 \times \frac{15}{100}$$

= Rs. 1.75 per day

The monthly power charges = Rs. 52.50

3) Attendant—one per month ... ... Rs. 150.00

4) Miscellaneous repairs per month (Rs. 600.00 per year) ... ... Rs. 50.00

Total running charges per month = Rs. 264.80

Total quantity of filtered water per day

= 20,000—Water required for backwashing gals

[At 100 gph (at the flowrate of 3.33 gals/sq ft/min) from the graph for turbidity range of 55 to 85 ppm the back wash water percentage is 4.5%]

= 20,000—900 gals per day of filtered water

= 19,100 gals per day of filtered water

For 30 days operation = 19100 x 30 gals of filtered water.

Treatment charges for 1000 gals of filtered water (including miscellaneous repairs)

$$= \text{Rs.} \frac{264.80 \times 1000}{19100 \times 30}$$

= Rs. 0.46 for 1000 gals of filtered water.

Discussions

The study was undertaken to assess the performance of the pressure filter for its applicability as a suitable treatment process for small communities.

The filter was operated at the following three rates:—

1) At 2.884 gal/sq ft/min. (850 gph)
2) At 3.318 gal/sq ft/min. (975 gph)
3) At 3.74 gal/sq ft/min. (1100 gph)

Due to operational difficulty at 975 gph flow rate irregular and shorter filter runs were obtained and the results are not much reliable. The turbidity during this stage could not be properly maintained and large settlable particles of clay were being sucked through the suction valve, thus resulting into choking of the filter. This trouble was later overcome when intake arrangements were modified by the use of wooden boxes, as described earlier. However, the results are included here to give a true picture of operational difficulties.

The rate of backwash water was usually kept at 20 gal/sq ft/min. There were no troubles caused by break through of turbidity, at any time, even with high filtration rate of 3.74 gal/sq ft/min. and terminal pressure of 20 lb/sq in.

The results obtained show that the effluent is of very good quality and the turbidity removal was practically 100% at all flow rates. During operation it was observed that when the filter runs were interrupted for longer time it showed definite pressure recovery. This pressure recovery extended the filter run by the time of operation required to reach that pressure again. When more than one interruptions were there, as in case of filter run for 850 gph for average influent turbidity of 60 units. (Fig. 3-b). The filter yield were considerably more.

The graphs plotted in Figs. 3 (b), 3 (c), 4 (b) show actual pressure vs. time relationship. The exact relationship between pressure and turbidity with time cannot be ascertained from these graphs due to limited data but it definitely shows that the rise in pressure is not a straight line function. Further work on this may give more information on pressure behaviour. The effect of interruption also makes it difficult to draw definite conclusions. Attempts have been made in Fig. 3 (a) & 4 (a) to give a tentative graph of uninterrupted behaviour of filter by correcting the runs. The correction applied is the omission of the extra time to obtain the same pressure when the last run was closed. The corrected new run was assumed as continuous for the comparision. The corrected pressure lines are drawn assuming that the pressure will follow the same trend if the filter run was not interrupted.

The reasons of the pressure recovery phenomenon of the pressure filter were not clear from the limited data. But it can be explained that due to high pressure, the top layer formed by the flocs on the sand bed gets compressed and becomes dense creating flow resistance to the water. When the pressure on the filter is reduced to zero this top layer expands and probably dis-

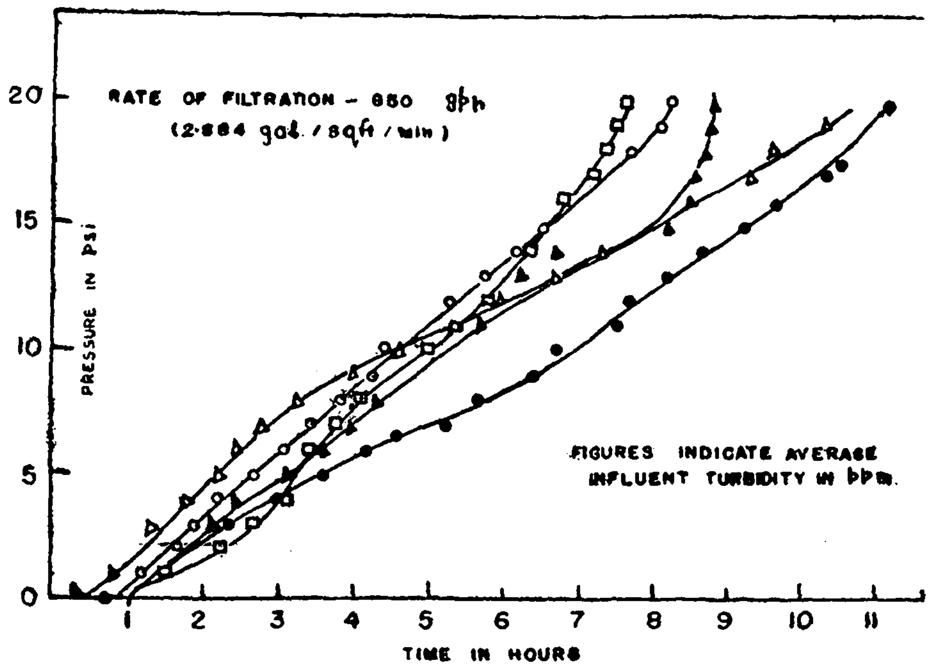

RATE OF FILTRATION – 850 gph
(2·884 gal./sqft/min)
PRESSURE IN Psi
FIGURES INDICATE AVERAGE
INFLUENT TURBIDITY IN ppm.
TIME IN HOURS
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11

Fig. 3 (a)

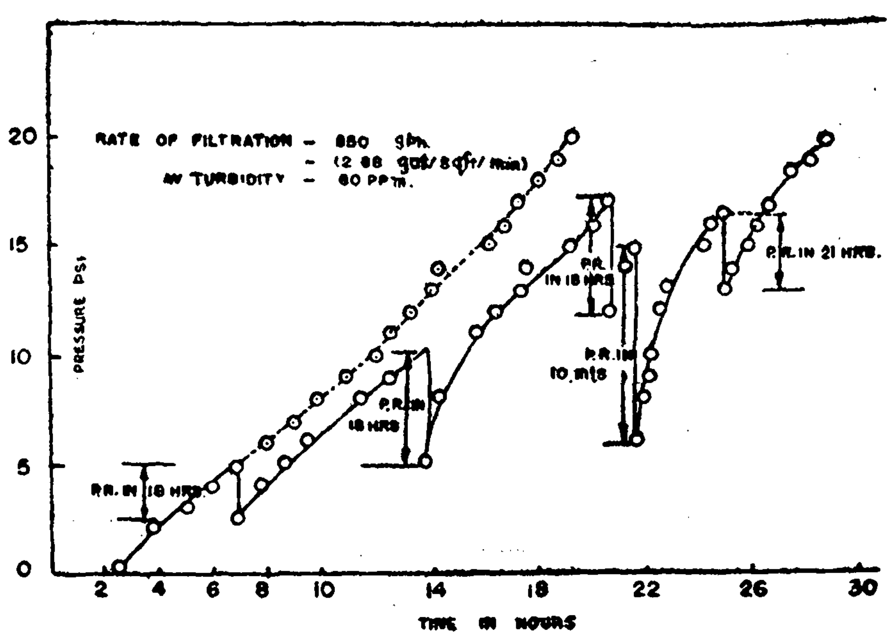

RATE OF FILTRATION – 850 gph.
– (2 88 gal/sqft/min)
AV TURBIDITY – 60 PPm.
PRESSURE Psi
P.R. IN 18 HRS.
P.R. IN 18 HRS
P.R. IN 18 HRS
P.R. IN 10 mts
P.R. IN 21 HRS.
TIME IN HOURS
0
5
10
15
20
2 4 6 8 10 14 18 22 26 30

Fig. 3 (b)

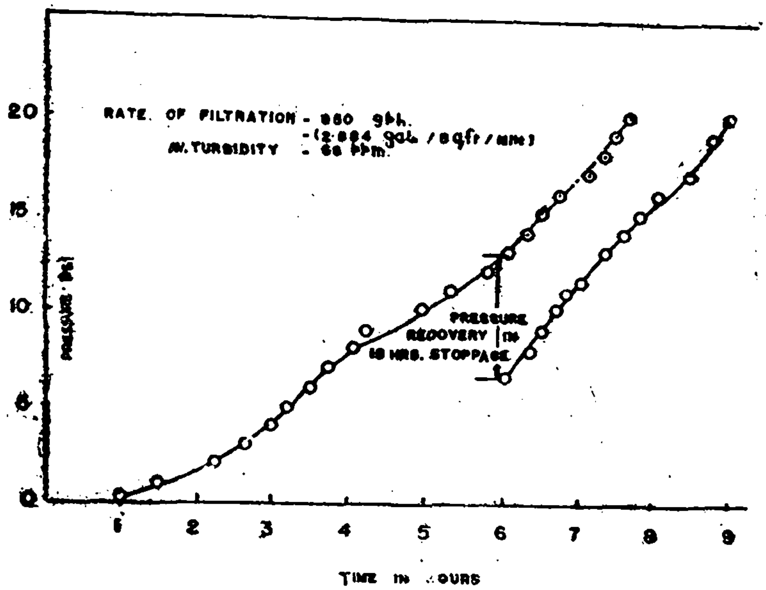

RATE. OF FILTRATION
AV. TURBIDITY
PRESSURE
RECOVERY
STOPPAGE
TIME IN HOURS
20
15
10
0
1
2
3
4
5
6
7
8
9

Fig. 3 (c)

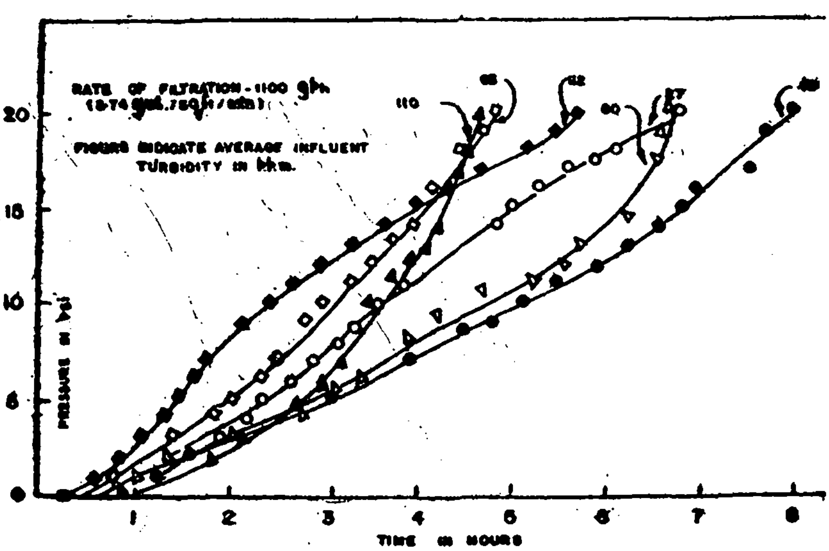

RATE OF FILTRATION - 1100 gph
FIGURES INDICATE AVERAGE INFLUENT
TURBIDITY IN ppm.
110
TIME IN HOURS
20
15
10
5
1
2
3
4
5
6
7
8

Fig. 4 (a)

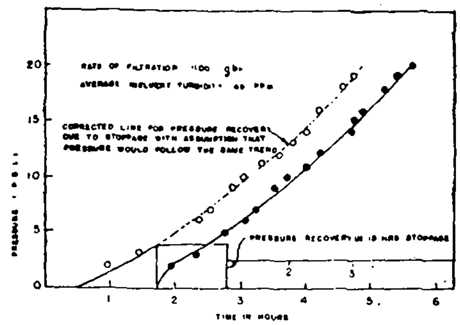


Fig. 4 (b)

integrates creating higher permeability. Thus when the filter is restarted the pressure is nearly reduced to zero. Some more studies are required to confirm this and further work is proposed for it on this filter too.

The graphs for flowrate vs. filter run in hours [Figs. 5 (a) and 5 (b)] show that for higher range of turbidity and higher rate of filtration the filter runs are shorter and vice-versa, for the same loss of head. The relationship appears to be a straight line.

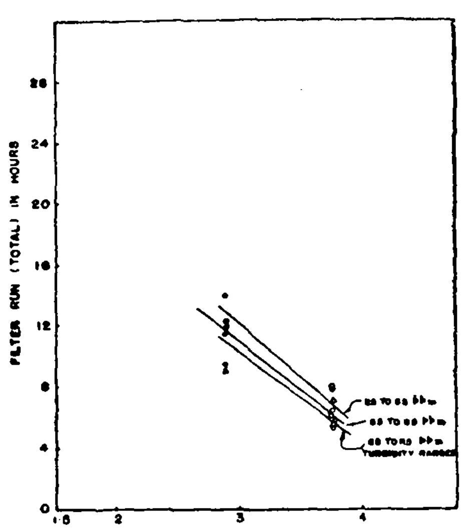


Fig. 5 (a)

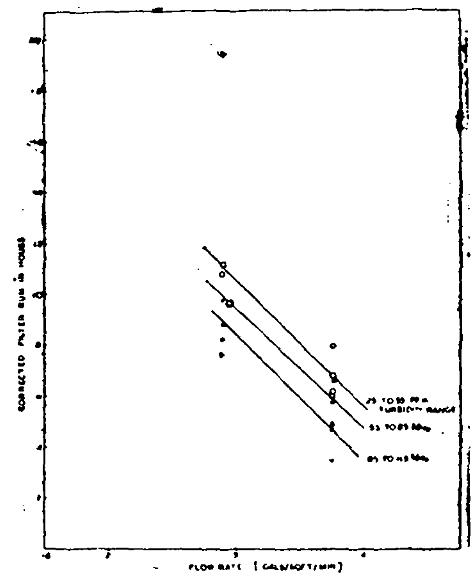


Fig. 5 (b)

The plot for flowrate vs. backwash water percentage [Fig. 6 (a)] shows that at higher rate of filtration of 3.74 gal/sq ft/min. and at higher turdity range of 85 to 115 units the backwash water percentage is as high as 6.15%. For the 55 to 85 and

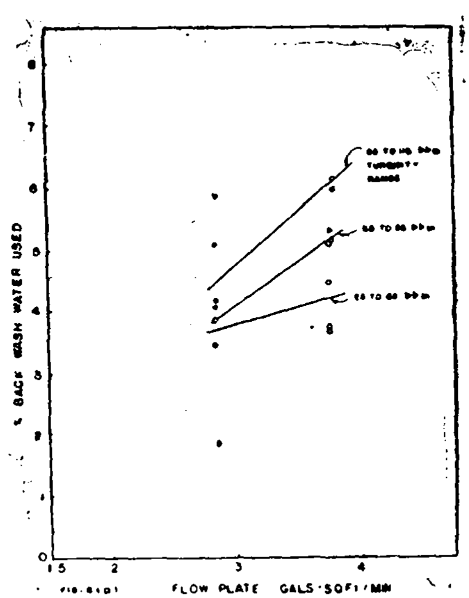


Fig. 6 (a)

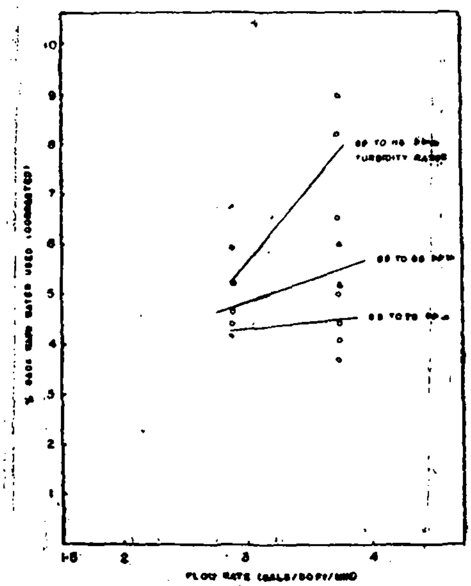


Fig. 6 (b)

25 to 55 units tubidity ranges, the backwash water percentage required ranges from 2 to 6 percent of the total out put.

The corrected run [Fig. 6 (b)] shows higher wash water percentage due to reduced through put of filter; even then, they are within the reasonable range of 12 to 3 percent. Normally pressure filters operated without pretreatment use backwash water as high as 15% of the output.

The operational cost comes to Rs. 264.80 per month. The cost of treatment of water including repairs comes to Rs. 0.46 per 1,000 gallons of filtered water. These costs are for water delivered at the outlet of the filter. Extra power may be required as per final lift in actual condition.

Conclusions

1. This design of pressure filter and its study show that it can be used as reasonably economical treatment process to give safe drinking water from surface sources with turbidity upto 120 units.
2. The pressure build up vs. the filter run relationship needs further study to understand the working of these filters.
3. The pressure recovery phenomenon can be further investigated and can be used effectively for elongating filter runs.
4. This pressure filter design has shown that backwash water requirement can be kept low upto 12 percent with high pressure of 20 psi and high flow rate of 3.74 gal/sq ft/min.
5. There is no break through of turbidity through the sand bed even with high rate of filtration of 3.74 gal/sq ft/min. and 20 psi pressure.

DISCUSSION

Shri S. Rajagopalan, CPHERI Zonal Centre, Calcutta: What is the efficiency of bacterial reduction in the filters studied? Have any observations been made with increasing bacterial load in the influent and if so, what are the results?

Shri J. M. Dave, CPHERI, Nagpur: The values of percentage bacterial reduction obtained are reported in tables. Average bacterial reduction obtained was 32.9 per cent.

It was observed that the bacterial load was fairly constant in the influent. Average influent load was found to be 4.2 x 10^4 organisms per ml.

Shri P. Balakrishna Rao, CBRI, Roorkee: Is the loss of head of 40 ft., as reported in the paper, a pre-determined design criteria? If not. what is the reason for such a great loss of head?

Shri J. M. Dave, CPHERI, Nagpur: Many steel pressure filters operate well over 50 psi. This unit is made up of aluminium to save weight and the ultimate pressure it can take is only 25 psi. The operation pressure of 20 psi nearly equals to a loss of head of 46 feet. This filter was designed to supply water for small communities with zero pressure at delivery end.

Shri Susikaran, Madras: How does the extra loss of head occur, when the loss of head through the sand bed is as in a rapid sand filter? Is the extra loss of head due to longer run?

Shri J. M. Dave, CPHERI, Nagpur: The extra loss of head occurred due to fine sand, and the resistance offered by the sand bed to the water being filtered. As mentioned earlier, it could have been even higher but the stresses in the aluminium did not allow it. This extra loss of head definitely gave longer runs as compared to the standard rapid sand filters. which operated without any pretreatment.

Shri M. Miakhar, Madras: How was the turbidity for the experiment obtained? What were the materials used? What was the turbidity of the filtrate?

Shri J. M. Dave, CPHERI, Nagpur: For the experimental purposes artificial turbidity was created by the addition of black cotton soil to raw water in fixed quantities at regular intervals. Details are given in the text of the paper.

The average turbidity figures of the filtrate are given in the tables. In the case of both the runs at 2.884 gal/sq ft/min. and 3.74 gal/sq ft/min. the average filtrate turbidity was found to be less than 0.5 units.

Shri A. D. Bhide, Roorkee: The authors report that there was no turbidial break through. But the bacterial efficiency has been given as only 32.9 per cent. I would like the authors to enlighten this point.

The filter runs at higher rates were reduced. Did the total output also reduce?

Shri S. K. Gadkari, CPHERI, Nagpur: The criteria for judging the filter performance was turbidity alone. Samples for turbidity analysis were taken at ½ hour interval whereas only one sample was taken per run for bacterial analysis when the pressure was 10 psi. Many a times erratic results were obtained in the case of bacterial reduction and as such the results are not reliable.

It was observed on corrected run basis that for the same range of turbidities at higher filtration rates, the total output decreases.

Prof. Patwardhan, Roorkee: I would like to know how the uniformity coefficient of 1.6 was fixed at, the type of turbidimeter used, and whether the quality of water was found out after break through.

Shri J. M. Dave, CPHERI, Nagpur: The Uniformity Coefficient of 1.6 was arrived at by trial and error, using 30 mesh sand at top. The actual arrangement of the sand in the filter is shown in Fig. 1.

Klett Summerson photoelectric calorimeter which was standardized with Jackson Candle turbidimeter was used for turbidity analysis.

When the effluent turbidity was observed to be more than 5 units, it was regarded as break through and the filter was stopped for backwash.

Shri A. S. Hariharan, Madras: What is the nature of alum used? Was there any residual aluminium in the filtered water?

Shri S. K. Gadkari, CPHERI, Nagpur: In the initial stages potash alum was used and later on ferric alum obtained from Kanhan water works was used.

As a small dose. alum in the order of about 15 mg/lit. was used. We did not check for the residual aluminium in the filtrate.

Shri B. P. Varma, LSGED, U.P.: Has the economics of allowing 40 ft loss of head in the filter been taken into account in the operational cost?

Shri J. M. Dave, CPHERI, Nagpur: Yes, it has been worked out and taken into account.

Proc. Symp. Community Wat. Supply & Waste Disposal
December 19-21 (1966), CPHERI, Nagpur.

Defluoridation of Community Waters: A Problem

T. S. BHAKUNI
Central Public Health Engineering Research Institute, Nagpur

Harmful effects due to ingestion of excess fluorides through drinking waters are well known. Amounts more than 1.0 mg/lit. cause mottling of dental enamel and affect different parts of skeletal system both in human beings and cattle. In fact, it has been reported (1) that same dose of fluoride causes more severe effects under the conditions available in this country possibly due to higher temperatures prevalent and low nutritional value of the diet.

In India, fluoride bearing waters have been reported to occur in several parts of the country like Madras (2, 3) Andhra Pradesh (4-7), Punjab (8-11), Bihar (12), Kerala (13), Maharashtra (14), and Rajasthan (15, 16). It has been observed that in such areas excess amounts of fluorides are generally present in well waters and their consumption is the cause of endemic fluorosis in those areas.

Inspite of the attempts made by various workers no suitable method for removal of excess fluorides from drinking water which could be of direct application in rural areas, is developed. Any method useful for the above purpose should be simple requiring not much of complicated techniques and cheap in capital as well as running costs. Fluoride exchange material used should be readily available at reasonable rates. The process, as far as possible, should avoid use of corrosive or toxic reagents eg. acids and alkalis. Tests used for assessing the plant efficiency should be quick, simple and easy.

Defluoridating Substance for Proposed Pilot Plant

Sulphonated carbons have been prepared from various carbonaceous waste materials by Sastry *et al.* (20) at Indian Institute of Science, Bangalore and Bhakuni and Sastry (21) in this Institute. These carbons when impregnated in filter alum solution (1-2 per cent) show good fluoride removing efficiency. Carbon from saw dust developed by this Institute removes fluorides to the extent of 1600-2400 mg as against 500-600 mg per kilogram of material, in case of other carbons (20). Therefore, it has been proposed to use sulphonated saw dust carbon in this Pilot Plant on account of its better efficiency and also due to easier availability of raw material (saw dust) in large scale. The spent substance can be regenerated with a passage of filter alum solution (1-2 per cent). Filter alum has been chosen as a regenerant because of its good regenerating capacity and noncorrosiveness. In an attempt to popularise the technique in rural areas a house-hold defluoridation unit (Fig. 1) has been designed. Fluoride containing water is allowed to percolate through the exchange media (1 cu ft) and collected for drinking purposes. Sulphonated saw dust developed in this Institute has been proposed to be used in such units.

Quite recently, a problem of removal of excess fluorides has been referred to the Institute by P.H.E. Department of Rajasthan. Water sample was tested and a treatment plant for fluoride removal has been designed.

Source of Water

Gangapur is a small township with a population of 10,000 and is situated in Tahsil Bhilwara in Rajasthan. The first community water supply scheme for this township was undertaken by the State Public Health Engineering Department about an year back. The proposed source of water supply is about 100 ft deep abandoned mica mine pit (quarry) which is full of water. The water level stands at a depth of about 20 ft below the ground, and during summer the same goes down further by four or five feet. The discharge of water has been measured by the State P.H.E. Deptt. and found to be about 5,000 gal/hr. Water is pumped through a five inch main pipe to an overhead tank (capacity 2 x 40,000) constructed at an elevated place (hillock) about two miles away from the quarry situated in the heart of the town. There is a natural head of about 125-150 feet for different supply points in the town. The water will be supplied from above tank (supply Reservoir) to the consumers after proper chlorination

Methods

Fluoride content was estimated using Zirconium erio-chrome cyanine-*R* method (17, 18) and confirmed after stream distillation (19). Standard Methods (19) were followed for analysing water for other items.

Quality and Chemical Characteristics of the Water

Samples of water were collected from the mica quarry and were analysed chemically. Results of analysis are given in Table I. The water was found to be quite clear except a few mica flakes floating in it. It was found quite suitable for drinking purposes from chemical point of view except its excessive fluoride

TABLE—I

ANALYSIS OF WATER SAMPLE

pH	8.3
Conductivity (μmho)	860
Total solids	536
Suspended solids	Nil
Total hardness ($CaCO_3$)	95
Calcium (Ca)	27.6
Magnesium (Mg)	12.5
Alkalinity ($CaCO_3$	372.0
Methyl Orange	372.0
Phenophthalein	16.0
Chlorides (Cl)	73.5
Sulphates (SO_4)	18.0
Sodium (Na)	200.0
Potassium (K)	2.4
Fluoride (F)	4.1

Note: All values except pH are in mg/lit.

concentration (4.0 mg/lit.). The water is sweet and has low dissolved solids and hardness. Since the fluoride content is much higher than permissible values (0.6-1.0 mg/lit.) the need for its removal was considered emergent. In this connection, State P.H.E. Department, Rajasthan sought the opinion of CPHERI and it was agreed to put up a community water treatment plant for fluoride removal. Jaipur Field Centre of this Institute has been entrusted with the task of carrying out these studies.

Treatment Process and Design of the Plant

Sulphonated saw dust (S.S.D.) cation exchanger (20) has been tested for its fluoride removing efficiency with a sample of above water. It was found to reduce fluoride content well below the permissible level. 100 ml of the S.S.D. carbon (alum-soaked) could bring down fluoride concentration to less than 1.0 mg/lit in 6 litres of water sample. Carbon-bed was regenerated with a passage of 3 bed volume of 2 per cent filter-alum solution and then washed with tap water which does not contain fluoride. The rate of flow through the bed during regeneration and washing was kept as low as 0.5 gal/min/cu ft. Water sample from an aspirator bottle was allowed to pass through the bed at 2.5 gal/min/cu ft., the filtrate was collected in 1 litre lots, and tested for fluoride and other chemical constituents. Results of one typical cycle of operation are presented in Table II. These results show that besides reduction in fluoride content, pH is lowered, and alkalinity and hardness of the water are also removed. Partial neutralisation of the alkalinity tells upon the reduced capacity of the material. A similar study was made with water after neutralisation of alkalinity. It was found that the volume of water that could be treated was about two and a half time more than that without neutralisation.

TABLE II—ANALYSIS OF TYPICAL SAMPLE AFTER TREATMENT WITH S.S.D. CARBON

Volume of Effluent in litres	pH	Total hardness ($CaCO_3$)	Alkalinity ($CaCO_3$)	Sulphate (SO_4)	Chlorides (Cl)	Fluoride (F)
First 1	6.75	Nil	18.0	22.0	70.0	—
Next 1	7.15	"	21.0	21.0	73.5	0.30
" 1	7.20	"	30.0	19.0	73.0	0.46
" 1	7.30	"	34.0	18.0	73.0	0.70
" 1	7.25	"	40.0	28.0	73.0	1.00
" 1	7.25	"	46.0	18.5	73.0	1.40

Note : All values except pH are in mg/lit.

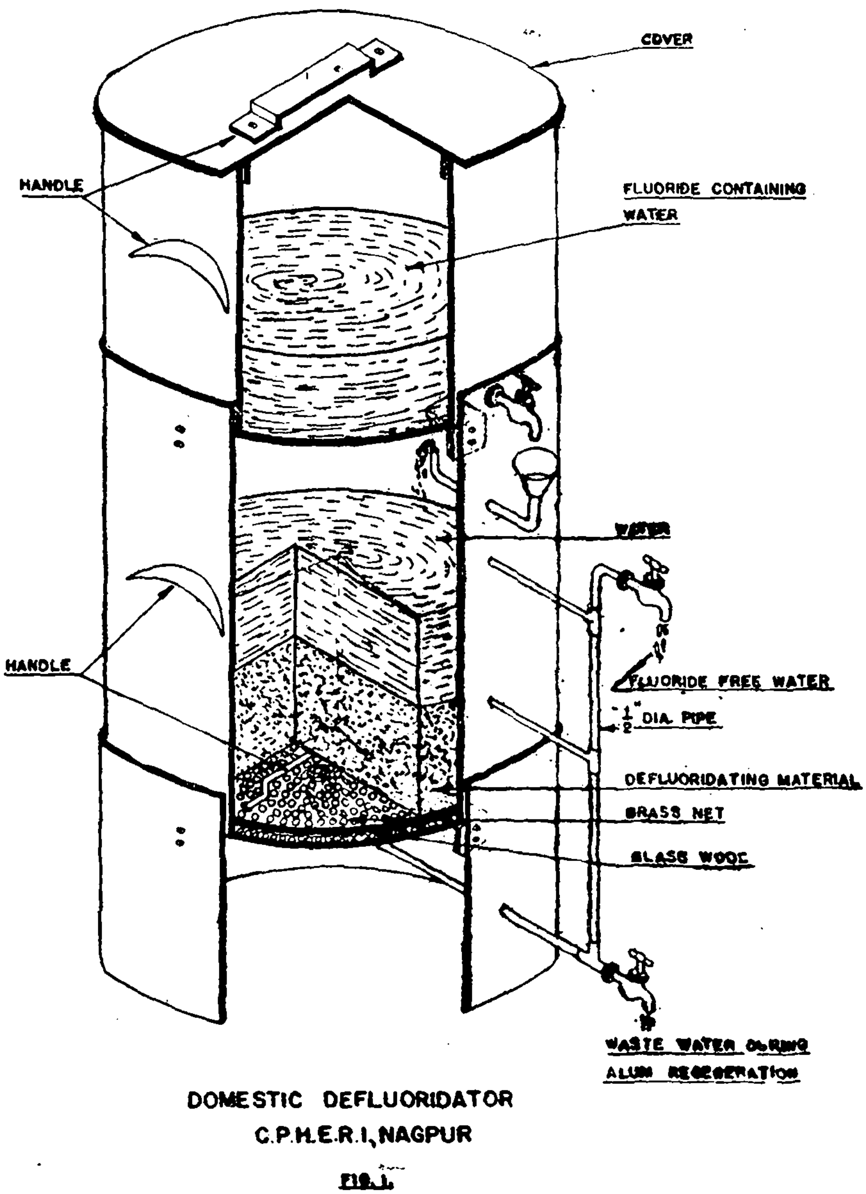

COVER
HANDLE
FLUORIDE CONTAINING WATER
WATER
HANDLE
FLUORIDE FREE WATER
$\frac{1}{2}$" DIA. PIPE
DEFLUORIDATING MATERIAL
BRASS NET
GLASS WOOL
WASTE WATER DURING ALUM REGENERATION
DOMESTIC DEFLUORIDATOR
C.P.H.E.R.I., NAGPUR
FIG. 1.

Fig 1.

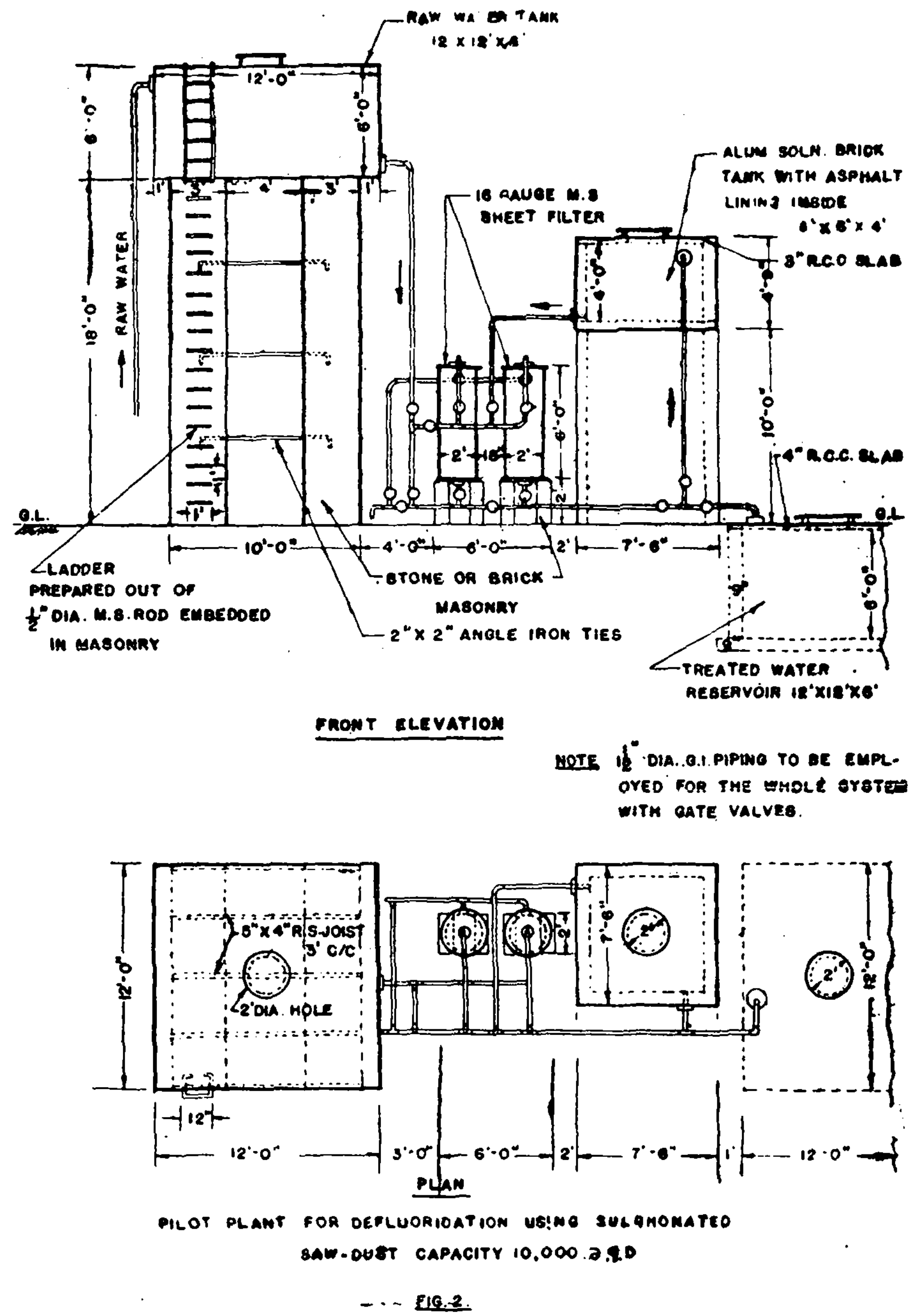

RAW WATER TANK
12 X 12' X 6'
12'-0"
6'-0"
18'-0"
RAW WATER
16 GAUGE M.S SHEET FILTER
ALUM SOLN. BRICK TANK WITH ASPHALT LINING INSIDE
3" R.C.C SLAB
4" R.C.C. SLAB
G.L.
10'-0"
4'-0"
6'-0"
2'
7'-6"
LADDER PREPARED OUT OF ½" DIA. M.S. ROD EMBEDDED IN MASONRY
STONE OR BRICK MASONRY
2" X 2" ANGLE IRON TIES
TREATED WATER RESERVOIR 12'X12'X6'
FRONT ELEVATION
NOTE 1½" DIA. G.I. PIPING TO BE EMPLOYED FOR THE WHOLE SYSTEM WITH GATE VALVES.
5"X4" R.S. JOIST 3' C/C
2' DIA. HOLE
12'-0"
3'-0"
12 -0"
PLAN
PILOT PLANT FOR DEFLUORIDATION USING SULPHONATED SAW-DUST CAPACITY 10,000 G.P.D
FIG. 2.

Fig. 2

Further studies on feasibility of neutralising the alkalinity with different acids and anion-exchange resins were made, but such course of water treatment was considered not very practical and hence discontinued. Based on the above studies, following calculations were made for a volume of 10,000 x 2 gal/day.

1. One cubic foot of the material will treat about 370 gallons of water in each cycle.

2. There can be loss in efficiency due to factors like faulty regeneration etc. So a margin of 20% is allowed. Hence the volume of water treated per cubic foot=300 gallons.

3. Material required for treating entire volume of 20,000 gallons in one cycle $= \frac{20,000}{300} = 67$ cu ft.

4. In case we run the plant in three 6-hourly shifts, the material volume will be 22.3 cu ft.

5. Since the treated water will contain 0.4 to 0.6 mg/lit. fluorides in initial stages of each exhaustion cycle it can be blended with raw water to the extent of 10 per cent. Volume of the material, thus works out to be about 20 cu ft.

6. Two M.S. cylinders (height 6 ft and diam. 2 ft) are proposed for holding the exchange media (10 cu ft each). Other details of the connecting pipes and position of tanks is given in Fig. 2.

Cost of Treatment

The estimated capital cost of the plant is about Rs. 12,000 which includes the cost of first charge of exchange media. Recurring cost involves maintenance and operation of the plant, and cost of filter alum required for regenerating the spent substance. Filter alum required per regeneration at 1 kilogram per cu ft. =20 kilogram. Cost of alum at Rs. 300.00 per metric tonne is Rs. 6.00 per regeneration. Since the carbon bed has to be regenerated three times in a day for getting 20,000 gal of treated water the recurring cost per 1000 gal. of treated water works out about Rs. 1.00. This cost could be reduced further by reusing the alum-waste solution in subsequent regenerations.

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DISCUSSION

Shri N. V. Ramamohanarao, Hyderabad: Sulphonated carbon acts as a cation exchanger. Our experience with the sulphonated carbons is that they remove the other cations as well thus bringing down the hardness to very low levels and reducing the pH much to the acidic side. I would like to know from the author the pH of the treated water and its hardness. I would also like to know the mesh size of the material developed and whether it can withstand hydraulic pressures.

Shri T. S. Bhakuni, CPHERI, Nagpur: Since the sulphonated saw dust carbon is a cation exchanger, it removes hardness of water and neutralises alkalinity partially. But I feel that after a few runs when the carbon is used repeatedly after alum regeneration the cation exchanging character of the carbon will not remain active and the removal of hardness and neutralisation of alkalinity will be quite insignificant. The pH of the different one litre effluent lots is given in Table II of the paper. The material possesses satisfactory hydraulic characteristics.

Prof. V. Chandrasekhar, Manipal: I understand that children of the age group 6-8 and 8-14 were surveyed. How is it that only children of age group 8-14 showed signs of dental fluorosis? Has the source been the same and if so, how the former age group is not affected ?

During defluoridation sulphonated saw dust is claimed to remove hardness and alkalinity. To what extent are these removed ?

Shri T. S. Bhakuni, CPHERI, Nagpur: Children of age group 6-14 years were surveyed for mottling of tooth enamel. It was found as reported in the main text that children of age group 6 to 8 years were not having mottled teeth, though most of these children were drinking fluoride bearing water. This is probably due to the difference in their age during which they changed the permanent teeth (permanent teeth are mainly affected after changing).

The second part of the question has been answered earlier.

Dr. K. R. Kabra: What is the chemistry involved in the removal of fluoride ion? What is the method of preparation of saw dust carbon? Does it act as an activated carbon or as a simple ion exchanger ?

Shri T. S. Bhakuni, CPHERI, Nagpur: The chemistry of fluoride removal with sulphonated saw dust carbon as explained by Dr. Jatkar is the formation of a comparatively insoluble complex of fluoride and aluminium ions. The material when treated with filter alum solution is converted to Al—form and while fluoride containing water is passed through it, the fluoride ions are absorbed forming an insoluble aluminium fluoride complex.

No doubt the carbon so prepared behaves as a carbonylic type of cation exchanger but being a porous carbonaceous material it also acts as an active carbon and removes colour, taste producing substances and chlorine from aquous solutions.

Shri M. Vishnumoorthi Rao, V.R.C.E., Nagpur: Is it possible to use these ion exchange materials sandwiched between the layers of sand generally used for filtration so as to reduce the operational costs ?

Shri T. S. Bhakuni, CPHERI, Nagpur: It will not be possible to use the active carbon sandwiched between the layers of filter sand for two main reasons viz. during back wash, the arrangement will be disturbed, the density of carbon being very low it will be floated and lost at high flow rates usually adopted in sand filters and secondly the carbon is required to be regenerated with filter alum solution after it is exhausted, which will also need large volumes of alum solution and wash water. Also if the water contains high turbidity it will spoil the carbon by clogging the pores.

Shri A. S. Hariharan, Madras: What are the criteria for the different grading of mottled teeth? What is the relationship of the F concentration to the dental mottling? What is the minimum F content with which mottling was associated ?

In making the specially processed material is there any contact period required for the alum in regeneration? What is the quantity of water required for washing the bed and is defluoridated water required to be used? What is the fluoride removal efficiency per cu ft. of the material if the water containing 4 mg/lit. tried to a break through of 1.5 mg/lit. of F ?

Shri T. S. Bhakuni, *CPHERI*, Nagpur: The criteria for grading the stages of mottled teeth is already described in the paper. Limits for fluoride concentration which would give mottled enamel are already known to be more than 1.5 mg/lit.

Time of contact required during regeneration with filter alum solution is about 30 min., for washing the carbon bed after regeneration we can use raw water containing fluoride the volume of which will be about 5 to 10 per cent of the treated water.

One cu ft. of the material would be able to treat about 300 gals. of water in order to bring fluoride concentration from 4.1 to 1.0 mg/lit.

Shri S. K. Dutta, Durgapur: The paper deals with defluoridation of water containing excess fluoride (1.5 mg/lit.). But presence of fluoride upto some minimum limit is also required in drinking water. Please clarify as to how you control the amount of fluoride in water which has been fluoridated. I want to know whether it is fluoridated again to keep the minimum amount or whether fluoridation is controlled upto some limit so that there is some residual fluoride in the treated water.

Shri T. S. Bhakuni, CPHERI, Nagpur: During defluoridation with sulphonates saw dust carbon, the removal of fluoride is not complete and slight amounts of it remain in the effluent as is evident from results given in table II in the paper. Still if there is any deficiency we can always either blend it with raw water or extend the exhaustion cycle so as to contain sufficient quantity of fluoride.

Shri R. K. Bhargava: Water in the mica mine pit contains some flakes of mica. Will the defluoridation unit need pre-filtration or mica flakes settled in the bed will give no trouble ?

If the pH is reduced to 6.0 and alkalinity and hardness is also reduced the water will need the provision for correction of corrosive action. Whether this provision has been made in the plant ?

Shri T. S. Bhakuni, CPHERI, Nagpur: A few mica flakes floating in the water will be retained on the carbon filter and will not interfere during defluoridation and the same will be washed out during back wash with the waste water.

It is true as shown in Table II that the alkalinity of water is partially neutralised and the pH comes down to 6.75. But after blending with the raw water it is expected to recover its non-corrosive nature. Blending is necessary to allow some minimum concentration of fluoride in treated water.

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Fluoride Menace in Certain Community Water Supplies of Andhra Pradesh

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As early as in April 1936, the clinical manifestations of fluorosis, a disease among the inhabitants of certain areas of Nellore district in erstwhile Madras Province, now Andhra, were described by the Health Inspectors of the State. The disease was characterised, at first, by pains in cervical and lambosacral regions of the spinal column and pain and stiffness in joints of both extremities. With the advancement of age, the disease assumed serious nature and even resulted in the death of the patients. An intensive investigation into the incidence, clinical features and aetiology of the disease was carried out by Raghavachari and Venkataraman (1) who reported high fluoride content in the water supply in the areas, where the disease was prevalent. Fluoride content ranging from 2.0 to 7.0 mg/lit. were present in water in the districts of Anantapur, Bellari, Cuddapah, Guntur, Kurnool and Nellore (Ceded districts of the then Madras Province), the highest of about 10 mg/lit. was reported from Darsi, Podili and Kanigiri taluks of Nellore district, the area where severe bone fluorosis incidence was at its highest. Pandit, Raghavachari and Subbarao (2) made further study of the causative factors in the areas of endemic fluorosis and they found the incidence of mottled teeth in Anantapur and Nellore districts varied from 50-90 per cent, in Cuddapah 60 per cent and in Bellari 70 per cent. They made a comprehensive diet survey of the areas and found vitamin A and C deficiencies in the diet taken by the patients. They concluded that symptoms of fluorosis were more severe in those patients consuming diet deficient in Vitamin A and C. This finding was later corroborated by nutritional experiments conducted on monkeys by Pandit and Rao (3). There is a possibility of mistaking the symptoms of fluorosis to that of diseases of malnutrition and unless the physician is experienced and competent, he may attribute the pains in the joints, initial stage of the disease, to the most common disease of arthritis.

Presence of fluorides in higher concentrations is now reported from various other places in the State. Table I shows the taluks with population in lakhs that is exposed to the menace of excessive fluoride content in the drinking water. It is clear

TABLE I—TALUK-WISE POPULATION EXPOSED TO THE FLUORIDE MENACE IN ANDHRA PRADESH

DISTRICT	TALUKA	POPULATION IN LAKHS
Srikakulam	Parvathipuram	2.18
	Bobbili	2.87
	Saluru	1.64
Visakhapatnam	Narsipatnam	2.41
	Srungavarapukota	2.08
	Chodavaram	3.00
Guntur	Palnadu	2.28
	Vinukonda	1.25
Nellore*	Kovur	2,14
	Kandukuru	2.33
	Kanigiri	1.71
	Podili	1.04
	Darsi	1.26
Anantapur*	Penukonda	1.42
	Kadiri	2.51
	Hindupur	1.83
	Rayadurg	1.43
Cuddapah*	Pulivendala	1.23
Kurnool	Pattikonda	1.50
Chittoor	Voyalpadu	2.14
	Palamaneru	2.08
Khammam	Khammammettu	2.75
Medak	Narspur	1.15
Nalagonda*	Nalagonda	2.30
	Total	46.53
	Total Population of Andhra Pradesh	375.00

* Severe symptoms of fluorosis observed.

from the table that 12·7 per cent of the total population of Andhra Pradesh is exposed to the risk of fluorosis. Out of 20 districts in Andhra Pradesh, no less than 8 are having community wells with excessive fluoride content which are the only sources of drinking water to the rural community. These areas are located in the map of Andhra Pradesh. The shaded areas in the map indicate the general distribution of fluorosis among the population and the dots marked indicate the concentration of fluorides in excess of 3 mg/lit.

The names of villages with fluoride content of water exceeding 1.5 mg/lit. are given in Table II. The areas of excessive fluoride content exceeding 4·0 mg/lit. and reaching upto 10.0 mg/lit. are from the districts of Nellore, Anantapur, Kurnool, Guntur and Nalgonda where the incidence of fluorosis is widely prevalent. Chemical Analyses of the well waters in these areas revealed that they belong to the classification of soft soda waters with sodium salts predominating. Rao and Bhaskaran (4) studied the distribution of fluorine content of water sources in Kurnool district and stated that fluorine concentration exceeds 1.5 mg/lit. in most of the waters with alkalinity exceeding twice the total hardness.

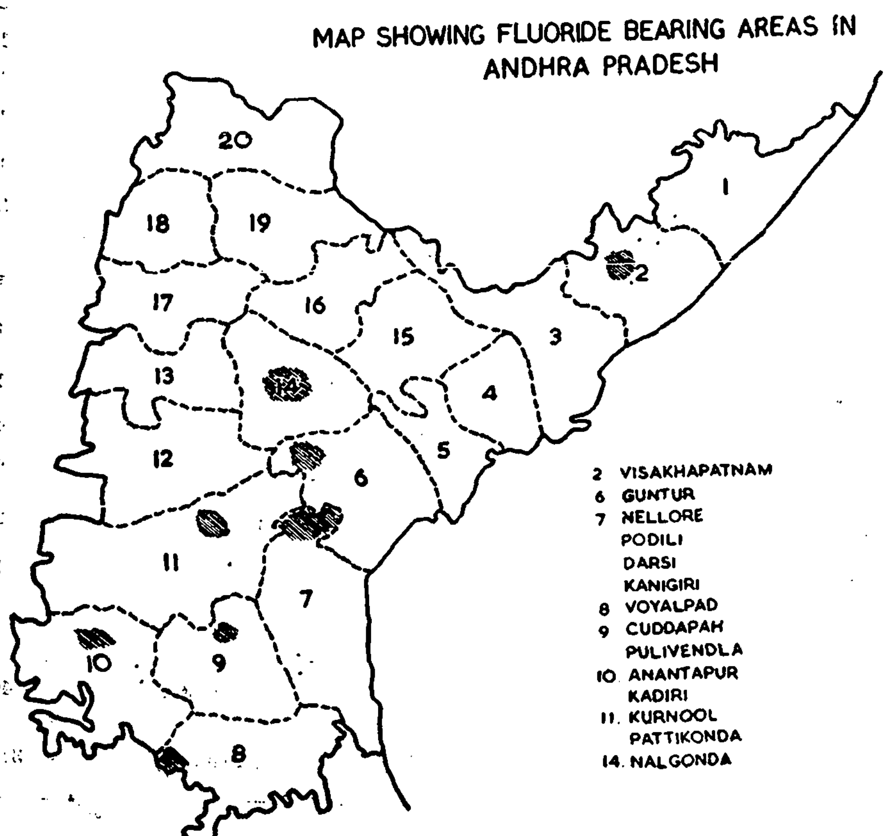

Fig. 1

TABLE II—FLUORIDE CONTENT IN COMMUNITY WATER SUPPLIES IN ANDHRA PRADESH

District	Village	Fluorine in mg/lit.
Srikakulam	Chilakalapalli	1.6
	Amadalavalasa	2.4
Visakhapatnam	Neelakantapuram Simhachalam	2.0
	Yellapuvaripalem Chintala Agraharamu,	2.2
	Jaggayyapalem	5.5
Guntur	Kotthuru, Kollagunta,	1.6
	Namburu, Kolagutla Nekarikallu	1.8
	Ongolu	3.6
	Gunturu	2.8
	Vinukonda	5.2
Nellore	Thimmareddipalem, Ramachandrapuram	2.0
	Kanigiri	2.2
	Cheerladinne, Kambhampadu	2.4
	Gudivaripalem, Vemulapadu, Narlapalem	2.8
	Kakarla	3.2
	Katurivaripalem	3.6
	Rajupalem	4.0
	Podili	4.4
	Jammigumpala, Umamaheswarapuram	5.0
	Mallavaram, Thummedalapadu Podili	7.0
Anantapur	Kotakamvaripalli	1.6
	Pulligundlapalli	1.8
	Munagalavaripalli Ubbaravandlapalli Gunduvaripalli Guntakallu	2.0
	Polevandlapalli Kamatooru Mathivarigondhi Veeramallayyavaripalli	2.2

TABLE II—Contd.

District	Village	Fluorine in mg/lit.
Anantapur (contd.)	Vankapalli Yerrappagaripalli	2.4
	Moturipalli, Talupula, Sabbannaguntlapalli	2.8
	Marlapalemu	3.0
	Jogannapenta Nangivandlapalli Reddayyavaripalli	3.2
	Kavalipalli	3.6
	Kalasamudramu, Puligondlapalli Rachavaripalli, Edukuntlapalli	4.0
	Maddivarigondi	5.5
	Kurraguntlavaripalli	10.00
Kurnool	Kallapari	2.0
	Bondimadugula	2.2
	Peddanelathuru	2.4
	Chinnamanibidi, Patthikonda, Brahmana Agraharam, Karidikonda Nandyala	2.8
	Chinnapendakal, Alvala,	3.6
	Dodagunda	4.8
	Byalapalli	8.0
Karimnagar	Badepalli	2.6
	Gangadhara	2.2
Mehaboobnagar	Narayanapet	2.0
Nalagonda	Kongal	2.0
	Mudampalli	2.0
	Pottichelama	2.4
Nizamabad	Kamareddy	1.8

Andhra Pradesh is the fifth largest state in India on area basis and ranks fourth in population according to 1961 Census. There are 9260 villages with a population of 2.97 crores existing in the State i.e., the rural population of Andhra Pradesh is about 80 per cent of its total population. 75 per cent out of this population is not served by protected water supply. A meagre sum of Rs. 74 lakhs have been spent during the First and Second Plan periods for constructing and renovating wells in rural areas. (5). Both surface and ground waters are being used as principal source of water supply in almost all the rural towns. The surface sources are few when compared to ground sources and they are invariably polluted. The ground water sources of fluoride bearing areas are not at all treated for the removal of fluorides and used as such by the inhabitants and hence the high incidence of reported fluorosis. No attempts have hitherto been made by the State Public Health Authorities for fluoride removal in rural areas, and no such programme is ever contemplated by the State. The people are left to their fate. It is a sad commentary on Medical and Public Health Administration of the State. The Government of Madras sometime past have initiated experiments on defluoridation as a joint venture with the authorities of Southern Railway at the premises of Guntakal Railway Station using paddy husk carbon impregnated with alum. The fluoride of the raw water ranges from 2.4 to 3.0 mg/lit. and it is reported that the pilot plant experiments were successful with respect to the quality of treated water but the treatment cost was high. Experiments were conducted on similar lines, but using saw-dust carbon in CPHERI and they are also reported successful. Low cost portable treatment units suitable for rural communities have been devised with this defluoridating material. It is claimed that these are economical. The principal author of this article has successfully tried several sulphonated ion-exchange carbons prepared from indigenous raw materials such as coconut shell and groundnut shell (6) which may be employed in the large scale treatment units after working out the treatment costs. Regarding the efficiency of this carbon, it was found that one pound of the material could treat about 160 to 180 lit. of water bringing down the fluoride content of water to 0.7 mg/lit.

Maier (7) has reviewed various processes of fluoride removal including synthetic resins. Defluorite (8), $Ca_3(PO_4)_2$ $Ca(OH)_2$ and activated alumina can be used successfully but are expensive. A Water Treatment Plant in U.S.A. (9) used gravity filters containing beds of calcium phosphate and treated water containing upto 4.0 mg/lit. of fluorides. One per cent caustic soda solution was used for regeneration of the beds. Cillie *et al* (10) used a similar method but employing granular superphosphate as exchange material which is impregnated with ten per cent caustic soda solution. Fink and Lindsay, (11) as early as in 1936, have devised a filter for home use, containing 9.75 lbs of alumina which reduced the fluorine from 5 to 1 mg/lit. or even less for a quantity of two fifty gallons at a rate of 0.4 gal/min. Regeneration was effected by 8 per cent caustic soda or by alkaline solution of sodium aluminite. The efficiency of removal was impaired by higher pH.

Conclusions

It is necessary to impress upon the Public Health authorities of the State the need for developing a cheap defluoridating material suitable for rural areas based on initial pilot plant experiments. Even if the results of experiments lead to a slightly costly process, it should not come in the way of the health of the community. The State should feel as its responsibility to protect the health of the community. The higher cost of the treatment can be compensated by a suitable levy of water cess or obtained as a Central Grant or can be included as a Scheme in the Fourth Five Year Plan. The Health of the People is the Wealth of the Nation.

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DISCUSSION

Shri M. Vishnumoorthi Rao, V.R.C.E., Nagpur: I understand that ion exchange method is successful in defluoridation. Such a method is already being practised satisfactorily in Guntakal Railway colony. I would like to know whether any measures are taken by the CPHERI or the Institute of Preventive Medicine to study the economics of the method.

Shri D. Seethapathi Rao, CPHERI Zonal Centre, Hyderabad: The CPHERI has in fact developed a defluoridating carbon from saw dust and this material is proposed to be used on a pilot plant scale in Rajasthan. The Government of Andhra Pradesh is also interested in this project and has offered financial assistance for conducting experiments on defluoridation using this material in Andhra Pradesh. I understand that a process for defluoridating water has been evolved in the Institute of Preventive Medicine and its economics are being studied.

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Endemic Fluorosis in Andhra Pradesh

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Introduction

The incidence of Fluorosis in endemic form in different parts of India was reported by several workers (2, 5, 6, 9, 10, 11, 13, 16, 17, 20, 21, 23, 25). In Andhra Pradesh, as early as 1937, the prevalence of fluorosis was shown by Shortt, Pandit and Raghavachari (17) in parts of Nellore district. Detailed investigations by Pandit *et al.* (11) revealed the incidence of this disease in endemic form in a wide area of the district and that it was associated with the presence of excessive fluorides in drinking waters. Subsequently the prevalence of the disease in some other districts of the State was also reported by other workers (5, 10, 18). However, these reports pertain to investigations made in selected places in the districts of Nellore, Visakapatnam, Nalgonda and Mahaboobnagar. To our knowledge no epidemiological survey of the affliction had been made in different other districts of the state. During the routine chemical analysis of the samples in this Institute and in the regional laboratories it was observed that many samples from various other districts also contained fluorides in excessive amounts. It was also learnt that people in some of the rural areas have been using such waters for drinking purposes without any defluoridation measures. While many of the towns in the state derive their drinking water from surface sources, most of the villages get it from ground sources. The analytical results of many a sample collected from ground water sources in rural areas showed that the waters would have been chemically satisfactory but for their excessive fluoride content. The presence of fluorides in toxic levels has thus become a menace and a hurdle in providing potable waters to the people in a number of villages in the state. In view of these observations a series of laboratory investigations have been undertaken with the following objectives :

(a) To evaluate the general distribution of fluoride in water sources in different districts of the state.

(b) To make a comprehensive study of the distribution of the ion in various available waters, in different selected places in a district so as to find out the possibility of obtaining sources having innocuous levels of the ion.

(c) To assess the relationship, if any, between the fluoride content and the other chemical features of water such as alkalinity, hardness, chlorides on the one hand and between the fluorides the strata of the soil and depth of the source on the other.

(d) To prepare and study the efficacy of activated carbons and ion exchange materials for defluoridation of waters.

The results of studies on the first three aspects have been recorded in this article.

Material and Methods

Samples were collected from several places in different districts of the state. The sources of water included all types of ground and surface waters in use for drinking and other domestic purposes. In the comprehensive survey conducted, all the places known to have excessive fluorides as observed from the routine analysis and many of their suburbs were selected. Places were also chosen on the basis of reported cases of fluorosis. The samples from different taluks were collected under similar atmospheric conditions to avoid seasonal variations. The nature of the source, its depth and the strata of the soil were noted while collecting the samples. The analytical estimations were made following the procedures described in Standard methods APHA and others (1) and Manual of methods for the examination of water, sewage and industrial wastes published by Indian Council of Medical Research (8). The estimation of fluorides was made by Scott Sanchis colorimetric method and hardness, chlorides and nitrates by EDTA, Mohr and Phenol disulphonic methods respectively.

Results

A total of 2569 samples collected in various districts of the state were analysed for their fluoride content and complete chemical analysis was done on a large number of them. The samples analysed were from 2327 ground water and 242 surface water sources. In all the districts wide variations in the fluoride content was observed. The presence of the ion in widely differing amounts in sources of the same locality was noticed. It was also observed that several water sources were present in all the districts with innocuous levels of the ion. The distribution of the element in different districts were analysed in Table I.

Out of 2569 as many as 1231 (47.9%) samples had fluorides in the range 0-1.0 mg/lit. followed by 752 (29.3%) in 1.1-2.0, 369 (14.2%) in 2.1-3.0, 165 (6.4%) in the range 3.1-5.0 and in 52 samples (2%) the quantity of fluoride exceeded 5 mg/lit. It could be seen from Table I that the number of samples containing fluoride in the wider range 0-2.0 mg/lit. is significantly high ($P < 0.05$) in all the districts except Nellore. It is also evident that there is gradual reduction in the number of samples having fluoride in the increasing ranges. In as many as 17 of the 20 districts water generally contain fluorides upto 3.0 mg/lit. and the sources having the ion in the range 3.1-5.0 mg/lit. are also in existence. It could also be noticed from the table that in Nellore, Nalgonda, Kurnool, Ananthapur and Visakhapatnam districts some of the existing sources had fluoride content exceeding 5 mg/lit. A maximum amount of 20 mg/lit. was found in a water source in Nalgonda district.

TABLE I—SHOWING THE DISTRIBUTION OF FLUORIDE IN WATERS IN THE STATE

District	Total No. of samples	Number of samples with the Fluorine content (mg/lit.) in the ranges :					
		0-1.0	1.1-2.0	2.1-3.0	3.1-5.0	Over 5.0	Maximum recorded
Adilabad	58	34	18	6	—	—	2.4
Anantapur	382	158	120	62	34	8	10.0
Chittoor	84	52	22	10	—	—	2.6
Cuddapah	161	72	58	25	6	—	3.8
Godavari (East)	47	42	5	—	—	—	1.5
Godavari (West)	54	46	6	2	—	—	1.8
Guntur	196	119	54	16	6	1	5.6
Hyderabad	68	46	20	1	1	—	4.6
Kareemnagar	68	22	35	10	1	—	3.8
Khammam	45	32	11	2	—	—	2.1
Krishna	36	30	4	2	—	—	2.8
Kurnool	432	235	112	55	24	6	8.0
Mahaboobnagar	58	18	32	6	2	—	3.8
Medak	21	13	8	—	—	—	2.0
Nalgonda	220	84	65	29	32	10	20.0
Nellore	371	68	102	125	52	24	12.0
Nizamabad	29	16	13	—	—	—	2.0
Srikakulam	62	48	12	2	—	—	2.8
Karangal	54	28	18	6	2	—	3.2
Visakhapatnam	123	68	37	10	5	3	9.2
	2569	1231	752	369	165	52	

Different intensities of levels of fluoride available in water sources in various districts of the state was represented in the map. As sources having the ion in the range 0—1.0 mg/lit. were definitely available in all the districts and as such concentrations were innocuous, they were omitted. It could be seen from the map that sources having excessive content of fluoride were situated away from different river beds in general and in particular from the delta areas of the Perennial rivers, Krishna and Godavari.

A systematic and comprehensive study of different available sources in each of the selected places in Kurnool and Anantapur districts was made. A total of 44 and 52 places respectively representing different parts of the districts were selected. The observations made in Kurnool district were already reported (15). The availability of sources having innocuous levels of the ion in all the places was shown. In the present study 382 samples were collected in Anantapur district from available sources in all the 52 selected places.

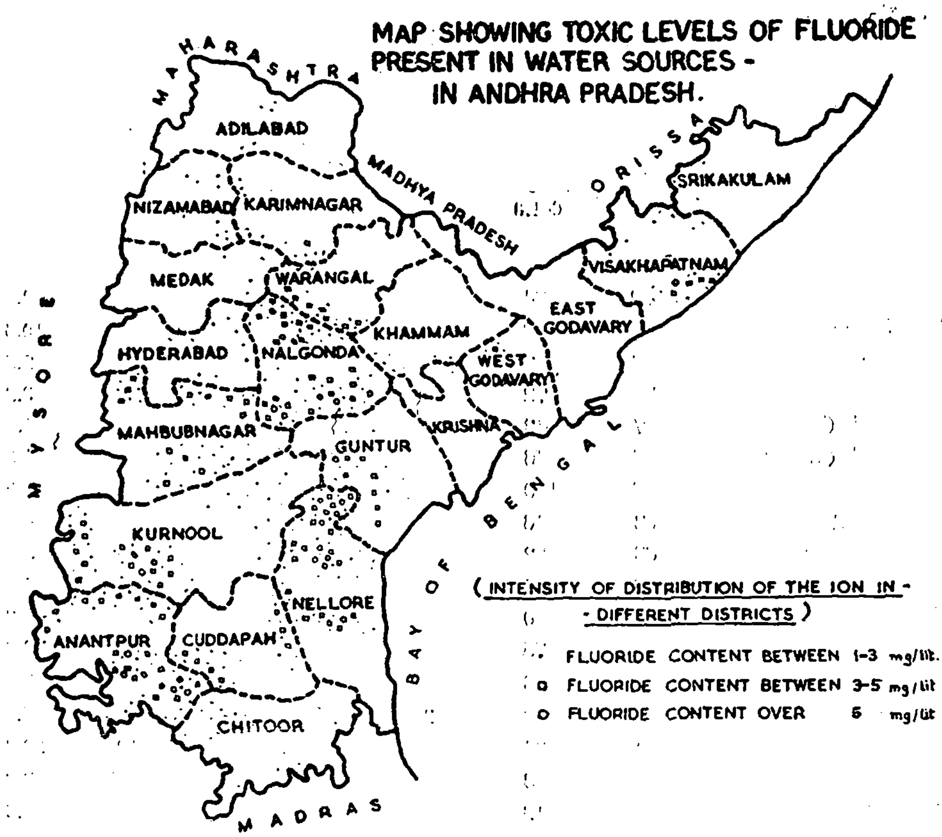

Fig. 1

Wide variation in the distribution ot fluoride was observed in every place examined. It was found that waters having fluoride less than 1.6 mg/lit. were in existence in 48 places and in four others sources with fluoride in the range 1.6 to 2.0 mg/lit. were available. The distribution of the ion in different taluks was represented in Table II.

Out of 382 samples as many as 229 (58.9%) had fluorides in the range 0-1.5 mg/lit. followed by 104 (37.2%) with fluoride above 2 mg/lit. and 49 (13.9%) had the ion in the range 1.6-2.0 mg/lit. It could be seen from Table II that there is significant difference ($P < 0.05$) in the number of samples with fluoride upto 1.5 mg/lit. and those having higher content of the ion in all the taluks except Anantapur, Penukonda and Kadiri. However, when the number of samples containing the ion upto 2.0 mg/lit. were considered against those having higher content the difference would be significant for Anantapur and Penukonda taluks also.

No relationship was observed between the fluoride content and pH, chlorides and nitrate contents of water. It was observed that most of the water samples having fluorides more than 1.5 mg/lit. were soft waters having high content of total alkalinity (above 350 mg/lit.). It was also noted that among the samples of the same place, such of those having

TABLE—II

DISTRIBUTION OF FLUORIDE IN WATER SOURCES IN DIFFERENT TALUKS:

Taluk	Total number of samples	Samples with fluoride content: in the ranges			
		0-1.5 mg/lit	1.6-2.0 mg/lit	Above 2.0 mg/lit	Range
Anantapur	62	33	11	18	0.3-4.8
Dharmavaram	24	16	3	5	0.1-3.2
Gooty	31	21	4	6	0.1-4.1
Hindupur	39	26	4	9	0.4-4.8
Kadiri	68	29	8	31	0.5-10.0
Kalyandurg	19	13	2	4	0.1-2.6
Madaksira	18	13	2	3	0.1-2.9
Penukonda	27	14	4	9	0.3-8.4
Rayadurg	26	18	2	6	0.2-3.5
Tadipatri	44	30	6	8	0.4-6.0
Uravakonda	24	16	3	5	0.2-5.4
	382	229	49	104	

high content of fluorides had higher total alkalinity and lower total hardness than the samples with low content of the ion. During the study of distribution of fluorides in Kurnool District a general relationship was also noted between fluoride content and ratio of total alkalinity to total hardness. The results of present study in Anantapur District were scrutinized for this relationship in Table III. The fluoride content was analysed against different ranges of the ratio of total alkalinity to total hardness. Averages of total alkalinity and total hardness of different samples examined were represented.

It could be seen from Table III that the number of samples with fluoride content upto 1.5 mg/lit. was highly significant for the ratio of alkalinity to hardness under 1.0 and in the ranges 1.0-1.5. It could also be observed that the number of samples with fluoride content above 1.5 mg/lit. was again significantly high for all the ratios over 2.0. The results of samples collected in different other districts were also scrutinized and the relationship was also observed. A closer study of those results involving consideration of the quantities of other constituents of water revealed the following features:

1. Deviations from the relationship occured with samples of those places where the concentration of fluoride in different water sources was low evidently due to smaller amounts of fluoride minerals present in the strata.

TABLE—III—RELATIONSHIP BETWEEN THE RATIO OF TOTAL ALKALINITY TO TOTAL HARDNESS AND FLUORIDE CONTENT OF WATER

RATIO	Average total alkalinity mg/lit.	Average total hardness mg/lit.	Number of samples with fluoride content:		RANGE
			0-1.5 mg/lit	above 1.5 mg/lit.	
Undee: 1	208	372	41	5	0.1-1.7
1.0-1.5	345	274	34	7	0.3-1.9
1.5-2.0	387	198	26	11	0.7-2.2
2.0-3.0	456	168	8	32	1.3-4.8
3.0-4.0	495	133	6	31	1.3-6.0
4.0-5.0	586	122	2	24	1.5-6.4
Over 5	640	106	—	16	2.6-8.0

2. The samples which had higher content of fluoride than can be visualised from the values of alkalinity and hardness contained excessive content of other ions especially chlorides.

Among different sources tested, surface waters-streams, rivers, canals and impounded reservoirs — were found to have low amount of ion mostly below 1.0 mg/lit. and invariably less than 1.5 mg/lit. In ground waters wide variations in the concentration of fluoride was observed in well waters even in rocky strata. Waters from wells dug in rocky strata had more content of the ion than from normal strata in the same district. Many of the samples containing ion above 2.0 mg/lit. belonged to wells dug in rocky strata and those having the ion in amounts more than 4.0 mg/lit. invariably belonged to such strata. It was also observed that rocky soil having granite and shale formations usually yielded waters with excessive fluorides.

Discussion

Since the first report of association of mottled enamel with the fluoride content of water by Churchill (3) different workers in various parts of the world have made numerous investigations and conclusively established this relation. From the literature it can be observed that while the onset of skeletal changes is usually associated with prolonged ingestion of high levels of fluoride (usually more than 3-4 mg/lit. (4, 7) the presence of the ion in drinking water in amounts as low as 1.0 mg/lit. gives rise to the hypoplasia of teeth. It can therefore be inferred from the distribution of fluoride recorded in Table-I that the incidence of fluorosis in general and mottled enamel in particular must have been present in considerable intensity in most of the districts. It can also be inferred from the results that the disease must have been prevalent in endemic form in Nellore, Nalgonda Kurnool, Anantapur, Cuddapah, Guntur and Visakhapatnam districts. In different places of these districts the levels of fluoride in waters are in correlation with the reported incidence of the disease (5, 10, 11, 17, 18). In all these places there is extensively area of rocky strata in the soil. However, as significant variations were observed in the fluoride content of waters collected even in such strata, it may be possible to obtain a source having innocuous levels of ion even in such localities. Waters from rocky soil having granite and shale formations were usually found to be contain excessive fluorides. These observations indicate that fluoride minerals must have been occuring in considerable amounts in such rock formations. In Visakhapatnam district, high content of fluorides in water was reported (22) to have been due to the occurence of apatites sometimes in abundance in a type of intrusive rocks called "Kodurites" which cut through the knondalite genisis. Apatites are known fluoride bearing. It is therefore essential to take cognizance of the physiographic conditions of the locality and to avoid strata known to be fluorine bearing while digging wells in search of potable waters. Alternatively, surface waters may be used for drinking purposes. In the present study, as anticipated, all the surface waters examined had low fluoride content. Similar observations were recorded by Singh *et al.* (10) during their study of fluoride content of canal waters from Bhakra Nangal project in Punjab.

The results of detailed studies made in Anantapur district indicate that there is every possibility of getting at a suitable source of potable water in different parts of the district irrespective of high fluoride content of an existing drinking water source and an attempt is worthwhile. It appears from the results that in a few places (in Kadiri taluk) the minimum amount of fluoride present in the waters of the locality may be slightly more than the permissible concentration. We feel that optimum concentration of the fluoride in potable waters fixed for a wide area comprising a state or a region need not be rigidly applied for every water supply and several other factors which may influence absorption of fluoride may be considered in such border cases. Several reports (11, 12, 18, 24) indicate that the incidence itself and severity of symptoms are influenced by factors such as nutritional standards of the people, climatic conditions (14) etc. We have found it worthwhile to evaluate the seasonal variation in the fluoride content of waters as significant changes were noticed in the concentration of fluorides in different seasons.

Wide variations in the fluoride content of samples of the same locality can be due to factors such as differences in the extent of fluoride minerals available, difference in the soil area percolated by the waters and the influence of other constituents of soil and water on the dissolution of these minerals. The results of the present study revealed that hardness and the alkalinity have bearing on the dissolution of fluoride minerals available in the strata. From the relationship noted in Table III it can be expected that waters having excessive hardness (above 400 mg/lit.) and low alkalinity (less than 200 mg/lit.) will have low fluoride content and higher alkalinity (above 350 mg/lit.) and lower hardness (below 150 mg/lit.) would be associated with excessive fluorides (more than 1.5 mg/lit.). It can be inferred that the dissolution of fluoride minerals in water is definitely augmented by lower hardness of water (soft water). These results also indicate that the fluoride bearing minerals must be containing insoluble salts of the ion. The presence of apatites containing CaF_2 in abundance in some places was already located. The presence of excessive alkalinity in the soils and in turn in the water may be influencing the dissolution of fluorides by way of "common ion effect". Greater dissolution of fluoride mineral might result from high concentrations of other ions (eg. chloride) due to "salt effects." It would therefore be advisable to avoid soils having excessive alkalinity, excessive concentration of other minerals (brackish soils) and low calcium and magnesium contents while digging wells in search of potable waters, especially in endemic areas.

The results of the present study show that detailed and systematic investigation on the distribution of fluorides and waters would be highly useful in finding out alternative water sources having innocuous levels of the ion. The study also indicate the urgent need for conducting exhaustive epidemiological surveys and further laboratory investigations. From the observations made we presume that concentration of different other constituents in the drinking water may have influence on the deposition, absorption and retention of the fluoride by bones and teeth. It is opined that field and laboratory investigations on these aspects would be useful in tackling this chronic problem of fluorosis which has assumed paramount public health importance.

Summary :

1. General distribution of fluoride in waters in different districts of Andhra Pradesh, was evaluated. A total of 2,569 samples were analysed for fluoride content. The presence of the ion in toxic amounts in most of the districts of the state, was shown. In as many as 17 of the 20 districts waters contained fluorides upto 3 mg/lit. and in 12 of them sources having the ion in the range 3.1-5 mg/lit. were also in existence. Maximum amount of 20 mg/lit. was recorded.

2. Wide variations were observed in the fluoride content of different waters, in every place examined. The approximate intensity of fluoride levels in different districts, was represented in the map. Most of the sources having excessive fluoride were found to be located away from the river beds.

3. Detailed study of the distribution of the ion in 52 selected places in Ananthapur Dist. was made. The probability of getting at a source having innocuous levels of the ion in the district was discussed.

4. Alkalinity and hardness of water were found to have influence on the dissolution of fluoride minerals. A general relationship between the fluoride content and the ratio of alkalinity to hardness was noted.

5. The results brought to light the urgent need for conducting exhaustive epidemiological surveys and further laboratory investigations.

Acknowledgement

The authors are thankful to the Analysts who have assisted them in carrying out the work. They wish to thank Mr. P. S. R. Haranath, M.Sc., Lecturer in Statistics, Osmania Medical College, Hyderabad for his help in the statistical treatment of results.

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DISCUSSION

Shri S. Chatterjee, Calcutta: As excessive fluorine is a problem which causes mottled teeth, the deficiency of fluorine in water also causes dental carries. As the areas having high fluorine contents in water are pin pointed, we could as well prepare a contour map showing different levels of fluorine concentration above and below 1 mg/lit. with an interval of 0.2 mg/lit. contour lines, both above and below the permissible level of 1 mg/lit.

Shri G. R. Kulkarni, Maharashtra: What is the effect of fluorosis on cattle and is there any provision for providing water supply free of fluorine for cattle?

Shri Ramamohanarao, Hyderabad: The effects of fluorosis on cattle are similar to those noticed in human beings. There is no special provision for providing fluoride free water for the cattle where such an amenity is lacking for human beings.

Shri T. S. Bhakuni, CPHERI, Nagpur: What is the criteria for selection of wells for fluoride concentration determination. Whether the yield and location of the wells were considered? Are the surface sources and sub-soil sources grouped separately. The authors may clarify whethere they have assessed the geological structure of a particular area. It was reported that while digging wells, fluoride bearing minerals can be avoided. How could this be achieved?

Shri N. V. Ramamohanarao, Hyderabad: In the systematic survey of well waters the wells that have been in regular use by the villagers were taken up for analysis and the yield was not considered.

Surface and sub-soil sources have been considered together and the former constitutes a small percentage of the total as reported in the paper.

The geological structure has not been particularly studied. All the sources examined were found to contain widely varying amounts of fluorine. It would clearly be inferred by statistical treatment of the results that it is definitely possible to get a suitable source of potable water in different other places throughout the area surveyed.

Prof. M. V. Bopardikar, CPHERI, Nagpur: High polystyrene resins are the only solution for removal of fluorides and other dissolved solids vis-a-vis other exchange materials such as paddy husk carbon and sulphonated saw dust carbon.

Dr. K. R. Kabra: The author pointed out that when Ca^{++} ion is more in water, F^- ion is found to be low. If this is so, can we add lime to water and decrease the F ion concentration?

Shri Ramamohanrao, Hyderabad: I agree with Dr. Kabra that addition of calcium and even magnesium will reduce the fluoride concentration to a certain extent. It requires large amount of calcium to bring down the fluoride concentration to innocuous levels. The addition of calcium ion to water containing excessive fluoride may afford protection against absorption and retention of fluorides in the body.

Dr. G. J. Mohanrao, CPHERI, Nagpur: Because of the relative insolubility of calcium fluoride, it may not be surprising to find lower values of fluoride in waters having high calcium. However, it should be noted that, in view of small concentration of these salts in waters the normal stoichiometric laws can not be expected to hold good. The removal of fluorides by the calcium ion may be achieved by precipitation, co-precipitation and adsorption.

With reference to finding a proper ion exchange resin of the polystyrene type, I would like to give a word of caution. Fluoride ion is known not to dissociate too much and hence ion exchange may not be a very promising venue for its removal. Adsorption, precipitation and co-precipitation may be better methods to try.

Shri T. S. Bhakuni, CPHERI, Nagpur: The authors have tried to correlate the ratio of total alkalinity to total hardness with the quantity of fluorides in the water. I feel that this type of relationship, if any, may be only of academic interest. Do the authors feel that by this relationship we can substitute the estimation of fluoride by analytical methods?

Shri N. V. Ramamohanarao, Hyderabad: A general relationship between the ratio of total alkalinity to total hardness and the fluoride content of water has been found by a close scrutiny of the results as mentioned in the paper. We are not tackling this problem for academic interest but for finding a solution to the problem of fluorosis. As explained in the paper the results indicate that soils having excessive alkalinity, excessive salinity and low calcium and magnesium contents have to be avoided while digging wells for drinking water. The results clearly show the range in which the fluoride content has been varying for different ratios of alkalinity to hardness.

Dr. Sushila Nayar, Ex-Minister for Health and Family Planning addressing the Symposium Delegates

Session—III

Shri U. J. Bhatt, Chairman and Shri R. S. Mehta

Proc. Symp. Community Wat. Supply & Waste Disposal
December 19-21 (1966), CPHERI, Nagpur.

Use of Solar Energy for Production and Supply of Water From Salt Water

S. K. GARG, S. D. GOMKALE & R. L. DATTA
Central Salt & Marine Chemicals Research Institute, Bhavnagar

Solar energy is utilised for production of fresh water from saline water by solar stills and Humidification-Dehumidification technique. Applicability of solar stills is restricted to lower water requirements, say upto 45 cu m/day though unavailability of power is no problem. This drawback is overcome by the Humidification-Dehumidification technique which is felt to be capable of supplying water upto say 5000 M^3 per day i.e. 1 mill gal/day. Hot sea water for the technique can be obtained by either heating sea water in solar collectors or withdrawing hot sea water discharged by many chemical industries. Second source gains an advantage over the first because solar collectors are not necessary and thus results in lower cost of water. Recovery of by-products in combination with Humidification-Dehumidification plant using concentrated discharge can bring about some reduction in cost of water.

Evaporation and condensation, the two operations occuring spontaneously in nature are responsible for producing huge quantity of fresh and pure water, be it from ocean or sea or lake or river or brackish well and lake. Radiation from the sun plays an important and significant part in such operations. These spontaneous operations being not under control, much of the fresh water so produced cannot be used by man. Nevertheless, when these operations are brought under control by suitable designs to trap solar radiation, fresh water of quality and quantity can be produced according to needs.

Solar Still Technique

In India, a tropical country, solar energy is available abundantly for a longer period of the year in many parts. An average value of solar radiation of 543 cal/cm^2 /day (2000 BTU/sq ft/day) is not uncommon in many parts of India. Such higher radiation intensity, if used optimally in a device say, in the solar still technique of desalination will yield 9.76 lit./m^2 /day (0.2 gallons of fresh water per square foot per day).

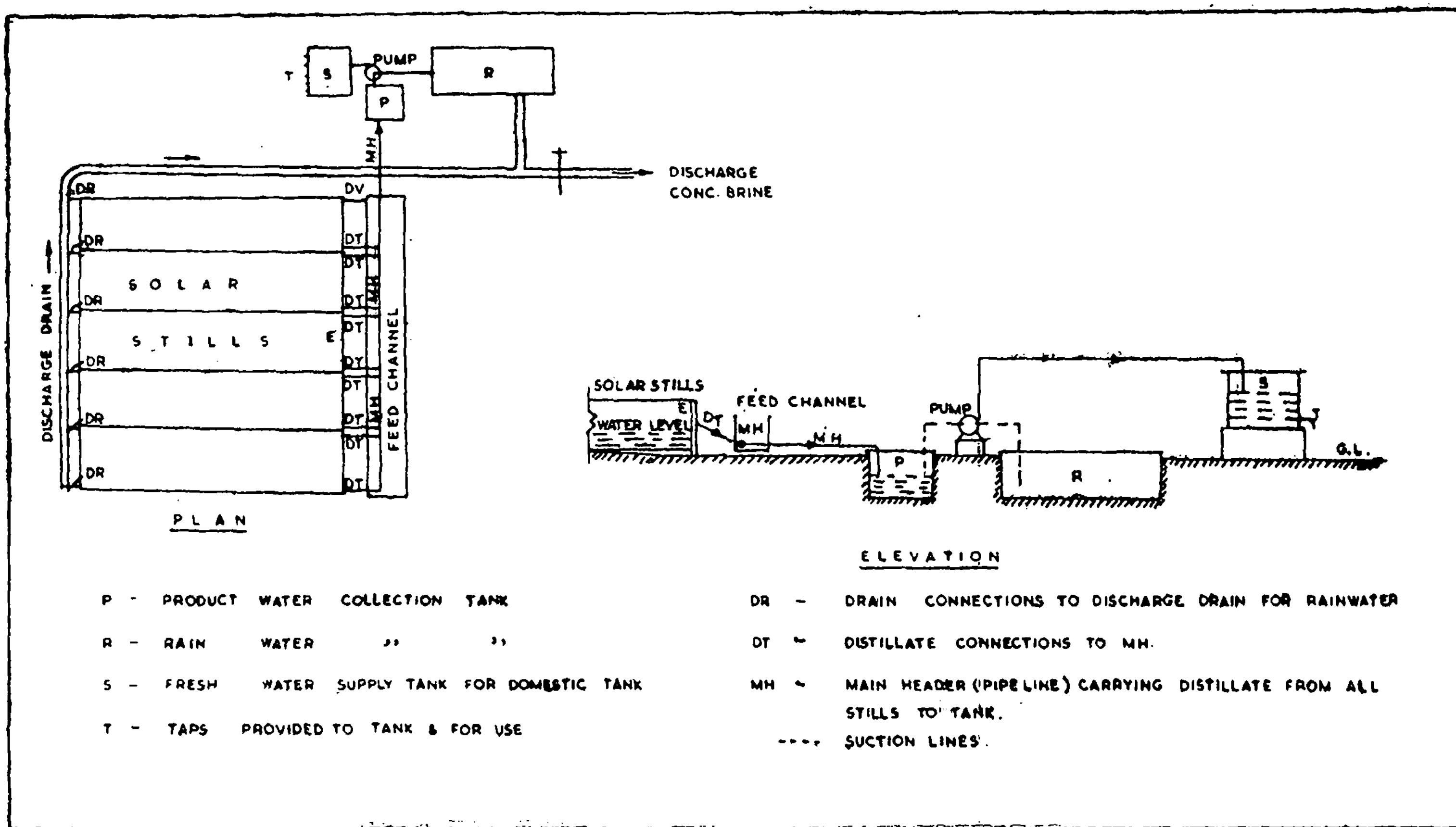
But in actual practice resulting efficiencies of stills are as low as 20 to 30% which need more area to be covered for water production. Efficiencies can be increased by use of reflectors or solar powered mechanisms (3) to make the units follow the sun or other means (2). But these result in higher costs without proportionate gain.

Based on the experimental observations, a pilot plant to produce about 250 gal/day was constructed to collect operational data. Details are indicated in our previous publication (4). Fig. 1 and 2 indicate the arrangements for supplying water by solar stills on the site of installation.

Limitations of Solar Still Technique

Our feasibility studies indicate that such a technique can be set up in isolated regions like salt farm areas or islands where power or fuel is not available for the purpose to supply water to smaller communities when the requirement of water is varying between a few hundred gallons to a few thousand gallons per day, and where no nearby natural source of water is available. In regard to both the limiting capacity of fresh water which can be produced by Solar Still technique, and the nearness (or distance) of the natural water source from the place of consumption, quantitative conclusions are arrived at from our feasibility studies. From Fig. 3, which gives the relationship between capacity of desalination plant and cost of fresh water per 1000 gallons for the Solar Still technique and the Humidification-Dehumidification technique (HD) (as developed by us and described below) it is evident that limiting capacity of plant of about 90,800 lit. (20,000 gal) of fresh water per day should not be exceeded for solar still plant. In practice, it may be even less, say, a few thousand gallons of fresh water per day only. Beyond this capacity, HD technique should be used. In isolated salt farm areas of Kutch and Saurashtra regions, our survey indicates that water is conveyed from distant places by trucks, tankers, bullock carts, camels and even head loads as a result of which the costs of water per 1000 gallons range as high as from Rs. 11/- to Rs. 40/- (4), or Rs. 2.42 to Rs. 8.80 per cubic meter, justifying establishment of Solar Still plants in many of the regions with cost of water not more than Rs. 8.45 per 1000 gallons. In order to compare the costs of conveying natural water of various quantities at different distances by galvanised iron (G.I.) pipes and R.C.C. pipes with that of the above mentioned cost of water of Solar Still Plant, Table I is prepared. Capacity of water beyond 90,000 lit. (20,00 gal.) per day is not included, as Solar Still technique is not to be applied beyond this capacity, R.C.C. pipings of low sizes are not available normally, and hence G.I. piping is to be used for smaller capacity water conveyance. Table I indicates that if the distance of natural water from the place of consumption is beyond, say, 10 to 15 miles for capacities up to 22,500 lit. (5000 gal.) to 45,000 lit. (10,000 gal.) of water per day, the cost of conveyance per (4500 lit.) 1000 gal. alone exceeds the cost of Solar Still Plant-produced water. Even at the places where present supplies of natural water are taken from nearby wells, one has to keep in view the fact that in certain regions, the level of water in wells is falling down at the rate of 60 cm per year (5).

Based on the above mentioned factors and considerations, designs of Solar Still Plant have been given to several companies, mostly for their salt farms.


T
S
PUMP
R
P
MH
DISCHARGE
CONC. BRINE
DR
DV
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SOLAR
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E
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DISCHARGE DRAIN
PLAN
SOLAR STILLS
WATER LEVEL
E
DT
FEED CHANNEL
MH
MH
PUMP
P
R
S
G.L.
ELEVATION
P - PRODUCT WATER COLLECTION TANK
R - RAIN WATER " "
S - FRESH WATER SUPPLY TANK FOR DOMESTIC TANK
T - TAPS PROVIDED TO TANK & FOR USE
DR - DRAIN CONNECTIONS TO DISCHARGE DRAIN FOR RAINWATER
DT - DISTILLATE CONNECTIONS TO MH.
MH - MAIN HEADER (PIPE LINE) CARRYING DISTILLATE FROM ALL STILLS TO TANK.
---- SUCTION LINES.

Fig. 1

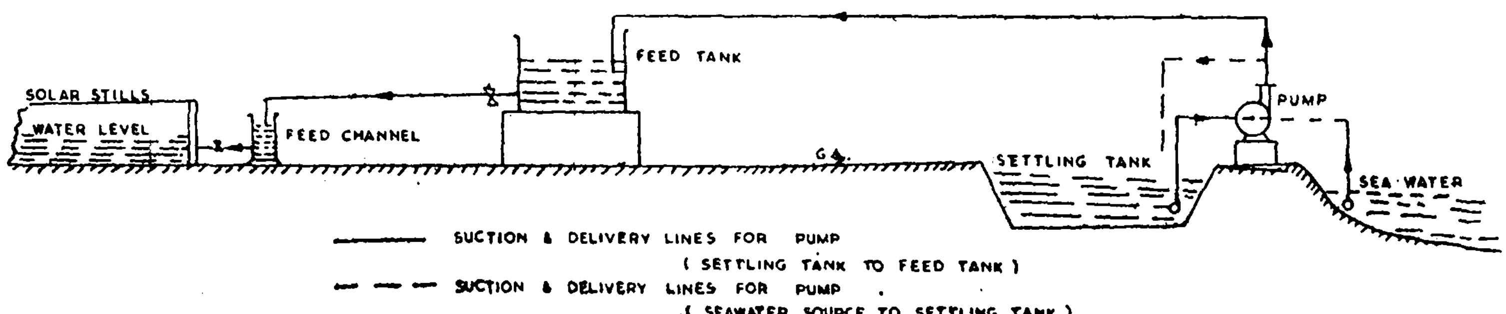
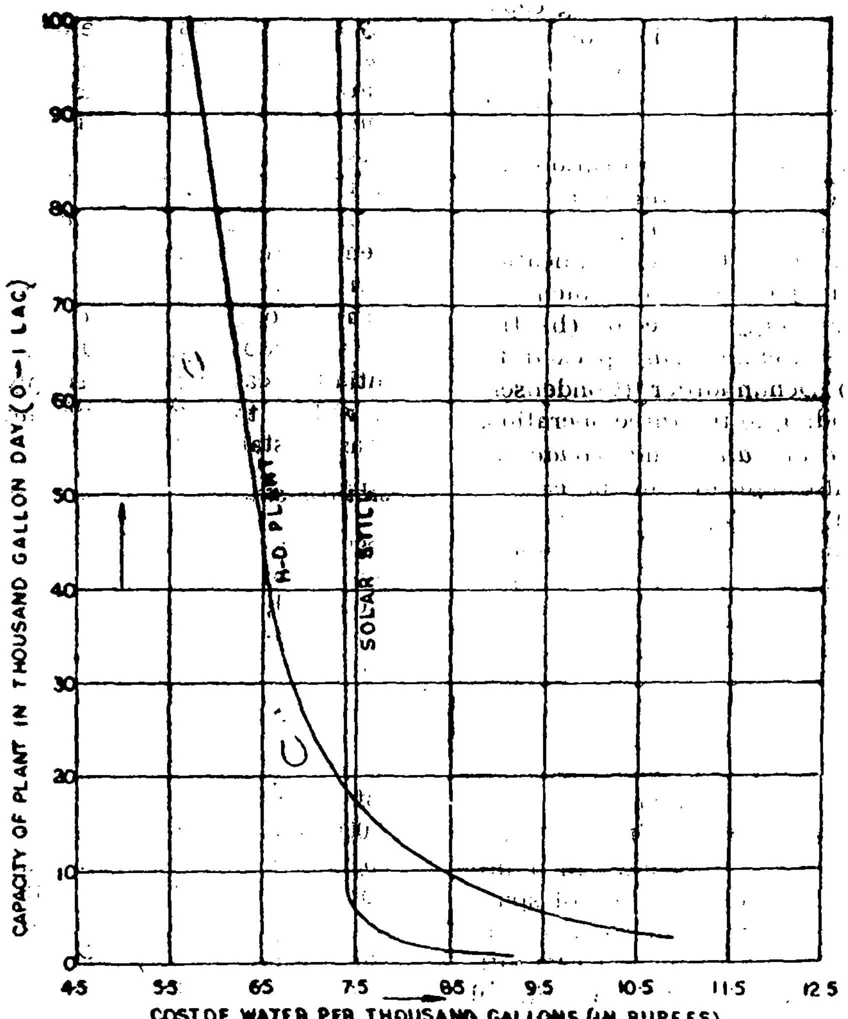

FEED TANK
SOLAR STILLS
WATER LEVEL
FEED CHANNEL
G.L.
PUMP
SETTLING TANK
SEA WATER
SUCTION & DELIVERY LINES FOR PUMP
(SETTLING TANK TO FEED TANK)
SUCTION & DELIVERY LINES FOR PUMP
(SEAWATER SOURCE TO SETTLING TANK)

Fig. 2

TABLE I—COSTS OF CONVEYING WATER BY G. I. AND R. C. C. PIPING FOR DIFFERENT DISTANCES AND CAPACITIES OF WATER

Water Requirement (gal/day) lit/day	Pipe size (in.)	Distance of source of natural water (miles)	*Cost of water (Rs. per 1000 gal.) Type of piping used	
			G.I.	R.C.C.
(500) 2250	1.0	2	19.70	
		5	36.90	
		10	61.40	
		15	94.65	
		20	122.60	
(1000) 4500	1.0	2	9.95	
		5	18.55	
		10	31.60	
		15	48.40	
		20	62.10	
(5000) 2,2500	2.0	2	3.06	
		5	6.04	
		10	11.25	
		15	16.20	
		20	21.25	
(10,000) 45,000	3.0	2	2.27	1.30
		5	4.73	2.31
		10	8.85	4.00
		15	12.86	5.68
		20	18.20	7.38
(20,000) 90,000	4.0	2	1.58	0.87
		5	3.32	1.53
		10	6.20	2.64
		15	9.10	3.77
		20	12.00	4.85

* To get costs in Rs./M^3 multiply values in Rs./1000 gal. by 0.220



COST OF WATER/1000 GAL. FOR SOLAR STILL PLANT & FOR HUMIDIFICATION-DEHUMIDIFICATION PLANT

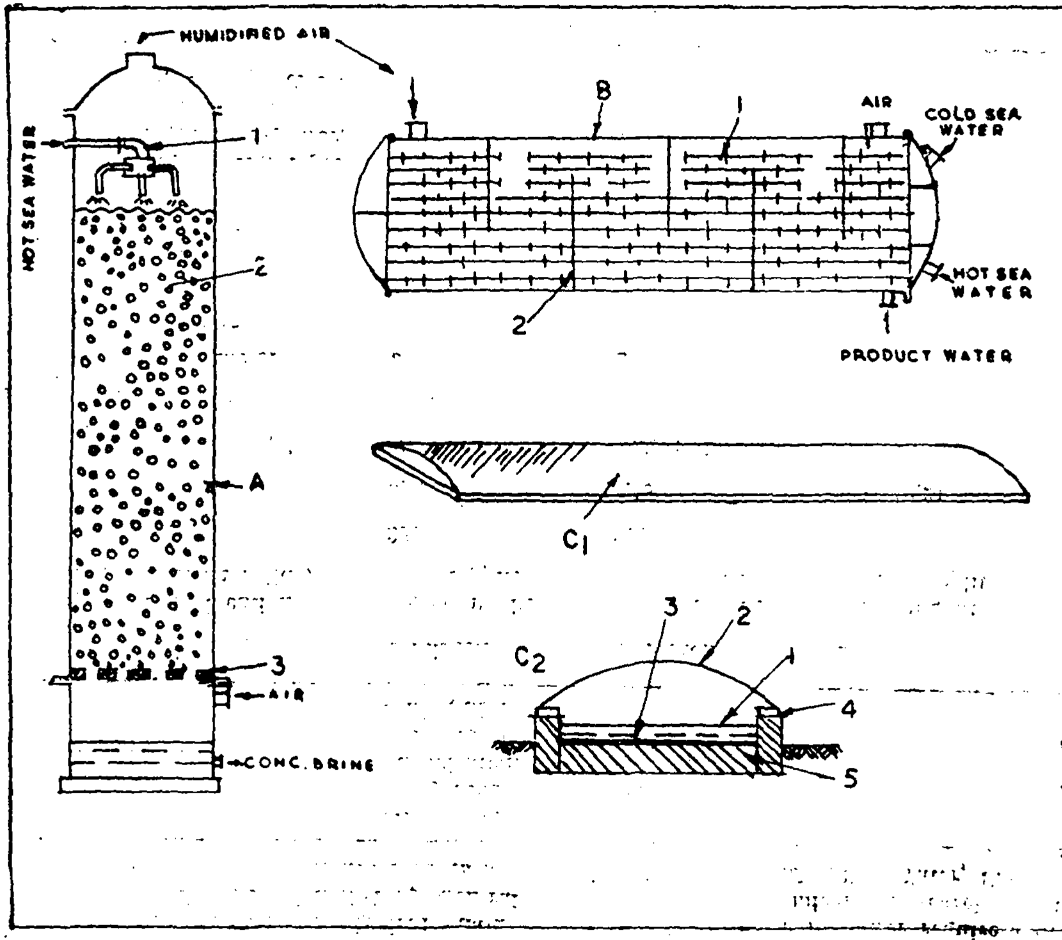
Fig. 3

Humidification-Dehumidification (HD) Technique

Limitations of the Solar Still technique with respects to limiting capacity of plant, utilisation of solar energy only to the extent of 30 per cent, requirement of larger space are overcome to a major extent in the Humidification-Dehumidification technique (HD) of desalination. The principle of this technique is described in an earlier communication (6), the major units of which are: (a) Solar energy collector (b) Humidifier (rasching ring packed tower) (c) Dehumidifier (Condenser) corresponding to the three operations *heating, evaporation* and *condensation* as also indicated in the case of Solar Still technique. The significant features of the HD technique which enable the above mentioned limitations to be overcome are that both evaporation (in tower) of hot brine and condensation (in condenser) of water vapour are much more controlled on account of design and operation of tower and condenser according to suitability of calculated performance. The important units of the HD Plant are shown in figure 4. On account of reduction of space to about ¼ in the plant compared to that for Solar Still plant better utilisation of Solar energy (to about 60 per cent) and more controllability of some of the important operations, not only the cost of fresh water by the HD plant is less but also the cost of investment per 1000 gal. (4500 lit.) decreases and earlier stated limiting capacity may be extended up to the million gallons of fresh water per day or more, but there is some requirement of artificial energy to the extent about 27 kwh per 1000 gal. (4500 lit.) to pump brine and blow air. This requirement of power is small compared to the power requirements for the other distillation techniques as shown in Table II, where energy requirements for the demonstration plant of the various techniques are compared with that for the million gallon capacity HD Plant. This table further shows that at 60°C, a concentration factor of 20 is obtainable implying a recovery of 5 per cent of fresh water in one cycle of operation. A HD Plant may be constructed out of indigenous materials. Consequently, a HD plant is potentially capable of supplying fresh water to bigger community, for reasons stated above.

Feasibility studies of HD technique

Based on the experiments with the laboratory plant of 140 lit. (30 gal.) of fresh water per day and design of 4,000 lit. (1000 gal.) per day capacity Pilot Plant, feasibility studies carried out for the HD Plants for various capacities indicate exponential relationships between capacity of the plant and investment cost per 1000 gal. (4500 lit.) as shown in Fig. 5, and capacity of plant and cost of water per 1000 gal. (4500 lit) as shown in Fig. 6. These relationships are significant in selecting a particular capacity of plant for a given duty. For example, if the requirement of water is one million gallons per day, the capital investment will be Rs. 78,20,000 and cost per 1000 gal. (4500 lit.) of water will be Rs. 4.69. There are ways of reducing both the cost of investment and the cost of fresh water. Use of waste heat of industrial plants (e.g. thermal power plants or Chemical industries using sea water as coolant) will reduce costs. In such a case the solar ener-



PARTS	DESCRIPTION
● A	HUMIDIFIER
1	DISTRIBUTOR
2	PACKING-RASCHIG RING
3	PACKING SUPPORT
B	DEHUMIDIFIER
1	FINNED TUBES
2	BAFFLE
C_1 C_2	SOLAR COLLECTOR
1	FIRST GLAZING
2	SECOND —DO—
3	BLACK BOTTOM
4	WOODEN CURB
5	BRICK MASONRY

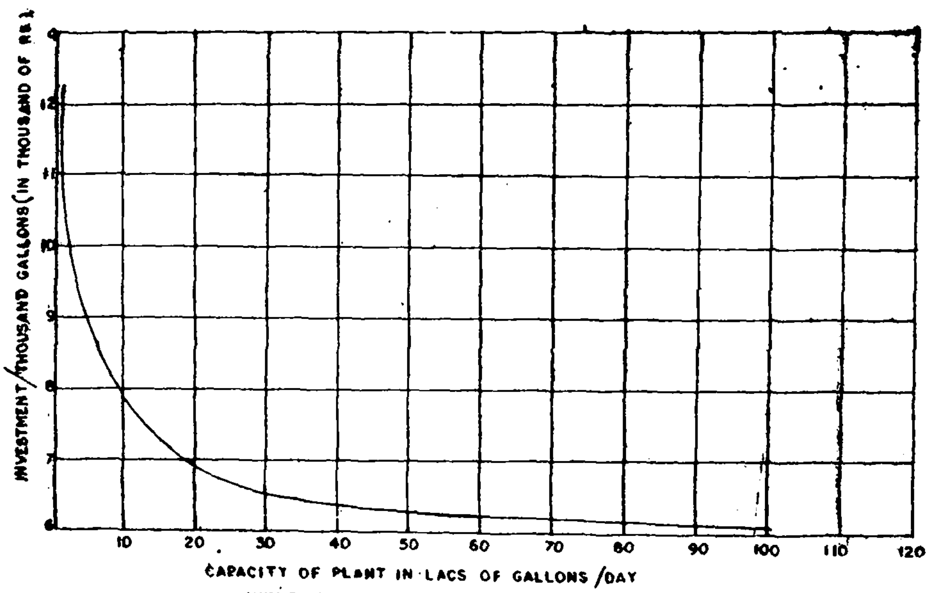
Fig. 4

TABLE II

Comparison of some typical data specially with reference to power requirement for various techniques of desalination as calculated by Central Salt and Marine Chemicals Research Institute, Bhavnagar. Some of the information for calculation of these data are from Office of Saline Water, U.S.A. (April, 1964).

	Distillation Long tube vaporisation (12 effects) falling film	Flash distillation (36 stages)	Electrodialysis (4 stages)	Distillation forced circulation vapour compression	Humidification → Dehumidification Calculated*
Capacity (gal./day)	1 million	1 million	2,50,000	1 million	1 million
Degree of purification (Total dissolved solids)	35,000 mg/lit —50 mg/lit	35,000 mg/lit —50 mg/lit	1 800 mg/lit —350 mg/lit	24,470 mg/lit —50 mg/lit	35,000 mg/lit —50 mg/lit.
Top temp. (°F.)	250	250	50	232	140
Power (KWH/1000 gal.)	8.11	3.18	6.4 (10.2)	55.9	27
Fuel, (BTU/1000 gal.)	0	0.95×10^6	0	3120	Solar energy
Steam, (BTU/1000 gal.)	0.846×10^6	0	0	0	Solar energy
Concentration factor (lbs of feed/lb of product)	3	2	2.2	4	20 (one cycle of operation).
$H_2SO_4 \frac{lbs}{1000}$ gal	1.3	1.3	3.0	0	0
Total energy in KWH per 1000 gal. (Electric power, fuel & steam converted into KWH, item 4, 5 & 6).	253.11	281.18	6.4	56.815	27

* CSMCRI, Bhavnagar



HUMIDIFICATION-DEHUMIDIFICATION PLANT
CAPACITY OF PLANT VS. INVESTMENT COST 1000 GAL

Fig. 5

gy collector of the HD Plant is not required if the temperature of the outlet sea water from the plants is reasonably high. Under such a condition, a million gallons capacity HD plant would cost Rs. 45,94,000 with cost of water per thousand gallons as Rs. 2.69. Costs of fresh water in HD Plants with or without solar energy collector may be reduced further by the recovery of costly by-product like Bromine. Investment cost and cost of fresh water by HD plant are compared with those for the techniques of desalination in operation in various parts of the world, as indicated in Table III, from which it is seen that both the costs for HD plants appear favourable. In this table investment cost and water cost for HD Plant without solar energy collector is not included. Nevertheless, both the costs of HD plant without solar collector will be less by more than 30 per cent of those of the HD Plant with solar collector at capacity of plant of one million gallons per day or more.

It is, therefore, evident from the above that depending on the capacity of requirement of water for smaller or medium sized or bigger communities, solar powered Solar Still plant or HD Plant may be used to produce and supply water for community in many parts of India where solar energy is in abundance for a long period of the year, although cost of such water may not be quite competitive immediately with that of the natural water unless chemical recovery plants are coupled with such plants or waste heat of industries are utilised. There exists immense possibility of implementing both these proposals in desalination plants.

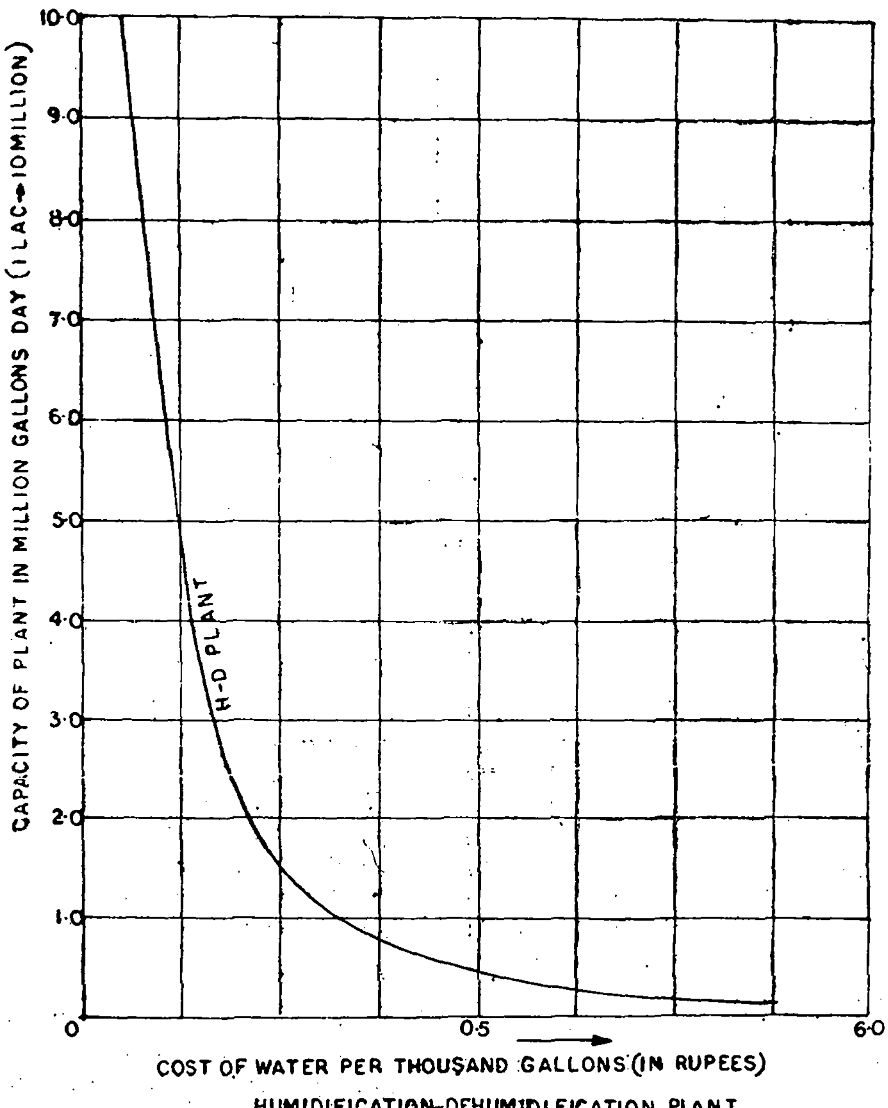

CAPACITY OF PLANT IN MILLION GALLONS DAY (1 LAC → 10MILLION)
10·0
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0
0·5
6·0
H-D PLANT
COST OF WATER PER THOUSAND GALLONS (IN RUPEES)
HUMIDIFICATION-DEHUMIDIFICATION PLANT

Fig. 6

TABLE III— CHARACTERISTICS OF SOME OF THE DESALINATION PLANTS UNDER OPERATION IN DIFFERENT COUNTRIES

CSMCRI, Bhavnagar

Technique	Location	Capacity (Rated) (gallons)	Degree of purification (mg/lit)	Investment cost (Rs./ 1000 gallons)	Cost of converted water (Rs./1000 gallons)
Submerged tube or multi-effect evaporation					
	Luderitz (S.W. Africa)	63,500	35,000 to 50	15,500	29.8
	Kuwait A	12,00,000	45,000 to 50	24,000	7.38
	Kuwait B	12,00,000	45,000 to 50	16,250	7.38
	Doha (Qatar)	2,38,000	45,000 to 24	—	26.50
	Salinas (Ecuador)	1,00,000	—	12,200	17.05
	Aruba	26,40,000	to 5	23,950	10.60
	Curacao	10,00,000	41,200 to —	30,200	18.95
	Freeport (U.S.A.)	10,00,000	35,000 to 50	9,200	6.25
Flash evaporation					
	Luderitz (S.W. Africa)	1,40,000	35,000 to 50	9,350	34.10
	Kuwait A	24,00,000	45,000 to 50	10,700	7.38
	Kuwait B	24,00,000	45,000 to 50	4,100	7.38
	Doha (Qatar)	3,60,000	45,000 to 24	—	26.50
	Safaniya Oilfields (S. Arabia)	5,000	45,000 to 50	1,94 000	50.00
	New Providence (Bahamas)	14,00,000	35,000 to 50	8,100	—
	Carlton Beach Hotel (Bermuda)	40,000	35,000 to 50	4,900	14.20
	Salinas (Ecuador)	50 000		15,200	17.05
	Virgin Islands	3,00,000	35 000 to 2	18,400	12.31
	Guernesey	6,00,000	35,000 to 100	6,800	9.28
	San Diego (U.S.A.)	10,00,000	35,000 to 50	8,050	6.00

TABLE III—(Contd.)

Technique	Location	Capacity (Rated) (gallons)	Degree of purification (mg/lit)	Investment cost (Rs./100 gallons)	Cost of converted water (Rs./1000 gallons)
Vapour compression evaporation					
	Port Etienne (Africa)	50,700	—	—	83.00
	Kingley Air Port Base (Bermuda)	2,00,000	35,000 to —	—	17.40
	Roswell (U.S.A.)	10,00,000	24,470 to 50	10,000	7.00
Electrodialysis					
	Zarzis (Tunisia)	6,600	6,300 to 1200	—	13.62
	Awali (Bahrain)	85 000	3,400 to 500	24.600	14.95
	Qom (Iran)	13,200	2,000 to —	10,700	—
	Dhaharan (Saudi Arabia)	1,15,000	2,500 to 500	—	30.00
	*Welkom (S. Africa)	28,80,000	3,000 to 500	1,380	1.52
	Buckeye, Arizona (U.S.A.)	6,50,000	2,076 or — 2,140 to 500	—	1.65
	Webster (U.S.A.)	2,50,000	1,800 to 350	8,230	5.00
Solar Evaporation					
	Florida (U.S.A.)	147	35,000 to 50	2,08,500	29.90
	Bhavnagar (India)	500	35,000 to 50	1,00,000	8.95
Humidification—Dehumidification					
	Puerto Penasco (Estimated)	10,00,000	35,000 to 50	8,675	4.55
	Bhavnagar (Estimated)	10,00,000	35,000 to 50	8,000	4.69 (3.9)
Zarchin Freezing Process					
	Eilat (Israel) (Estimated)	5,30,000	35,000 to 50	8,000	5.00
Ion Exchange					
	Eilat (Israel)	7,920	2,600 to —	—	43.5

*Used as stand by

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DISCUSSION

Shri C. B. Kharkar, Bhilai: What is the cost per 1000 gallons with respect to maintenance operation, interest on capital, sinking fund etc? Why not dispense with the containers and reduce the cost?

Shri S. D. Gomkale, Bhavnagar: HD technique is more suitable for higher capacities of fresh water (in millions of gallons). The higher the capacity of the plant, there is portional increase in the cost of investment and cost of water is decreased.

Based on one lakh gal/day capacity plant the cost per 1000 gallons is given:

Total plant investment (approximate rough estimation) = Rs. 12,24,000

1. Maintenance labour and maintenance material @ $2\frac{1}{2}\%$ of T.P.I
2. Operating, power, $\frac{27 \text{ KWH}}{10000 \text{ gallons}} = 2.7$ @ Rs. 0.10 per KWH.
3. Interest and sinking fund (Depreciation) = Rs. 3.0 @ 7.4% (20 years life of the plant).
4. Regarding containers for keeping saline waters for evaporation it is to be noted that in laboratory units metallic trays are indispensable. But in actual practice, one can go in for cement concrete basins of required dimensions for producing more water. Even stabilized soil basins can be used along with plastic linings.

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Studies on Solar Still for Production of Water for Small Communities in Arid Zones

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Introduction

In arid zones like Rajasthan and several other regions in India, the availability of surface water is very limited. The ground water available is brackish and is not suitable for domestic use. Therefore, for Rajasthan and other several states in India, where large tracts of under ground brackish water are found, it is a uphill task to get water which is fit for drinking purposes. In these areas, the sources of surface water are very few due to scanty rainfall In summers, the situation becomes quite precarious as even the meagre surface water sources are dried up leaving the people of these areas with no alternative except to use the brackish water for drinking also. The chloride content of these waters ranges from 500 to 8,000 mg/lit., 2,000 to 4,000 mg/lit., being the common range. The use of this water for drinking is, therefore, bound to affect the health of the users.

Several sophisticated processes of desalting the Saline Water have been developed. These processes are Distillation, Humidification, Membrane, Ion Exchange, Freezing, Hydrate and Solvent Extraction (1).

All these processes have their advantages and disadvantages when examined for desalting a particular water. However, one factor is common to all of them, they are quite complicated and costly. Moreover they require a specialised skill for their design, operation and maintenance and therefore, may not be suitable for our country. Humidification process includes multi-effect humidification and solar still processes. Solar still process seems to be of great interest for developing countries like India. They require solar energy, which fortunately is available in plenty, especially in arid and semi-arid zones where brackish water is a problem.

It is with this background that the present studies were taken up by the authors.

Objective of the Studies

Two experimental working models were set up with two major objectives in mind: (1) To arrive at a design of Solar Still which can utilize

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the maximum Solar energy, (2) To estimate the possible yield of the water for a set of conditions

Design Features

A model admeasuring 5′-6″ x 6′-6″ and having mild steel evaporating pan (3′ x 6′ x 3″) covered with glass at an inclination of 45° was set up. The data on the yield of this unit for the period of January 1965 to May 1965 showed that at an average 0.5 gal/day yield was achieved at 32.8% efficiency of collection for the total surface of water.

The low efficiency of collection and consequent low yield was traced due to leaks developed in the model and some initial shortcomings of the erection. Therefore, an improved model was erected based on the experience of running the first model.

The main improvements made in the new model were: (i) plugging of the leaks was achieved by rubber beadings, (ii) collection channels for condensed water were provided in all four sides instead of two as was done in old model, and (iii) the model was constructed in such a fashion that it was easily accessible for repairs from inside. Figures 1 and 2 show the pictorial view and the side sectional view of the model.

In addition to this, another model similar to the one described above was set up with an angle of inclination of 30°. This model was erected to see whether the angle of inclination of glazing has some effect on the yield. The design features of the two models (called here A & B) are given in *Table I*.

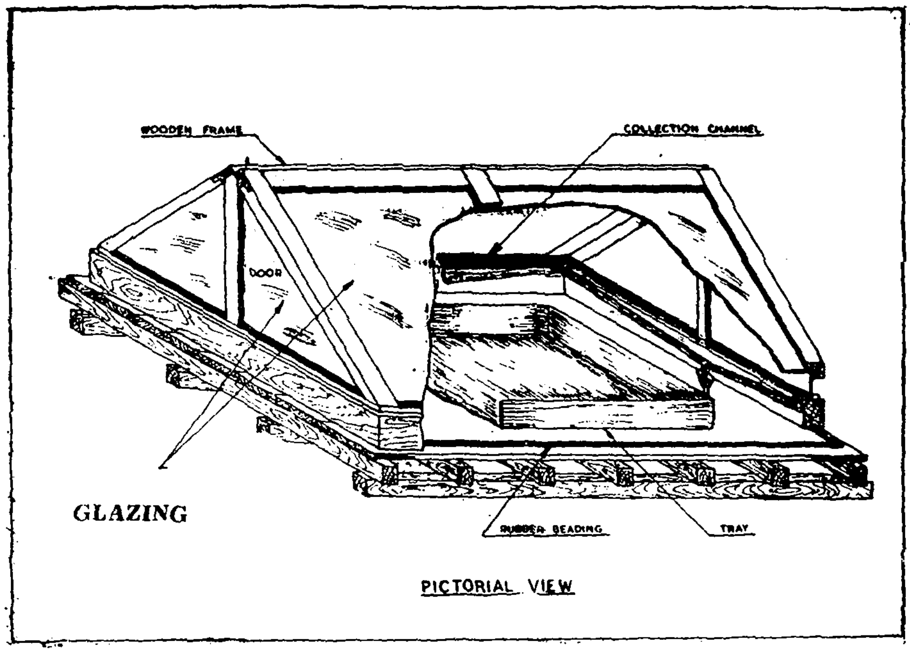

Fig 1

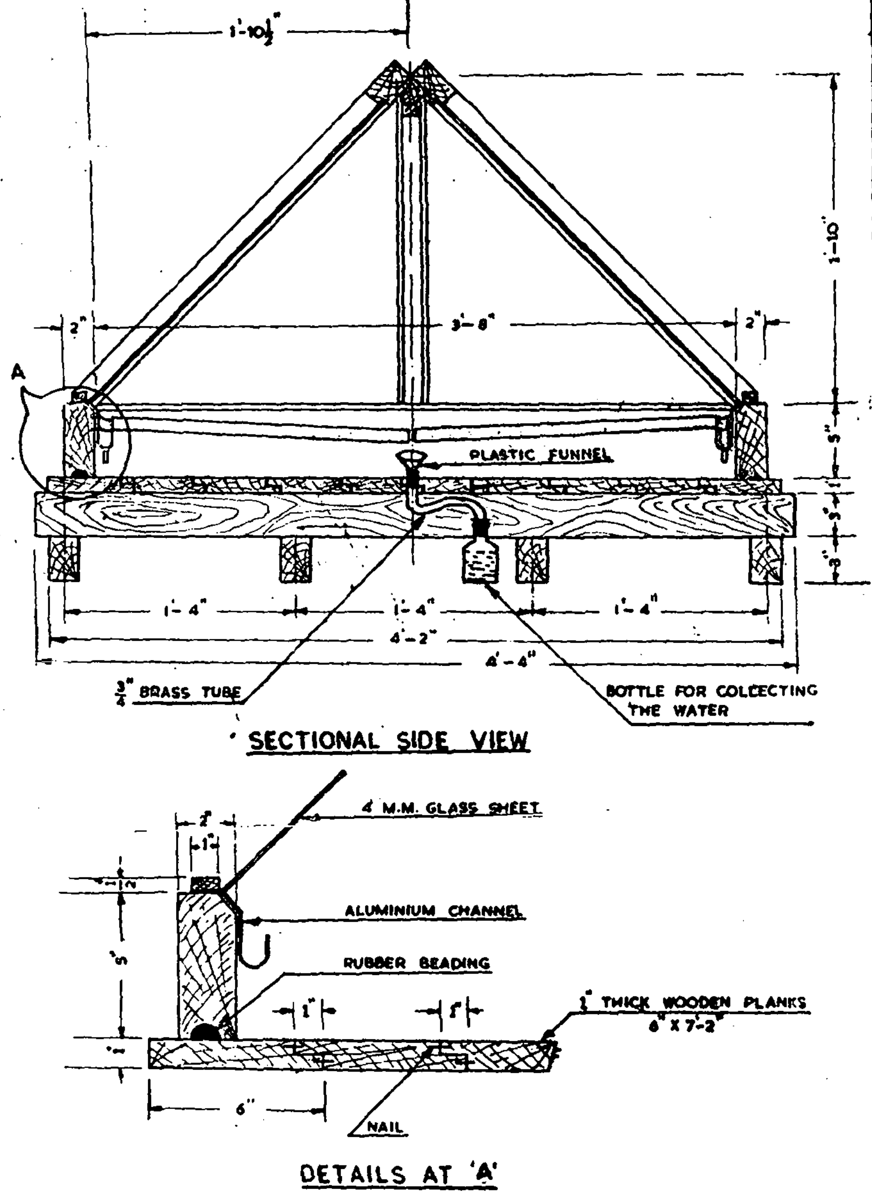
1'-10½"
1'-10"
3'-8"
2"
2"
A
5"
PLASTIC FUNNEL
1'-4"
1'-4"
1'-4"
4'-2"
4'-4"
3/4" BRASS TUBE
BOTTLE FOR COLLECTING THE WATER
SECTIONAL SIDE VIEW
4 M.M. GLASS SHEET
2"
1"
ALUMINIUM CHANNEL
RUBBER BEADING
1"
1"
1" THICK WOODEN PLANKS 6" X 7'-2"
6"
NAIL
DETAILS AT 'A'

FIG. 2

TABLE I—DESIGN FEATURES OF MODELS A & B

Tray material used	20 gauge copper & M.S. sheet painted black	20 gauge copper sheet painted black
Inclination of glazing	45°	30°
Area of trays	1.62 sq. meters (17.5 sq ft)	1.62 sq meters (17.5 sq ft)
Effective glazing surface	3.22 sq. meters (34.6 sq ft)	2.106 sq meters (22.6 sq ft)
Depth of water in the pan	13 cm 6 cm	13 cm 6 cm
Total Depth of the pan	15.2 cm (copper) 6 inches 7.6 cm (M.S.) (3 inches)	15.2 cm (copper) (6 inches)

Data Collected

The following data were collected during these studies: (1) Solar radiation in langleys (2) maximum and minimum temperatures (3) total quantity of water evaporated which has been calculated by multiplying the surface area of the pan and the reduction in water level measured with the help of glass tube suitably calibrated and attached to the pan containing water/brine over a period of particular duration, (4) actual collection of water per day (yield). The data collected have been tabulated in Tables II & III (see appendix).

A graph showing yield of solar stills is shown in Fig. 3 wherein solar radiation versus yield per sq m. area of effective glazing surface is plotted.

Analysis of Results

From Table II and III, it can be seen that the solar still performance during the period from Dec. 1965 to May 1966 has markedly improved as compared to results obtained during January 1965 to May 1965 which are given in Table II. The latter unit gave an average yield of 2.09 litres (approx. 0.5 gallons) per day at 32.8% (average) efficiency while the former gave an average yield of 4.51 litres/day (1 gallon) at an efficiency of 73%. These figures pertaining to pan 'A' made of Mild Steel are arrived at by taking the average of three months (March, April & May, 1966). These three months were selected as the pan used during this period was of mild steel similar to the one used in earlier studies (Jan. 1965 to May

1965). In this comparision, inclination of glazing in both the cases was 45 degrees.

On further examining the table III, it will be seen that both the units i.e. Models 'A' & 'B' had evaporation pan made of copper during the period between Dec. 1965 to March 1966. The model 'A' represents the unit which had glazing inclined at 45° to the base while model 'B' stands for unit having glazing inclined at 30°. From the average monthly yields of the period Dec. 1965 to March 1966 it can be observed the Model 'B' having inclination of 30° gives consistently better results, as compared to Model 'A' which has glazing inclined 45° to its base. In both the models, the evaporation pan areas exposed to solar radiation are the same i.e. 1.62 sq m. (17.5 sq ft). But the glazing areas are different. The average yield of model 'A' during the period Jan. '66 to March '66 comes to 3.58 lit/day for 3.22 sq m. of (34.6 sq ft) glazing area. The average yield for model 'B' during the same period comes to 3.172 lit/day for 2.101 sq m (22.6 sq ft) of

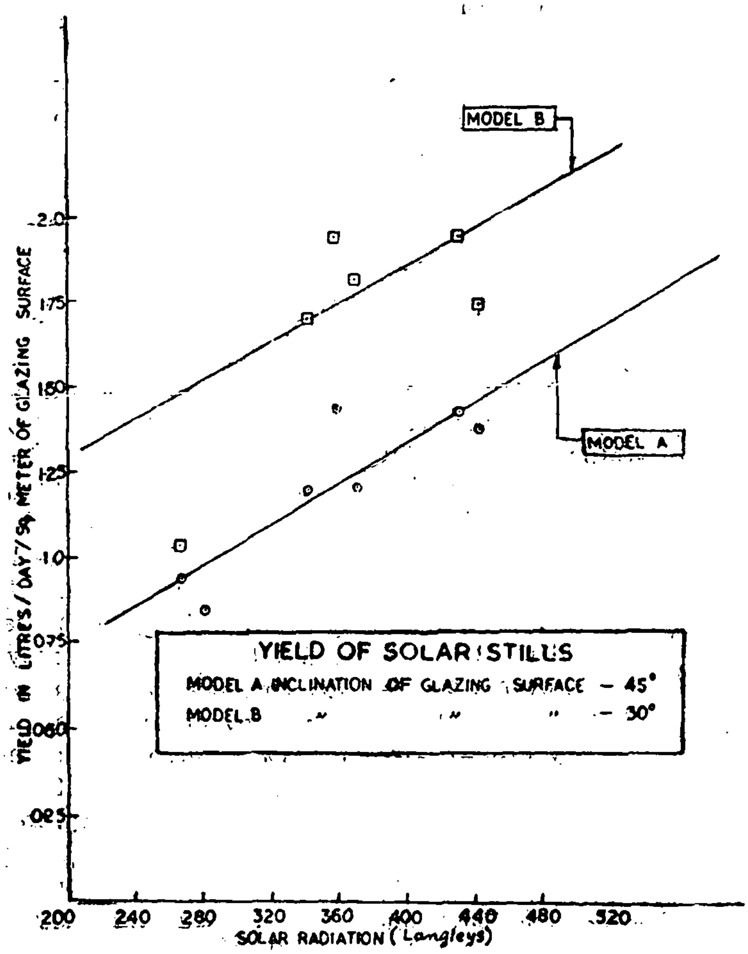

Fig. 3

TABLE II—RATE OF YIELD OF FRESH WATER (JAN—MAY 1965) RESULTS OBTAINED BY OLD MODEL OF 45° INCLINATION

Year Month	Duration (hrs)	Incident Solar radiation langleys (average)	Total Qty. evaporated litres	Total Qty. collected litres	Collection Efficiency (%)		Collection (litres/day)	Collection 2.31 sq met. of effective glazing.
					Ave. based on daily efficiency	Ave. based on overall efficiency		
1965 Jan.	472	—	104.53	51.175	48.01	48.85	2.60	1,695
Feb.	432	308.6	95.21	35.00	40.56	40.40	1.85	1.173
Mar.	744	493.0	205.56	44.80	25.06	21.61	1.52	1,542
Apr.	432.5	535.0	141.61	40.30	25.73	30.28	2.33	1,478
May	529.5	544.6	178.58	47.05	24.74	26.30	2.156	1.365

TABLE III—RATE OF YIELD OF FRESH WATER (DEC. 1965—MAY 1966)

Month & year	Duration (hrs.)	Incident Solar radiation-(Langleys) (Average)	Ave. Temp Max oC	Ave. Temp Min oC	Model	Total Qty. evaporated (litres) (overall)	Total Qty. collected (litres)	Collection Efficiency % Ave. of the daily efficiency	Collection Efficiency % Ave. based on overall efficiency	Collection (litres/day)	Collection/2.31 sq met. effective glazing	Salt concentration mg/lit. (NaCl)	Salt concentration of collected water (mg/lit)	Tray material
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Dec. '65	192	281.15	26.81	15.65	A	24.22	21.67	88.70	89.50	2.708	1.954	—	—	Copper
Jan. '66	382.5	267	28.52	14.57	A	56.72	47.95	82.80	83.53	3.008	2.170	—	—	,,
	430.5				B	47.49	39.11	81.60	82.35	2.180	2.411	—	—	,,
Feb. '66	547.5	343.0	34.91	16.31	A	103.89	87.77	85.55	84.45	3.847	2.775	—	—	,,
					B	96.62	81.15	87.41	84.50	3.557	3.932	—	—	,,
Mar. '66	306.75	371.0	36.16	20.94	A	64.32	49.72	68.00	77.35	3.890	2.805	2014	—	,,
	258.75				B	58.50	40.75	66.42	69.65	3.778	4.177	1958	—	,,
Mar. '66	98.00	432.0			A	23.04	18.73	80.30	81.43	4.588	3.30	2119	—	M.S.
					B	24.53	16.76	66.06	68.00	4.086	4.494	1980	—	Copper
Apr. '66	404.50	359.0	42.53	26.59	A	103.68	77.50	79.27	74.52	4.600	3.312	2775	10.09	M.S.
	247.00				B	48.95	42.07	77.14	81.29	4.080	4.438	3055	7.37	Copper
May '66	168	444.5			A	48.96	30.31	66.00	63.00	4.33	3.18	1551	6.51	M.S.
					B	55.44	25.63	47.48	48.50	3.66	4.026	1676	7.61	Copper

glazing area. In both these models for this period, the trays used were made of copper. If model 'B' had the same glazing, area as Model 'A', the yield per day would have increased to 5.1 lit/day which is more than a gal/day. The solar radiation during the period Dec. '65 to May '66 ranged between 267 to 445 langleys while during Jan. '65 to May '65 it ranged between 309 to 545 langleys.

The major part of the experiments was conducted with tap water. But from March 1966 to May 1966, the water was used having salt concentration between 1551 to 3055 mg/lit. as NaCl. This was done in order to see whether the model performance is affected when the brackish water is used in the evaporation trays, as for practical purposes, the saline water will form the evaporating surface. But no particular effect is observed on the yield performance in the range of salt concentration used. However, the data collected in this respect is meagre and, therefore, no conclusion can be drawn at this stage.

Cost Analysis

The cost of erection, including labour and material, works out to Rs. 600.00. This unit can give a yield of approx. one gal/day (1.62 sq m surface area) of distilled water. It is rather difficult to give the cost for a solar still plant which can serve a small community based on these small scale studies. An estimated cost of fresh water from a 500 gal/day capacity solar still by Datta *et al* (2) is reported as Rs. 8.45 per 1,000 gallons. This is 8 to 10 times the cost of the water obtained by conventional methods. Other desalination processes such as multi-effect evaporation, multistage flash evaporation, electrodialysis etc. are equally expensive and more elaborate and complicated.

Conclusions

From the present study, three conclusions can be drawn. (1) A solar Still with a 30° inclined glazing gives much better yield than the one having 45° inclined glazing; both having the same evaporating surface area and the effective glazing area. (2) The yield is considerably increased if the collecting channels are provided on all sides of the solar still (3) Corrosion is a problem in the case of mild steel trays. But copper is very expensive to be used for this purpose. Therefore, some other material such as Aluminium should be tried out.

Applicability of the Process

There is no doubt that solar still process or, for that matter, any other desalination method can not complete with the conventional method of obtaining the fresh water. However, solar stills have a place in arid and semi-arid zones where solar energy is in plenty and the water available is brackish. The solar still can be thought of as domestic supply units. In areas, where brackish water is necessary to be converted in to fresh water, these units can be used on the tops of residential buildings supplying water to the individual houses. Perhaps the cost of the water obtained by solar still may not be considered very prohibitive in areas such as Rajasthan, where, in summer, the drinking water is transported from distant places. The cost of the water produced can be reduced if the distilled water is mixed with the brackish water in suitable proportions to keep the salt concentration within the limit.

For small towns and villages having problem of brackish water, the use of solar still seems to be advantageous in the absence of any other source of potable water in the vicinity. The process has special attraction because it is simple in construction and easy to maintain and has no mechanical part for wear and tear. Moreover, no energy is required for its operation. For large scale plants, the evaporating trays can be made of cement concrete and the wooden frames can be replaced by iron angle frames. This will bring down the cost of the units and their repairs. In the Pilot Plant constructed by the Central Salt & Marine Chemicals Research Institute (2) the bottom of the still is made of cement concrete painted black.

Acknowledgement

The authors are thankful to Shri R. S. Mehta Director, Central Public Health Engineering Research Institute who first initiated the idea of taking up this study and shown a keen interest all through this work.

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DISCUSSION

Shri J. M. Dave, Nagpur: With results of both the workers it should be possible to arrive at an economical design of "still" using prefabricated or plastic material. I think there should be no difficulty in this matter to give good solution.

Shri J. S. Jain: The economy of the solar still using plastic material is not yet studied in India. In the U.S.A., however, plastic solar stills have been tried. But these types of stills are developed for army purposes for very small yields. The author does not know if the economy of the process using plastic material is studied even in the U.S.A.

Dr. G. J. Mohanrao: Is there any relationship between humidity and the yield of water in a solar still?

Shri J. S. Jain: Yes. Humidity should affect the yield normally. But in the case of solar still, the system is closed and therefore the humidity of the atmosphere does not come into picture and will not affect the evaporation or condensation which are responsible for the yield of pure water.

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Importance of Bacteriological Standards in Water Supply

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Introduction

A direct search for the presence of specific pathogenic bacteria in water is impracticable for routine control practices and is, therefore, ruled out. The detection in water of coliform organisms and *E. coli I* in particular which are constantly present in large numbers in the faeces of all warm blooded animals and man, shows that recent excretal pollution has occurred. Although by itself this pollution may not constitute a conclusive evidence of danger, it is sufficient to indicate that the water is potentially dangerous for consumption.

It is indeed difficult to define pure water. A water may look clear, free from dirt, organic matter and odour but still it may be "Chemically" or "Bacteriologically" impure or unsafe. Scientifically, therefore, wholesome water means water that is chemically and bacteriologically pure besides being aesthetically acceptable and such waters should always conform to the prescribed standards.

Both chemical and bacteriological standards for drinking waters are recommended by different agencies. Bacteriological standards provide more simple and direct criteria for the maintenance of water quality. The incidence of enteric diseases in some of the advanced countries has been practically eliminated mainly due to the supply of pure water, made possible by the use of improved water treatment procedures. The waters supplied to the consumers were regularly checked for their bacteriological quality. When they did not meet the standards, remedial measures were always taken to see that the quality improved and the water met the required bacteriological standards.

Some piped water supplies in small towns are distributed without disinfection and in others they are chlorinated or otherwise disinfected before distribution. The question may arise whether the bacteriological standards should be different for chlorinated and unchlorinated piped water supplies. According to the European Standards for Drinking Water (1) there appears to be no logical reasons for setting up different bacteriological standards for such waters. United States Public Health Service (2) also does not prescribe different standards for treated and untreated waters. However, Report No. 71 of the Ministry of Health, England (3) states that *there should be separate standards* for chlorinated and raw piped water supplies and that the standards must not be interpreted too rigidly. On the other hand no serious departure from them ought to be viewed with complacency. Some bacteriologists are of the view that once a drinking water supply falls below a certain standard it is definitely unsatisfactory for drinking whether it is disinfected or not. At present the majority, however, appear to favour the concept that there should be separate standards for treated and untreated drinking water supplies. This is because in some countries economical and technological considerations besides other factors do not permit to have high standards for treated as well as untreated waters (3).

As a routine measure bacteriological examination of water meant for drinking purposes should be made for:

1) Standard plate count

2) The coliforms

3) The *E. coli* type I (Faecal coliforms)

4) The faecal streptococci or enterococci.

Standard Plate Count And Raw Water Classification

The tests for coliforms, *E. coli I* and faecal streptococci throw light on the sanitary quality of water whereas the plate count indicates the general nature of water. This test is more important to check the efficiency of treatment processes like coagulation, sedimentation and filtration. A sudden increase in the standard plate count is a cause for suspicion which may be due to faulty operation processes or an initially high concentration of bacteria due to unexpected and heavy pollution at the source. A high plate count is indirectly a measure of the available organic matter present in water. Any water containing organic matter in appreciable quantities is harmful for human consumption. As the standard plate counts do not necessarily reflect the sanitary quality of water, none has fixed standards based on this. Thresh and Beale (4) make an interesting comparison of early bacterial criteria relating the bacterial count to the quality of water. His tabulation of the recommendations of Miquel and Mace is shown below:

Designation of Quality	Number of Bacteria per ml after	
	Miquel	Mace
Very pure water	0-10	0-10
Very good water	10-100	20-100
Good or Pure water	100-1000	100-200
Passable water	1.000-10.000	200-500
Impure water	10,000-100,000	500-1000
Very impure water	Over-100.000	Over 1000

Group	Limiting monthly average coliform density (MPN/100 ml)	Treatment requirement
I	Nil	No treatment is required
II	Less than 50	Simple chlorination or equivalent.
III	Less than 5000 (20% of samples should not exceed 5000)	Complete treatment with rapid sand filtration and post-chlorination.
IV	More than 20% of samples may exceed 5000 but not more than 5% of these samples should exceed 20,000	Auxiliary treatment in addition to complete treatment.

Coliforms And Raw Water Classification

Based on the coliform density the raw waters can be classified into 4 groups with respect to their treatment requirements (5).

The above classification of raw waters is given for general guidance. It is now known that waters which are much more polluted than group IV, are successfully treated in the modern water treatment plants.

Evolutionary History

The data on which the present bacteriological standards have evolved were mostly from the United States and England. Miquel, in 1881 attempted to classify the potable waters on the basis of their plate counts. In 1903, Whipple suggested the standards based on positive tubes of *B. coli*. In 1914, the United States Treasury Department promulgated its first standards based on agar plate count and presenc of *E. coli* in water. The standards were revised by the United States Public Health Service in 1925 in which importance was placed on the results of a series of samples rather than on the examination of a single sample and standards based on agar counts were omitted. Further, these standards were revised in 1942 wherein coliforms in place of *E. coli* were substituted. They were further revised in 1946 and 1962 to the present day form.

In England, the first official bacteriological standards were prepared in 1934 jointly by late Dr. Thomas Carnwath, late Sir Alexander Houston, representatives from the Lister Institute of Preventive Medicine, the London School of Hygiene and Tropical Medicine and the Counties Public Health Laboratories. These standards were amended in 1939, 1956 and 1960.

The basis and need for the standards

Epidemiological data, general knowledge, experience with the use of polluted waters and the efficiency of the modern water treatment plants are the most important factors governing the standards. The need for the bacteriological standards is mainly (a) to judge the quality of any water supply with respect to the transmission of enteric diseases, (b) to provide greatest possible protection to the consumers against water borne diseases and (c) to strive for the improvement in water quality.

Rationale of bacteriological standards

The presence of pathogenic organisms in drinking water is sometimes responsible for the outbreak of diseases. Since the methods of detecting pathogens are time consuming, difficult, complicated and uncertain, it is not practicable to examine drinking waters for the pathogens. The use of coliforms as the indicator of faecal pollution is universally accepted because they are always present in large numbers in the faeces of man and animals. Whenever enteric pathogens are present in faeces they are greatly outnumberd by coliforms. The presence of coliforms in water, therefore, indicates excretal pollution. Hence, the quality of a drinking water is based on the coliform density and not on the number of pathogens. Since *E. coli* is exclusively faecal in origin the standards are more rigid about their presence in drinking water.

The salient features of the bacteriological standards for treated and untreated drinking waters recommended by the British Ministry of Health (3) United States Public Health Service (2), World Health Organisation (6 & 1), the Indian Council of Medical Research (7) and the committee on Public Health Engineering Manual and Code of Practice, Govt. of India (8) are given in Appendix I.

Results and Observations

In order to find out how far the waters in and around Nagpur conform to the prescribed standards, samples were collected from Kanhan river, Ambazari and Gorewara lakes, wells, water treatment plants and from the distribution system. Altogether 301 water samples were analysed for coliforms and *E. coli I* over a period of one year out of which 123 constituted untreated and 178 treated samples. Multitube technique as recommended in Standard Methods (9) was used for the estimation of coliforms and *E. coli I*. The split up of the samples and the MPN counts per 100 ml. for coliforms and *E. coli I* are presented in the Table I. Arithmetic and geometric mean counts and median values are also given for comparison.

It will be observed from Table I that among the raw water sources Kanhan river water was most polluted showing a geometic mean of 3949 as against 1374 and 38 of wells and lakes respectively. The geometric mean of *E. coli I* for river water is 1263 while those of wells and lakes are 353 and 9 respectively. The median values of coliforms in these sources were always greater than 20.

In case of treated waters the geometric mean values could not be calculated because of the frequent zero counts for coliforms and *E. coli I*. The arithmetic mean counts for freshly chlorinated waters and tap waters at the consumer's end were 114 and 78 respectively, whereas the *E. coli I* count was 22 in both. Fresh-

APPENDIX—I

SALIENT FEATURES OF THE BACTERIOLOGICAL STANDARDS FOR DRINKING WATERS RECOMMENDED BY DIFFERENT AGENCIES

Agency	Treated Water	Untreated Water
British Ministry of Health (3) (1957)	All chlorinated supplies should yield samples free from coliforms in 100 ml. Even a count of 1 or 2 organisms per 100 ml should throw doubt on the efficiency of treatment.	In case of non-chlorinated piped water supplies 80% of the samples examined **during the year** should show less than 1-2 presumptive coliforms per 100 ml.
U.S.P.H.S. (2) (1946 and 1961)	The standards depend on the number of standard portions of the sample that show the presence of coliforms.	
	When the standard sample volumes consist of 5 equal portions of 10 ml each, not more than 10% of all such standard samples should show the presence of the coliform group. Similarly when the standard sample volumes consist of 5 equal portions of 100 ml each, not more than 60% of all standard samples examined **per month** should show the presence of the coliform group.	They do not prescribe a different standard for untreated water. The standards prescribed for treated waters are applicable.
W.H.O. (6) (International *Standards)*.	In 90% of the samples examined throughout **any year** coliform bacteria should not *be detected or the MPN index of coliform* organisms shall be less than 1 and none of the samples should have the MPN index of coliforms in excess of 10.	In 90% of the samples examined **throughout any year** the MPN index of coliforms *should be less than 10* and none of the sample should show MPN index greater than 20. Not more than 40% of the number of coliforms as shown by the MPN index shall be faecal coliform bacteria. An MPN index of 15 or more should not be permited in consecutive samples. If MF technique is used the arithmetic mean of the coliform group should be less than 10 per 100 ml and shall not exceed 20 per 100 ml in two consecutive samples or in more than 10% of the samples.
I.C.M.R. (7) (1962) and P.H.E. Manual and Code of Practice (8) (1962).	In 90% of samples examined **in a month** coliform bacteria should be absent or the MPN index should be less than 1.0. No sample should contain an MPN of coliform exceeding 10/100 ml. MPN index of coliform bacteria of 8 to 10/100 ml should not occur in consecutive samples.	Throughout any **month**, none of the samples should show MPN of coliform in excess of 10/100 ml. MPN of 20/100 ml may be permitted occasionally if **E. coli I** is absent. **For rural water supplies:** Because it is difficult to provide treatment facilities, means should be adopted to prevent access of pollution by adopting all sanitary measures to ensure its hygienic safety. The bacteriological standard recommended for the untreated water supplies may be applied to small rural water supplies.
W.H.O. (1) (1961) (European Standards)	Coliform organism must be absent from any water entering the distribution system. In aggregate results, a limit of tolerance of the presence of 1 or more coliform organisms in a 100 ml sample of water can be permitted in 5% of samples examined provided that positive result is not obtained in 2 or more consecutive samples and that at least 100 samples of 100 ml each, regularly distributed **over a year**, are examined.	Same as for treated waters.

TABLE I—AVERAGE MEAN COUNTS AND MEDIAN VALUES FOR COLIFORMS AND E. COLI I

Source	No.		MPN/100 ml coliforms	MPN/100 ml E. coli I
UNTREATED				
Kanhan	21	A.M.	23572	6667
river		G.M.	3949	1263
		Md.	2950	1850
Well	42	G.M.	4800	1925
		A.M.	1374	353
		Md.	1700	490
Ambazari		A.M.	1066	170
& Gorewara	60	G.M.	38	9
lakes		Md.	26	5
TREATED				
Freshly		A.M.	114	22
chlorinated	88	G.M.	—	—
		Md.	1	1
		A.M.	78	22
Tap	90	G.M.	—	—
		Md.	0	0
Total	301			

A.M.=Arithmetic Mean G.M.=Geometric Mean Md=Median

ly chlorinated and tap waters showed median values of 1 and 0 respectively.

Table II depicts the number of samples free from coliforms and *E. coli I* in untreated and treated waters.

It can be noticed that not a single sample from river or well showed absence of coliform group. In fact 100 per cent of river water samples showed the presence of coliforms and *E. coli I*. Only 4.76 and 13.33 per cent of well and lake water samples showed absence of *E. coli I* respectively. In other words these sources were found to be grossly polluted. Water from the distribution system was found to be free from coliforms and *E. coli I* in 53.55 and 75.56 per cent of samples examined.

The data obtained in this study are analysed in the light of the International Standards for Drinking Water (6) and presented in Table III and IV for raw and treated waters respectively.

TABLE II—SAMPLES FREE FROM COLIFORMS AND E. COLI I

Source	Samples analysed	Free from coliforms No.	%	Free from E. coli I No.	%
Untreated					
River	21	0	0	0	0
Well	42	0	0	2	4.76
Lake	60	2	3.33	8	13.33
Total	123	2	1.63	10	8.13
Treated					
Freshly Chlorinated	88	32	36.4	61	69.32
Tap	90	48	53.3	68	75.56
Total	178	80	44.94	129	72.47

TABLE III—ANALYSIS OF DATA OF RAW WATERS IN TERMS OF INTERNATIONAL STANDARDS

	River	Wells	Lakes
(1) No. of samples analysed	21	42	60
(2) No. of samples showing coliforms less than 10 per 100 ml.	0 (0)	3 (7.1)	8 13.3)
(3) No. of samples showing coliforms in the range of 10-20 per 100 ml.	0 (0)	0 (0)	14 (23.4)
(4) No. of samples showing coliforms greater than 20 per 100 ml.	21 (100)	39 (92.9)	38 (63.3)

The figures in brackets represent percentages of the samples tested.

TABLE IV—ANALYSIS OF DATA OF TREATED WATER IN TERMS OF INTERNATIONAL STANDARDS

	Immediately after chlorination	Distribution system
(1) No. of samples analysed	88	90
(2) No. of samples free from coliforms	32 (36.4)	48 (53.3)
(3) No. of samples showing coliforms in the range of 1-10 per 100 ml.	36 (40.9)	22 (24.5)
(4) No. of samples showing more than 10 coliforms per 100 ml.	20 (22.7)	20 (22.2)
(5) MPN index for coliforms	114	78

The figures in brackets represent percentages of the samples tested.

Discussion and Conclusion

The investigation was spread over a period of one year to ascertain the bacteriological quality of raw and treated waters. According to the standards recommended by W.H.O. in the "International Standards for Drinking Water" (6) for untreated waters, in 90 per cent of the samples examined throughout any year, the MPN index of coliforms should be less than 10. Not a single sample of river water showed coliforms less than 10 per 100 ml. For well and lake waters only 7·1 and 13.3 per cent of the samples (Table III) examined showed coliform counts less than 10/100 ml. When all the raw water samples analysed are considered together 8·9 per cent had less than 10 coliforms per 100 ml. Hence, it is obvious that regular heavy pollution was occurring. Though the coliforms and *E. coli* were absent in 1·63 and 8.13 per cent of the raw water samples analysed (Table II) the average MPN of coliform counts in these waters were very high. It is clear from the results (Table II) that the river and well water samples were always found positive for coliforms. While 3·3 per cent of lake water samples were negative for coliforms, the geometric means of lake water was 38. This indicates that all these 3 sources were definitely getting regular faecal pollution. Taking into consideration the standards recommended by WHO for raw/untreated waters to be used for drinking purposes, it is obvious from the results that the raw waters analysed here fall far below the standards and hence they cannot possibly the considered for drinking without any treatment.

According to the International Standards for treated waters, in 90 per cent of the samples examined throughout any year, coliforms should not be detected or MPN index should be less than 1 and none of the samples should have the MPN index of coliforms in excess of 10. The results in Table II and IV show that freshly chlorinated waters and waters from the distribution system were free from coliforms in only 36.4 and 53.3 per cent of the samples examined. Water samples collected immediately after chlorination showed a smaller percentage of negative samples than those from the distribution system because of very little contact time involved.

In the light of the above standards it would appear that water at the consumer's end, though fairly good, does not conform to the recommended bacteriological standards. Efforts should, therefore, be made to improve upon the existing treatment facilities and also to have a close supervision on the network of distribution system.

Based on monthly averages of coliform MPN it was observed that Gorewara lake was less polluted than the Ambazari lake. The monthly average MPN index of the coliforms was less than 50 in Gorewara lake waters for all the months in the year except June, July, September and October. From the existing classification of raw water sources with respect to their treatment requirements, simple chlorination for Gorewara water is not sufficient to make it potable during these 4 months. The monthly average coliform index for Ambazari lake normally exceeded 50 and such a water, according to its treatment requirements needs complete treatment with coagulation, rapid sand filtration and chlorination. For Kanhan raw water the monthly average MPN index of coliforms exceeded 5000 in April, May, June, July and August. Therefore, this water needs auxiliary treatment in addition to the regular treatment now being carried out.

The question may naturally be asked whether it is possible to attain the recommended bacteriological standards for our raw water supplies. While it may not be feasible to achieve the present bacteriological standards for our raw or untreated surface water supplies, efforts can be made to protect the water supply sources from pollution. Eighty two per cent of the people in India live in villages and most of them use raw water from sources like wells, rivers and lakes for drinking purposes. Unless the overall sanitary conditions in the country improve, it is very difficult to improve the quality of these raw waters. The only solution under the existing conditions seems to be to disinfect the rural water supplies for improving the water quality.

In the case of treated water supplies, however, there should not be any laxity and all chlorinated piped water supplies from the distribution system must conform to the prescribed standards. The International Standards for Drinking Water proposes minimum standards which are considered to be within the reach of all countries throughout the world at the present time. The observations made here and elsewhere reveal that the finished waters from some of our water treatment plants do not conform to the bacteriological standards. Large amounts of public money is spent in designing and excuting the construction of water treatment plants in many big cities of our country. Though the designs of these plants are good, some of them fail to achieve the results because of lack of vigilance on the part of the operators and improper checking of the performance of the unit processes of treatment. In some of our plants waters having more than 100,000 MPN of coliforms are made safe by good vigilance and effective treatment. Hence, with proper care it is felt that the performances of the existing water treatment plants can be improved and we should be able to attain the recommended standards for drinking waters in our country.

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DISCUSSION

Shri A. S. Hariharan, Madras: Out of 38 samples of free chlorinated water, only 32 samples were satisfactory. Were the samples tested for residual chlorine?

Shri R. P. Mishra: Residual chlorine was not determined in the samples analysed in this study. Perhaps, it would have been useful to have measured the residual chlorine in these samples to correlate the results with the bacteriological analysis.

G. R. Mir, Kashmir: Some of our tube well waters have methane gas. On analysis methane is found to be 70%, CO_2 3% and Air 27%. Presence of methane makes such water toxic and unsafe. Inspite of aeration, methane could not be eliminated and eventhough MPN is zero we do not know whether such water is potable? I would like to know if any standards have been laid down for gas content and if so, how much.

Most of our villages are on river banks, where water is not free from coliform organisms. Yet, people have not fallen prey to epidemic gastro-intestinal diseases. Necessity for fixation of regional standards is very much vital.

Shri R. P. Mishra: The procedure involved in the estimation of methane is very difficult one. It can be done only in the laboratories equipped for this purpose. The percentage of methane in tube well waters mentioned by Mr. Mir appears to be excessively high and doubtful. The analysis results may please be checked by sending duplicate samples to Central Fuel Research Institute, Jelgora where facilities for estimating methane are available.

Literature too very scanty about the permissible limits for dissolved gases in waters. This is particularly so regarding methane in drinking waters.

It is true that in many of the rural areas in our country, people have been consuming water which are not free from coliforms and they do not also seem to suffer from gastrointestinal disorders.

Firstly, the presence of coliform organisms in water only indicates pollution but does not necessarily prove the presence of pathogens. Secondly, factors like individual resistance and the development of active immunity due to exposure to subclinical doses of pathogens also play a significant role in restricting the occurrence of enteric water-borne diseases among the consumers.

Since many of these gastro-intestinal disorders are of less severity, they are not often reported. Hence the epidemiological data may not give the correct picture about the incidence of such diseases. This is very much true in our country. As such thousands of cases of water borne diseases are not recorded just because they do not occur in an epidemic form to invite public attention. Drinking water standards cannot be fixed on regional basis but may be fixed separately for untreated and treated drinking waters.

Shri Vishnu Moorthi Rao, VRCE, Nagpur: It is seen from Mr. Mishra's experimental results on water supplied by Nagpur Water Works, that we are consuming lot of Coliform group of organisms. It is well known that the enteric pathogens are mostly associated with this group. That is why we do not conduct any separate experiments for their detection. Moreover by this time we might have consumed thousands of them in these two days. Hence, with the permission of the Chairman, may I request the house to resolve and to convey the concerned authorities to protect us from these pathogenic organisms at least in future.

Shri R. P. Mishra: It will not be correct to assume that the water supply of Nagpur city is contaminated just because a few coliforms could be detected in samples collected from certain fixed points in the distribution system. The mere presence of these organisms in the water supply in few numbers does not necessarily indicate the presence of pathogenic organisms too. We however, agree that immediate investigation and remedial measures should be taken to avoid recurrence of positive samples in the distribution system.

Shri A. G. Lakhani: What is the residual chlorine in the sample after a 4 mg/lit. chlorine dose was given.

Table IV shows that 40% of the treated water samples and 24 of samples from distribution system in Nagpur City are contaminated. Eltor has also been detected by CPHERI from samples received from Nagpur division. So it is necessary to inform the Corporation to be more vigilant over the water supply at Nagpur.

Shri R. P. Mishra: It would be more correct to say that the treated water supply of Nagpur city does not always conform to the bacteriological standards recommended by WHO in their "International Standards for Drinking Water" than to assume that the water supply of the city is contaminated. It is interesting to note that water samples collected only from a few fixed points in the distribution system showed the presence of coliforms. Unfortunately, the sampling points used do not represent the entire distribution system of the city.

Whatever be the cause, it is desirable that the water works authorities should take more care to see that the treated waters always conform to the bacteriological standards prescribed.

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Disinfection of Water in the Field

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Introduction

In small communities protection of water sources is very difficult, particularly in case of surface supplies. This is especially true in developing countries where laws regulating pollution neither exist nor are enforced if they do. Conventional treatment of these waters is not possible in small communities because of the lack of funds and trained personnel. Hence, the only method of ensuring the hygienic quality of water is disinfection with suitable chemicals. This is also true for waters available in the field for both army and civilian camps.

Chlorine has been enjoying the position of a popular disinfectant from a very long time. But recently much interest has been shown in the use of iodine as its bactericidal activity is less influenced by pH ammonia and organic content of water.

While evaluating the antibacterial efficiency of halogens, Gershenfeld and Witline (1-4) found iodine to be better than chlorine over a wide range of pH and in presence of organic matter. Pond and Willand (5) recommended the use of two drops of 7 per cent USP tincture iodine to make a litre of water safe for drinking. Chambers *et al.* (6) found that a minimum concentration of 4.3 mg/lit. of iodine was needed to kill all the species tested within one minute under adverse conditions of pH (9.15) and temperature (2° to 5°C). Chang *et al.*, (7) recommended 8 to 10 mg/lit. of iodine for field disinfection of water.

The present study was undertaken to find out the efficiency of chlorine and iodine for disinfecting small quantities of water under different conditions. Though other workers used pure cultures of bacteria in similar studies, water contaminated with raw sewage was used in these experiments, since it is well known that pure cultures of bacteria respond quite different from those present in mixed population under natural conditions.

Experimental Procedure

Water was contaminated by adding 40 ml of domestic sewage to 960 ml of water to give 4 per cent sewage. This was taken to be equivalent to the worst type of waters that a small community might have to drink in the absence of conventional treatment.

The sewage used here was obtained from the influent of the Institute's sewage treatment plant. The strength of the sewage is not high because of the 24 hr water supply in the laboratories and the staff quarters. The water with 4 per cent sewage had a chlorine demand in the range of 1 to 1.5 mg/lit., free ammonia contents of 0.2 to 0.3 mg/lit. and the coliform count of about 10^6 per 100 ml.

Disinfection was considered satisfactory when the coliform count was reduced to 5 or below per 100 ml. After thorough mixing, coliforms were estimated by MPN method using 5 tubes for each dilution of the sample. Lactose and BGB broths were used for presumptive and confirmatory tests respectively. Tincture iodine 2 per cent (BP) was used as a source of iodine. Bleaching powder was used as a source of chlorine. The disinfectants were added and coliforms were estimated as above, at different contact periods, after neutralizing the disinfectant with thiosulphate.

Sewage was freshly collected for every experiment from quite a steady source. Unless mentioned otherwise, all experiments were carried out using 4 per cent sewage in the temperature range of 28° to 31°C (room temperature). The term water whenever used indicates such water.

The disinfection experiments were carried out initially between pH 7 and 8, since most of the waters generally fall in this pH range. Further experiments were carried out by lowering pH to 6 or increasing to 9. as natural acid or alkaline waters will not be usually found beyond this range. Experiments were also carried out at 10°C to study the activity of these disinfectants at lower temperature. These experiments were done since we find occasions where disinfection of waters at low temperature has to be accomplished. This type of situation occur in hill stations and for the army stationed at high altitudes.

Results and Discussion

The results of experiments carried out to determine a suitable concentration of chlorine and iodine which may satisfactorily disinfect water within 20 minutes at pH 8 are presented in Table I and II.

TABLE I—DISINFECTION OF WATER WITH CHLORINE & IODINE
(Coliform MPN per 100 ml at room temp. and pH 8)

CHLORINE				IODINE			
Dose mg/lit	5 min.	10 min.	20 min.	Dose mg/lit	5 min.	10 min.	20 min.
0.5	2400+	2400+	2400+	1.5	2400+	2400+	540
1.0	2400+	2400+	2400+	2.0	920	350	920
	2400+	2400+	2400+				
1.5	2400+	2400+	540	4.0	920	920	350
	2400+	2400+	130		1600	110	70
2.0	2400+	2400+	49	6.0	70	24	5
	2400+	130	11		49	79	170
4.0	0	0	0	8.0	17	13	0
	23	0	0		0	5	2

TABLE II—BACTERICIDAL EFFICIENCY OF 4.0 mg/lit. OF CHLORINE AND 8.0 mg/lit. OF IODINE AT pH 8 & ROOM TEMPERATURE

CHLORINE 4 mg/lit			IODINE 8 mg/lit		
Coliforms MNP per 100 ml			**Coliform MPN per 100 ml**		
5 min.	20 min.	30 min.	5 min.	20 min.	30 min.
2	0	0	2	0	0
33	2	2	7	0	0
33	0	0	2	0	0
8	0	0	46	0	0
2	0	0	7	2	0
5	0	[illegible]	17	8	0

From Table I it will be observed that 0.5, 1.0, 1.5 and 2.0 mg/lit. of chlorine and 1.5, 2, 4 and 6 mg/lit. of iodine are not adequate concentrations for this purpose. From this table it can also be noted that a concentration of 4.0 mg/lit. of chlorine and 8.0 mg/lit. of iodine achieve satisfactory disinfection of water within 20 min. Additional experiments were carried out to verify the activity of chlorine and iodine at 4 and 8 mg/lit. respectively at 20 min. contact period and the results are recorded in table II. Hence these concentrations of the disinfectants were used to study the effect of changes in pH, temperature and the ammonia content.

Effect of pH, Temperature and Ammonia

Experiments were carried out at pH 6 and 9 to test the activities of these disinfectants. Results are presented in table III. It can be noted from the results that the bactericidal activity of chlorine and iodine at the concentrations used, was not much influenced by pH. A contact period of 20 minutes was sufficient for satisfactory disinfection of water.

The effect of pH was not observed probably because these concentrations are above the threshold concentrations needed for the disinfection of 4 per cent sewage. Hence, lower concentrations of chlorine and iodine were tried.

Table IV shows that the activity of chlorine of 1, 1.5 and 2 mg/lit. is significantly affected by change in pH from 6 to 8. With iodine of 1.5, 2, 4 and 6 mg/lit. this effect of pH was not observed. The activity of iodine seems to be same at pH 6 and 8. To study the effect of temperature on the activity of 4 mg/lit. of chlorine and 8 mg/lit. of iodine, experiments were carried out at 10°C, at pH 8 and 9. From the results reported in table V it can be observed that the activities of these disinfectants at the concentrations tested are not affected except in the case of chlorine of 4 mg/lit. and at pH 9.0. Its activity seems to be lowered at 10°C.

TABLE III—EFFECT OF pH ON THE ACTIVITY OF 4 mg/lit. CHLORINE AND 8 mg/lit. IODINE AT pH 6 & 9

(Room temperature)

CHLORINE						IODINE					
Coliform MPN per 100 ml						Coliform MPN per 100 ml					
pH 6			pH 9			pH 6			pH 9		
5 min.	10 min.	20 min.	5 min.	10 min.	20 min.	5 min.	10 min.	20 min.	5 min.	10 min.	20 min.
2	2	0	2	2	0	2	2	0	5	5	0
33	33	2	70	22	5	33	7	0	5	17	2
22	8	0	22	2	2	46	46	0	130	130	2
0	0	0	11	0	0	0	0	0	11	5	0
5	2	0	8	8	0	8	0	2	13	14	0
8	0	0	0	0	0	33	8	0	33	33	2
4	0	0	33	4	2	6	12	2	23	8	5
28	0	0	2	2	0	2	2	0	0	0	0

TABLE IV—EFFECT OF pH ON LOWER CONCENTRATIONS OF CHLORINE & IODINE

(The numbers refer to coliform MPN/100 ml of water)

(Room Temperature)

Dose mg/lit	pH 6			pH 8		
	5 min.	10 min.	20 min.	5 min.	10 min.	20 min.
			CHLORINE			
0.5	2400+	2400+	2400+	2400+	2400+	2400+
1.0	2400+	2400+	1600	2400+	2400+	2400+
	2400+	2400+	130	2400+	2400+	2400+
1.5	2400+	2400+	5	2400+	2400+	540
	2400+	540	22	2400+	2400+	130
2.0	2400+	17	13	2400+	2400+	49
	920	11	8	2400+	130	11
			IODINE			
1.5	920	2400+	280	2400+	2400+	540
2.0	280	210	540	920	350	920
4.0	170	920	920	920	920	350
	540	79	21	1600	110	70
6.0	95	95	47	70	24	5
	180	110	14	49	79	170

TABLE V—EFFECT OF TEMPERATURE ON THE ACTIVITY OF 4.0 mg/lit OF CHLORINE AND 8.0 mg/lit of IODINE

Time in min.	CHLORINE					IODINE					
	Room Temp.			10°C		Room Temp.				10°C	
					pH 8						
5	0	23	5	920	120	17	0	7	2	10	5
10	0	0	2	5	33	13	5	—	0	2	2
20	0	0	0	0	[illegible]	0	2	0	0	0	0
30	—	—	0	0	0	0	0	0	0	0	0
					pH 9						
5	11	5	130	34		23	130	2	49	49	5
10	0	0	70	17		8	13	0	8	8	2
20	0	0	33	7		5	8	0	5	2	0
30	0	0	5	5		2	0	0	0	2	0

Sewage may contain 15 to 50 mg/lit. of ammonia. When water is polluted with sewage, ammonia will also be present. Hence the effect of 1 and 2 mg/lit. of ammonia on the activity of 4 mg/lit. chlorine and 8 mg/lit. of iodine was investigated.

Ammonia in these concentrations (Table VI) significantly influenced the activity of 4 mg/lit. of chlorine within 5 minutes. But longer contact period of 20 minutes showed no difference in the bactericidal activity from the control. Ammonia did not affect the activity of iodine even in 5 minutes contact period. When considerable quantities of ammonia are present in contaminated waters, larger quantities of these disinfectants have to be used for satisfactory disinfection.

Experiments with Halazone

Halazone (p-Carboxy benzene sulphon dichloroamide) is used by the Indian Army for disinfection of individual water supply. The compound is dispensed in the form of tablets known as "Sterilizing" tablets. Each tablet weighs 3 grains (0.2 grams) and consists of a mixture of halazone 7.5 per cent, sodium carbonate anhydrous 10.5 per cent and sodium chloride 82 per cent. Thus each tablet contains 15 mg of halazone. One sterilizing tablet is added to a quart (1136 ml) of water and the water is consumed only after 30 minutes contact period. Halazone tablets containing 4 mg each of halazone were used in our studies. Four such tablets were added to a litre of 4 per cent sewage.

From the results reported in table VII, it can be observed that a contact period of 20 minutes was required for satisfactory disinfection of vater at pH 8 and room temperature. Experiments carried out at pH 9 showed that this concentration could not satisfactorily disinfect water even with

TABLE VI—EFFECT OF 1 AND 2 mg/lit. OF AMMONIA, ON 4 mg/lit OF CHLORINE 8 mg/lit OF IODINE AND 16 mg/lit of HALAZONE

(Numbers refer to coliform MPN per 100 ml)

(Room temperature)

Control			1 mg/lit Ammonia			2 mg/lit Ammonia		
5 min.	10 min.	20 min.	5 min.	10 min.	20 min.	5 min.	10 min.	20 min.
CHLORINE (4 mg/lit)								
220	240	5	2400+	350	10	2400+	240	2
66	6	5	2400+	33	4	2400+	110	4
IODINE (8 mg/lit)								
33	13	11	17	8	2	110	13	5
8	5	7	5	34	2	26	7	0
HALAZONE (16 mg/lit)								
5	0	5	0	0	0	4	0	0
0	5	2	0	0	5	0	5	0

TABLE VII—EFFECT OF pH AND TEMPERATURE ON THE ACTIVITY OF 16 mg/lit of HALAZONE

(Numbers refer to coliform MPN/100 ml)

Room Temperature							
pH 8				pH 9			
5 min.	10 min.	20 min	30 min.	5 min.	10 min.	20 min.	30 min.
2400+	30	2	0	2400+	110	0	0
1600	95	5	0	2400+	240	110	9
10°C							
2400+	2400+	33	0	2400+	2400+	2400+	2400+
2400+	920	5	0	2400+	2400+	2400+	2400+

30 minutes contact period at room temperature. Tests carried out at 10°C, at pH 8 and 9 to test the activity of halazone at lower temperature indicate that at a 30 minutes contact period, disinfection was complete at pH 8 while at pH 9 it was not.

Experiments carried out with the addition of 1 and 2 mg/lit. of ammonia to water showed that the bactericidal activity of halazone is not affected by ammonia (Table VI).

Conclusions

Disinfection of water containing 4 per cent raw domestic sewage with chlorine, iodine and halazone was studied. Taking 6 or less MPN of coliform as indicative of satisfactory disinfection, 4 mg/lit. of chlorine, 8 mg/lit. of iodine and 16 mg/lit. of halazone were found adequate to disinfect these waters at room temperature and at pH 7 and 8 with a 20 minute contact period.

Chlorine in concentrations of 0.5, 1.0, 1.5 and 2 mg/lit. was not suitable for satisfactory disinfection of water within 20 minutes at room temperature and pH 8. A higher concentration of 4.0 mg/lit. of chlorine was found suitable for this purpose. This concentration was found to be satisfactory only after 30 minutes contact period at a higher pH of 9 and a lower temperature of 10°C. 1.5, 2. 4, and 6 mg/lit. of iodine were not able to achieve satisfactory disinfection of water with 20 minutes contact period at pH 8 and room temprature. A concentration of 8 mg/lit. was found satisfactory for this purpose. This concentration was also found to satisfactorily disinfect water at pH 9 and at 10°C, with a contact period of 30 minutes instead of 20 minutes.

Halazone in a concentration of 16 mg/lit. at pH 8 and room and 10°C temperature could satisfactorily disinfect water with 20 minutes and 30 minutes contact period respectively. At pH 9, and room and 10°C temperature, even a contact period of 30 minutes could not satisfactorily disinfect water.

The disinfecting activity of chlorine was found to be affected by change in pH while that of iodine was not. This was observed when low concentrations of these disinfectants were used.

In terms of mg/lit. chlorine was found to be more bactericidal than iodine and halazone. While 4.0 mg/lit. of chlorine could satisfactorily disinfect water within 20 minutes a concentration of 8.0 mg/lit. of iodine and 16 mg/lit. of halazone were needed for this purpose.

4.0 mg/lit. of chlorine and 8 mg/lit. of iodine with a 30 minute contact period are found to be satisfactory for disinfection of water in the field. Since we come across waters of different hydrogen ion concentrations, having varying amounts of nitrogenous matter, iodine is recommended for disinfection, as its action is least influenced by changes in pH and ammonia content in water.

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DISCUSSION

Dr. A. S. Hariharan: The coliform density of 4% sewage, the study material, is more than 5,000 and hence complete treatment is necessary. Then why was mere chlorination or addition of I_2 tried? Was there any taste or colour resulting from addition of 8 mg/lit. Iodine.

Shri M. D. Patil: The experiments were carried out to find out the concentrations of disinfectants to be used in the field. Thus for Campers, travellers, or soldiers, it will not be possible to characterise the water. The most convenient way in the field for making water satisfactory for drinking, will be to disinfect it straight way.

Shri T. Durairaj: What is the effect of 4 mg/lit. Cl_2 on pathogens other than bacterial?

Shri M. D. Patil: The study was limited to bacterial pathogens only.

Shri T. Durairaj: *It is not clear why* the values for chlorine demand were not taken into account while fixing 4 mg/lit. dose of chlorine, a dose which is pretty high for rural water supplies.

Shri M. D. Patil: The object of the study was to find out an initial dose of the disinfectant that will serve in the field where facilities for chlorine estimation are not available. Four per cent sewage was taken as the worst type of water which may be encountered and may have to be drunk in the field.

Shri B. K. Lonsane: How will you use iodine in the field or in the rural areas? On what basis have you considered the water containing 5 coliforms per 100 ml as properly disinfected water or as a safe water since 90% of the samples of drinking water should be free from coliforms or MPN index should be less than the I.S. for drinking water?

Shri M. D. Patil: Iodine in the field can be used in the form of liquid, and can be carried in a bottle. 0.5 ml of 1.6% liquid Iodine will give 8 mg of elemental Iodine. Ofcourse some convenient dispenser has to be developed. Iodine can also be dispensed in tablet form. These tablets when dissolved liberate elemental iodine. In their studies on Iodine as disinfectant for drinking water, Chang, S. L. & Morris, J. C. used this criterion of 5 or less number of viable bacteria per 100 ml for satisfactory disinfection of water in the field. We also find that this criterion is practical and satisfactory for field use.

Shri D. Seethapathi Rao: I would like to know from the authors, whether Chlorination and Iodination experiments were carried out with varying organic matter content in water, as this influences the doses of disinfectants.

Shri M. D. Patil: Sewage which was added to the water had been the source of organic matter in the experiments. Since the concentration of sewage is not constant and varies day to day, organic matter in the experiments also varied. This is reflected by chlorine demand of water which varied in the range 1 to 1.5 mg/lit.

Shri V. C. Khasnis: The samples were prepared by adding 4% sewage. It is likely that even virus may also be present in the samples apart from *B. Coli* It is stated that a dose of 4 mg/lit. of chlorine and 8 mg/lit. of Iodine was found sufficient to reduce the *B. Coli* count to less than 5 with 20 minutes contact periods. But have any experiments been carried out to see whether this dose is sufficient to eliminate viral infections?

Shri M. D. Patil: Viral elimination has not been studied.

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Potable Water for Villages

M. R. THAKKAR*

Food, water and air are most essential things for human life. Food undergoes many treatments before being consumed by human beings. Water hardly undergoes any treatment after being delivered from tap. There are 5,50,000 villages in our country and more than 80 per cent of population is living in villages. In our country most of the public health problems are associated with lack of safe water supply and sanitary waste disposal. Statistics shows light on the facts that 2 million lives are lost and 50 million persons are partially incapacitated annually due to water filth borne diseases in our country. This partial incapacitation is causing a loss of agricultural production. This is mainly due to the fact that villagers have to drink the polluted water charged with bacterial infection. We can get rid of this situation only if we are able to evolve a method or a process by which water supply can be chlorinated.

The role of unfiltered water supply in the spread of diseases is well known. Results of laboratory experiment showed that a does of chlorine sufficient to leave a residual of 0.5 mg/lit. at the end of 10 min. contact is adequate to destroy *cholera vibrios* added to unfiltered samples.

Chlorination procedure is effective in preventing the entry of all vibrios including *cholera vibrio* Chlorination also brings about more than 99 per cent reduction in the MPN of coliform organisms in the water supply thereby leading to marked improvement in overall bacteriological quality of water.

The village water supplied cannot afford costly chlorinating equipment like Patterson chloronome. In some of the villages matka method is employed. In this process, bleaching powder solution is prepared and a porous earthen pot which is commonly used for storing water for domestic purposes is taken. This pot is known as matka. The matka used for this purpose may be made porous. The bleaching powder solution is placed on the surface of the water, in the well. The bleaching powder solution slowly diffuses through the pores of matka. After a certain period of time, the bleaching powder solution is exhausted and the whole process is repeated. This method is quite good for open wells but for

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villages where water is pumped in service reservoirs, this may not be suitable.

Automatic Chlorinating Unit

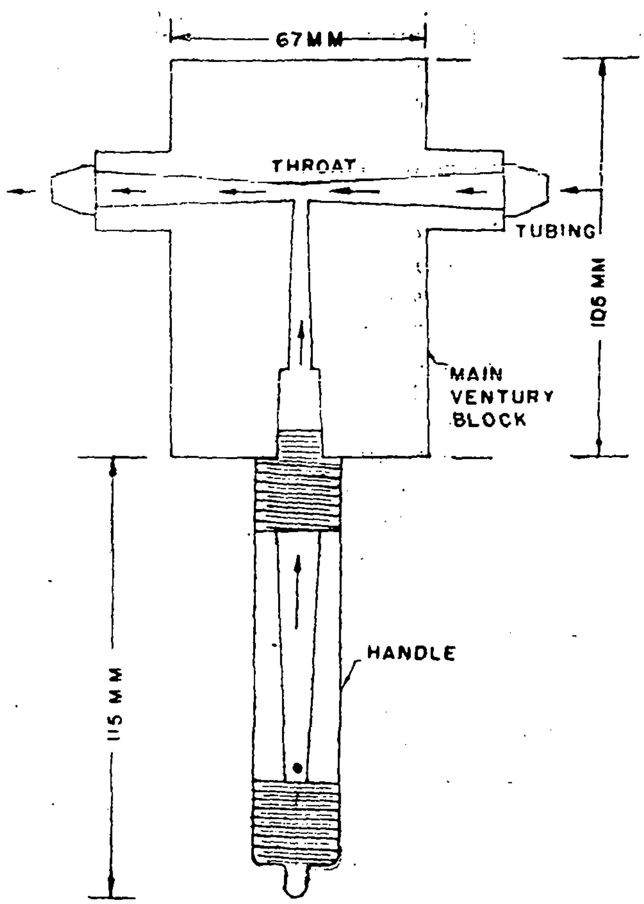
An automatic water chlorinating unit employing the principle of venturi is thought of. This unit is a chemical feeder and will feed water soluble chemicals. The bleaching powder is therefore proposed to give the necessary chlorination dose. It is designed for automatic introduction of chlorine into the flow of water. The dose of chlorination can be adjusted by changing the concentration of bleaching powder solution in the container. The sketch details the main feature of the automatic chlorinating unit.

In will be seen that if

x = delivery of the pump

ax = the discharge through the polythelene tubing

abx = flow of the bleaching powder solution in the neck.



AUTOMATIC CHLORINATING UNIT

Fig 1

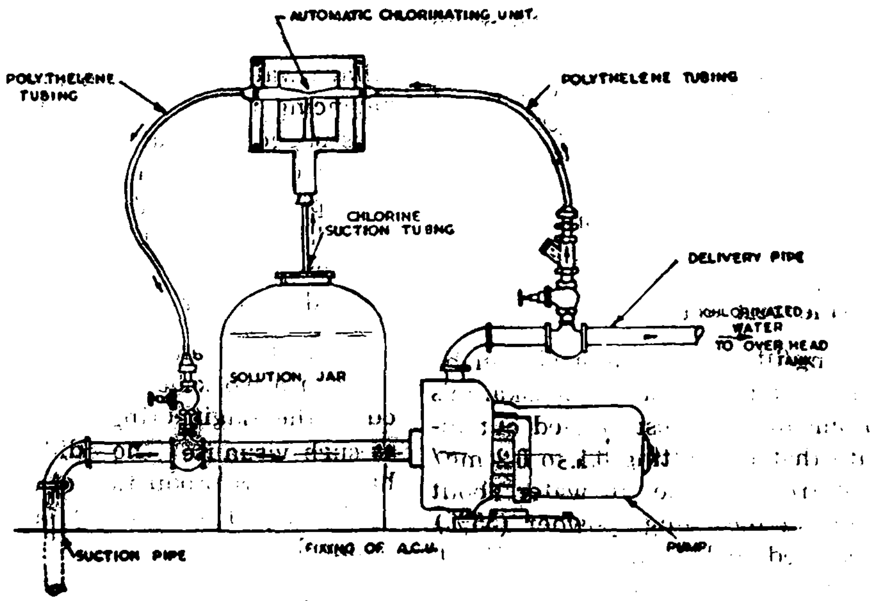
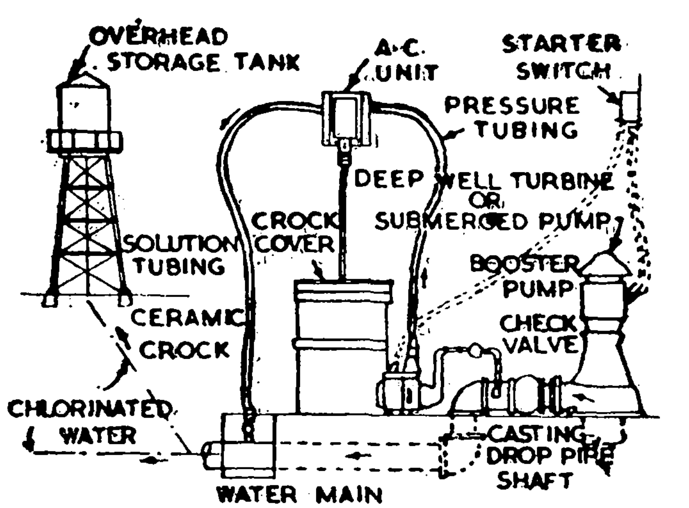


Fig. 2



DEEP WELL TURBINE OR SUBMERGED PUMP BOOSTER PUMP AND OVERHEAD STORAGE TANK

Fig. 3

abcx = Chlorine dose to x gallons of delivery where c is the concentration of chlorine in the solution in the container which can be controlled. By adjusting the concentration of the bleaching powder in the feed solution the necessary dose of chlorination say 0.5 mg/lit. can be maintained.

Chlorine Test Set

By mg/lit. of free chlorine can be easily found out using Bhaskaran's equipment. The test carried out indicate that for getting 0.1 to 0.2 mg/lit. of free chlorine in water about 500 gm of bleaching powder (35%) is required to be mixed with 17 lit. of water. The proportion of bleaching powder and the concentration of chlorine liquid can easily be adjusted according to the flow of water.

The unit is manufactured from acrylic plastic sheets. Such sheets are available at rate of about Rs. 150/- sq ft. in the Bombay market and round rods of about 2.5 cm diam. is also available at the rate of Rs 30 per rft.

Such unit can easily be fitted to the village water supplies by providing a balancing tank and a booster pump. It is suggested that the chlorinating equipment can be fitted to the delivery pipe of the tubewell pumping installations by the provision of a booster pumping arrangement as indicated in the sketch below.

Such unit can be manufactured even in a workshop like that attached to the Engineering Colleges. We as such visualise no difficulty in having mass production of such unit by industrial adventurer at an economical cost.

Acknowledgement

The author expresses his due thanks to Prof. C. H. Khadilkar Professor of Public Health Engineering and Shri R. L. Gandhi, Lecturer in Civil Engineering, Faculty of Technology and Engineering. M. S. University of Baroda, Baroda, for their valuable guidance.

DISCUSSION

Shri J. M. Dave: The device is already available in this country in more refined form with a rotameter and stainless steel needle valve at Rs. 800 per piece.

The air leakage into the suction by improper operation will stop pump functioning and the better way to prevent it is to put the chlorine delivery in a basket along wih suction foot valve so that, if air is sucked in, it will escape to atmosphere without interfering with pump performance.

Shri M. R. Thakkar: This is an attempt to manufacture a simpler type of chlorinator locally. The cost is going to be less. There may be defects but then these defects are to be overcome by some modification.

Prof. Khadilkar: The automatic chlorination can be manufactured by local technician. I support that the Public Health Engineering Research Institute should take steps to make it available at an economical cost to parties or organizations responsible for supplying safe water to the public.

Shri M. R. Thakkar: It has been manufactured locally and it is going to be cheaper one than available in market. I fully agree to your proposal.

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Cement Joint for Cast-Iron Water Pipe

V. RAGHU*

Introduction

In any developing country, the demand of raw materials for industry and construction generally outstrips the production, and this has to be made good by importation, utilizing the foreign exchange. In India, on account of the progressively ambitious plans and difficult foreign exchange position, this imbalance between demand and production has become all the more critical. Under such conditions the economical use of the materials and the substitute or alternate materials cannot be over-emphasized.

One of these materials is the use of lead for jointing bell and spigot water pipes. This practice is in use for more than a century and the method remains practically unchanged to this day in this country.

With increasing restrictions on foreign exchange, the procurement of imported lead has almost come to a standstill. With the stringent control on non-ferrous metals under the present emergency, it is almost impossible to secure any quantity of lead for the water supply schemes that are in progress and for the Herculian task of providing safe and portable water supply for all the communities in the country in the near future under the five year plans.

With the added importance to water supply schemes in the fourth five year plan, the allocation being Rs. 376 crores, the problem of substitute or alternate material for lead as jointing material in water supply lines poses a challenge.

Requirement of Material

The bell-and-spigot joint, using lead as the jointing material, is most commonly used. The quantity of lead required per joint varies from 4.5 lbs for 3 inch diameter pipe to 71.50 lbs for 36 in. diam. pipe and this on an average works out to 1100 lbs per in. diam. per mile length. At the present rate of Rs. 1600 per Metric tonne, it amounts to nearly Rs. 800/-.

As hundreds of communities (Table-I) are to be supplied with potable water through thousands of miles of distribution pipes especially 3″ to 18″ diameter, the cost of this imported lead works out to some tens of crores. This is really a staggering figure which in the present foreign exchange critical stage of the country the water supply schemes can hardly expect to secure even a percentage of this amount.

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TABLE I

Population	No. of towns/ villages as per census 1951	1961
Less than 500	3,80,019	3,51,650
501— 1,000	1,04,268	1,19,086
1,001— 2,000	51,769	65,377
2,001— 5,000	20,508	26,565
5,001— 10,000	3,101	4,268
10,001— 20,000	856	—
20,001— 50,000	401	518
50,001—1,00,000	111	139
1,00,001 and over	73	107

Therefore, focussing attention of the Public Health Engineers to this important aspect in the community water supply, an alternative or substitute material, viz., cement, which has been tried and standardised in other countries is suggested here.

Joint Materials

Desirable features in joint materials include elasticity, strength, durability, adhesiveness, workability, availability and economy. Materials used for joints in water pipes include lead, cement, rubber (1), sulphur compounds (2), Lead wool (3), Metalium (4). Leadite (5), Hydrolite (5) Tegul (6), Sinterite (7), Tyton (8), All-Tite (8), Bell-Tite (8), Fastite (8) and others.

Of these several jointing materials, cement is probably the best alternate material so far as this country is concerned the others being proprietary materials which have to be imported except the Tyton joint. The Tyton joint, which involves the manufacture of Spun C. I. Pipes and fittings with a modified socket design and the use of a special rubber gasket to effect the joint is now manufactured in India by the Indian Iron & Steel Co. Ltd. and it offers the advantage of the savings in the price of lead to make the joint.

Cast iron bell and spigot pipe of all sizes offers a greatest and obvious use for cement joints. Any joint that is designed for calking, however, can be made tight with cement. Cement has long been used as a substitute for lead in pipe joints in other countries. It is cheap and easy to make; moreover, it is permanent, probably as permanent as the pipe itself, and capable of withstanding excessive shock (9).

History

Portland cement was first used for joints in cast iron water pipe between 1879 and 1889 in Redlands and San Jose, Calif., and has since been adopted in cities throughout the United States. Los Angeles which began to employ such joints in 1894 has more than 4000 miles of cast-iron water pipe calked with cement by 1949 (10).

From 1917 to 1929 cement was used in all cast-iron pipeline constructions in San Francisco. In 1929 and for the next two or three years, cement sulphur joints were employed in an effort to reduce costs. No savings were effected but instead several pipes were destroyed by what was evidently an expansion of the joint material. Consequently, cement was again adopted and has been the standard joint material there since that time (11). Wertz, C. F. (12) reports that from 1932 to 1942 practically all joints were made with cement in Miami, Fla., and Table II shows the diameter and length of pipes to which the cement joint was used there.

TABLE II—CEMENT JOINT MAINS IN MIAMI

Pipe size inches	Cement Joint Mains feet
4	36,144
6	1,55,792
8	84,191
10	14,663
12	24,000
16	13,178
18	280
20	18,772
24	10,641
30	10,932
36	30,470
48	174

In India (13) the Chief Engineer, Public Health, Madras has suggested the desirability of using cement mortar in the place of lead in view of the experience reported in the USA in this behalf. The Public Health Engineering Department, Mysore State reports that an old 16 inches cast iron pipeline with cement joints has stood satisfactorily against pressures upto 300 ft for the past three decades and more. It is also reported that they have adopted cement mortar joints for cast iron pipelines in their schemes during the past six months, in all cases where the working pressure does not exceed 100'. A similar practice was in fact in vogue in the old Mysore State and it is reported that the results have been satisfactory.

Procedure for Making Cement Joint

The spigot end is put into the bell just the same as for a lead joint, taking care to align so that the calking space is concentric. The joint is then yarned. American Water Works Association specification (14) recommends that the yarning or packing in the case of cement joint may be omitted at the discretion of the Engineer. It also excludes the use of hemp, jute and braided cotton as yarning material on the basis of disinfection. It suggests (i) moulded or tubular rubber rings; (ii) asbestos rope; or (iii) treated paper rope as the suitable packing materials. In order to eliminate possible contamination caused by jute and also offensive odours and tastes, Alexander and Ebaugh (20) used cement alone in their cast iron lines with success, the leakage being zero and the construction crew having little difficulty in carrying out the work.

Cement (14)

All cement shall be of an approved brand acceptable to the Engineer and shall comply with the current specifications of the American Society of Testing Materials.

Proportions of Cement and Water

One quart of cement shall be thoroughly mixed with about 1/4 pint of water. The mixture shall be such that when it is tightly compressed by hand into a ball and the ball is broken into pieces, the break shall be clean (It is wet enough to mold but still dry enough to crumble when dropped a distance of 12 inches). If the hand is waterstained, the mixture is too wet. If there is evidence of crumbling in the break the mixture is too dry. The cement mixture shall ring with a metallic sound while being calked.

Cause for Rejection

No cement shall be used after having been wet more than one hour or after its initial set.

Calking Cement Joints

Starting at the bottom, the joint space shall be filled with the cement mixture and the mixture calked. The remaining joint space shall then be refilled and calked until the joint is practically flush with the face of the bell. The mixture shall be thoroughly compacted to make a water-tight joint without overstraining the bell.

Trench Water and Initial Set

No water shall be allowed to touch the joint until the initial set has taken place.

Joints kept Moist Until Set

Cement joints shall be covered immediately with damp burlap, or other material approved by the engineer, for the proper time to insure complete hydration. In cold weather, care shall be taken to prevent freezing of the cement mixture before and after the joint is made.

Time Interval Before Filling Pipe

Pipe laid with cement joints shall not be filled with water until lapse of twelve hours after the last joint in any valved section has been made, and pipes shall not be subjected to hydrostatic pressure and inspected and tested for leakage until at least 36 hours have elapsed after the main was filled with water.

Leakage Through Joint

Many say that very few joints weep a little when just put under pressure, but stops usually within 48 hours. If a cement joint leaks enough to make a stream, instead of dripping, it probably will not stop. In such cases it can be repaired, by chipping the leaky portion of the joint alone and calking in lead wool (11) (15).

The leakage test shall be carried out for nearly two hours. The test section will not be accepted until the leakage is less than the number of gallons per hour as determined by the formula (14) :

$$L = \frac{N D \sqrt{P}}{1{,}850} \qquad \text{(2220 for Imperial gallon)}$$

in which L equals the allowable leakage, in gallons per hour;

N is the number of joints in the length of pipeline tested;

D is the nominal diameter of the pipe in inches; and

P is the average test pressure during the leakage test, in pounds per square inch.

(The allowable leakage according to the formula is equivalent to 70 US gallons per 24 hours per mile of pipe per inch nominal diameter, for pipe in 12 ft lengths evaluated on a pressure basis of 150 psi).

The allowable leakage at various pressures for pipe of various diameters is shown in Table III (14).

Cost of Cement Joint

Cement joints are by far the cheapest to make. Labour and material costs were both less than for poured joints. In 1932 (16) a cement joint could be made for 1/5 of the cost of a lead joint. In 1949, that relation is approximately one to seven. Table IV presents a rough estimate of the costs of cement and lead joints.

Discussion

Cement joints in bell-and-spigot pipe, either of cast iron or steel, have proved their practicability and economy in hundreds of miles of mains laid in United States in the last several decades. It has been found entirely satisfactory as a jointing material. In fact, cement joints are stated to have withstood settlement, vibration and shock better than lead joints (9) (11) (17). Pipelines with cement joints can be lowered to a reasonable degree without any trouble in the joints. If a leaky spot does appear in a joint, it can be repaired by chipping it out and calking in lead wool. One lead joint may be poured at every gate valve, at every five hydrant lateral and, at intervals of about 300 to 500 ft in a long line without valves and fittings (14) (18). Regarding the damage of the joint by the thermal contraction due to cold temperature (10) (11) (16), the opinions are evenly divided. Moreover, as the pipe must be laid deep enough to prevent freezing where very cold climate exists, no temperature troubles should arise. One indirect advantage of cement joint is that they act as insulating joints. This characteristic has the effect of breaking the line into short sections each of which may have an opportunity to collect and discharge the stray currents (15) (16) and prevent rusting

If lead alone were used for the water supply work shown in the Table V as joining material, it would have required approximately 50,000 lbs of this material in place of cement. This represents a considerable saving in money, not to mention the fact that cement makes an efficient joint.

A majority make cement joints without any yarn or other packing, using cement straight (20). The purpose of the packing seems to be primarily to centre and steady the spigot in the bell. This can very well be accomplished with wedging chisels or cement blocks. Alabama Pipe Company (21) suggests that joints of pipe 8-inches in diameter or longer should be firmly spaced with three lead sludges, about 1½" long, one inch wide and a thickness triffle thinner than the joint space. Joints on 4 inch and 6 inch diameter pipe may be temporarily spaced with chisels. The yarn or packing material is used where there is considerable deflection in the line, so as to prevent cement from going around the spigot into the pipe. Laurence E. Goit (16) reports that out of the 23 small communities and large

TABLE III—ALLOWABLE LEAKAGE FOR VARIOUS PRESSURES AND PIPE DIAMETERS

Avg. test pressure. psi	Allowable leakage per 100 joints-gph (US)*																
	Pipe Diameter—in.																
	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48	54	60
150	1.33	1.99	2.65	3.97	5.30	6.62	7.94	9.27	10.59	11.92	13.24	15.89	19.86	23.83	27.81	31.78	35.75	39.72
145	1.30	1.95	2.60	3.91	5.21	6.51	7.81	9.11	10.41	11.72	13.02	15.62	19.53	23.43	27.34	31.24	35.15	39.05
140	1.28	1.92	2.56	3.84	5.12	6.40	7.68	8.95	10.23	11.51	12.79	15.35	19.19	23.03	26.86	30.70	34.54	38.38
135	1.26	1.88	2.51	3.77	5.02	6.28	7.54	8.75	10.05	11.30	12.56	15.07	18.84	22.61	26.38	30.15	33.92	37.68
130	1.25	1.85	2.47	3.70	4.93	6.16	7.40	8.63	9.86	11.09	12.33	14.79	18.49	22.19	25.89	29.58	33.28	36.98
125	1.21	1.81	2.42	3.63	4.84	6.04	7.25	8.46	9.67	10.88	12.09	14.50	18.13	21.76	25.38	29.01	32.64	36.26
120	1.18	1.78	2.37	3.55	4.74	5.92	7.11	8.29	9.47	10.66	11.84	14.21	17.76	21.32	24.87	28.42	31.97	35.53
115	1.16	1.74	2.32	3.48	4.64	5.80	6.96	8.12	9.28	10.43	11.59	13.91	17.39	21.87	24.35	27.82	31.30	34.78
110	1.13	1.70	2.27	3.40	4.54	5.67	6.80	7.94	9.07	10.20	11.34	13.61	17.01	20.41	23.81	27.21	30.61	34.02
105	1.11	1.66	2.22	3.32	4.43	5.54	6.65	7.75	8.86	9.97	11.08	13.29	16.62	19.94	23.26	26.59	29.91	33.23
110	1.08	1.62	2.16	3.24	4.32	5.41	6.49	7.57	8.65	9.73	10.81	12.97	16.22	19.46	22.70	25.95	29.19	32.43
95	1.05	1.58	2.11	3.16	4.22	5.27	6.32	7.38	8.43	9.48	10.54	12.64	15.81	18.97	22.13	25.29	28.45	31.61
90	1.02	1.54	2.05	3.08	4.10	5.19	6.15	7.18	8.21	9.23	10.26	11.31	15.38	18.46	21.54	24.61	27.69	31.77
85	0.99	1.50	1.99	2.99	3.99	4.98	5.98	6.98	7.97	8.97	9.97	11.96	14.95	17.94	20.93	23.92	26.91	29.90
80	0.96	1.45	1.93	2.90	3.87	4.84	5.80	6.77	7.74	8.70	9.67	11.60	14.50	17.41	20.31	23.21	26.11	29.01
75	0.93	1.40	1.87	2.81	3.75	4.68	5.62	6.55	7.49	8.43	9.46	11.24	14.04	16.85	19.66	22.47	25.28	28.09
70	0.90	1.36	1.81	2.71	3.62	4.52	5.43	6.33	7.24	8.14	9.05	10.85	13.87	16.28	18.99	21.71	24.42	27.14
65	0.87	1.31	1.74	2.61	3.49	4.36	5.23	6.10	6.97	7.84	8.72	10.46	13.07	15.69	18.30	20.92	23.53	26.15
60	0.83	1.26	1.67	2.51	3.35	4.19	5.02	5.86	6.70	7.54	8.37	10.05	12.56	15.07	17.59	20.10	22.61	25.12
55	0.80	1.20	1.60	2.41	3.21	4.01	4.83	5.61	6.41	7.22	8.02	9.62	12.03	14.43	16.84	19.24	22.65	24.05
50	0.76	1.15	1.53	2.29	3.06	3.82	4.59	5.35	6.12	6.88	7.64	9.17	11.47	13.76	16.05	18.35	20.64	22.21
45	0.72	1.09	1.45	2.18	2.90	3.63	4.35	5.08	5.18	6.53	7.25	8.70	10.88	13.05	15.23	17.41	19.58	21.76

* If the Imperial gallon is used the figures must be reduced to one-sixth.

The allowable leakage for a pipe line is calculated by multiplying the leakage per hour per 100 joints at the average test pressure and for the diameter of pipe tested as obtained from the above table, by the duration of the test in hours and the total number of joints in the line divided by 100. If the section under test contains joints of various diameters, the allowable leakage will be the sum of the computed leakage for each size of the joint.

RAGHU

TABLE IV—COST OF CEMENT AND LEAD JOINTS IN CAST-IRON PIPE

Pipe size in.	Material per joint lb.		Cost of Finished joint in dollar		% Saving by cement joint
	Lead	Cement	Lead	Cement	
6	10	5	2.20	0.28	87.4
8	13	6	3.05	0.35	88.8
12	18	9	4.00	0.53	86.6
16	30	15	6.70	0.84	87.5
20	37	19	8.25	1.15	86.0
24	44	23	9.80	1.40	85.6
30	56	28	12.50	1.75	86.0

TABLE V

Size of pipe in inches	Length in miles	Cement in pounds	Lead in pounds
6	2.7	3,525	2,507
8	5.4	12,040	4,372
10	0.2	1,200	300
12	3.5	11,054	4,411
16	0.3	1,000	1,120
Total	12.1	28,819	12,710

cities, he enquired through a questioner, 19 replied that they use cement for their joints regularly and that ten out of these use no hemp or yarn in making the joint.

The life expectancy of the cement joint reported is approximately 60 years, many reporting that the joint is in use in their communities for more than 35 years (16).

Pressures of 100 pounds per square inch and more may be applied 48 hours after the joint has been completed. At Long Beach, California (22), there are sixty miles of cast-iron water pipes, ranging from 4 inches to 24 inches in diameter laid with cement joint, and all these pipes are under pressures ranging from 10 lbs to 80 lbs per sq in. Clark H. Shaw (23) reports that over a mile of piping jointed in this manner has been in use under 175 lbs per sq in. pressure for more than two years without requiring any repairs.

Conclusion

It is felt that there is a definite place in the water works for this type of jointing material. If properly handled, it will insure a joint which, in actual tightness, will be comparable to other materials.

The Public Health Engineer, however, is ultimately interested in overall economy and to some extent on expeditious completion of the work. If the availability and comparative cost of alternative material; (2) time and facilities available; and (3) comparative costs of completed work are encouraging, he will be prepared to accept the substitute material.

As cement joint answers these qualities and has been a standard practice in other countries, in this country also with careful technique, cement can be used as a substitute or alternate material which can replace or help to save lead and thus make a headway in carrying out the objectives of the Five Year Plans concerning the community water supply schemes.

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