Development and Optimum Composition of Locally Developed Potable - Water Treatment Tablets

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Abstract

Current high level of energy cost and operational cost of membrane technologies and couple with difficulties in obtaining chemicals for potable water treatment give rooms for development of local substance and low cost adsorbents for water treatment. This paper presents a follow-up study on an earlier work in which some water treatment Tablets were produced and tested. The current work was directed at establishing the optimum composition of the tablets. Alum, calcium hypochlorite and lime were combined in proportion and made into pastes and tablets. Residual chlorine contents of the tablets were determined. The quality of stream water samples treated with the tablets was measured by chlorine content, pH and turbidity removal. It is concluded that the best composition is one part alum, two parts hypochlorite and three parts lime and this produced treated water pH of 7.8, chlorine residual of 5.0 mg/l and settled water turbidity 3.0 NTU. The product is aimed for use in rural communities to reduce rampaging death from water borne diseases.

Keywords

Water Borne Diseases; Water Treatment Tablets; pH; Chlorine Content; Turbidity

Introduction

In an earlier study, Babatola et al [1] have presented the results obtained by preparing and testing water treatment tablets for use especially in rural and semi-rural communities that lack pipe- borne water supplies. The study showed that Tablets made up of some judicious combinations of four chemicals, namely; alum, iron (III), hypochlorite and lime, when used to treat water imparted residual chlorine, drastically reduced microbial content and lowered the turbidity of the water.

The background to the study referred to above (and indeed to the current study) is that, using the Nigerian situation as referencing point, most rural dwellers still depend largely on untreated water obtained from shallow hand dug wells, streams, and brooks for drinking and culinary purposes. As a consequence, residents of such communities still get afflicted by, and often die of water–borne and water-washed diseases, including cholera, typhoid fever, infectious hepatitis, diarrhoea, onchocerciasis, schistosomiasis, and guinea worm [2,3].

In the said earlier study commercial alum (aluminium sulphate), iron (III) (ferric sulphate), hypochlorite ($Ca(OCl)_2$), and lime ($Ca(OH)_2$) were combined at low and high levels and made into pastes and tablets. Samples of stream water were treated with the tablets. The quality-parameters used were microbial inactivation (based on raw data and also Yates' Algorithm), chlorine residual and settled water turbidity. The best three tablets were found to be those which consisted of high hypochlorite in combination with high pH and some alum.

The current study is an effort to optimise composition of the tablets. It is intended to advance the prospect of providing some stop-gap remedy that could be used to reduce incidents of water–borne diseases in rural and semi-urban communities. The goal is that people in the communities concerned would use the tablets to treat waters that they obtain from hand-dug wells and/or streams.

As indicated in the earlier work under reference the plan of the study was based on the knowledge of the coagulating properties of alum (and iron III) on the one hand and the disinfecting properties of hypochlorite especially under high pH condition [4]. It has been decided based on the results already obtained to exclude iron from subsequent composition as it tends to impart brown colour to the tablets.

Materials and Methods

In terms of an overview, the work involved in this study can be viewed to consist of four elements. These are preparation of the tablets; determination of the residual chlorine content of the tablets, computation of the theoretical chlorine content of the tablets, and treatment of stream water samples with the tablets to determine optimum composition.

As mentioned in the introductory section above, Fe (III) was left out of the current composition of the water treatment tablet. This is because the earlier work [1] had shown that although iron has some coagulating properties, it imparted an undesirable reddish brown colour to the tablets and subsequently to the treated water. Ten sets of tablets were prepared by mixing alum, Calcium hypochlorite and lime in pre-determined proportions by weight, making each composition into pastes and subsequently into tablets each weighing approximately 1.0 gram.

The residual chlorine content of each tablet was determined by dissolving it in 100 ml of distilled water (chlorine-free water) and titrating it with 0.01 N sodium thiosulphate. This was the standard iodometric method as described in APHA [5]. For comparison, the theoretical chlorine content of each tablet was computed. This was to show whether, and to what extent the theoretical values could predict experimental ones.

Finally, two-litre samples of stream waters were treated with the tablets. Each tablet was ground and stirred into the water samples. The pH of each sample was taken and the turbidity and chlorine residual of the samples were measured after one hour of settling.

Results and Discussion

Table 1 presents the results of the ten sets of the tablets as composed in the study. It also shows the chlorine content of each type of tablet as determined by titration and also as calculated. Details of the theoretical computation are presented in the Appendix.

As can be seen in the table, the authors' expectation that the experimental data would bear a consistent relationship with the theoretical data was not met. No consistent pattern is seen. The discrepancy cannot be explained in terms of interferences in the samples. This is because the tablet was dissolved in distilled water (100 ml) not raw water. And the residual chlorine content in milligram was determined in mg/l and then in mg/ 100ml. FIGURE graphically shows the relationship between the theoretical and experimental values as developed with simple computer software. The lack of agreement could suggest, possibly, that the chlorine combined with alum and /or lime (the other two components of the tablet) to form chlorides of aluminium or of calcium. The conclusion that can be drawn from this is simply that the chlorine can only be determined experimentally not stoichiometrically.

Table 1. Chlorine content of each composed tablet

Serial number	Composition of Tablets (g)				Number of tablets (approximately 1.0 gram)	Chlorine content per tablet (mg)	
	Alum	Iron	Hypochlorite	Lime		Theoretical*	By titration
1	4	0	4	0	8	18.3	0.0
2	3	0	4	1	8	21.2	2.1
3	2	0	4	2	8	25.3	10.4
4	1	0	4	3	8	31.3	24.1
5	0	0	4	4	8	40.9	22.8
6	4	0	2	0	6	14.3	0.0
7	3	0	2	1	6	17.1	1.0
8	2	0	2	2	6	21.2	24.3
9	1	0	2	3	6	27.8	17.2
10	0	0	2	4	6	40.7	26.6

*The theoretical values are based on the assumption that alum and lime do not individually or in combination exert chlorine demand.

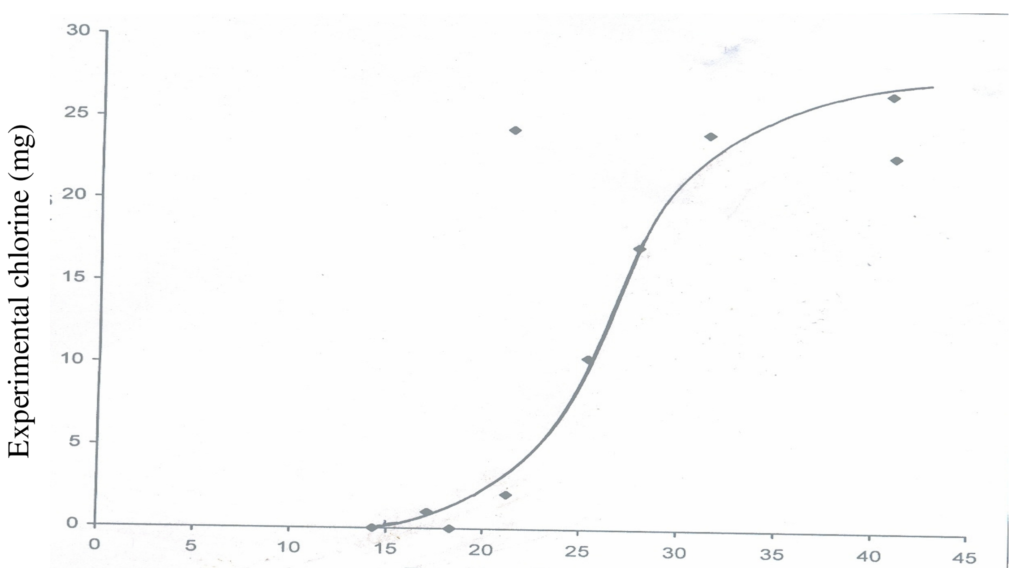

Figure 1. *Relationship between the theoretical and experimental quantities of chlorine per tablet*

Table 2. Optimum composition of the water treatment tablets.

Serial number	Composition of Tablets (g)				Chlorine content per tablet (mg)	Quality of treated water		
	Alum	Iron	Hypochlorite	Lime		Chlorine residue (mg)	pH	Turbidity (NTU)
1	4	0	4	0	0.0	0.0	5.2	11.1
2	3	0	4	1	2.1	0.0	5.7	10.7
3	2	0	4	2	10.4	2.8	6.3	8.5
4	1	0	4	3	24.1	9.2	7.5	7.2
5	0	0	4	4	22.8	10.5	8.3	5.7
6	4	0	2	0	0.0	0.0	3.8	6.8
7	3	0	2	1	1.0	0.0	5.6	11.4
8	2	0	2	2	24.3	12.2	7.2	6.7
9	1	0	2	3	17.2	5.0	7.8	3.0
10	0	0	2	4	26.6	8.5	9.0	3.5

Table 2 presents data to show the optimum composition of the tablets. It shows that in terms of pH of treated water, the chlorine residual and ability to reduce turbidity, tablet number 9 is the best. Its composition is one part of alum, two parts of hypochlorite and three parts of lime.

Conclusion and Recommendation

From the results presented in this paper it can be concluded that the earlier work by Babatola et al [1] has been advanced further and that the optimum composition the developed water treatment tablet is composed by one part of alum, two parts of calcium hypochlorite and three parts of lime. This is based on the pH, residual chlorine and turbidity of water samples treated with the tablet. In particular the level of chlorine is moderate yet sufficient to kill pathogens that may be in the water. This fact was used to excuse the need to include microbial inactivation as one of the quality-parameters (bacteria count using the method of Madigan et al [6] used in a previous work did not give consistent results).

Further work is on-going to determine the shelve-life of the product and to conduct trial runs with it in neighbouring villages around Akure and Ile-Ife, to start with.

Acknowledgement

Mr. O.O Gbadamosi of the Department Civil Engineering, FUT, Akure and Mr. S.A. Owolade of Civil Engineering Department (Environmental Engineering Laboratory), Obafemi

Awolowo University, Ile-Ife (Nigeria) both worked hard in their laboratories as technical staff to produce comparable results in the data presented in this work.

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Appendix: Calculation of Theoretical Chlorine Content of tablets

In making the tablets the following chemicals were combined in various proportions

$$n_1Al_2(SO_4)_3 \quad + n_2Fe_2(SO_4)_3 \quad + n_3Ca(OCl)_2 \quad + n_4Ca(OH)_2$$

From this, the quantity of chlorine is $n_3\ Cl_2$. Thus chlorine content can be calculated as:

$$\frac{n_3Cl_2}{n_1Al_2(SO_4)_3 \quad + n_2Fe_2(SO_4)_3 \quad + n_3Ca(OCl)_2 \quad + n_4Ca(OH)_2} \text{ x } \frac{1}{n_1 + n_2 + n_3 + n_4}$$

It should be noted that 'n' represents no of grams of chemical. And since each tablet was approximately 1.0 gram in weight then $n_1 + n_2 + n_3 + n_4$ represents total number of tablets in each combination.

$Al_2(SO_4)_3$	$Fe_2(SO_4)_3$	$Ca(OCl)_2$	$Ca(OH)_2$	Cl_2
$27*2+(32+64)*3$	$56*2+(32+64)*3$	$40+(16+35.5)*2$	$40+(16+1)*2$	$2*35.5$
342	400	143	74	71

Thus weight of chlorine in each tablet of composition 1 (See table 1) for instance can be calculated by noting that n_1= 4; n_2= 0; n_3= 4 and n_4= 0. Weight of chlorine per tablet (in that composition) will be:

4,71/ (4,342+0,400×+4,143+0,74) ,[1/ (4+0+4+0)] = 0.0183g = 18.3mg.