Technology Section

Pak. j. sci. ind. res., vol. 32, no. 12, December 1989

INEXPENSIVE TECHNOLOGIES FOR WATER DECONTAMINATION
PART I. Studies on disinfection of Well Waters by Simple Diffusion Chlorinators

Mirza Arshad Ali Beg, S. Naeem Mahmood, A.H.K. Yousufzai, Najma Basit and Farzana Siddiqui

PCSIR Laboratories Complex, Karachi-39, Pakistan

((Received July 19, 1989; revised December 15, 1989)

Performance of a simple diffusion chlorinator is described for two wells in which sewage contamination seeps in continuously [1]. The average amount of residual chlorine was found to be 0.5 ppm for a period of about 40 days [2]. During the first three weeks MPN/dl reduced to >3 from 1100⁺ and 960 MPN/dl in both wells and during the fourth weeks it fluctuated between 4 and 11 MPN/dl, whereas Eijkman test became -ve from +ve and remained -ve upto six weeks [3]. There is no significant change in the average chemical composition of the waters after the installation of chlorinators. Studies have been carried out on the development, performance and evaluation of a simple method for the slow release of chlorine and for the debacterification of highly contaminated well waters. Data on the disinfection potential of diffusion chlorinator and the chemical and microbiological quality of the resulting waters have been collected. The developed in-expensive chlorinator removes coliform and faccal coliform satisfactorily and makes the water free from pathogenic bacteria. The developed technique, if applied appropriately to the polluted wells of rural and urban areas, may produce a tolerable water which could be used safely for human consumption.

Key words: Water decontamination, Chlorinator, Microorganism

Introduction

Tube wells, dug wells and hand pumps constitute 64% of the water supply system in the rural and urban areas of Pakistan [4]. The presence of Shigella Dysenteriae, Shigella Sonnei, Streptococcus Faecalis etc. and other organisms, beyond permissible limits as per WHO guidelines for potable waters, has rendered the water from these sources unfit and unsafe for human consumption. This constitutes the main reason for the incidence of water borne diseases which account for 30 to 40% of the total ailments.

Disinfection of drinking water by using chlorine dates back to the 1920s and bleaching powder is a readily available source for this disinfectant[7]. Addition of chlorine into the well water or of bleaching powder is problematic and to overcome the difficulties pot chlorinators containing bleaching powder mixed with sand have been in use in certain parts of India [10]. This paper reports the development and evaluation of a simple and inexpensive method for the slow release of chlorine and for the debacterification of well waters. This is an outcome of more than 2 years of extensive study on the disinfection of two local wells which were highly contaminated due to the seepage of the sewage organisms and the accompanying health problems for which had already been reported.

The debacterification method is a modification of the diffusion chlorinators and comprises a mixture of treated/ graded sand and bleaching powder packed in nylon cloth bags in calculated amounts. The bag was suspended in the well at the offtake point for the withdrawal of water. The slow diffusion of chlorine in the immediate environment of the offtake ensured the reaction between chlorine and the pathogenic organisms. The data on the chemical and microbiological quality of the resulting water is presented here graphically to evaluate the efficiency of the system.

Materials and Methods

Samples were collected in 500 ml sterilized glass stoppered flasks and preserved at 40° in an ice box. The collected samples were immediately transported to the laboratories for chemical and microbiological analysis. Microbiological tests were performed in accordance with standard methods [6,9]. MacConkey broth (Merck) was used to carry out presumptive Colii tests. Each set of samples consisted of three tubes containing 10 ml, 1 ml and 0.1 ml of the sample and Most Probable Numbers (MPN/dl) were ascertained from McGrady's Table. Eijkman test was performed in brilliant green bile 2% broth and production of acid and gas was observed at 44°. Organisms showing to be Eijkman positive were also investigated for indol production at 44.5°C. For the total count, serial dilutions were made in saline and aliquots were seeded in petri dishes overlaid with 20 ml sterile molten 160 plate agar (Merck). The plates were run in triplicate and the duration of incubation was 48 hrs. at 37°.

Total available residual chlorine was estimated by an iodometric titration [1,8] utilizing phenylarsine oxide as the titrating agent and starch as indicator. The bleaching powder used in these experiments contained 32% available chlorine.

Two dug wells, located approximately 300 meters apart in a local hospital were chosen to carry out the debacterification studies since they were properly protected from outside and it was convenient to carry out the desired investigations. The specifications of both wells are as under:

		Well-I	Well-II
1	Diameter	0.83 meters	1.016 meters
2	Depth	9.7 meters	7.0 meters
3	Water depth	2.64 meters	2.84 meters
4	Water quantity (Average)	1575 liters	2250 liters
5	Water Consumption Drawn (Average)	12,000 lit./day	18,000 lit/day

Water from each well was pumped to two separate overhead tanks, to which an addition quantity from city water supply was also pumped and the mixture was used for drinking, cooking, bathing and washing etc.

The well waters were initially given a shock treatment with a mixture of sand and calcium hypochlorite to disinfect the wells completely. Two days thereafter seepage of contaminated water started raising the level of bacterial load. The bags were then suspended in the well water since controlled disinfection was possible at this stage of relatively low bacterial count.

3 to 5 duplicate water samples were collected weekly from both wells for one years starting from December 1984 to December 1985 and they were analysed for total available residual chlorine and bacterial load. The relevant data are presented in Fig 1. Chemical analysis of the treated water was also carried out twice a month to assess the variation in their chemical composition. Fresh chlorinators were placed in both the wells every month; eleven such chlorinators were used for each well during the whole period.

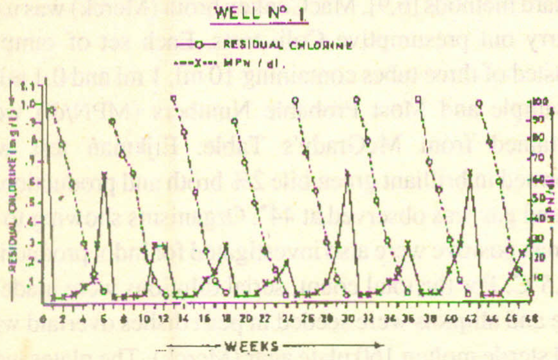

Fig 1. Variation of bacterial load with placement of chlorinator during a 48 weeks cycle

The performance of the chlorinators and the approximate pattern of chlorine release taking place in wells under treatment was estimated by taking duplicate samples regularly from both wells at 10 a.m. and 2 p.m. daily for forty days viz., March 16 1986 to April 24 1987. The relevant data are recorded in Fig 2. Additionally the treatment was scaled down by taking a plastic tank of about 1/10th the dimension of the hospital wells. The tank was filled with about 175 liters of well water and a small chlorinator containing the mixture of active ingredient and graded sand in the same ratio was installed in the tank. 150 liter of water was taken out after an interval of one hr. from 9 a.m. to 4 p.m. daily and the same quantity was replaced by fresh well water. This was done so that chlorine in the tank could diffuse in similar manner as in the wells.

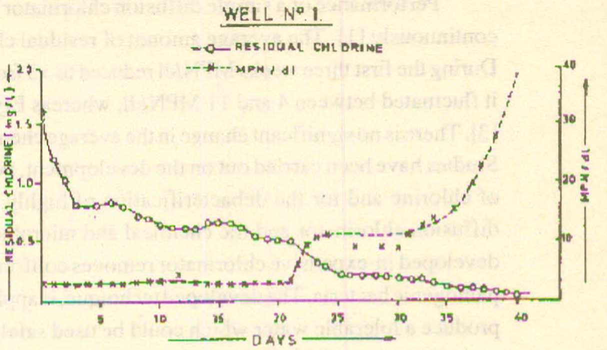

Fig 2. Balance between chlorine demand and bacterial load during a 40 days cycle.

Results and Discussion

The weekly average results of the microbiological examination as well as total available residual chlorine of the treated water samples collected from well I, is presented in Fig. 1. Data for well II is almost identical. It was noted that the waters were highly contaminated before the treatment, having 1100^+ and 960 MPN/dl (Coliform organisms), Eijkman test +ve, Confirming faecal contamination, and the total count was of the order of $3x10^4$ and $2x10^2$ for wells I and II respectively. Even the water samples from overhead tanks which were mixed with city water supply carried high bacterial load and were not safe for human consumption.

It would be observed from the recorded data that the chlorinators released adequate amount of chlorine each day to deal with the incoming load of bacteria since after their installation in the well waters the bacterial load reduced significantly, Eijkman test became -ve, while MPN/dl and total count/ml decreased substantially. Available residual chlorine in well I found to be between 1.05 and 1.18 mg/lit. After placement of a new chlorinator every first week, it gradually decreased, ranging between 0.7 and 0.9 to 0.02 and 0.05 mg/lit. from the second week onwards to the sixth week respectively.

The concentration of chlorine in well II ranged between 1.09 and 1.3 in the first week and decreased subsequently and gradually to between 0.02 and 0.06 mg/lit. in the sixth week.

It would be noted that during the first two weeks after installation of a new chlorinator, MPN/dl was >3 in both wells.

In third weeks, it was 7 out of 9 times> 3 in well II and 4 times > 3 in Well I. In the fourth week it > out of 9 times> 3 in slightly increased in well II but remained between 4 and 9 MPN/dl wheras in well I it fluctuated between 4 and 11 MPN/dl. During the fifth week MPN/dl was found to be between 11 and 25 and 11 and 23 in well I and II respectively, and during the sixth week it fluctuated between 20 and 64 and 28 and 64 in wells I and II respectively.

It would also be observed from Fig. 1 that upto four weeks it was quite sufficient to keep the bacterial load below subinfectious level and the water was free from sewage organisms. After the fourth week the chlorine level significantly decreased and consequently the MPN/dl increased but the Eijkman test was negative in each sample.

It was observed that after a period of 40 days the residual chlorine in the chlorinator ranged from 0.3 to 0.8% which suggests that adequate chlorine was released to disinfect coliform, faecal coliform and other microorganisms. The amount of residual chlorine present in the well waters calculated at an average rate of 0.5 ppm for the 40 days life of the chlorinator accounts for 15% of total released and remaining 85% was used towards bacterial disinfection. This is borne out more precisely by the data in Fig. 2. A balance seems to be striking each day between the chlorine demand from microorganisms and chlorine released by chlorinators. In any case the seepage of sewage water was quite high resulting in high deplation of residual chlorine during the fifth and sixth week.

A critical examination of the results reveals that the pattern of available residual chlorine in both the wells and the tank is similar to a large extent and Fig. 2 is their fair representative. Available residual chlorine was maximum on the first day after the installation of chlorinator viz. 1.6 and 1.9 mg/lit. in the well I and well II respectively; it then gradually decreased until after the 25th day it became less than 0.3 mg/lit. in both the wells. Upto the 16th day it was either 0.5 mg/lit. or more excepting once in well I when it was quite significantly low i.e. 0.06 mg/lit perhaps due to the fact that at the time of sampling, water was being pumped to overhead tanks and adequate contact time of reaction between the water and chlorinator could not be achieved. It was noted that during the experimental period Eijkman test was -ve in all the collected samples of both wells, the MPN/dl was <3 for 13 days in well II and for 10 days in well I.

A slight difference in the concentration of available chlorine, MPN/dl and total count/ml was noticed between the two wells, although, the chlorinators installed at the wells had the same quantity of active ingredients i.e. calcium hypochlorite and sand, the quantity of available chlorine was slightly lower in well I as compared to well II. Well I was comparatively more polluted than well II which is evident from the high MPN/dl and total count/ml in well I.

Disinfection by chlorination depends upon various parameters like contact time, temperature, degree of mixing pH, turbidity and interfering substances [3]. The slightly high MPN/dl in some of the collected samples may be due to insufficient contact time i.e. time taken by chlorine to act on the microorganisms, and degree of mixing because it was observed several times that water was being pumped to overhead tanks despite the instruction that at least an hour interval should be allowed between the two withdrawals.

Minor fluctuations in chlorine demand or flow have caused variation in the residual chlorine concentration but this has, on an average, remained between 0.2 and 1.0 mg/l ensuring accomplishment of a satisfactory disinfection. A residual chlorine concentration of 0.2 mg/lit. is usually sufficient for distribution systems carrying treated water, if a minimum of 20 minutes contact time is maintained [2,5] and the turbidity is kept below 1 Jackson unit. Mostly well waters in Pakistan have turbidities as low as 0.1 to 0.5 and hence it is possible to suggest that adequate coliform removal can be achieved by simple chlorination through diffusion chlorinators used during this study.

Table. 1 shows the chemical constituents of the wells under investigation. Well I is typical ground water of Karachi city and has TDS concentration of about 1000 mg/lit., whereas well II, has a better chemical composition. Ground water in Karachi region is of very poor quality. It has high concentration of TDS ranging between 2000 and 4000 and is usually mixed with domestic and industrial waste water due to leaking seawerage pipes. The chemical composition as well as microbiological examination of the wells under study confirms the mixing of municipal waste water due to inadequate sanitary facilities and improper waste disposal. The objective of monitoring the chemical composition of wells was to assess the resulting change, if any, after the treatment with chlorinators. Analytical data on chemical constituents of the samples collected during 12 months do not show any significant change in the average composition of waters after the installation of chlorinators. The light variations noted were mainly due to seasonal changes and mixing with underground seepage due to leaking pipes. TDS of wells I and II ranged between 908 and 1042, and 578 and 735 mg/lit. while calcium ion fluctuated between 30 and 65, and 30 and 64 mg/lit. respectively.

The foregoing study suggests that the developed chlorinators remove coliform and faecal coliform satisfactorily and make the water free from pathogenic bacteria. The water obtained after treatment may not be a superior product but it is tolerable water and can be safely used for human consumption

Table 1. Chemical Composition of Well Waters, Monthly Mean 198

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept		Oct		Nov		Dec	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
pH	7.1	6.8	7.0	7.2	7.2	7.3	7.3	7.1	7.4	7.4	7.4	7.8	7.0	7.0	7.1	6.9	7.0	7.2	7.3	7.2	7.3	7.2	7.4	7.3
Chloride	227	89	244	98	220	110	213	89	218	85	208	87	215	90	229	89	152	92	213	92	215	82	244	78
Sulphate	172	77	137	79	135	81	149	86	167	79	152	88	153	85	137	77	110	82	149	79	150	82	159	79
Bicarbonate	317	235	365	323	352	285	355	244	327	235	270	250	311	344	354	335	372	332	348	292	342	305	305	225
Calcium	40	32	50	59	51	43	53	30	37	40	30	37	46	64	55	64	65	63	53	41	53	54	43	39
Magnesium	38	28	37	31	35	31	35	27	36	25	35	28	34	29	36	28	32	28	35	31	35	27	38	28
Sodium	232	50	235	94	218	100	208	82	230	78	210	82	212	89	220	82	150	88	211	89	215	82	230	78
Potasium	6	16	5	16	6	16	5	18	6	21	6	19	7	91	6	20	8	17	5	17	5	18	6	19
Total dissolvedsolids	1045	578	1088	710	1037	676	1040	602	1035	608	933	612	990	735	1058	712	908	720	1027	652	1030	668	1042	596

and domestic purposes since it meets the WHO guidelines of zero *E. colii* count and not more than 10 coliformsper 100 ml. Furthermore the chlorinators have several advantages: (i) the technique is simple and does not require sophistication, (ii) their handling is safe, only a small quantity of chlorine is released, which is sufficient to get rid of pathogenic organisms, (iii) there is no change in the chemical composition nor is any colour or significant odour imparted to the treated water (iv) the system is very inexpensive and work satisfactorily for three months. The advantages of this approach may be immediately pronounced in the rural areas where wells are the main source of water supply but are unfortunately polluted and unsafe for human consumption. The technique, if applied appropriately to the wells of rural as well as urban areas of developing countries, like Pakistan, may give desired results. Wholesome and potable water could thus be made available before the end of the International Safe Drinking Water and Sanitation Decade.

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