Efficacy of Ef-Chlor for Drinking Water Purification and Multipurpose Disinfection

Abhishek Bajpai [1], R.S. Goswami [2], Aayush Goswami [3], Shrikant Garde [4], Preeti Phadnis [5]

[1] M.Sc. Biotechnology student, VIT University Vellore, T.N., India
[2] CEO, Hind Pharma, Bhopal, M.P., India
[3] COO, Hind Pharma, Bhopal, M.P., India
[4] Manager Marketing and Sales, Hind Pharma, Bhopal, M.P., India
[5]QC Manager, Hind Pharma, Bhopal, M.P., India.

Abstract- Ef-Chlor is a product manufactured by Hind Pharma containing Sodium dichloroisocyanurate (NaDCC) as its major component, which is an effective compound used for water purification, disinfection and sterilization. Ef-Chlor ensures maximum protection against a wide range of disease-causing pathogens. This paper provides information on different areas where Ef-Chlor tablets containing NaDCC can act in an effective manner and could substitute the old methods, formulations and compounds still used for purifying water. This paper summarizes the effectiveness of NaDCC (major component of Ef-Chlor) over of all other traditional formulations with emphasize on its good antimicrobial activity, more safety, better stability, long shelf life, prolonged protection and affordability. The efficiency of Ef-Chlor {NaDCC} was also analysed against harmful pathogens in microbial testing where it demonstrated its immense effectiveness. Research papers, literatures, articles, studies and experimentation results available for reference have supported the claim stating NaDCC as a superior product over others. Ef-Chlor's capability for use in broad domestic and industrial applications, its efficiency to work from small to large volumes and its strength to kill maximum pathogens makes it an ideal product in the market. Ef-Chlor could be used for municipal water supplies, household purposes, hospital uses, fruits and vegetable disinfection, janitorial cleaning, marine applications, poultry and many more areas as well as in emergencies and disaster situations where there is a demand for immediate disinfection and a need for clean drinking water. Ef-Chlor can act as a preventive aid for the various water borne diseases prevailing globally and thus it can contribute towards improving the global health conditions.

Index Terms- Disinfection, Ef-Chlor, Hind Pharma, NaDCC, Sterilization

I. INTRODUCTION

The spread of diseases from contaminated water has taken a vigorous rise globally. There is an increasing demand for a product that can be useful in disinfecting water from various disease causing microbes. Among various water-borne diseases, the common ones which are found in India are Diarrhoea, Typhoid, Malaria, Amoebiasis (Amoebic dysentery), Cholera, Giardiasis and Filariasis (Chabba, 2013)[1]. The contamination levels in water have taken a hike causing an increase in health hazards in societies globally. Water borne pathogens have major health impacts, relatively causing more damage to young children, underdeveloped and developing regions that lack proper supply of treated water. With the change in climate, the threat of water borne diseases also increase as seen in the rainy season where an escalation in spread of these diseases are observed. Water contamination level rises during emergencies like floods, tsunami, and heavy rains causing a massive outbreak of infectious diseases spreading via water.

A global study states that in developing countries diarrhoea accounted for 21% deaths of most children fewer than 5 years of age and total 2.5 million deaths per year (Kosek & Guerrant, 2003)[2]. An article of WHO stated that the water related diseases caused by microorganisms present in contaminated water leads to death of more than 3.4 million people each year in which most of the victims are young children. Also according to an assessment done by United Nations says that 4000 children die each day from diseases caused by ingestion of filthy water. Reports state that four out of every ten people in world do not have access to clean drinking water, particularly in African and Asian regions (Berman, 2009)[3]. A study gives information on outbreak of different water-associated infectious diseases spreading worldwide corelating it with socio-environmental factors and showing its impact on all regions globally (Yang, 2009)[4].A mandatory access to pure water is required for improvement in the health conditions of people in India too. Reports have stated that between 400000 and 500000 children with an age of around 5 years die every year from diarrhoea (a major water-borne disease) due to lack of personal and home hygiene in India (Murdur, 2003)[5]. There is a need to purify available water to make it free from microbial contaminations that will help to slow down and cease the spread of water borne diseases in people and also mainly among children who are living in underdeveloped, poor and rural areas where contamination in water is high. There is an increasing demand for a product that can disinfect the water and make it suitable for the purposes of drinking, household works, washing, cleaning, cooking and other related activities.

A product that can be beneficiary in all the situations is Ef-Chlor, which is being manufactured by Hind Pharma, India. Ef-Chlor (manufactured in tablets as well as granules form) can be used for Water Purification, Sterilization and General Disinfection on nearly all objects. These are Sterilising Effervescent Tablets, which act as a broad-spectrum fast acting sanitizers and water sterilizers that are quick and effective against a wide range of Bacteria, Viruses, Fungi and Protozoa. These tablets are useful in a wide range of

industries for disinfection of water and sterilization (Hind Pharma)[6]. Ef-Chlor consists of Sodium Dichloroisocyanurate (NaDCC) that maintains a continuous and prolonged supply of Chlorine, which reacts with organic matter and the various pathogens present in the water and kills them. Environmental Protection Agency (EPA), World Health Organisation (WHO) and The United Nations Children's Fund (UNICEF) have marked NaDCC safe for usage. In addition to this United States and many other countries have listed NaDCC to be used in emergencies for the purpose of drinking water disinfection (Kuznesof, 2004)[7].

Ef-Chlor:- Genreal composition and working

Ef-Chlor is a product manufactured and marketed by Hind Pharma, India consisting adequate amount of NaDCC present in them. Each tablet of ef chlor is designed to supply a specific quantity of chlorine which can be used for disinfection of a particular volume of water. NaDCC has chlorine present in the hypochlorous forms (HOCl) which is an active antimicrobial agent showing effectiveness against a broad range of bacterias, fungi, viruses and protozoas. The production of NaDCC, its formulation, safety aspects, its working efficiency and other details are briefly presented by Paul M. Kuznesof (Kuznesof, 2004)[7] in his works. Ef-Chlor tablets containing NaDCC are dissolved in water to decontaminate it and make it suitable to be used for drinking and other household purposes. The high disinfecting ability of NaDCC and its antimicrobrial properties makes Ef-Chlor an advisable product to be used for disnfection and sterilization purposes. NaDCC works on a broad spectrum of pathogens and a wide pH range. NaDCC has proven to be effective against different bacterial species and gave positive results in killing various pathogens. In addition to this NaDCC has delivered better working efficiency and shown higher activity then other formulations like NaOCl (Bloomfield, 1979)[8]. Biofilms are a mojor contaminant of water and thus their presence makes water unfit for any use and increases the possibility in the spread of water borne diseases. NaDCC has been tested and found to be effective against bacteria growing in planktonic as well as in biofilm cell populations. NaDCC did not only eliminated bacterias is planktonic population but also inhibited biofilms formation inactivating the existing biofilms (Morgenthaua, 2012)[9]. The high antibacterial properties of NaDCC makes Ef-Chlor convininet to be used for drinking water purification, household purposes, baby products sterilization, hospital disinfection, janitorial cleaning and other related application.

Chemical action of Ef-Chlor (NaDCC in water)

$NaDCC + H_2O = HClO + Na^+ + H_2C_4^-$

Hydrolysis of chlorine compound Formation of hypochlorous acid

$HClO = H^+ + ClO^-$

Stabilization of hypochlorous acid at the pH of water

$HClO = HCl + [O]$

Decomposition of HClO to liberate nascent oxygen

[O] + MICROORGANISM = HCl + OXIDISED MICRO ORGANISM

(DEATH OF GERMS)

Oxidation & destruction of germs by nascent oxygen

Hypochlorous acid (HOCl) is electrically neutral and hypochlorite ions (OCl-) are electrically negative in nature. The cell wall of pathogenic microorganisms is negatively charged usually which can be penetrated by the neutral hypochlorous acid, rather than by the negatively charged hypochlorite ion. Thus the free available chlorine released by NaDCC (and other chlorine donors, including the chlorinated isocyanurates) in solution will oxidise many organic and inorganic compounds in water.

Properties of Ef-Chlor

Ef-Chlor has more free available chlorine (FAC) in the form of hypochlorides (HOCl) and it is manufactured in both tablets as well as granular forms. NaDCC (major component present in Ef-Chlor) is marked totally safe by WHO, EPA and UNICEF for the use of drinking water purification and other household works (Kuznesof, 2004)[7]. Ef-Chlor does chlorination of water, which is an effectively known method for disinfection of water (World Health Organization , 2004)[10]. Ef-Chlor does not impart any strange colour or taste in the water which it is dissolved. Sodium dichloroisocyanurate (NaDCC) have more stability and longer shelf life then any other compound used for water purification purposes. NaDCC is environmental friendly and does not react with any other non pathogenic (non-harmfull) biomolecules present in water. A toxicological review on cyanurates and its chlorinated derivatives gives information on non-toxic and harmless attributes of dichloroisocyanurates and also advice the acceptable dossage of it to be used (Hammond, 1986)[11]. Ef-Chlor is designed in tablet form which gives an advantage of using specific dossage for a particular volume, eliminating the chances of underdosing or overdosing. The tablet structure of Ef-Chlor makes it a product that is easy to handle and store, moreover it could be used for traveling and camping purposes for purification of water. Ef-Chlor shows high efficiency in less time and works on a far-reaching ranges of pH and temperatures. It works on a broad spectrum of microbes including different species of bacterias, viruses, fungi, protozoas, mycoplasma, etc. The antimicrobial activity of sodium dichloroisocyanurate was tested against 66 strains of fungi, 28 gram positive bacteria and 29 gram negative bacteria, protozoa such as *Trichomonas vaginalis*, on which it presented exceptionally good results even in the presence of 1% organic substance (D'Auria, 1989)[12].

General Uses of Ef-Chlor

The maximum use of Ef-Chlor can be drained for the purpose of purification of drinking water. As Ef-Chlor has efficient working against a wide spectrum of water borne pathogens, it can be used for improving and enhancing the water quality and making it free from microbial load. Sodium dichloroisocyanurate has shown effective working as an antimicrobial agent in purification of drinking water at household level. It has many advantages over tradional water purification practices as well as it has proven as a safe and non toxic way in which water is efficienty treated wiping out the maximum pathogenic population (Clasen, 2006)[13]. Ef-Chlor can be used with water serving different purposes in household work like cleaning, washing, bathing and cooking. The high antimicrobial activity of NaDCC discussed earlier makes Ef-Chlor an optimum choice to be used for sanitization applications, bottle sterilization, fruits and vegetable disinfection and other similar activities. The hygiene maintaning and disease controling capability of NaDCC makes Ef-Chlor a preferable choice to be used in janitorial cleaning too. The tablet manufacturing and strip packaging of Ef-Chlor extends its appliance for use in travelling and camping. Ef-Chlor is safe, easy to handle, smooth in storage and trasport as well as simple for evaluating its usable dossage. It is largely used in the fields of poultry and dairy animals and their products. There is an enormous range of pathogens which can multiply, survive and infect the poultry animals and their products leading to a decrease in their yield. Ef-Chlor tablets can be used in proper dossage by dissolving them in water served to animals or can be sprayed which will result in disinfection of water and surroundings, not only killing the bacterias but also stopping the spread of water borne infectious diseases, which would help the farmers and breeders to increase the yield and productivity. Ef-Chlor can be used in Broiler/Layer farms, Breeder farms, Hatchery units, Cattle Breeding/Dairy Production and Milk Plants. When a large number of animals are living together, there is a high risk concerning the spread of infectious diseases from one animal to other. In these situations Ef-Chlor can be used in purifying drinking water which is fed to livestock as it does not impart any uncommon colour, foul smell or unpleasant taste in water, so there won't be any change in the water intake of animals. Regular surface disinfection, disinfection of the cages and feeding utensils of animals used at zoos, clinics and farms can help in reducing the spread of infectious diseases among animals and to humans via contaminated animal products. In Fisheries there is a danger of cross contamination to fishes from the surface and water which they come in contact with as there is presence of a diverse natural microflora in water. Fish tissues are an ideal medium for the growth of bacteria and therefore washing and rinsing the fish with NaDCC before consumption reduces the chances of spread of water borne diseases. Ef-Chlor is also effective against viruses associated with food borne diseases, especially in shellfish and it also inactivates the formation of biofilms which is generally observed at room temperature (Hind Pharma) [6].Sodium dichloroisocyanurate was also found powerful for the sterilization of explants and cultures and disinfecting micropropagated plants from a broad range of bacterial species. It was found to be stable at room temperature (in tablets as well as solution), it was able to sterilize plants contaminated heavily from bacterial species and also reduced the phytotoxicity (Parkinson, 1996)[14].More uses of Ef-Chlor in essential sectors like Drinking water purification, Hospital purposes, Municipal water supplies and during Emergencies and Disasters will be discussed in this paper later.

Activity of Ef-Chlor against Bacterial Species

Bacterial species commonly found in water are *E.Coli, Shigella, Salmonella*, etc. leading to food poisoning, diarrhea, in some severe cases cause bloody diarrhea, watery diarrhea, urinary tract infection, etc. Elimination of these bacterias from water is a necessity to make water potable and more suitable for purpose of drinking, cooking, washing and other works. The antibacterial properties of NaDCC were evaluated by testing it against 28 gram- positive bacteria and 29 gram-negative bacteria including strains of *E.Coli, Salmonella typhimurium*. NaDCC demonstrated good antibacterial activity against all the tested strains and there was no decrease observed in its activity even in the presence of 1 % organic substance (D'Auria, 1989)[12]. Presence of *E.Coli* in water is a major cause of urinary tract infection. NaDCC's effectiveness was checked against multiple bacterial species like *E.coli, Staphylococcus aureus, Salmonella typhi,* etc. using varying parameters like pH and dilution factors. Higher bacteriocidal and disinfecting capabilities of NaDCC were observed against these organisms (Bloomfield, 1979)[8]. The susceptibility of NaDCC has been established for bacterial species like *Escherichia coli, Salmonella dysenteriae, Shigella sonnei, Campylobacter jejuni* and *Yersinia enterocolitica* (Clasen, 2006)[13].These species are the main contributers in the spread of water borne infectious diseases. The cytotoxic effects of NaDCC were tested in-vitro using human fibroblast culture taking minimal inhibitory concentration and minimal bacteriocidal concentraion of NaDCC against *Streptococcus sobrinus, Streptococcus salivarius, Enterococcus faecalis* and *Streptococcus mutans*. NaDCC was found to be very effective in killing these bacterial species and also its non lethal concentration range for fibroblasts was evaluated (Heling, 2001)[15]. NaDCC tablets were tested for bacteriocidal activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. It was concluded that NaDCC was effective in killing these bacterias and had minimum level of available chlorine and greater stability (Coates, 1985)[16]. NaDCC used in specific concentrations have shown effective disinfection against *Pseudomonas aeruginosa* growing as planktonic cells and against aquatic biofilms which are the major conatminants of water in environment contributing in the spread of water borne diseases like diarrhoea. Aquatic biofilms even provide protection for multiplication and development of pathogens like *E.coli, P.aeruginosa, Yersinia pestis, Helicobacter pylori* and many more which are the primary sources of water borne diseases (Morgenthaua, 2012)[9]. *Clostridium difficile* is a major cause of hospital-associated infective diarrhea and its spores can linger around for months in the hospital environment. Chlorine (dichloroisocyanurate) containing germicides were able to inhibit the growth of *C.difficile* as well as inactivate *C.difficile* spores showing greater effectiveness than other compounds used (Fawley, 2007)[17]. Fecal *Coliform* bacteria are primary indicator for presence of disease causing organisms. Presence of *Coliforms* in water hints towards the possiblitily of presence of organisms that can cause water borne diseases. A experiment was carried out in broiler carcass combined with chilling systems used in poultry resulted that sodium dichloroisocyanurate was not only

effective against *Salmonella* and *Campylobacter* species but was also efficient in reducing Fecal *Coliform* count in the water samples (Whyte, 2002)[18].

Activity of Ef-Chlor against Protozoan Species

Entameoba histolytica is the highest prevailing protozoa in water causing amebiasis and amebic liver abscess. It is capable of causing multiple illnesses like dysentery, abdominal pain, bloody diarrhoea, severe colitis, etc. In severe cases, it may lead to anaemia due to excessive loss of blood. *Giardia lamblia* is the causative agent of Giardiasis that is a major diarrheal disease found throughout the world, largely spreading through contamination of raw water supplies. Cryptosporidiosis caused by infection from protozoan species of genus *Cryptosporidium* leads to a self-limited diarrheal illness in healthy individuals. Cryptosporidiosis causes prolonged and persistent diarrhoea chiefly in people with weak immune systems. Species of *Cyclospora* causes Cyclosporiasis and *Microsporidia* species cause Microsporidiasis. These both are responsible for intestinal infection and illness causing diarrhoea in immunocomprimised individuals. A study conducted to analyse the efficacy of NaDCC against these protozoan species revealed that all of these parasites were susceptible to NaDCC. It was stated that *E.histolytica* and *G.lamblia* were most susceptible by the action of NaDCC on them (El Zawawy, 2010)[19].

Activity of Ef-Chlor against Virus Species

Rotavirus is a leading cause of diarrhea and dehydration worldwide extensively affecting the infants and the children. Severe and untreated attack from *Rotavirus* may lead to death because of dehydration. *Adenovirus* are capable of causing asymptomatic respiratory tract infection creating a damage in the tissues and cells of respiratory tract. *Calicivirus* species causes respiratory infection in cats and acute gastroenteritis in human beings. The lehal virus species like Hepatitis A causes inflammation of liver cells and Poliovirus (type 1) causes Polio (poliomyelitis), which can also spread through contamination of water. Susceptibility to hypochlorus acid formed on dissociation of NaDCC is seen in all the above mentioned virus species (D'Auria, 1989)[12] (Block, 2001)[20]. Gastrointestinal infections (GI) is the most common spreaded infection in community and hospitals especially affecting the children below 5 years of age. GI mostly spread through *Rotavirus* and *Novovirus* species and causes diarrhea, cramps, nausea, vomiting and fever. Chlorine compounds can be used as surface decontaminants combined with appropriate cleaning procedures to reduce the risk of presence and spread of viral GI (Protano, 2008)[21]. Duck Hepatitis B Virus (DHBV) is the causative agent of Hepatitis B in ducks. NaDCC when used in a concentration dependent manner inactivates DHBV (Sofer, 2003)[22]. NaDCC when used in appropriate conentration kills Hepatitis viruses in about five minutes. It also destroys the surface antigen of type B Hepatitis virus and is said to shown better killing effects in acidic conditions (Sodium dichloroisocyanurate)[23]. Human Immunodeficiency Virus (HIV) is a Lentivirus (a subgroup of Retrovirus) that causes Acquired Immunodeficiency Syndrome (AIDS) which is a mortal disease. HIV is very sensitive to action from hypochlorites and thus specific concentrations of NaDCC can be used for disinfection of soiled surfaces, dirty surfaces and also for the decontamination of blood and body fluid spillages (Bloomfield, 1990)[24]. NaDCC granules (in adequate concentrations) when dissolved in water provide a much longer and stable supply of hypochlorous acid producing higher level of available chlorine that could effectively be used on spillages for inactivation of HIV viruses (Van Bueren, 1995)[25].

Activity of Ef-Chlor against Fungal Species

Candidiasis is a fungal infection caused by yeasts from the genus *Candida*. Sodium dichloroisocyanurate was tested against 66 strains of fungi. It was able to kill *Candida* rapidly in non cultural conditions but the growth phase of yeast influenced its activity. NaDCC required a longer contact time than yeast to work against the mycelial form of *Aspergillus* and *Penicillium* (D'Auria, 1989)[12]. *Aspergillus* causes Aspergillosis resulting in acute and chronic lung infections whereas *Penicllium* produces mycotoxins which are a toxic contaminant. NaDCC represented a synergistic antifungal activity when it was combined with gamma irradiation in specific doses against *Penicillium expansum* on pear fruits (Jeong, 2015)[26].

Microbial Testing of Ef-Chlor (3.5 mg) tablets.

For testing the effectiveness of Ef-Chlor, it's activity was visualised against 5 major species of bacteria responsible for causing water-borne diseases. Ef-Chlor tablets 3.5 mg that are meant for drinking water purification were used which demonstrate effective activity with 4 PPM of available chlorine when used for purifying 500 ml of water. Table 1 mentions the bacterial species on which the action of Ef-Chlor tablets was analyzed. These bacterial species were cultured using 2 types of water – Normal water and Ef-Chlor treated water and there 3rd dilution (10^{-3}) was streaked on specific growth media. The plates were incubated at 37°C in incubators after streaking and then presence of bacterial colonies was checked after 12 hours and 24 hours of incubation. The reporting was done on the mentioned time periods for the media plates with normal bacterial culture and Ef-Chlor treated bacterial culture. Table 2 gives a detailed information on the Microbial testing done mentioning the media used and CFU count observed in the plates. Figure 1 to Figure 10 display the growth observed in normal bacterial culture and the Ef-Chlor treated bacterial culture of the 5 different bacterial species selected for analysis.

Table 1:- The bacterial species on which action of Ef-Chlor was tested and the possible diseases that can be caused by them.

S.No.	Bacterial species analyzed	Disease they can cause
1	*Escherichia coli* (ATCC2065)	Urinary Tract Infections (UTI), Diarrhea and bloody diarrhea
2	*Shigella flexneri* (ATCC12022)	Shigellosis (Stomach cramps, fever, diarrhea), Bacillary dysentery
3	*Vibrio chlolerae* (ATCC39315)	Cholera (watery diarrhea, vomiting and dehydration)
4	*Salmonella typhi* (ATCC6539)	Typhoid fever (headache, nausea, abdominal pain andconstipation), sometimes associated with diarrhea and vomiting.
5	*Staphylococcus aureus* (ATCC6538)	Skin infections, repiratory tract infections, food poisoning and Bacteremia

Table 2–Microbial Testing Report of the selected 5 bacterial species on which Ef-Chlor's action was analyzed

Parameters Observed	**Media plates with Normal Bacterial Culture**	**Media Plates with Ef-Chlor treated Bacterial Culture**
1.) Species analysed – *Escherichia coli* (ATCC 2065) Media used – MacConkey agar media		
Volume of media used	20 ml.	20 ml.
Initial growth observed after 12 hours of incubation	Growth observed	Growth not observed
CFU count after 12 hours of incubation	10×10^3	Nil
CFU count after 24 hours of incubation	28×10^3	Nil
2.) Species analysed – *Shigella flexneri* (ATCC12022) Media used – XLD agar media		
Volume of media used	20 ml.	20 ml.
Initial growth observed after 12 hours of incubation	Growth observed	Growth not observed
CFU count after 12 hours of incubation	12×10^3	Nil
CFU count after 24 hours of incubation	30×10^3	Nil
3.) Species analysed – *Vibrio cholera* (ATCC39315) Media used – TCBS agar media		
Volume of media used	20 ml.	20 ml.
Initial growth observed after 12 hours of incubation	Growth observed	Growth not observed
CFU count after 12 hours of incubation	12×10^3	Nil
CFU count after 24 hours of incubation	30×10^3	Nil
4.) Species analysed – *Salmonella typhi* (ATCC6539) Media used – XLD agar media		

Volume of media used	20 ml.	20 ml.
Initial growth observed after 12 hours of incubation	Growth observed	Growth not observed
CFU count after 12 hours of incubation	7×10^3	Nil
CFU count after 24 hours of incubation	16×10^3	Nil
5.) Species analysed – *Staphylococcus aureus* (ATCC6538) Media used – MSA media		
Volume of media used	20 ml.	20 ml.
Initial growth observed after 12 hours of incubation	Growth observed	Growth not observed
CFU count after 12 hours of incubation	19×10^3	Nil
CFU count after 24 hours of incubation	44×10^3	Nil

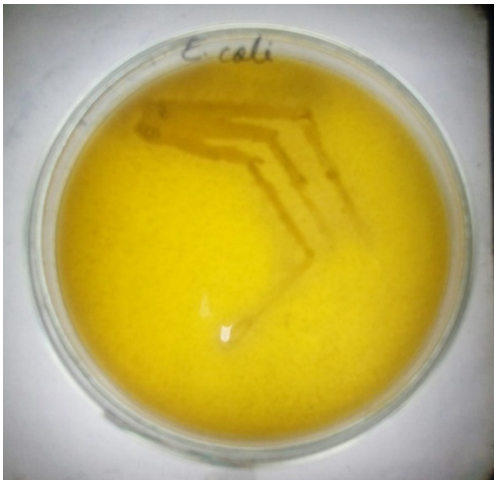

Figure 1: *E.coli* media plate with normal after 24 hours of incubation

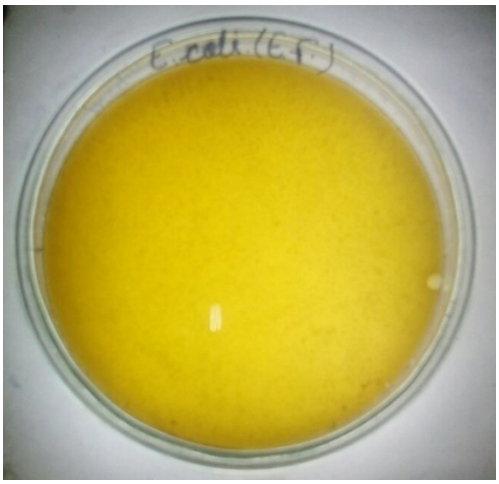

Figure 2: *E.coli* media plate with Ef-Chlor treated bacterial culture bacterial culture after 24 hours of incubation

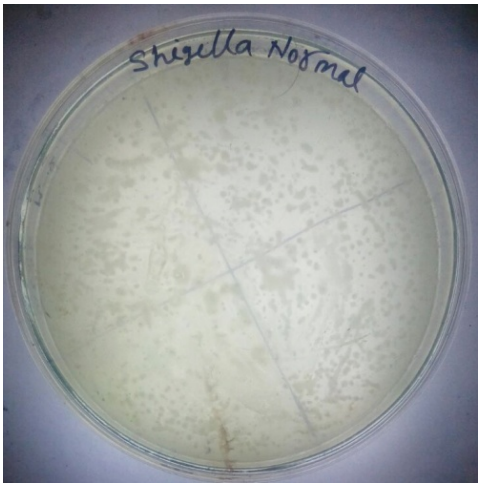

Figure 3: *Shigella* media plate with normal culture after 24 hours of incubation

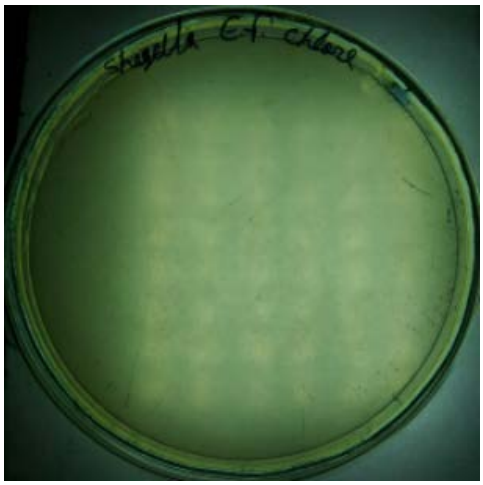

Figure 4: *Shigella* media plate with Ef-Chlor treated bacterial bacterial culture after 24 hours of incubation

Figure 5: *Vibrio* media plate with normal after 24 hours of incubation

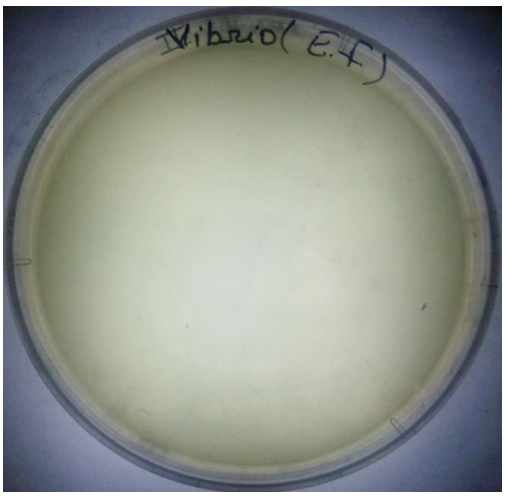

Figure 6: *Vibrio* media plate with Ef-Chlor treated bacterial culture bacterial culture after 24 hours of Incubation

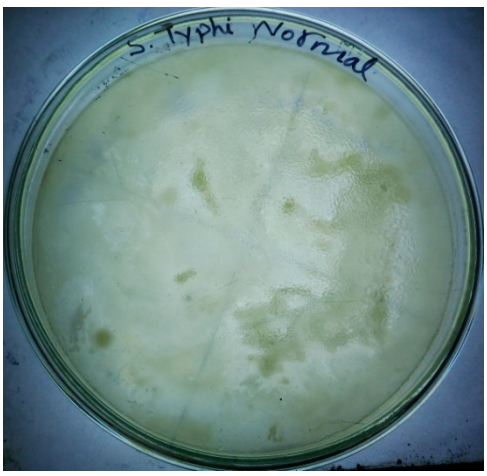

Figure 7: *S.typhi* media plate with normal after 24 hours of incubation

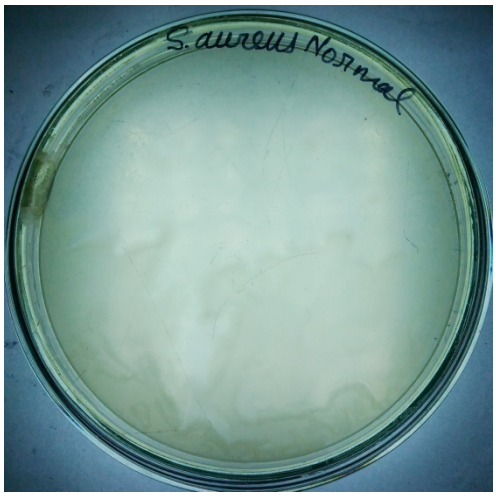

Figure 8: *S.typhi* media plate with Ef-Chlor treated bacterial culture bacterial culture after 24 hours of incubation

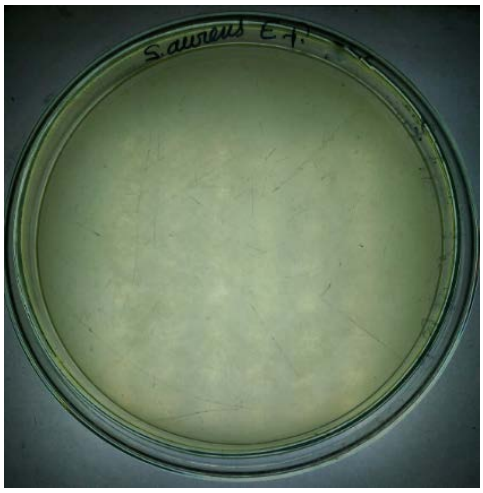

Figure 9: *S.aureus* media plate with normal culture after 24 hours of incubation

Figure 10: *S. aureus* media plate with Ef-Chlor treated bacterial bacterial culture after 24 hours of incubation

Use of Ef-Chlor for drinking water purification

One of the vital and most important application of Ef-Chlor is its ability to purify water and make it fit for consumption. It is highly important to maintain good water quality to ensure there is no spread of conatmination and vulnerable diseases. Ef-Chlor can be a good choice for Household Water Treatment and Safe Storage (HWTS) as it removes contamination from the water making it free from any kind of pathogenic species. NaDCC releases hypochloric acid which reacts through oxidization killing microorganisms and thus purifying the water from any kind of microbial load. Also the excess chlorine that remains in water after its antimicrobial action is called free residual chlorine (FRC) which is the most effective form of chlorine (especially for viruses) and prevents recontaminatoin of water that has already been treated. Ef-Chlor tablets which contain NaDCC do not impart any foul odour, unpleasant taste or off-color to the water being treated and ensure that the water is safe to drink after 30 minutes once the tablet has been dissolved.

NaDCC tablets are among the most preffered techniques for water purification. These tablets have newly developed applications in the HWTS sector. NaDCC effervescent tablets which have been used for emergency water purification since 30 years, have now evolved as an alternative to other products for HWTS purposes and for water purification and its disinfection. Many trials conducted have shown NaDCC as an effective product for treating drinking water. The distribution of specific size NaDCC tablets for drinking water treatment and other household purposes has taken a hike in recent times. Different researches have been done to prove efficacy of NaDCC in Kenya, Tanzania, Ghana, Bangladesh, etc. NaDCC tablets have been successful in disinfecting water by making it free from fecal coliforms which can cause water-borne diseases (Clasen, 2009)[27]. Many other trails have been done to test the antibacterial properties of NaDCC tablets in Orissa, Bangladesh to purify drinking water and slow down the spread of water-borne diseases like diarrhea. Among the many companies manufacturing NaDCC tablets, Hind Pharma, India is World's largest manufacturer of NaDCC tablets supplying its product called "Ef-Chlor" to over 40 different countries.

Use of Ef-Chlor for disinfection purposes in Hospitals

Ef-Chlor can be used as a hospital disinfectant as it contains NaDCC which has high microbial killing abilities. Ef-Chlor can be dissolved in water used for cleaning of floors, mopping, cleaning instruments or apparatus and also in the water that is used for washing hands and bathing purposes. Transmission of diseases can easily occur in hospital surroundings and can lead to spread of fatal and viral diseases. Ef-Chlor can be used to reduce the risk of spread of diseases in hospital environment by showing its action on different pathogens prevalent at that time. The spread of viral diseases can occur from blood spillages if not disinfected properly. Thus NaDCC could be used on blood spillages to stop the spread of diseases via them. A survey indiacted NaDCC was able to perform a critical disinfection of Hepatits B and other viruses propably to be present in blood spillages and thus it is more reliable (Ching, 1989)[28]. Unbuffered NaDCC offered highly effective disinfection for hospital environment showing strong action on vegetative bacterias too (Bloomfield, 1985)[29]. There is also a possibility of using NaDCC as a root canal irrigation solution which could be applied in root canal within 1 week after dilution as it has shown antimicrobial effectiveness against *E.faecalis* (Hye-Jeong Kim, 2007)[30].

Use of Ef-Chlor during Emergencies and Disasters

During the time of an emergency or a disaster, there is an arising need for a water treatment process. Ef-Chlor acting as a water purifier as well as a disinfectant can be used in such situations. NaDCC has a history of being widely used in emergencies as it offers better advantages over other products on the grounds of stability, safety, low capital investment and convenience in packaging and transport. NaDCC might be preferred chlorination technique because of its easy and convenient handling properties that allows its rapid deployment in the regions of acute emergencies (Loo, 2012)[31].

Advantages of Ef-Chlor tablets (NaDCC tablets) compared to other compounds

Various advantages of Ef-Chlor in comparison with other compounds commonly used for disinfection purposes are given in Table 3.

Table 3 – Advantages of Ef-Chlor over all other commonly used Disinfectants.

Parameters	**Sodium Dichloroiso-cyanurate [Ef-Chlor tablets]**	**Calcium hypochlorite (Bleach) [$Ca(ClO)_2$]**	**Chlorine Gas [Cl_2]**	**Sodium Hypochlorite [NaOCl]**	**Halazone [$C_7H_5Cl_2NO_4S$]**
Category	Chloramines	Chlorinated Compound	Chlorinated Compound	Chlorinated Compound	Chlorinated Compound
Available Chlorine	60%	>65%	100% Active 12.5% (HOCl)	20%	50%
Stability in Water	48 hours	2-4 hours	2 hours, Low Hydrolysis constant	2 hours, Low Hydrolysis constant	12 hours
Hazards	Very Safe	Hazardous	Very Hazardous	Heavy Dusting Liquid	Safe
Taste of Water	No Significant change	No Significant change	Chlorine Gas	Alkaline	No Significant change
Odour	No Significant change	Strong Chlorine odour	Chlorine Gas	Chlorine odour	No Significant change
Shelf-life	3 years	3 months – 6 months	1 year	20-30 days	2 years
Environment	Eco-Friendly	Hazardous	Toxic	Eco-Friendly	Eco-Friendly
Formulation type (Effervescent Tablets)	Effervescent Tablets	Granules and Tablets	Cannot form Effervescent Tablets	Cannot form Effervescent Tablets	Cannot form Effervescent Tablets
Handling	Easy	Easy but store in dry place	Heavy Weight Cylinders	Problem in High Volume Transportation	Easy

Advantages of Ef-Chlor over boiling water as a purification technique

Boiling is one of the oldest and most used method for treating water to make it suitable for consumption. Though it has high effectiveness, it has many disadvantages too. It turns out to be costly due to large fuel consumption. Use of firewood leads to deforestation when boiling water procedure is being performed for household use. It is a time consuming method and does not remove turbidity, chemicals, unpleasant taste and smell from the water. Also water needs to be cooled down after boiling so that it can be used for drinking purposes (Shrestha)[32]. There have been multiple issues arising related to drinking water quality and tap water quality as well as safety concerns of drinking bottled water. The people are not sure that how safe is the available water for drinking. An article

published on September 7, 2014 by Gulf News informed that more than 10,000 illegal packaged water-bottling units are operating in Delhi using the labels of 64 licensed manufacturers risking the health of all the people consuming bottled water. It was also stated in the article that while licensed plant sold 10,000 bottles per day, unlicensed bottling plants were selling about 30,000-40,000 bottles everyday (Gulf News India, 2014)[33]. Instances like this scare the people drinking bottled water and raise a suspicion concerning the safety of drinking water. Ef-Chlor is a very safe product that can be used for purification of drinking water. It should be dissolved in bottled water 30 minutes prior to its consumption, which would ensure that the water being consumed is free from any kind of disease causing microbe. This purification technique can be an additional safety check on drinking water. While travelling it is certainly not possible to boil drinking water before use. Therefore, for travelling purposes Ef-Chlor tablets can be utilised to provide on spot, assured and relatively fast purification and disinfection of water to before consumption.

Hind Pharma – Manufacturer of Ef-Chlor

Hind Pharma is World's no. 1 manufacturer of water purification NaDCC tablets sold by the name of Ef-Chlor. Established in 1977, now with an experience of 40 years Hind Pharma's manufactured water purification tablets – "Ef-Chlor" is no. 1 brand of India available in 18 different sizes. Hind Pharma is currently exporting its water purification and disinfectant products to more than 40 countries and is making a big impact in the global markets. Ef-Chlor tablets are manufactured in different sizes providing varying amount of available chlorine to treat small to large ranging volumes of water. These different ranges helps in accuracy of dosage and ensures easy, simple and smooth working for users. Its packaging is mostly done in strips that makes it easy for transportation and storage. Detailed information on different ranges of Ef-Chlor are mentioned in Table 4 taken from official website of Hind Pharma. The instructions of using Ef-Chlor for emergency conditions with clouded water and for clear and household drinking water is printed on the back of every mono carton in which tablet strips are packed. Major cautions and storage conditions are also mentioned beside instructions for use for user's safety. Both Manufacture (Mfg.) and Expiry (Exp.) dates are printed on the mono cartons as well as on individual strips present in it to ensure that the product is used under its mentioned duration. More information on applications and advantages of Ef-Chlor are mentioned in the Ef-Chlor selection under the Products tab of Hind Pharma's official website. Hind Pharma has received several certifications for its marvellous service provided by putting efforts towards improving water quality and making it cleaner and healthier. Hind Pharma has been awarded many certificates from Food and Drug Administration (FDA) that includes Drug Licence certificate, Good Manufacturing Practices (GMP) certificate, Good Laboratory Practices (GLP) certificate and Free Sale Certificate (FSC). The company has also been ISO 9001:2008 certified by Intertek Certification Limited, United Kingdom. All the above-mentioned certificates can be viewed under the company info tab present in the Hind Pharma's website. All these certification act as a token of guarantee assuring that Ef-Chlor tablets are produced and packed in sterile conditions and are totally safe for purification, sterilization and disinfection purposes.

Table 4 – Range of Ef-Chlor

Range of Ef-Chlor			
Name of Product	Available Chlorine	Volume of Water to be treated	Packing
Ef-Chlor 3.5 mg	2 mg	1 litre	10 x 10 / 10 x 5 Strips
Ef-Chlor 8.5 mg	5 mg	1-2 litres	10 x 10 Strips
Ef-Chlor 17 mg	10 mg	4-5 litres	10 x 10 Strips
Ef-Chlor 33 mg	20 mg	8 litres	10 x 10 Strips
Ef-Chlor 67 mg	40 mg	10-12 litres	10 x 10 Strips
Ef-Chlor 75 mg	45 mg	20 litres	10 x 10 Strips
Ef-Chlor 167 mg	100 mg	25-30 litres	10 x 10 Strips
Ef-Chlor 400 mg	240 mg	50-80 litres	8 x 8 Strips
Ef-Chlor 500 mg	300 mg	100-120 litres	8 x 8 Strips
Ef-Chlor 1.67 gm	1000 mg	500 litres	50 Tablets Jar
Ef-Chlor 2.75 gm	1500 mg	750 litres	200 Tablets Jar
Ef-Chlor 3.5 gm	2100 mg	1000 litres	142 Tablets Jar
Ef-Chlor 4 gm	2400 mg	1000-1200 litres	20 Tablets Jar

Ef-Chlor 8.68 gm	5,000 mg	2500 litres	50 Tablets Jar
Ef-Chlor 15 gm	9,000 mg	4500 litres	50 Tablets Jar
Ef-Chlor 200 gm	1,20,000 mg	50000 litres	5 Tablets Jar
Ef-Chlor granules	60 %	50000 litres	1 kg Jar

II. Conclusion

Using Ef-Chlor (NaDCC) tablets is an effective and fast way to purify water. The results obtained from microbial testing of these tablets prove that they are remarkably effective against harmful water borne disease-causing pathogens. The researches performed in the past and their results obtained do match with our currently performed experiment's results supporting that Ef-Chlor (NaDCC) is a powerful antimicrobial disinfectant. The data compiled from different researches and studies suggest that NaDCC is safer, non-toxic, stable and efficient in working compared to any other compound used for the purpose of drinking water purification, water disinfection and sterilization. Ef-Chlor tablets can be used as a multipurpose disinfectant and are more stable formulation having a higher shelf life compared to other chlorinated products. There are various fields where Ef-Chlor can be effectively applicable in improving the water quality and making it fit for consumption and other works. The wide range of Ef-Chlor manufactured that contains optimum amount of chlorine, which can be used for treating specific volume of water helps in eliminating the dosage problems. Thus, use of Ef-Chlor (NaDCC) tablets for water purification and general disinfection could prosper in making a healthy society by eliminating the risk of diseases spreading via contaminated water.

Acknowledgment

This research was fully funded and supported by Hind Pharma, Bhopal, M.P., India. We thank our colleagues of the company who provided with knowledge, insight and expertise that greatly assisted our research.

We would also like to thank Center for Microbiology & Biotechnology Research & Training Institute (CMBT) for assistance with Microbial Testing of Ef-Chlor tablets that greatly improved the quality of paper.

References

[1] Chabba Ajay Pal Singh, *Water-Borne Diseases in India*. Retrieved from RESET- Smart approaches to Sustainability, (31-05-2013) : https://en.reset.org/blog/water-borne-diseases-india

[2] Kosek Margaret, Guerrant L. Richard, Bern Caryn. (2003). The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. *Bulletin of the World Health Organization*. 81(3), 197-204.

[3] Berman J. *WHO: Waterborne Disease is World's Leading Killer*. Retrieved from VOA News, (2009, October 29).: https://www.voanews.com/a/a-13-2005-03-17-voa34-67381152/274768.html

[4] Yang Kun, LeJeune Jeffrey, Alsdorf Doug, Lu Bo, Shum C. K., Liang Song. (2012). Global Distribution of Outbreaks of Water-Associated Infectious Diseases. *PLoS Neglected Tropical Diseases*. 6(2):e1483. doi:10.1371/journal.pntd.0001483.

[5] Mudur G. (2003). India's burden of waterborne diseases is underestimated. *BMJ : British Medical Journal*. 326 (7402):1284. doi: 10.1136/bmj.326.7402.1284

[6] Hind Pharma. Water Purification Tablets: http://www.hindpharma.com/water_purification_tablets.html

[7] Kuznesof P. M. (2004). Sodium Dichloroisocyanurate (NaDCC – anhydrous and dihydrate). *Chemical and Technical Assessment 61st JECFA FAO* .

[8] Bloomfield Sally F., Miles Gwynedd A. (1979). The Antibacterial Properties of Sodium Dichloroisocyanurate and Sodium Hypochlorite Formulations. *Journal of Applied Bacteriology*, 46, 65-73.

[9] Morgenthau Ari , Nicolae Alexandru M., Andrew E. Laursen , Daniel A. Foucher , Gideon M. Wolfaardt & Martina Hausner (2012). Assessment of the working range and effect of sodium dichloroisocyanurate on Pseudomonas aeruginosa biofilms and planktonic cells, Biofouling: *The Journal of Bioadhesion and Biofilm Research*. 28:1, 111-120.

[10] World Health Organization . (2004). *Guidelines for Drinking-water Quality, Third Edition, Volume 1* . Geneva: WHO.

[11] Hammond Bruce G., Steve J. Barbee, Takeshi Inoue , Norihisa Ishida, George J. Levinskas, Michel W.Stevens, Allen G. Wheeler and Tito Cascieri (1986). A Review of Toxicology Studies on Cyanurate and its Chlorinated Derivatives. *Environmental Health Perspectives* , Vol. 69, pp. 287-292.

[12] D'Auria, F.D., Simonetti, G., Strippoli, V., 1989. Antimicrobial activity exerted by sodium dichloroisocyanurate. Ann. Ig. 1 (6), 1445–58.

[13] Clasen Thomas, Paul Edmondson. (2006). Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. *International Journal of Hygiene and Environmental Health* , 209, 173–181.

[14] Parkinson M., M. Prendergast & A.J. Sayegh. (1996). Sterilisation of explants and cultures with sodium dichloroisocyanurate. *Plant Growth Regulation* , 20, 61–66. doi: https://doi.org/10.1007/BF00024060

[15]

[16] Heling I., Rotstein I., Dinur T., Szwec-Levine Y. and Steinberg D. (2001). Bactericidal and Cytotoxic Effects of Sodium Hypochlorite and Sodium Dichloroisocyanurate Solutions In Vitro. *Journal of Endodontics* , VOL. 27, NO. 4, APRIL 2001.

[17] Coates D. (1985). A comparison of sodium hypochlorite and sodium dichloroisocyanurate products . *Journal of Hospital Infection* (1985), 6, 31-40.

[18] Fawley Warren N., Sarah Underwood, Jane Freeman, Simon D. Baines, Katie Saxton, Keith Stephenson, Robert C. Owens, Mark H. Wilcox. (2007). Efficacy of Hospital Cleaning Agents and Germicides Against Epidemic *Clostridium difficile* Strains. *Infection control and hospital epidemiology* , vol. 28, no. 8.

[19] Whyte Paul, John Daniel Collins, Kevina McGill and Claire Monahan (2002). Assessment of sodium dichloroisocyanurate in the control of microbiological cross contamination in broiler carcass immersion chilling systems . *Journal of food safety* , volume 22, issue 1, pages 55–65.

[20] El Zawawy LA, El-Said D, Ali SM, Fathy FM. (2010). Disinfection efficacy of sodium dichloroisocyanurate (NADCC) against common food-borne intestinal protozoa. *J Egypt Soc Parasitol* , 40(1):165-85.

[21] Block, Seymour Stanton, Dychdala. (2001). Chlorine and chlorine compounds. In:Block, S.S. (Ed.), Disinfection, Sterilization and Preservation,5th ed. Lippincott Williams & Wilkins, Philadelphia,PA, USA, pp. 135–157.

[22] Protano C., M. Vitali, A. Raitano, A. Sancin, G. Agolini. (2008). Is there still space for the implementation of antisepsis and disinfection to prevent rotavirus and norovirus gastroenteritis outbreaks? *J prev med hyg* 2008; 49: 55-60

[23] Sofer G. (2003). Part 5, Disinfection. BioPharm International, http://alfresco.ubm-us.net/alfresco_images/pharma/2014/08/22/dd7d914d-32ec-4d61-85cb-f8a1524c9d95/article-62865.pdf

[24] *Sodium dichloroisocyanurate*. (n.d.). Retrieved from Chemical Book: http://www.chemicalbook.com/ChemicalProductProperty_EN_CB9181452.htm

[25] Bloomfield S. F., Smith-Burchnell C. A. and Dalgleish A.G. (1990). Evaluation of Hypochlorite-releasing disinfectants against the human immunodeficiency virus (HIV). *Journal of Hospital Infection* ,15 273-278.

[26] Van Bueren J, Simpson R.A., Salman H., Farrelly H.D., Cookson B.D. (1995). Inactivation of HIV-1 by chemical disinfectants: sodium hypochlorite. *Epideniiol. Inifect.* , 115, 567-579.

[27] Jeong, R.-D., Chu, E.-H., Shin, E.-J., Lee, E.-S., Kwak, Y.-S. and Park, H.-J. (2015), Antifungal effect of gamma irradiation and sodium dichloroisocyanurate against Penicillium expansum on pears. Lett Appl Microbiol, 61: 437–445. doi:10.1111/lam.12466

[28] Clasen Thomas F. (2009). Scaling Up Household Water Treatment Among Low-Income Populations. *Public Health and Environment Water, Sanitation, Hygiene and Health - WHO* , pg no 25-28.

[29] Ching T.Y., Seto W.H. (1989). Hospital use of chlorine disinfectants in a hepatitis B endemic area - a prevalence survey in twenty hospitals. *Journal of Hospital Infection* , 14, 39-47.

[30] Bloomfield S. F. and Uso E. E. (1985). The antibacterial properties of sodium hypochlorite and sodium dichloroisocyanurate as hospital disinfectants. *Journal of Hospital Infection* , 6, 20-30.

[31] Hye-Jeong Kim, Se-Hee Park, Kyung-Mo Cho, Jin-Woo Kim. (2007). Evaluation of time-dependent antimicrobial effect of sodium dichloroisocyanurate (NaDCC) on Enterococcus faecalis in the root canal. *J Korean Acad Conserv Dent.* , 32(2):121-129.

[32] Loo SL, Fane AG, Krantz WB, Lim TT. (2012). Emergency water supply: A review of potential technologies and selection criteria. *Water Res*. 2012 Jun 15;46(10):3125-51. doi: 10.1016/j.watres.2012.03.030. Epub 2012 Apr 3

[33] Shrestha Lerica G., Shrestha Raju, Dorothee Spuhler. *Boiling*. Retrieved from sustainable sanitation and water management: http://www.sswm.info/category/implementation-tools/water-purification/hardware/point-use-water-treatment/boiling

[34] Gulf News India. (2014, September 7). India: More than 10,000 illegal bottled water units in Delhi put lives at risk. *Gulf News India*; http://gulfnews.com/news/asia/india/india-more-than-10-000-illegal-bottled-water-units-in-delhi-put-lives-at-risk-1.1382051

AUTHORS

First Author – Abhishek Bajpai, M.Sc. Biotechnology student, VIT University Vellore, T.N., India, abhishek.bajpai2013@vit.ac.in
Second Author - R.S. Goswami, CEO, Hind Pharma, Bhopal, M.P., India.
Third Author - Aayush Goswami, COO, Hind Pharma, Bhopal, M.P., India.
Fourth Author - Shrikant Garde, Manager Marketing and Sales, Hind Pharma, Bhopal, M.P., India.
Fifth author - Preeti Phadnis, QC Manager, Hind Pharma, Bhopal, M.P., India.

Correspondence Author – Abhishek Bajpai, abhishek.bajpai2013@vit.ac.in , a.bajpai.0603@gmail.com , +66-641327977