

A comparative study of efficacy of water sterilizing formulations

Saibal Adhya¹, Arun Tyagi^{2,*}

¹Colonel Health, HQ Eastern Command, Kolkata, West Bengal, ²Professor & HOD, Dept. of Medicine, DVVPF's Medical College, Ahmednagar, Gujarat

***Corresponding Author:**

Email: aruntyagidr@gmail.com

Abstract

Introduction: Potable water is one of the most basic logistics requirements of Armed Forces, in camps, on official as well as personal moves. It directly affects the health of the soldier as well as the combat readiness of committed forces. This study was undertaken to assess the effectiveness of major water sterilization formulations available currently and make recommendations regarding usage in the armed forces.

Materials and Method: A comparative study was conducted to assess the effectiveness as well as acceptability for use of four water sterilizing formulations: OFWS; Halazone; NaDcc; and Iodine which can be used for purification of water at individual level. Eight regiments in a forward location were selected by random procedure and all personnel proceeding on leave during a three month period formed part of the study. These eight units were then randomized into four groups.

Results: NaDcc was most acceptable followed by Halazone and OFWS with Iodine being least acceptable. Iodine users –mentioned inability to understand usage, unacceptable taste and odour, complicated usage, longer duration to act. Halazone and OFWS users mentioned that these were complicated to use and took a longer duration for the formulation to take effect. Halazone was found to have the least acceptable taste followed by OFWS. There was no statistical difference between the protective effectiveness of the formulations as per tests conducted in lab.

Conclusion: NaDcc was the most acceptable formulation and its benefits were demonstrated to far outweigh that of older formulations like OFWS, it should be immediately introduced in the Armed Forces.

Keywords: Water Purification; Water Purification Formulation; Acceptability; Effectiveness

Introduction

Potable water is one of the most basic logistics requirements of the Armed Forces, particularly on move. It directly affects the health and welfare of the individual soldier as well as the combat readiness of committed forces. An old Quartermaster Corps adage captures water's importance to service members: "The ultimate weapon runs on water, and everything else runs on fuel."⁽¹⁾ In the US, statistics during the Civil Wars highlighted for the first time the risk of diarrheas and dysenteries in combat troops - more sickness and mortality than any other diseases (741.2 per annum per 1,000). Subsequently during World War I, the Army benefited from the great improvements in environmental sanitation of the preceding two decades- a rate of 28.9 admissions per 1,000, which declined further during World War II (European theater)- 14 per 1,000. Incidence was high in theaters of operations when the environment sanitation and water quality was poor.⁽²⁾ This trend has continued even as recent as UN peace keeping missions too. Health surveillance of Brazilian military UN peacekeepers in Haiti during 2009 established that a large majority of morbidity was due to gastroenteritis (11%) and was attributed to insanitary drinking water.⁽³⁾ Troops deployed in the forward locations are especially susceptible to health hazards arising out of unsafe drinking water because of their nature of duty. Hence during military missions, or while proceeding on leave/ duty moves the troops have to

either carry sufficient quantity of potable water in person or procure the same from locally available sources.

The best method to purify water in small scale is by boiling. However, since it is not practical while travelling, mobile filters (which are costly) and disinfectants have been established as the two most feasible options. There are five classes of disinfectants that are currently used in individual water purification devices, each with advantages and disadvantages with respect to effectiveness against waterborne pathogens, ease-of-use, and safety. These are- Chlorine Dioxide, Chlorine, Electrochemically Generated Oxidant, Iodine Solution and UV Disinfection.⁽⁴⁾ Over the years the Indian army has stuck to the chlorine based Outfit Water Sterilizing (OFWS) which contains sodium hypochlorite. But lately commercial water-purification systems have become popular among hikers and campers, and outdoor magazines and catalogs tout their benefits. With this background, a project was undertaken to evaluate the acceptability and efficacy of certain major formulations of water sterilization which can be used for purification of water at individual level and make recommendations for introduction in armed forces.

Materials and Method

A randomized field trial was conducted to assess the efficacy as well as acceptability for use of four water sterilizing formulations viz., Outfit Field Water Sterilizing (OFWS), Dichloroisocyanurate (NaDcc), Halazone and Iodine. Troops from a field location, out

of 08 randomly selected regiments in a forward location, proceeding on leave during a three- month period formed part of the study.

Sample size was calculated with an expected parameter estimate of 0.03 with a view to obtain 95% confidence interval and worst acceptable as 0.015. The optimum sample size to evaluate each item worked out to 500, thus making the sample size to be 2000 for the study which would be sufficient to shortlist the best one suited for troops on move.

The water sterilizing formulations were standardized by using only tablet forms of similar strength, i.e., one tablet to purify one liter of water. All personnel of a particular Battalion were given a single type of tablet, before they started their journey and their correct use was demonstrated individually.

A pretested questionnaire was self-administered after they reported back from leave to collect data on their acceptability of the product and preference including the problems faced while use. Single blinding was ensured with each questionnaire being allotted an Accession Number.

The efficacy of all the three items was also tested by treating one liter of water from all three types of sources viz., deep tube well water, spring water and water from two prominent railway platforms and bus stations i.e. Jammu and Delhi. Thereafter estimation of free chlorine was carried out at half hour and two hours interval by

using the standard chloroscope. Similarly, bacteriological exam of water was carried out at the respective MHs (Jammu and Delhi) after treatment, for presence of coliforms by MPN method.

All troops were also put under surveillance for development of GI disorders after their return from leave. A comparison of the disease rate between the regiments gave a rough estimate of the efficacy of the product in vivo too.

Results

Use of various water sterilizing formulations by the troops was studied regarding their frequency of use, understanding its usage, and acceptability. The frequency of use of water sterilizing formulations after their distribution was 95% (56% every time; 39% occasionally). The pattern of use of various water sterilizing tablets is shown in Table 1. Among always users, NaDcc (66%) were maximum and Iodine (26%) minimum. Only 129 out of the 2000 participants gave history of not having used any water sterilizing formulation (6.5%, with 5.4% to 7.6% as 95% CI). However, a large number was also found to be occasional users (39%, with 38% to 46% as 95%CI). Iodine was least favored (74%) and NaDcc most popular (34%). This difference was statistically significant ($p < 0.00001$).

Table 1: Use of water sterilization formulations

Formulations	Frequency of Use			Understand Use	
	Always	Occasionally	Never	Yes(%)	No (%)
OFWS	263 (52%)	232 (46%)	8(2%)	493(98%)	9(2%)
Iodine	131(26%)	303 (60%)	70(14%)	438(83%)	66(13%)
Halazone	294 (59%)	183 (36%)	20(5%)	479(95%)	24(5%)
Na DCC	322(66%)	135 (27%)	31(7%)	457(92%)	41(8%)
$X^2 = 133.86$ with $p < 0.00001$				1867(93%)	140 (7%)

Comprehending the use of various formulations was not a major problem since 93% of the population did not find any difficulty. Only 1.8% OFWS users did not understand its use. However newer formulation users like Iodine (13.1%), NaDcc (8.2%) and Halazone (4.8%) had higher numbers who could not comprehend.

The reasons for non-acceptance are tabulated in Table 2. Only 6.9% (138) of the study population found the taste as not acceptable. The change of taste was maximum with NaDcc (68.2%) and least with OFWS (18.8%). Non-acceptability due to bad taste was maximum with Halazone (13.6%) and least with Iodine (1.6%). Iodine users perceived maximum change in odor (32%) and Halazone users least (13%). On enquiring about any perceived difficulty in usage, only 49 people identified some form of difficulty in the use of the formulations offered (2.45%), with OFWS most complex and NaDcc easiest to use (only 1.6% had some difficulty in usage). Only 9.6% felt that the treatment was time consuming. Halazone (20.4%) and OFWS (16.6%) took longer time to treat whereas none of the NaDcc users felt the same. Only 8.5% of the study population felt that it was useless. NaDcc and OFWS were perceived to be most useful.

The incidence of gastrointestinal disease immediately within 2-3 days after return, among those provided with the water sterilizing formulations was compared with those who were not part of the study in the same regiment. A total of 16 persons who were given one of the four water sterilizing formulations suffered from some form of gastrointestinal disorders after their travel (0.8%) compared to 3.68% - the normal incidence rate of gastrointestinal diseases following return from leave in these four regiments during the period of 06 months of study. This difference was statistically significant ($p < 0.00001$). The distribution of gastrointestinal disease cases in various user groups is as shown in Table 3. Thus, OFWS users had maximum cases (1.3%) compared to 1% among Halazone users, 0.6% among NaDcc users and least among Iodine users (0.2%).

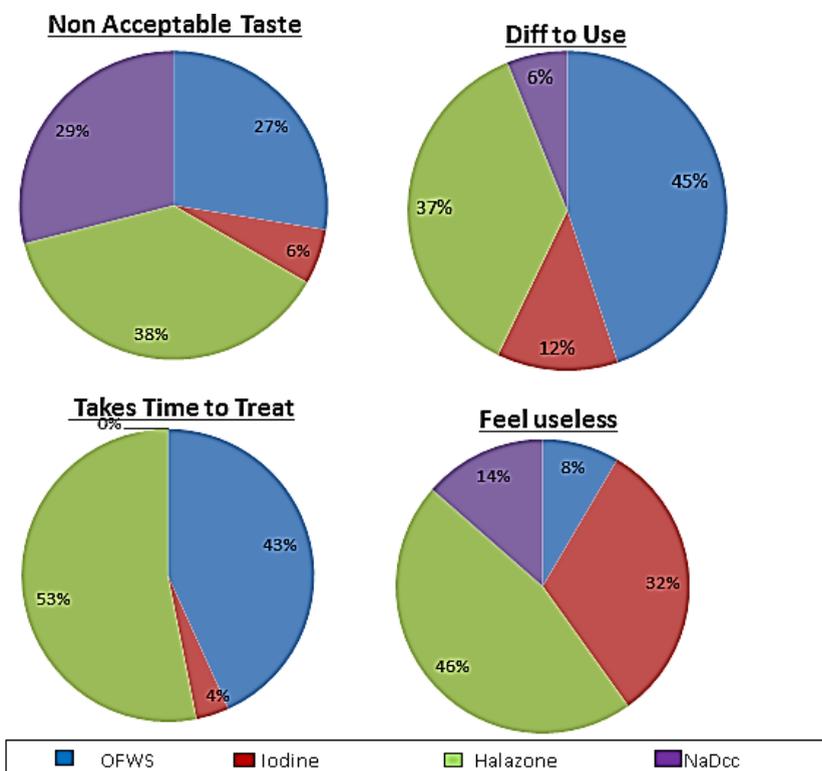


Fig. 1: Reasons for non-acceptance: different formulations

Table 2: Reasons for non-acceptance

	Taste	Odour	Feel useless	Diff to use	Long time to treat
OFWS	38 (7.6%)	102(21%)	15(3.0%)	22 (4.4%)	83(16.6%)
Iodine	8 (1.6%)	164(32.5%)	56(11.1%)	6 (1.2%)	7(1.4%)
Halazone	52 (10.3%)	64(13%)	82(16.2%)	18(3.6%)	102(20.2%)
Na DCC	40 (8.1%)	97(21%)	24(5.2%)	3(0.6%)	0
Total	138 (7%)	427 (21.4%)	177 (9%)	49 (2.5%)	192 (10%)

Table 3: Distribution of GI diseases among users of various formulations

	Yes	No	% with GI Diseases
OFWS	7	493	1.4%
Iodine	1	499	0.2%
Halazone	5	495	1%
NaDcc	3	497	0.6%
Total	16	1984	0.8%
Normal GI disease rate			3.68%

$X^2 = 37.62, p 0.00001$

Table 4: Bacteriological exam of water samples before and after use of formulations

Locations		Rly Stn		Bus Terminus		Spring Water	Tube Well
		Delhi	Jammu	Delhi	Jammu		
Before Treatment		Satisfactory	Satisfactory	Satisfactory	Unsatisfactory	Unsatisfactory	Satisfactory
After Treatment	OFWS	Excellent	Excellent	Excellent	Excellent	Satisfactory	Excellent
	Iodine	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
	Halazone	Excellent	Excellent	Excellent	Excellent	Satisfactory	Excellent
	NaDcc	Excellent	Excellent	Excellent	Excellent	Satisfactory	Excellent

After application of the four water sterilizing tablets, water was tested both by bacteriological examination and estimation of free chlorine, from two cities, Jammu and Delhi from both locations – railway station and bus terminus. The results are tabulated in Table 4. The bacteriological quality of water prior to treatment was found to be unsatisfactory at Jammu bus terminal whereas it was satisfactory at the remaining locations. After treatment with all the four formulations 100% samples of water at both the railway station as well as the bus terminus at both the cities were bacteriologically of excellent quality. Similarly, free chlorine was detected in 100% of samples (except Iodine treated water) after half hour, one hour and 2 hours of treatment.

Water was also collected from fresh mountain springs and untreated deep tube well water of MES pump house and treated with all the four formulations. The bacteriological quality of spring water prior treatment was found to be *unsatisfactory* and *satisfactory* for deep tube well water. Post-treatment, the bacteriological quality of deep tube well water was *excellent* for all four formulations. However, water quality standard was *satisfactory* for spring water post treatment. Free chlorine was detected in all instances (except after Iodine treatment) from both sources after treatment.

Discussion

Various literature and studies have touted the advantages of the diverse range of water sterilizing formulations available as under:

Hypochlorites (Sodium and Calcium) are universally accepted as a safe and effective water disinfectant with action through release of free chlorine or hypochlorous acid. However, presence of excess chlorine and formation of carcinogenic chloramines due reaction with organic compounds are disadvantages.⁽⁵⁾

Advantage of Halazone lies in having a tremendous self spreading solubility - due to the presence of P-Dichlorosulfamoyl benzoic acid. It carries a fixed strength having no hassle of excess chlorine release. The disadvantages of chlorine as mentioned above are of course present.⁽⁶⁾

NaDcc releases a measured dose of hypochlorous acid, is not dangerous to handle, is completely stable and inert, without the traditional unpleasant chlorine taste and odor. Moreover it has a much longer shelf life and has no negative health effects.⁽⁷⁾

Iodine, the oldest form of water purification is the most effective. Disadvantages being sensitivity to light, unpleasant taste & odor and yellow decolorization. Water also need to be clear before treatment.⁽²⁾

Verification of these aspects specially in terms of efficacy and acceptability among the four main formulations was carried out.

In the present study, since only 5% were averse to using the water sterilizing formulations at all, it can be assumed that the overall acceptability was good. Formulation wise analysis revealed that NaDcc was most

acceptable followed by Halazone and OFWS with Iodine being least acceptable. However, since a large section of the population (39%) were using it occasionally, there were certain factors which could be the reason for non-acceptance like - inability to understand usage, taste unacceptable, complicated usage, unacceptable odor, felt longer duration to act and felt formulation was useless.

Taste and odor are the two foremost features for acceptance of any drinking water. Halazone was found to have the least acceptable taste followed by OFWS. This can be explained by the fact that both items emit chlorine whose odor is largely unacceptable if present in large quantity. Of those who complained of unacceptable odor Iodine and OFWS users were on top of the list. Iodine has a strong odor and hence may be unacceptable. Halazone and OFWS users had maximum complaints of longer duration for the formulation to take effect. OFWS and Halazone have to be consumed after half an hour of contact period and naturally would take longer. Although a very small percent (2.5%) felt difficulty in usage of the formulation, Halazone and OFWS users complained that the items were complicated to use. OFWS treatment involves use of two tablets-chlorination and test removing tablets, and hence more complicated. However, Iodine also involves 2 tablet usage but was not perceived to be complicated. Feeling the usefulness of the formulation was seen maximum among OFWS users compared to others. This again could be as a result of its use over a long period in the armed forces and hence perceived to be beneficial. Other studies also corroborate these findings. Thomas Clasen and Paul Edmondson also pointed out that the advantages of NaDCC far outweigh that of Hypochlorites regarding compliance, acceptability, affordability and sustainability.⁽⁸⁾ Studies of interventions involving household water treatment using NaOCl have generally reported compliance of around 70% (Quick et al. in 1999 and 2002; Semenza et al. in 1998).^(9,10,11) Daniele S et al in Tanzania had similar observations regarding NaDCC over other chlorine based disinfectants including a shelf life of five years, resistance to degradation from sunlight, single-use packaging, and low weight in distribution.⁽¹²⁾ Heiner JD et al while comparing the palatability of two field water disinfectants: one iodine-based and the other chlorine-based confirmed that palatability was much better with chlorine compared to iodine formulation.⁽¹³⁾

Since only 7% had difficulty in comprehending their use, it shows that tablet formulations were not difficult to use. However, there was a statistically significant difference between different formulations with OFWS being least difficult to understand while Iodine formulation was most difficult to comprehend. The probable cause of this difference can be attributed to OFWS being used by troops for a long time in the army. Iodine formulations are in fact a very recent addition in the Indian market and hence difficult to comprehend.

Thus, from the above analysis it seems that NaDcc formulation was the most acceptable among all formulations with least number of its users having any problems of its acceptance. OFWS, though a time-tested formulation seems to be one of the least popular items with majority of the complaints of unacceptable taste and odor, complicated usage and longer time to take effect. Halazone, because of the strong chlorine taste and odor was also less popular. Iodine was perceived to have the best taste and was quick acting but its unacceptable odor was a drawback. The results of our study thus validates the advantages and disadvantages of each formulation as available from various literatures and almost matched majority of what the manufacturers claimed.

The drop from 3.68% to 0.8% in the incidence of GI tract infections was substantial, pointing to the strong evidence of beneficial effects of all the formulations. All formulations were able to accomplish the desired sterility standards provisionally, which is what the requirement is during travel. A number of studies have confirmed that use of a disinfectant in the drinking water in the community reduces the rates of diarrheal diseases appreciably. Lule JR et al noticed in rural Uganda that HIV positives who are prone to intractable diarrheas had 25% fewer episodes if given a compulsory formulation of chlorine based disinfectant.⁽¹⁴⁾ M.D. Sobsey et al in Bangladesh also had similar findings with 43% of community diarrhea being preventable by using Chlorine disinfection.⁽¹⁵⁾ Studies by Mahfouz et al (1995), Quick R, Mong et al (2001) and Semenza et al (1998) also showed appreciable reduction in rates of diarrheal diseases ranging from 48% to 90% while using chlorine based disinfectants in the community.^(16,17,18) The free chlorine estimation periodically, upto 2 hours of treatment, for each of the formulations, reinforced their protective efficacy over prolonged period. In the present study since the tests on protozoans and viruses could not be performed the distinction between the individual formulations could not be ascertained.

However, as the available knowledge indicates, Iodine is graded as the most effective disinfectant among the chemicals available commercially.⁽²⁾ NaDcc is comparable to Iodine for effectiveness and efficacy against waterborne bacteria, viruses and cysts.⁽⁷⁾ Halazone also has properties of effective disinfection of water against bacteria, fungi, yeasts algae, some viruses and protozoa.⁽⁶⁾ Hypochlorites (OFWS) though are known to be effective against almost all bacteria, viruses and cysts, because it is volatile, slow to disinfect and works differently against protozoa and viruses at various pH levels, it may not produce the best result.⁽⁵⁾

Conclusion

It is our foremost duty to ensure that Safe drinking water is available to every citizen during move; be it a body of troops or a group of civilian traveling by train or road. In case, the basic safety drinking water cannot be ensured at all times, it becomes mandatory for all to carry

some or other water sterilizing formulation. Since the benefits of newer water sterilizing formulations like NaDcc were demonstrated to far outweigh that of older formulations like OFWS, these need to be made available to all at affordable rates, if not freely. An item which has a much better user acceptance and found easy to use, will always be much more frequently used if made available to the population.

References

1. Dusenbury JS editor. Military land-based water purification and distribution program. Proceedings of the NATO RTO-MP-HFM-086 meeting; 2003; Warren MI.TACOM Research development and Engineering Centre. Dec 03. Available from ftp.rta.nato.int /RTO-MP-HFM-086. Accessed on July 2014.
2. Philbrook Frank and Gordon John. Army experience with diarrheal disorders before World War II. US Army Medical Department- Office of Medical History, Chapter XVII. 319-331.
3. De Andrade-Lima JRP and Batista RB. Health surveillance of Brazilian military peacekeepers deployed in the United Nations Stabilization Mission in Haiti (MINUSTAH). 2007 – 2009.
4. Clarke S, Bettin W. Iodine disinfection in the use of Individual Water Purification Devices; U.S. Army Center for Health Promotion and Preventive Medicine; 2006 Mar. Technical information paper # 31-005-0306.
5. Directorate General Armed Forces Medical Services. Water Supply, Manual of Health for the Armed Forces. 2003;1:271-320.
6. Kahn H F, Visscher B. A simple safe method of water purification for Backpackers. Backpacker. 1978; 6: 35-36.
7. Andrew M. Aquatabs- water purification tablets. Global Hydration. 2006;1 Available from www.aquatabs.ca Accessed on July 2014.
8. Thomas C and Edmondson P. Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. Int. J. Hyg. Environ.-Health. 2006;209:173–181.
9. Quick RE, Venczel LV, Mintz ED, Soletto L, Aparicio J and Gironaz. Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. Epidemiol. Infect.1999; 122: 83–90.
10. Quick RE, Kimura A, Thevos A, Tembo M, Shamputa I, Hutwagner L, et al. Diarrhoea prevention through household-level water disinfection and safe storage in Zambia. Am J Trop Med Hyg. 2002; 66 (5): 584–589.
11. Semenza JC, Roberts L, Henderson A, Bogan J, Rubin CH. Water distribution system and diarrhoeal disease transmission: a case study in Uzbekistan. Am J Trop. Med Hyg. 1998; 59: 941–946.
12. Lantagne DS, Cardinali F and Blount BC. Disinfection by-product formation and mitigation strategies in point-of-use chlorination with sodium dichloroisocyanurate in Tanzania. Am J Trop Med Hyg. 2010; 83(1): 135–143.
13. Heiner JD, Simmons EA, Hile DC and Wedmore IS. A blinded, randomized, palatability study comparing variations of 2 popular field water disinfection tablets. Wilderness Environ Med. 2011; 22(4): 329-332.
14. Lule JR, Mermin J, Ekwaru JP, Malamba S, Downing R, Ransom R et al. Effect of home-based water chlorination and safe storage on diarrhea among persons with human immunodeficiency virus in Uganda. Am J Trop Med Hyg. 2005; 73(5): 926-33.

15. Sobsey MD, Handzel T and Venczel L. Chlorination and safe storage of household drinking water in developing countries to reduce waterborne diseases. *Water Sci Technol.* 2003; 47(3): 221-228.
16. Mahfouz AA., Abdel-Moneim M, Al-Erian RA and Al-Amari OM. Impact of chlorination of water in domestic storage tanks on childhood diarrhoea: a community trial in the rural areas of Saudi Arabia. *J Trop Med Hyg.* 1995; 98(2):126–130.
17. Quick RE, Venczel LV, González O, Mintz ED, Highsmith AK and Espada A. Narrow-mouthed water storage vessels and in situ chlorination in a Bolivian community: a simple method to improve drinking water quality. *Am J Trop Med Hyg.* 1996; 54(5): 511–516.
18. Mong Y, Kaiser R, Rasoatiana DI, Razafimbololona I and Quick RE. Impact of the safe water system on water quality in cyclone-affected communities in Madagascar. *Am J Publ Hlth.* 2001; 91(10): 1577–1579.