dispersed farming community, with the result that India was close to overdeveloping its resources.

In introducing the discussion, Mr C. J. A. Binnie (W. A. Atkins) used slides to summarize the salient points of each of the four papers, paying tribute to the authors as he did so. He referred to his own experience of overseas problems relating to demography, climate and conflicts between potable and agricultural users. Referring to Mr Johnson's paper, he suggested water authorities needed to show their achievements and plans for future management through business plans, performance measures, etc. He commented that the choice of Mr Ramsden's proposed methods would depend on how water authorities and the Government of the day saw their future roles, particularly in relation to regulatory organization. Mr Shearer (Northumbrian Water) indicated why performance measurement or, preferably, performance comparison was necessary to maintain faith with customers as well as for regulatory purposes. Comparisons were important to highlight areas where there was scope for improvement. He stressed the importance of the credibility of the performance comparators and the confidentiality of the information between monitors and operators. Mr Brady (Northumbrian Water) was uneasy about the use of operational contracting in water supply. It was necessary to retain skills to repair and maintain our systems. There would also be a moral problem with our own staff. Finally, Mr Gascoyne (Southern Water), referring to Mr Ramsden's political scenarios, felt that legal impediments, through European Community (EC) rulings, plus the opposition of the Confederation of British Industry (CBI), farming and the Greens to privatization of regulatory functions would prove to be insurmountable.

The Symposium was summed up by Mr R. White of the Water Authorities Association. He began by observing that the conference had been overhung by the privatization issue. He paid tribute to the officials in the DoE on the way in which COPA II was now being implemented with the emphasis on controlling pollution. He referred to the way in which small corporate planning teams had been able to facilitate better use of resources than would have been possible in the separate components of the authority. He saw the growing interest of the private contractors in the industry as a healthy development and welcomed the increasing concern for conservation and environmental management. Finally, Mr White concluded that the combination of preparing for privatization and the EC Directives would lead to there being greater regulation in the water industry in future.

N. R. Chadwick

DESIGN AND PERFORMANCE OF A COMMUNITY TYPE IRON REMOVAL PLANT FOR HAND PUMP TUBEWELLS

By F. Ahmed, BSc, MSc, and P. G. Smith, BSc, MSc, PhD, MIPHE

ABSTRACT

In Bangladesh, groundwater collected through hand pump tubewells is a major source of safe water for drinking and other domestic purposes. This groundwater may have an iron content in excess of 10 mg/l. This paper describes the design and operation of a low cost iron removal plant. It is based on aeration, sedimentation, and adsorption of iron precipitates on brick chips. This plant has been installed in over 250 locations in rural Bangladesh. Field investigations of over 100 of these plants show an iron removal in excess of 90 per cent.

INTRODUCTION

Collecting groundwater through hand pump tubewells is considered as the only means of getting safe water for drinking and other domestic purposes for the rural population of many developing countries, for various economic, technical and social reasons. However, in many cases this groundwater may have a soluble iron content in excess of 10 mg/l, causing taste, odour and colour problems[1]. Soluble iron compounds in the ferrous form are oxidized into insoluble ferric compounds which are responsible for the colour problem. Unpleasant taste and odour arise due to decay of some organisms (iron bacteria) present in iron rich water.

Due to aesthetic reasons, rural people generally refuse to use tubewell water in iron problem areas and they are more inclined to use the unprotected surface water sources. The absence of sanitary excreta disposal, and non-hygienic practices, render many of these surface water sources dangerously contaminated and completely unsuitable for domestic uses without any treatment.

In a survey conducted by UNICEF and the World Health Organization (WHO) in Bangladesh in 1976, it was found that the attack rate of diarrhoeal diseases in iron problem areas was 53 per cent higher than in non-iron problem areas, and the use of tubewells was significantly less in those areas[2]. It seems that high iron content is deterring the installation and use of tubewell water and the health of the rural community is affected as a result of using unsafe surface water. Therefore, development of an efficient package type iron removal plant is essential for the best utilization of the hand pump tubewells in iron problem areas.

Compounds of iron found in groundwater are usually in the form of ferrous bicarbonate, $Fe(HCO_3)_2$, which is stable only in the absence of oxygen. In the presence of oxygen it is quickly oxidized to ferric hydroxide, $Fe(OH)_3$, which is insoluble in water. In the absence of organic matter, aeration of tubewell water helps to form a red precipitation of $Fe(OH)_3$ which can be removed by sedimentation and filtration. Aeration also reduces the dissolved CO_2 in water and thus the pH value is increased. If iron is loosely bound with organic matter, oxidation will not occur with aeration alone unless the water is brought into contact with previously precipitated iron which will act as a catalytic agent. Several techniques exist for removal of iron from a city water supply, but in tubewell water supply, construction of sophisticated aeration and filtration plant is

This paper was received on 20th October 1986 and was accepted for publication on 14th January 1987.

Mr Ahmed works in the Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh. Dr Smith works in the Department of Civil Engineering, University of Strathclyde, Glasgow.

not possible and addition of chemicals is not desirable or practicable. Tubewell water has to be improved through a simple technique either on a household basis or a community basis.

PREVIOUS TECHNIQUES

Iron removal at the household level was attempted in some places in India and Bangladesh with four earthen pitchers placed one above the other. Raw water from the top pitcher dripped through a hole and passed through two pitchers filled with burnt wood charcoal and sand. The treated water was collected in the bottom pitcher. Although it was a low cost system, it was very slow and unsuitable for all domestic uses.

In some places a 'force and lift' pump was used to spray the water onto a filter bed enclosed in a brick chamber and then allowed to pass through a gravel under-drainage system[3]. The filtrate was tapped slightly above the bottom. Efficient removal of iron was possible, but such a type of plant involved a high initial cost and the maintenance of a force pump, and frequent cleaning of the large filter bed was not easy. In other places, a 200 l steel barrel, partially filled with filter materials, was placed below the discharge mouth (spout) of the hand pump by raising it to a higher elevated position from the ground. Treated water was collected through a tap fixed at the bottom portion of the barrel. As the pump was fixed at a higher level, normal operation and maintenance facilities were greatly hampered.

The operation and maintenance difficulties of the previous plants in rural living conditions led to the necessity to develop a simple iron removal plant with easy operation and maintenance facilities which would be acceptable to rural people. Moreover, the present maintenance and operation facility of the tubewell must be maintained as usual. In recent years in the rural areas of Bangladesh, one tubewell has been provided for approximately every 15–20 households, so there is no desire or necessity to construct large removal plants. Thus a new iron removal plant has been designed and developed.

PLANT DESIGN

The plant, shown in Fig. 1, consists of four major units: aeration channel, sedimentation, and two brick-chip adsorption chambers.

The aeration channel, A, is made of 135 cm long, 10 cm diameter polyvinyl chloride (PVC) pipe, which is capped at the two ends but is provided with an inlet opening near the left end and an outlet opening near the right end of the pipe. The pipe top is finely slotted (8–10 slots, 5 cm long) allowing air to enter the pipe. One third of the depth of the pipe is filled with 1.5–2.0 cm size brick chips. The inlet of the pipe is connected to the spout of the tubewell. The size of the inlet is made to fit the outer diameter of the spout. Water discharged through the spout directly enters the PVC pipe and flows horizontally over the brick chips. The water is sufficiently aerated due to the increased contact surface with air. The aerated water then drips into the sedimentation chamber, via a thin layer of charcoal, through the slotted outlet opening of the pipe and a small hole in the cover of the sedimentation chamber located below the outlet opening. The 135 cm long PVC pipe rests on the cover of the sedimentation chamber.

The sedimentation chamber, B, is a rectangular brick chamber and it provides a minimum detention time of 8 mins for the previously aerated water, during which some portion of the already precipitated iron flocs settle at the bottom of the chamber. Water from the sedimentation chamber then enters the adjacent chamber through small holes, 1.5 cm diameter, arranged at different heights near the bottom (Fig. 2).

The adsorption chamber, C, is a rectangular brick chamber filled with well graded, 1.5–2.5 cm brick chips in two layers. During the upward flow of the water, the small iron

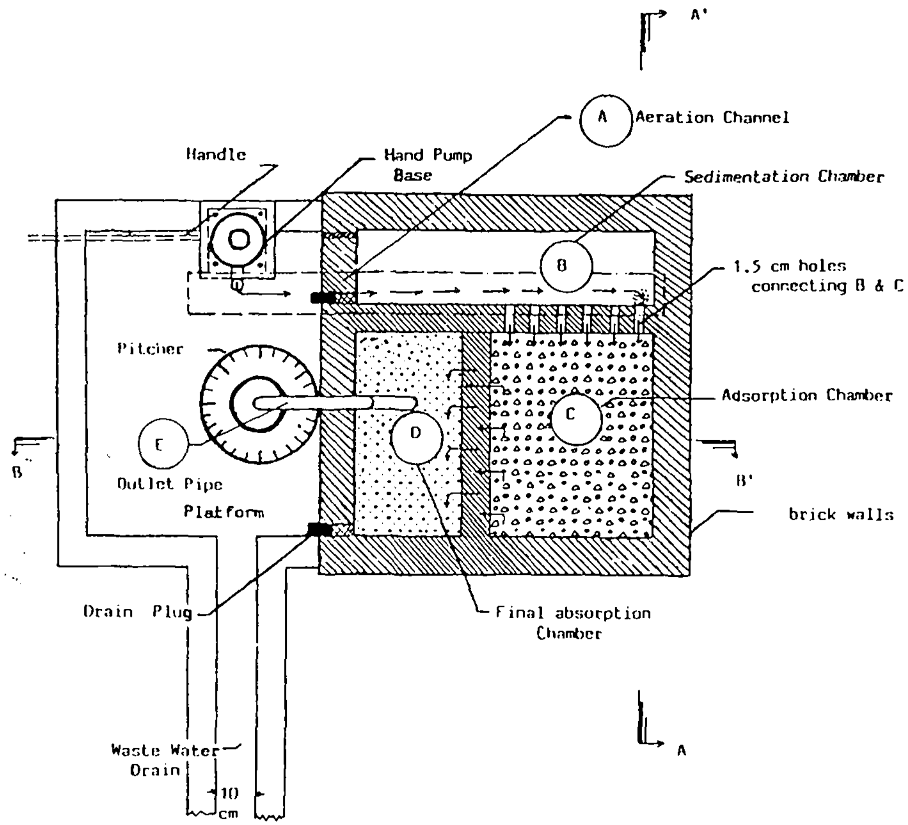

Fig. 1. Plan of a community type iron removal plant

flocs adhere to the surface of the brick chips, initially due to surface attraction. Gradually, when a film of adsorbed iron flocs has developed on the surface of the brick chips, the fine precipitated iron in the water adheres to this surface. Gradual upward flow also helps in settling of particles in this chamber. Water from the adsorption chamber flows over a weir and enters into the final adsorption chamber, D, (Fig. 3).

The final adsorption chamber, D, is filled with graded brick chips arranged in layers. A perforated ferrocement plate helps in distributing the incoming water uniformly over the bed.

Treated water flows out from the lower portion of the chamber, through a 38 mm diameter PVC pipe (E), fixed about 5 cm above the bottom.

The mouth of the outlet pipe is located about 40 cm above the tubewell platform and below the spout of the tubewell. There is no stop valve in the outlet pipe. The water level in the chamber remains at the same height as the outlet mouth. When water is pumped, the water level is raised in chamber D, and an amount of water equal to the volume of water pumped, and previously stored in the filter chamber, overflows through the outlet mouth. Therefore, for a continuous pumping rate of 20 l/min, about 20 mins elapses between a fixed quantity of water entering the treatment system and leaving it. A tubewell is seldom operated continuously and the actual detention time is generally much longer.

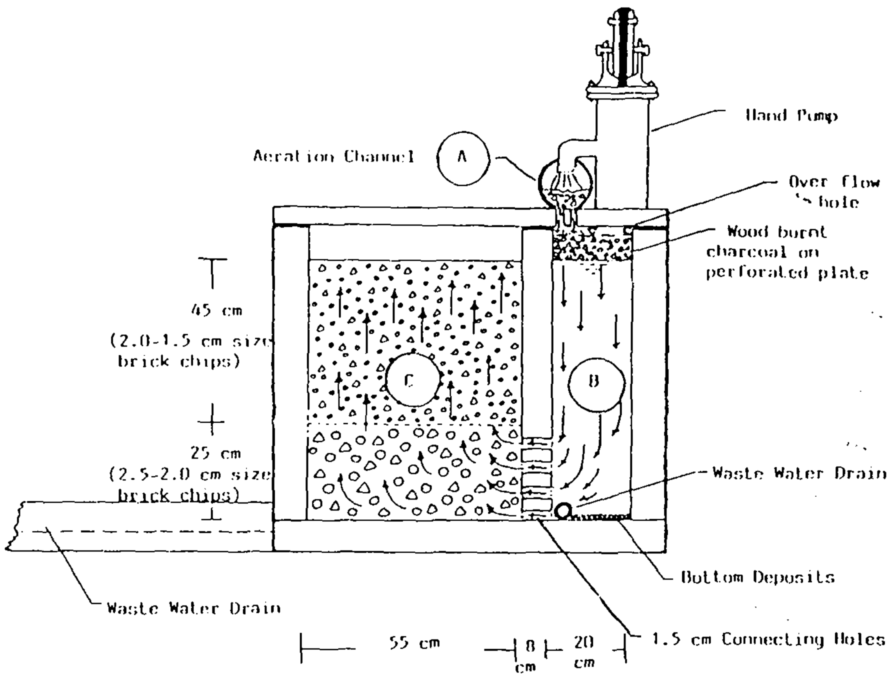

Fig. 2. Section A–A′, community type iron removal plant

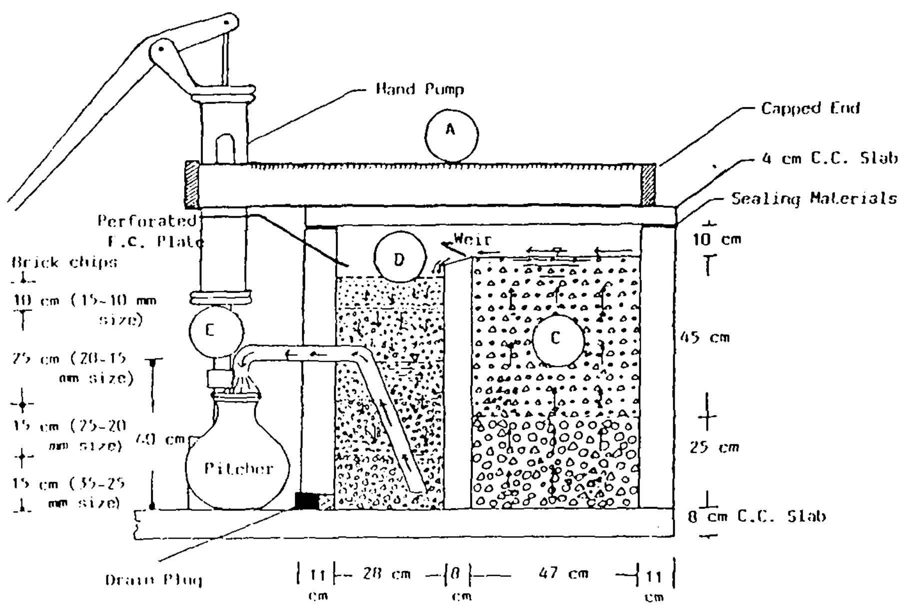

Fig. 3. Section B–B′, community type iron removal plant

The outer walls are made of 13 cm brick and the inner walls are 8 cm brick. The top is covered with a 4 cm concrete slab.

The following facilities have also been provided in the plant:

(*a*) The sedimentation chamber is provided with one overflow hole at the top which is covered with a fine mesh to prevent the entrance of any foreign material.

(*b*) For cleaning purposes, the sedimentation and adsorption chambers are provided with 38 mm diameter drains, which are normally plugged during operation. When the discharge from the outlet decreases, the top cover is removed, clean water is poured from the top and the bottom plugs are opened. Loosely bound iron particles around the brick chips in the adsorption chamber are washed out at the bottom due to the hydraulic thrust via the sedimentation chamber.

(*c*) The plant has been constructed utilizing a part of the existing tubewell platform. A space has been left near the base of the tubewell to facilitate maintenance of the tubewell.

(*d*) The tubewell has been raised only by a 23 cm long pipe to maintain the operational facility as before.

(*e*) The 10 cm PVC pipe (A) is loosely connected to the spout of the tubewell and can be disconnected easily in an emergency. In that case the tubewell will be completely separated from the plant and can be utilized as a normal tubewell.

PLANT PERFORMANCE

The water use patterns of some iron problem rural areas of Bangladesh were observed carefully[4]. It was observed that, on average, there is one tubewell for every 20–25 households, i.e., for approximately 150 to 200 people. Although the per capita daily water consumption is around 55 l under rural living conditions, less than 11 l is collected from the tubewell where the tubewell water supply is associated with iron and other problems. After improving the water quality through constructing the iron removal plant, an average increase of 11 l water collection per capita was observed. With an average of 20 collection journeys made per hour, within the community, and 14 l collected per journey, then the total collection from a tubewell is approximately 4.2 to 4.5 m^3/d for 15 to 16 hours of collection. The normal capacity of a No. 6 hand pump tubewell is 20 l/min, but the yield capacity of the iron removal plant is 9 to 13 l/min. Therefore more time is required to fill a container compared to pumping. Moreover, additional time is required for washing and placing the container at the tubewell site.

The plant has been found suitable for the rural areas of Bangladesh, and the Department of Public Health Engineering (DPHE), Government of the People's Republic of Bangladesh, with UNICEF assistance, constructed 40 iron removal plants during the year 1981–82. In the 1983–85 period, in the light of previous performance, some design modifications were made, such as:

(i) Putting the aeration channel, A, under a ferrocement cover slab.

(ii) Using a perforated PVC separator between the different layers of coarse media in chambers C and D.

(iii) Providing a 25 mm gate valve at the end of the effluent pipe, E.

In the last three years, about another 250 plants have been constructed in two phases, under a DPHE–UNICEF–DANIDA research and development (R and D) project. The estimated cost of construction of each plant is about £50, and mostly local materials have been used, with local labour. An appreciable increase in per capita water consumption from tubewells has been observed in the project areas. A summary of inspection reports of some operating iron removal plants is presented in Table I. The data show that these simple and cheap plants greatly reduce the iron concentration in the water supply.

In many places, rural people have been found to use tubewell water which has an iron content around 1 mg/l without raising any specific objection. Since iron in water normally

TABLE I. SUMMARY OF IRON REMOVAL DATA OBTAINED DURING INSPECTION OF IRON REMOVAL PLANTS OPERATING IN VILLAGES IN BANGLADESH[5]

Area	No. of plants monitored	Inspection period	Iron, mg/l		Average number of users/well
			Raw	Treated	
Sialkool	17	19–22 February 1985	11	0.4	175
Sialkool	20	6–12 March 1985	15	0.5	175
K. Haripur	20	24–27 February 1985	15	1.1	200
K. Haripur	23	6–17 March 1985	14	0.7	200
Sreemongal	35	20–23 September 1984	15	0.5	250
Sreemongal	35	5–8 October 1984	15	0.4	250
Sindurkhan	15	23–25 September 1984	13	0.7	200
Sindurkhan	15	9–10 October 1984	13	0.6	225

Note: In general, the same plants were monitored during the two inspections in a given area.

does not involve any health risk and staining of plumbing fixtures is not a problem in a tubewell water supply, a concentration below 1 mg/l may be considered desirable where iron is a major problem in rural areas.

SUMMARY

The high concentration of iron in groundwater in some areas is the main reason for the low consumption of tubewell water and this indirectly affects the health of the rural community due to the use of unsafe surface water sources.

Community type iron removal plants have been designed and constructed at over 250 sites in iron problem areas without hampering the existing operation and maintenance facilities of the hand pump tubewells. The plants operate on the principles of simple aeration through the flow of water over a coarse medium, sedimentation, and adsorption of precipitated iron particles on brick chips.

The plants have been found to be very effective in removing soluble iron from tubewell waters to an iron concentration often less than 1 mg/l. Use of local materials, easy maintenance and overall performance of the plants have motivated the rural people to use more tubewell water from ferruginous groundwater sources.

The authors are continuing research efforts into understanding the variables involved in the performance of the plants with a view to establishing general design criteria applicable in other parts of the world.

ACKNOWLEDGEMENTS

This paper is the result of a research project financed by BUET, DPHE, UNICEF and WHO, Dhaka, Bangladesh.

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POLYETHYLENE PIPE FOR GAS—A FLEXIBLE FUTURE

By M. C. STREET, BSc, CEng, FIGasE

SYNOPSIS

FOR MANY YEARS the materials and working practices within the Gas and Water Industries were of a similar nature.

Following the success of gas in the early sixties, a new era was born within the Gas Industry and a change in use of materials from conventional to polyethylene (PE) pipe was introduced.

This paper sets out to explain the reasons for the introduction and development of the PE pipe system up to the present day and highlights the advantages and problems that were encountered. Two areas that merit particular mention are:

(1) The introduction of new technology associated with PE pipe. For example, soil displacement techniques and mains replacement by insertion or bursting.
(2) The benefits that have accrued from the associated higher levels of productivity.

The paper concludes by looking at some of the new innovations that are currently being developed and reflects on the experience of the past fifteen years.

INTRODUCTION

The Water and Gas Industries have had a close relationship for many years due to the similarities between their operations.

Indeed, many were constituted at the same time under the management of the Local Authority and consequently their distribution systems were developed along similar lines. This situation remained until nationalization.

Now, both industries are large public utilities with regional organizations employing large direct labour workforces. It is not surprising therefore, that the two industries have common interests and should share experiences in the field of new technology.

Since 1969, the Gas Industry has embarked upon the introduction and development of a PE distribution system, in order to sustain its rapid expansion programme. PE is now the principal pipe material accounting for 95 per cent of our current pipe usage.

The purpose of this paper is to set out the manner in which this was achieved, such that others may draw from our experience.

HISTORICAL ASPECTS

In order to fully understand the reasons for changing to a polyethylene system, it is necessary to have an appreciation of the history of the Gas Industry.

PRODUCTION

From the Industry's beginnings until the late 1950s, the production of towns gas relied on the process of carbonization of coal.

This paper was presented at the Institution's 1986 Summer Conference in Nottingham on 14th May. It was accepted for publication on 10th July 1986.

The author is Regional Distribution Engineer, British Gas East Midlands.