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DISINFECTION OF POLLUTED WATER BY CHLORINE-FLOCCULANT TABLET

R. Kfir, B. W. Bateman, B. A. Pitout and P. Coubrough

Division of Water Technology, CSIR, P.O. Box 395, Pretoria 0001, South Africa

ABSTRACT

Two water treatment tablets were evaluated for their efficacy of removal of *E. coli* bacteria, coliphage V_1 and polio 1 from water. The activity of both tablets is based on flocculation as well as disinfection with additional straining. The tablets differ from each other only in their disinfectant source, i.e. Chlor-floc A contains Halazone and Chlor-floc B contains dichloro-S-triazine-trione. Tests were carried out using simulated hard and coloured water at room temperature. Results indicated both tablets to be efficient but showed tablet B to be of superior quality. Tablet B was shown to eliminate all bacteria and viruses from the test water after 4 minutes at room temperature (22 °C). Studies on partial removal of the test organisms by filtration or flocculation without chlorination showed that both steps partially removed the organisms, but the combined process of flocculation chlorination followed by filtration proved to be the most effective treatment.

KEYWORDS

Disinfection, flocculation, tablets, enteric viruses, *E. coli*, Coliphages, individual water treatment.

INTRODUCTION

Water has been implicated as a medium for the transmission of diseases for many years (Scarpino, 1971; Snow, 1855; Sykes, 1967). Estimates by the World Health Organization (WHO, 1976) indicated that about 500 million people were affected yearly by water-borne or water associated diseases. Of these, 10 million die each year (WHO, 1976). Diseases such as typhoid, paratyphoid, bacillary dysentery and cholera caused by bacteria as well as diseases caused by viruses and parasites have been associated with polluted water (Geldreich, 1972; White, 1972). The provision of pure water supplies is therefore essential to human health.

A wide variety of treatment processes have been developed for the production of potable water (Grabow 1979). In developed countries potable water of high microbiological quality is supplied to individual households via a central distribution system. In undeveloped countries, especially in rural areas where there are no waterworks, individual water treatment is of prime importance. Even in highly developed countries there are numerous occasions when a reliable method of individual water treatment is needed, for example when available water supplies are destroyed by natural disasters such as floods. Backpackers, campers and military units operating where no potable water is available may also require individual water treatment (Burrous, 1963; Johnson 1977; Kapoor, 1969; Morris *et al.*, 1953, Rogers *et al.*, 1977). On such occasions water treatment must be carried out on a small scale, often under adverse conditions.

Different water disinfecting agents are available in tablet form for the sterilization of small volumes of polluted water. The tablets are halogen based, consisting of iodine or chlorine as the disinfecting agent (Morris *et al.*, 1953, *Thompson et al.*, 1985). The tablets are aimed at the reduction of pathogenic microorganisms to acceptable levels (Harvard Report, 1945).

Conventional treatment processes include steps such as coagulation and flocculation before final disinfection (Bitton 1980). Previously available tablets are aimed only at water disinfection. This gives a water which does not necessarily meet the turbidity and colour criteria for pure water. A tablet in which coagulation and flocculation are included in addition to disinfection, will provide small volumes of treated water which is close to the quality of conventionally treated drinking water, thus providing high-quality potable water for individual users.

In this study two water treatment tablets were evaluated for their efficacy of removal of bacteria and viruses from polluted water. The two tablets are based on a combination of flocculation and disinfection and have different disinfecting chlorine sources.

MATERIALS AND METHODS

Preparation of Test Water

Simulated hard water with organic colouring was prepared by the addition of 10 ml of bicarbonates (0.4 M $NaHCO_3$, 0.24 M $KHCO_3$) and 10 ml of chlorides (0.1 M $CaCl_2$, 0.6 M $MgCl_2.6H_2O$) to 980 ml of 0.15% tea infusion water. The tea infusion water was prepared by addition of highly concentrated tea (1.5 ml) to sterile distilled water (made up to 1 000 ml). The simulated coloured hard water was used at room temperature unless otherwise stated.

Bacteria and viruses

Escherichia coli strain E25 has been described previously (Grabow and Prozesky, 1973). *E. coli* E25 was cultured overnight in nutrient broth and an aliquot of 1 ml was added to a litre of test water. Survival of the faecal bacteria was tested using the membrane filtration technique on a selective m-FC agar at 44 °C (Grabow *et al.*, 1981). Coliphage V_1 which produces large lytic plaques on *E. coli* C603 was also added to the test water (1 ml per litre). Both coliphage V_1 and its host have been described previously; phage survival was tested using the double agar technique (Grabow *et al.*, 1980).

The enteric virus polio 1 (a vaccine strain) was used. Virus stocks were kept at -70 °C and aliquots of 1 ml were introduced to the test water. Survival of the virus was tested by culturing on primary vervet kidney cells as described by Grabow & Nupen (1981).

Tablets

Treatment tablets were supplied by Control Chemical Limited (South Africa). The tablets are referred to as Chlor-floc A and B. Chlor-floc A contains 5% W/W Halazone p-(dichlorosulphamoyl) benzoic acid while Chlor-floc B contains 2.5% W/W sodium-dichloro-S-triazine-trione. The mass of each tablet is 600 ± 0.5 mg and each tablet contains aluminium sulphate $Al_2(SO_4)_3.14H_2O$ and approved flocculant aids.

Test procedure

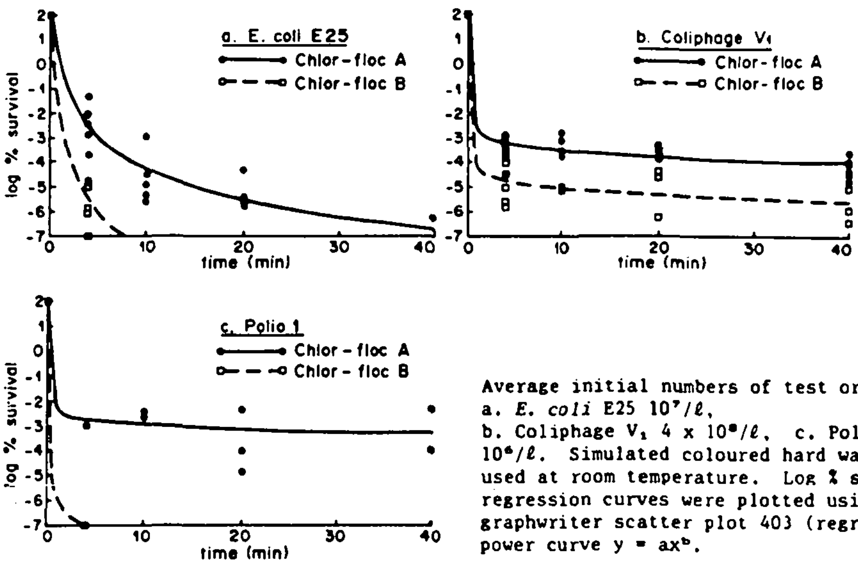
All studies were carried out at room temperature unless otherwise stated. After addition of all the test microorganisms, one tablet per litre of seeded simulated hard and coloured water was added. The treated water was then shaken for one minute, swirled for 10 seconds and left to settle for 4 minutes unless otherwise stated. After settling, the water was again swirled for 10 seconds and then filtered through a cotton bag into sterile beakers. Samples (9 ml) for microorganism analysis were removed and neutralized with 1 ml of sodium thiosulphate (2mg/ml $Na_2S_2O_3$). Samples used for viral studies were chloroformed. In experiments where filtration and flocculation were studied, either no Chlor- floc tablets were added or sodium thiosulphate was added prior to the addition of the tablets.

Chlorine determination

Free available chlorine levels in the treated water (simulated hard water with and without tea) were monitored using the Standard Method (1965). The pH of the treated water was also monitored.

RESULTS

The final treated water appeared clear with no trace of tea colouring. Treated water also appeared free of any offensive taste and odour.



Average initial numbers of test organisms a. *E. coli* E25 $10^7/\ell$, b. Coliphage V_1 $4 \times 10^8/\ell$, c. Polio 1 $10^6/\ell$. Simulated coloured hard water was used at room temperature. Log % survival regression curves were plotted using the graphwriter scatter plot 403 (regression) power curve $y = ax^b$.

Fig. 1. Removal of microorganisms by two Chlor-floc tablets

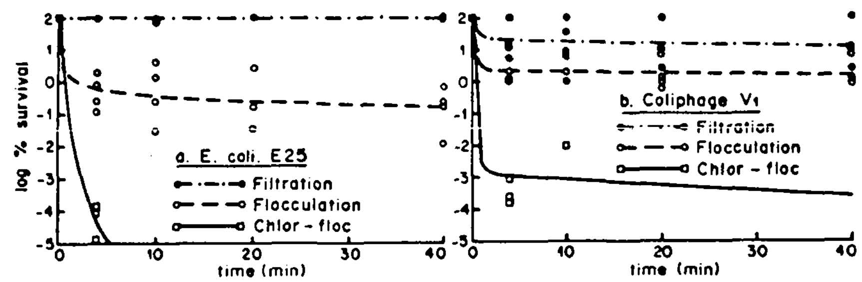
A comparison of the removal of bacteria and viruses by the Chlor-floc tablets is shown in Fig. 1a-c. The two tablets contributed to a marked reduction of all microorganisms in the simulated hard and coloured water. As shown in Fig. 1, Chlor-floc B tablets were more effective for the removal of all test organisms. The log percentage survival of the bacteria *E. coli* E25 (Fig. 1a) was reduced by 9 logs after only 4 minutes of exposure to Chlor-floc B, whereas a similar reduction was only shown by tablet A after 40 minutes. Coliphage V_1 (Fig. 1b) showed a 7 log reduction after 4 minutes of exposure to Chlor-floc B. Chlor-floc A, on the other hand, only contributed to a 5 log reduction in 4 minutes with less than one additional log reduction after 40 minutes. Polio 1 virus was rapidly eliminated by Chlor-floc B, as shown in Fig. 1c. A 9 log reduction was shown after 4 minutes exposure to tablet B, while tablet A only showed a 5 log reduction. The log percentage survival curves for most of the different microorganisms tested displayed tailing which varied with relative survival rates (Fig. 1). Both polio 1 and *E. coli* E25 showed the same sensitivity to Chlor-floc B, but polio 1 showed marked resistance to Chlor-floc A in comparison to *E. coli* E25. The bacteria also showed a greater reduction relative to time of exposure to Chlor-floc A, whereas no such increase was observed for both coliphage V_1 and polio 1 virus after 4 minutes of exposure. Coliphage V_1 showed the highest resistance to both Chlor-floc tablets when compared with the other test organisms used.

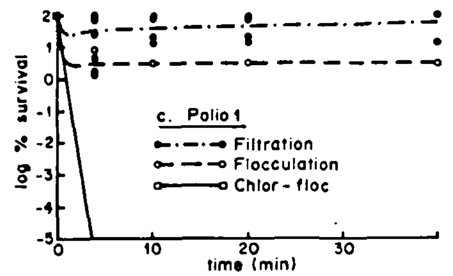
TABLE 1: Chlorine and pH determination of the Chlor-floc A and B mixed in simulated hard coloured water.

Determinand	Hard Coloured Water	Hard Water
Free Available Chlorine	mg/l	
A	0.2	2.0
B	2.5	9.0
pH		
A	6.98	7.07
B	7.25	7.22

Chlorine and pH were measured 1 min after addition of tablets.

Chlorine and pH determinations are summarized in Table 1. The level of free available chlorine differed between hard water with and without organic colouring for both Chlor-floc tablets. Very low free chlorine levels were shown for Tablet A in coloured water (0.2 mg/l). The pH of simulated hard water with both Chlor-floc tablets was recorded in the neutral range of 7. The organic colouring had little effect on the pH.





Simulated hard coloured water was used at room temperature. Only Chlor-floc B tablets were tested. Average initial numbers of test organisms: a. *E. coli* E25 $10^7/\ell$. b. Coliphage V_1 $10^8/\ell$. c. Polio 1 $10^4/\ell$. Log % survival regression curves were plotted using the graphwriter scatter plot 403 (regresssion) power curve $y = ax^b$

Fig. 2. Removal of microorganisms by filtration flocculation and a Chlor-floc tablet

Only partial removal of test organisms was achieved by filtration and flocculation as shown in Fig. 2a-c. Only Chlor-floc B tablet was used without filtration, at room temperature in simulated hard coloured water. Fig. 2a shows the relative reduction of log percentage survival of the *E. coli* bacteria. Filtration alone did not result in any removal of

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bacteria. Flocculation followed by filtration resulted in a partial reduction of 2-3 logs. Both Polio 1 and Coliphage V_1 were partially removed by the filtration process as indicated by less than one log reduction in log percentage survival (Figs 2b-c). Flocculation followed by filtration contributed to a 1-1.5 log reduction in the virus log percentage survival, which was very low when compared to the 5-7 log reduction achieved using the intact Chlor-floc B tablet. Increase in time of exposure of test organisms to the hard water with no tablet or the chlorine neutralized tablet, did not affect the log percentage survival of the organisms.

DISCUSSION

The Chlor-floc tablets meet the requirements of the Harvard Report (1945) regarding size and the use of only a single tablet for small volumes of water. The technique of application is simple and the final product is a clear water with no traces of organic colouring as specified by the Harvard Report (1945). Other available tablets used for disinfection, for example a tablet containing iodine, have been reported as having unacceptable colour and taste (Thompson *et al.*, 1985). The Chlor-floc final product was comparable to spring water for taste, clarity and odour.

The marked difference in reduction of bacteria and viruses between the two Chlor-floc tablets in the simulated hard coloured water, can be attributed to their different chlorine sources. Although the active component of both tablets is hypochlorous acid, which is considered to be the most effective disinfectant of all chlorine forms (Kott *et al.*, 1975), and although both tablets are buffered at a neutral to acid pH in which most of the free available chlorine will be in the form of hypochlorous acid, the level of free available chlorine monitored for Chlor-floc A in simulated coloured hard water was very low in comparison to tablet B. The addition of tea to the simulated hard water produced a very high chlorine demand. Such a high chlorine demand by organics has been reported previously (White, 1972).

Even though the reduction of microorganisms by Chlor-floc B exceeded that of Chlor-floc A, both tablets rendered an acceptable product. When the two tablets were compared using simulated hard water with no tea or phosphate buffer, no difference in their removal of microorganisms was observed (Kfir, 1988 unpublished data). Both tablets seem to release their active component readily as most curves of percentage log survival showed tailing after 4 minutes of exposure. This is in agreement with another recommendation of the Harvard Report (1945).

Polio 1 and *E. coli* E25 showed similar survival curves with Chlor-floc B tablets. Polio 1 showed higher resistance to Chlor-floc A tablets. Coliphage V_1 showed the highest resistance to both tablets. This finding is in agreement with other studies in which this microorganism was exposed to chlorine (Grabow *et al.*, 1984). The higher resistance of coliphage makes it a good indicator of enteric viruses in water (Grabow *et al.* 1980, IAWPRC, 1982).

The increased reduction of the coliform bacteria as a function of exposure time to Chlor-floc A can be explained by the differences in modes on action of chlorine on bacteria and viruses (Grabow, 1982). Another explanation could be the attachment/adsorption of the bacteria to the floc material and the partial remainder of Halazone on the floc which increases the functioning of the Halazone component. As shown, the bacteria and the viruses showed different removal patterns when only filtration, or flocculation and filtration was applied. This can be explained by the mode of action of adsorption of viruses and bacteria colloid material which varies according to pH and charge (Thorup *et al.* 1970). The difference in the removal of bacteria and viruses by the cotton bag filtration could also be due to the differences in size of those organisms. A larger degree of removal of phages by coagulation and filtration has been shown previously (Thorup *et al.*, 1970, Chaudhuri and Engelbrecht, 1971).

The Chlor-floc B tablet proved to be highly effective for the removal of bacteria and viruses from water.

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