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DISINFECTION OF DRINKING WATER-CONSTRAINTS AND OPTIMIZATION PERSPECTIVES IN ALGERIA

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ABSTRACT

Drinking water is disinfected to inactivate waterborne pathogens. The most common form of disinfection is chlorination, although ozone and UV light are also used in some plants of the world. Disinfection equipment depends on the type of disinfectant used. In developing countries, the water disinfection problem is large and complex. There are a number of appropriate methods but chlorine continues to be one of the most popular options. In Algeria, it is the only method of disinfection used. Chlorine is a very effective disinfectant, it is relatively easy to handle, the capital costs of chlorine installation are low, simple to dose, measure and control and it has a relatively good residual effect. Chlorination efficiency depends on chlorine residual, contact time, type of chemical used, location in the treatment process, and on characteristics of the water being treated. The chlorine demand involves the reaction of chlorine with compounds in water, reducing the amount of chlorine available to kill microorganisms. Chlorination of humic substances in drinking water is known to produce mutagenic and carcinogenic compounds such as trihalomethanes. Because of their chemical quality, Algerian waters could lead to complex and competitive reactions during chlorination step. The widespread detection of chloroform and other organohalogenated compounds contamination in the water reservoirs appear to be largely a consequence of the use of chlorination for the disinfection of drinking water. Those documented as probable human carcinogens and mutagens have been detected in large amounts and have been considered as the major component of DBPs. Taking into account above drawn conclusions, greater efforts are needed to evaluate and set priorities for drinking water disinfection in Algeria. The challenge is to maintain the level of microbial protection while minimizing the exposure of the consumers to DBPs. If disinfection by chlorination is maintained, the best way to reduce THM generation is to reduce the concentration of precursors through various water treatment techniques prior to chlorination.

Keywords: Drinking water, Disinfection, Chlorination, Organohalogenated compounds, Humic substances, Break point.

RESUME

Les eaux de consommation sont désinfectées dans le but d'inactiver les microorganismes pathogènes. Bien que les procédés de désinfection par l'ozone et l'ultraviolet soient parfois utilisés dans le monde, la chloration reste la technique la plus répandue dans le domaine des eaux potables. Dans les pays en développement, la problématique de la désinfection est encore ardue et n'est que partiellement résolue. En Algérie, la chloration est à ce jour le seul procédé de désinfection appliqué. Le chlore est encore considéré comme le désinfectant le plus sûr, dont la mise en œuvre est simple et permettant un résiduel de chlore au cours de la distribution. Son efficacité dépend néanmoins de plusieurs facteurs dont la qualité chimique de l'eau. La demande en chlore par des réactions complexes et compétitives peut diminuer le pouvoir biocide du chlore et mener à la formation de sous-produits suspectés de toxicité. Les eaux algériennes peuvent ainsi mener à une formation notable de chloroforme et d'autres composés organohalogénés potentiellement mutagènes et cancérigènes. La surveillance des ressources hydriques, le contrôle de leur qualité et leur traitement est alors indispensable et doit être améliorée pour assurer une bonne qualité de l'eau, éviter les épidémies liées aux maladies à transmission hydrique ainsi que les effets chroniques liés aux sous-produits de la chloration. La formation de ces composés toxiques peut être réduite en optimisant les traitements de l'eau avant la phase finale de chloration.

Mots clés : Eaux de consommation, Désinfection, Chloration, Composés organohalogénés, Substances humiques, Break point.

INTRODUCTION

The need for optimization of water systems from source to tap, and the inherent complexity associated with such an endeavour, has long been recognized. While there are several safe drinking water act regulations that target distribution system-related parameters such as pathogens, chemical toxics, disinfectants, and disinfection by-products, the various regulatory compliance strategies can result sometimes in competing priorities. Potable water is defined as having acceptable quality in terms of its physical, chemical, and bacteriological parameters so that it can be safely used for drinking (JORADP, 2011; WHO, 2004a). The increasing concern for pathogenic related water diseases promotes the implementation of more and more stringent standards on microbiological pollution of drinking waters. In developing countries, the most common and deadly pollutants in the drinking water are of biological origin. WHO (2004b) states that the "infectious diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water". It is reported that nearly half of the population in the developing countries suffers from health problems associated with lack of potable drinking water as well as the presence of microbiologically contaminated water. Although conventional treatment processes such as coagulation-flocculation, sedimentation and filtration are known to remove up a significant percentage of microorganisms, their performance is not sufficient to meet existing requirements for safe drinking water. Therefore, specific disinfection/oxidation steps must be included in the treatment chains in order to ensure better public health and environmental protection. As such, disinfection by is considered of major importance for public health. In addition to deactivating pathogens, a disinfectant should have several properties such as to be no toxic and fast acting, to leave a residual to protect the distribution system, to not produce toxic byproducts and to be inexpensive (White, 1992; USEPA, 2011).

Many chemicals can be used to disinfect water as free and combined chlorine, ozone, iodine, hydrogen peroxide, potassium permanganate, metals. Physical processes that can be used in drinking water treatment include heat, ultraviolet radiation, membrane filtration and advanced oxidation processes (USEPA, 2005; WCC, 2008). Although all of these technologies are available, only chlorine, ozone, and ultraviolet radiation are used for drinking water disinfection with any frequency and ultraviolet radiation is typically only used for small or individual systems (Safferman, 2010).

The aim of this paper was to describe the purposes of drinking water disinfection as well as advantages and disadvantages of various disinfectants. Finally, Algerian disinfection practice and its perspectives were discussed.

WATER DISINFECTION METHODS. AN OVERVIEW.

Objectives of drinking water disinfection.

Our natural environment contains numerous microorganisms. Most of these present no concerns. However, some bacteria such as coliforms, various viruses and protozoa, which can be present in water supplies, are extremely harmful and can cause disease in humans. These disease-causing organisms are known as pathogens. Most of these pathogens are transmitted by the fecal-oral cycle. Table 1 lists some potential waterborne disease causing organisms that can be transmitted by drinking water.

Table 1: Main waterborne diseases transmitted through drinking water (Maier et al., 2000)

Group	Pathogen	Disease or Condition
Viruses	Enteroviruses (polio, echo, coxsackie) Hepatitis A & E Norwalk virus	Meningitis, paralysis, fever, diarrhea Hepatitis Diarrhea
Bacteria	*Salmonella* *Shigella* *Campylobacter* *Vibrio cholerae* *Escherichia coli* *Legionella*	Typhoid, diarrhea Diarrhea Diarrhea Diarrhea Diarrhea Pneumonia
Protozoa	*Giardia lamblia* *Cryptosporidium*	Diarrhea Diarrhea
Blue-green algae	*Anabaena* *Microcystis*	Diarrhea, possible production of carcinogens
Helminths	*Necuter americanus* *Taenia saginata*	Hookworm Tapeworm

Because pathogens can be present in drinking water supplies, disinfection is very important. The effectiveness of disinfection is judged by analyzing for an indicator organism such as total coliform bacteria or fecal coliform (USEPA, 2011). Disinfectants can act by different mechanisms such as damaging the cell wall of the pathogen, altering the permeability of the cell wall or reacting with the pathogen's enzymes (Cabral, 2010).

The required time depends on the disinfectant used, its concentration, and the quality of the water being disinfected. The contact time and concentration of the disinfectant are often combined and represented as the CT value where the concentration of disinfectant (C) is multiplied by the contact time (T). A CT value is applicable for a given water and deactivation goal, 99% kill of total colifor ms, for example. The two parameters are inversely related (Table 2).

Table 2: Values of CT for an inactivation at 99 % for 5 °C (Hoff, 1986, USEPA, 1999)

Disinfectant	pH	*E. coli* (mg.min/L)	*Giardia lamblia* (mg.min/L)	Poliovirus 1 (mg.min/L)
Free Chlorine	6-7	0.034-0.05	32-46	1.1-2.5
Chloramines	8-9	95-180	1470	768-3740
Chlorine Dioxide	6-7	0.4-0.75	17	0.2-6.7
Ozone	6-7	2	13	0.1-0.2

Characteristics of the water to be treated influence the design of appropriate water treatment systems. Characteristics for disinfection include the water source, turbidity, color, pathogen content, and hardness (Safferman, 2010).
Disinfection is required for surface water and groundwater. When combined with conventional treatment, such as coagulation, flocculation, sedimentation, and filtration, good results have been obtained. There are two kinds of disinfection: primary disinfection achieves the desired level of microorganism kill or inactivation, while secondary disinfection maintains a disinfectant residual in the finished water that prevents the regrowth of microorganisms. Drinking water disinfection eliminates pathogenic microorganisms and maintains the microbiological quality of water until it reaches the consumer's tap, but may lead to the formation of by-products (DBPs). To date, studies have identified more than 600 DBPs. These parameters are generated during the disinfection step by chemical reactions between precursors naturally present in the water and the oxidants used (Dore, 1989; Gruau, 2004; Noorsji et al, 2008; USEPA, 2011).
Also, since some disinfectants produce chemical by-products, the dual objective of disinfection is to provide the required level of organism destruction and remain within the maximum contaminant level for the disinfection by-products set by drinking water standards (WHO, 2005).

Advantages and limitations of disinfection methods

Chlorine, chloramines, or chlorine dioxide are most often used because they are very effective disinfectants, not only at the treatment plant but also in the pipes that distribute water to our homes and businesses. Ozone is a powerful disinfectant, and ultraviolet radiation is an effective disinfectant and treatment for relatively clean source waters, but neither of these is effective in controlling biological contaminants in the distribution pipes (WCC, 2008; Safferman, 2010). At present, chemicals are the most widely used treatment method worldwide.

Chlorine disinfection

Chlorine was introduced as a disinfectant to the urban water supply at the beginning of the 20th century to improve the hygienic quality by eliminating waterborne bacterial pathogens and the consequent transmission of water borne diseases. Chlorine is the most common form of water treatment used worldwide. Chlorine is relatively low cost, widely available, and can be applied in many forms and ways. As such, it is considered of major importance for public health and most drinking water originating from surface water supplies is currently disinfected with chlorine (White, 1992; WHO/WEDC, 2013). Automated dosing plants using chlorine gas, are suitable only for larger towns with trained operators and accessible repair infrastructures. Bleach or sodium hypochlorite is generally used in developing countries because it is easier to transport and handle safely. It may be applied as a liquid solution using a dosing pump (Burch, 1998; WCC, 2008).

Chlorine is used not only as a primary disinfectant in water treatment, but is also added to provide a disinfectant residual to preserve the water in distribution, where the chlorine is in contact with the water for much longer than during treatment. In many situations, this is the more significant factor in terms of organochlorine by-product formation. So, chlorine and its compounds are the most commonly used disinfectants for the treatment of water and its popularity is due to higher oxidizing potential, provides a minimum level of chlorine residual throughout the distribution system and protects against microbial recontamination. It is also commonly used in the oxidation and removal of iron and manganese in water treatment upstream of disinfection.

Ammonia can be removed from water and reacts with the hypochlorous acid and produce a chloramine (Figure 1). The breakpoint is the point at which the chlorine demand has been totally satisfied. The chlorine has reacted with all reducing agents, organics, and ammonia in the water. When more chlorine is added past the breakpoint, the chlorine reacts with water and forms hypochlorous acid in direct proportion to the amount of chlorine added. This process, known as breakpoint chlorination, is the most common form of chlorination, in which enough chlorine is added to the water to bring it past the breakpoint and to create some free chlorine residual.

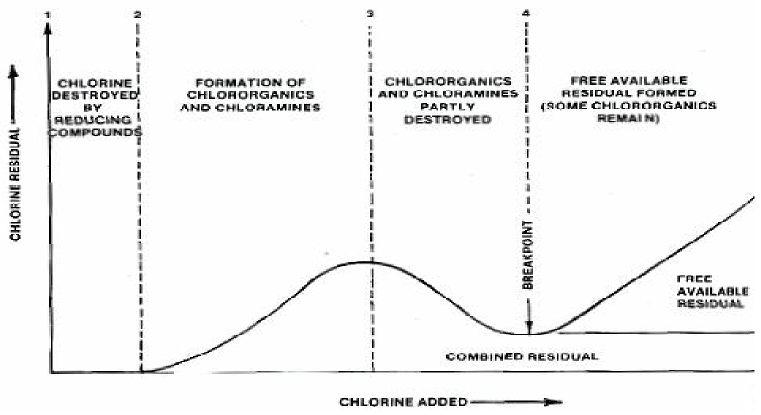

Figure 1: Break point curve (White, 1992; USEPA, 1999)

Use of chlorination reduces the risk of pathogenic infection but may pose chemical threat to human health due to disinfection residues and their byproducts. DBPs will be produced upon chlorination only if the water contains DBP precursors.

Chlorine, which exists as hypochlorous acid (HClO) and hypochlorite ion (ClO^-) in water, reacts with natural organic compounds such as humic and fulvic acids to form a wide range of unwanted halogenated organic compounds including trihalométhanes (THMs), haloacetic acids (HAAs), chlorophenols, chloral hydrate, and haloacetonitriles (HANs) . Drinking water from surface waters generally contains higher concentrations of DBPs than ground water due to the higher concentrations of organic material.

The potential long-term health effects of carcinogenic and mutagenic drinking-water chlorination by-products have caused concern in several countries. There have been epidemiological evidences of close relationship between its exposure and adverse outcomes particularly the cancers of vital organs in human beings (Ref). Most organic compounds in drinking water, including most of the mutagenic ones, are known to be non volatile, whereas trihalomethanes represent the volatile fraction of chlorination by-products. The formation of chlorination by-products depends on the raw water quality and chlorination practices. The total concentration of trihalomethanes and the formation of individual THM species in chlorinated water strongly depend on the composition of the raw water, on operational parameters and on the occurrence of residual chlorine in the distribution system (Table 3).

Treatment upstream of disinfection is also crucial to the performance of any disinfection processes. With chlorination, for example, this would require removal of organic precursors for THMs and HAAs .These precursors are very effectively removed by well operated chemical coagulation, enhanced coagulation and adsorption processes (Table 4).

Table 3 : Trihalomethanes in various chlorinated waters across the world

Surface Water	THM (µg/l)	Reference
River OHIO (USA)	37.4 – 116.8	Bellar and Lichtenberg, 1974
Tap water(USA)	04-164	Krasner et al, 2012
Water supply Nancy (France)	49.2-126.8	Mouly et al, 2008
Youngsan River (Korea)	48.9 – 93.3	Kim et al., 2002
Saint Laurent (Quebec)	30 - 150	Guay et al., 2005
River Arusha (Tanzania)	49.6- 122.9	Lantagne et al, 2010
Water of Tetova (Macedonia)	16.2-45.5	Bujar et al, 2013
Karachi city (Pakistan)	19.8-176.2	Seddique et al, 2012
Treatment plant at Pekin (China)	9.8-69.9	Wei et al, 2010
Keddara dam (Algeria)	80 – 129.6	Achour and Moussaoui, 1993
Foum El Gherza dam (Algeria)	39-77	Achour et al, 2002 ; 2009

Table 4 : Effect of chlorination on quality of flocculated water dam of Souk El Djemaa (SED) and Foum El Gherza (FEG) (Achour, 2001)

<table>
<tr><th rowspan="2">Parameters</th><th colspan="2">Prechlorination</th><th colspan="2">Prechlorination
+
Coagulation-flocculation</th><th colspan="2">Coagulation-flocculation+
Bentonite + post chlorination</th></tr>
<tr><th>SED</th><th>FEG</th><th>SED</th><th>FEG</th><th>SED</th><th>FEG</th></tr>
<tr><td>Chlorine Demand ($mgCl_2/l$)</td><td>9.2</td><td>9.4</td><td>7.1</td><td>6.9</td><td>3.8</td><td>2.9</td></tr>
<tr><td>$CHCl_3$ (µg/l)</td><td>62.0</td><td>38.0</td><td>54.5</td><td>30.8</td><td>18.5</td><td>12.8</td></tr>
</table>

Alternative disinfectants to chlorine (USEPA, 2005; WCC, 2008;USEPA, 2011).

Chemical disinfection methods are the most often used for treating water and wastewater. Oxidizing chemicals such as the halogens (chlorine, bromine, and iodine), ozone, and potassium permanganate can be used as disinfectants. Lime has been previously employed in water and wastewater treatment over many years as a coagulant aid and also as a means of controlling biological growth.

- Chlorine-based alternative disinfectants: Alternative chemicals such as chloramine (chlorine reacted with ammonia) and chlorine dioxide have also been used as disinfectants, although to a much lesser extent. Monochloramine is less effective as a disinfectant than chlorine, but provides a much more stable residual in distribution, and has the added benefit that it does not produce THMs or HAAs. Chlorine dioxide is used as a primary disinfectant and in distribution worldwide, but there are limitations to its use because of the inorganic by-products chlorite and to a lesser extent chlorate. Chlorine dioxide is likely to be substantially more expensive than chlorine.
- Ozone, a triatomic form of oxygen (O_3), is the strongest oxidant of the common disinfectant agents. A wider spectrum of organisms is destroyed by ozone than by chlorine. The reactions are rapid but only after an initial demand of ozone are satisfied. . For water treatment, ozone is produced by an electrical corona discharge or ultraviolet radiation of dry air or oxygen. Ozone can be injected or diffused into the water supply stream. As chlorine, ozone is used for the large-scale disinfection of drinking water in the world. Ozonation is commonly used in Europe but there are many unanswered questions about health hazards of by-products of ozone. Ozone forms by-products, particularly bromate. It is also an expensive disinfection technology in terms of capital and operating costs and to date it is been used as a pre-disinfection treatment process for the destruction of organic micropollutants, particularly pesticides and taste and odour compounds, and their removal, when used in conjunction with Granular Activated Carbon (GAC) filtration. Ozone is unstable so cannot be produced and transported to the point of use. It must be generated at the point of use. Furthermore, it is negligible for preventive measures short life span of ozone residual in distribution systems. A secondary disinfectant, usually chlorine, is required.
- Ultraviolet (UV) radiation, generated by mercury arc lamps, is a non-chemical disinfectant. When UV radiation penetrates the cell wall of an organism, it damages genetic material, and prevents the cell from reproducing. Although it has a limited track record in drinking water applications, UV has been shown to effectively inactivate many pathogens while forming limited disinfection by-products. UV radiation is unsuitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. These materials can react with or absorb the UV radiation, reducing the disinfection performance. As with ozone, a secondary disinfectant must be used to prevent regrowth of microorganisms.
- Low-pressure membrane filtration: Membrane technologies (Microfiltration, ultrafiltration, reverse osmosis) offer an alternative to the disinfection process. These processes have been demonstrated to be capable for removing protozoa cysts to below detection limits. Removal of virus is more variable and depends of membrane properties and solution chemistry. Membrane technologies require suitable pretreatment in order to maintain membrane efficiency by

preventing fouling and module damage. Such technologies produce a high-quality clarified effluent and do not require the addition of chemical reagent, thus avoiding the formation of harmful by-products. Microfiltration and Ultrafiltration have gained considerable acceptance in the water treatment industry over the last decades. However, lacks of formal guidance that adequately addresses this technology still slows a generalization of its use. Furthermore, membrane technologies are often considered unsuitable owing to high cost of both installations and system operation. The table 5 summaries some advantages and disadvantages of the most used disinfection methods.

Table 5: Main characteristics of some disinfection methods (WCC, 2008; USEPA, 2011)

Disinfection Method	**Disinfection Process Advantages Disadvantages**	**Uses**
Chlorine	-Chemical reaction with pathogens -oxidizes ammonia, iron, manganese, sulfide -a small dose kills bacteria rapidly; residual can be maintained -in some cases, chlorination can cause the formation of trihalomethanes	-Widespread use to disinfect water; -also used in color, taste, and odor removal, improving coagulation, and killing algae.
Iodine	-chemical reaction with pathogens,good disinfectant -high cost; harmful to pregnant women	-emergency treatment of water supplies -disinfecting small, non-permanent water supplies
Bromine	-chemical reaction with pathogens -handling difficulties; -residuals hard to obtain;	-very limited use, -primarily for treating swimming pool water
Bases (sodium hydroxide and lime)	-chemical reaction with pathogens -bitter taste in the water; handling difficulties	-sterilize water pipes
Ozone	-chemical reaction with pathogens, good disinfectant; better virucide than chlorine; -oxidizes iron, manganese, sulfide, and organics; -high cost; lack of residual; storage difficulties; maintenance requirements; safety problems; unpredictable disinfection;	-disinfection; treating iron and manganese, -removes color, odor, and taste -helping flocculation, -removing algae, oxidizing organics, removing color, treating tastes and odors
Ultraviolet	-UV light causes biological changes which kill the pathogens -lack of dangerous by-products -lack of measurable residual; -cost of operation; turbidity interferes with disinfection	small or local systems and industrial applications

- Combined disinfection treatments: Combining disinfectants has recently attracted increasing attention, because of benefits such as disinfection of a wider range of pathogens, improved reliability through redundancy, reduced disinfection byproducts (DBPs). Many studies have evaluated the efficiency of combined Chlorine, chloramines, ozone, ultraviolet irradiation (UV), peracetic acid or H_2O_2 treatments to determine if the microbial inactivation was synergistic. Results were variable and suggest that these methods could sometimes improve the efficiency and reliability of disinfection in water treatment plants. But other combined methods such as H_2O_2/UV disinfection only slightly influenced the microbial reductions compared to UV treatments and showed some antagonism and no synergies. A study showed also that a combined photocatalytic/UV (TiO_2/UV) system was effective in decomposing virus particules and reducing the concentration in the effluent. The process of adsorption using graphite based adsorbents with electrochemical regeneration was developed for disinfecting a high concentration of E. *coli* at low current density and low energy consumption. Observation indicates that this process of disinfection could be employed for disinfection without the formation of chlorinated disinfection by–products.

DRINKING WATER DISINFECTION IN ALGERIA

Health issues and disinfection

In Algeria, more and more often water sources are suffering from a worsening of their quality due to the indiscriminate discharge of both domestic and industrial effluents without adequate treatments. The national park of sewage treatment plants reached only 123 treatment plants in 2011(ONA, 2011). Therefore, the waterborne diseases remain a major public health problem in Algeria. This is even more important that the effects are short-term health. pathogenic microbes continue to be a major cause of waterborne disease globally, and they cause documented illness and death in Algeria. Observational studies have assessed endemic waterborne risks in many parts of country (Mesbah, 2009; INSP, 2011). Figure 2a shows incidence of typhoid between 2000 and 2011 year while Figure 2b shows annual incidence of Hepatitis A.

a) Typhoid b) Hepatitis A

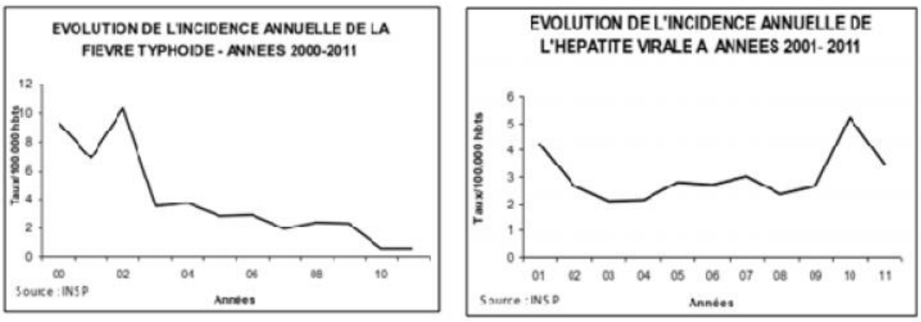

Figure 2: Annual evolution of waterborne diseases between 2000 and 2011 in Algeria (INSP,2011).

This is even more important that the effects are short-term health. Various programs of prevention and control against the MTH were set up as of changes in the epidemiological situation. The results recorded even if they appear encouraging for certain pathologies, remains insufficient for all those that require multisectoral action (Mesbah, 2009). Diseases transmitted by water (typhoid, cholera, bacillary dysentery and amoebic, viral hépathites) nevertheless showed a downward trend and a decrease in levels of child mortality over the past decade. This, through a national control program against the MTH set up in 1987 by the National Institute of Public Health (INSP) (Achour, 2001). The major lines of action have been directed for epidemiological surveillance and control of water resources (chemical and bacteriological control). In 2008, a survey by the INSP through 24 wilaya showed that nearly 18% of water samples collected in water reservoirs did not meet bacteriological standards. Similarly, 16% of the individual taps recorded showed positive results coliforms. Of 43 treatment plants for drinking water, 9 revealed non-compliance with the microbiological standards waters (INSP, 2008).

According to the national guidelines, drinking water must not contain any pathogenic germ and thus no fecal coliform (JORADP, 2011) . So, disinfection of drinking water, especially when the supply originates from a surface source, is needed to maintain water quality and protect public health.

Chlorination practice

One of the actions covered by the water sector has aimed to the identification, protection and regular treatment reservoirs and water towers managed by companies of production and distribution of water.

However, inventory outcome of hydraulic structures performed between 1987 and 2008 show that the execution of this control program is still fairly limited and could be improved (Table 6).

Table 6: Reservoirs and water towers controlled (Ouahdi, 1995; Achour; 2001; INSP, 2008)

Waterholes	**Reservoirs and water towers**		**S o u r c e s**	
Year	**Inventoried**	**Treated**	**Inventoried**	**Treated**
1987	3801	3058	15521	13696
1994	4623	1057	11950	5433
2008	343	115	756	163

- In Algeria, a number of factors may establish the performance efficiency of water disinfection process. Chlorine is the exclusive disinfectant utilized for drinking water treatment due to the ability of the chlorination process to meet disinfection standards more economically than any alternative. Chlorination is a relatively simple and cost effective process which does not require extensive technical expertise and which is capable of dealing with supply systems of varying size by altering dosing systems or storage for chemical contact accordingly.

Chlorine may be purchased as liquified chlorine gas or as sodium hypochlorite (NaOCI). Chlorine gas has been achieved using systems involving the storage and dosage of chlorine gas, at the greatest drinking water treatment plants. These installations have required ongoing guidance on their use for water disinfection and for management of associated health and safety risks. Chlorine is manufactured off site as a gas, liquefied under pressure and stored as a liquid. The liquefied gas is delivered to treatment works as cylinders. Chlorine is highly toxic and these installations have serious health and safety risks, which have to be managed (Leopold and Freese, 2009; WHO/WEDC, 2013).. Many of algerian treatment plants use liquid sodium hypochlorite technology as alternative to gaseous chlorination. The availability of this other chlorination method could allow water suppliers to reconsider the use of hypochlorite instead of chlorine gas. This will minimize the risks and the cost of implementing of the chlorination process.

Commercial sodium hypochlorite is manufactured by reaction between chlorine and sodium hydroxide and is supplied as an aqueous solution with a maximum concentration equivalent to 45 to 50 chlorometric degree in Algeria. It is not only less expensive than chlorine gas in Algeria, but it is also easier and safer to use and reduces the risk of chlorine gas release especially when installations are in close proximity to surrounding properties. Sodium hypochlorite is chemically unstable and gradually converts to sodium chlorate the commercial product has caustic soda added to improve stability. It must be handled with care as it is extremely corrosive with a high pH (11-13) which will attack and corrode all metal including metal pipe and fittings. Another problem in algerian treatment plants is the deterioration of sodium hypochlorite solution with time which is more rapid at higher temperature.

In order to prevent excessive degradation of hypochlorite product and excessive dosage of consequential chlorates formed, water suppliers should consider whether the concentration of hypochlorite ordered could be reduced, the available storage tank volume, the size of cost effective chemical delivery to site, the ambient temperature expected during the estimated storage period and the appropriateness of using chillers to regulate temperature.

As this decomposition is associated with a reduction in chlorine concentration, the continued dosing of the hypochlorite solution requires a continuous adjustment of chlorine dosage as storage time increases to achieve the same

chlorine residual into the treated water. One issue of concern with this practice that does not leave residual disinfectant in the water is the potential for recontamination of the water after treatment and before consumer's tap.
Although chlorination can reliably meet present bacteriological standards for drinking water treatment, serious deficiencies are inherent in current practices. Interfering substances, such as ammonia nitrogen and organic compounds, limit the effectiveness of a given chlorine dose (Figure 2). Chlorination of certain surface waters may result in the formation of halogenated organic compounds that are potentially toxic to human health (Table7).

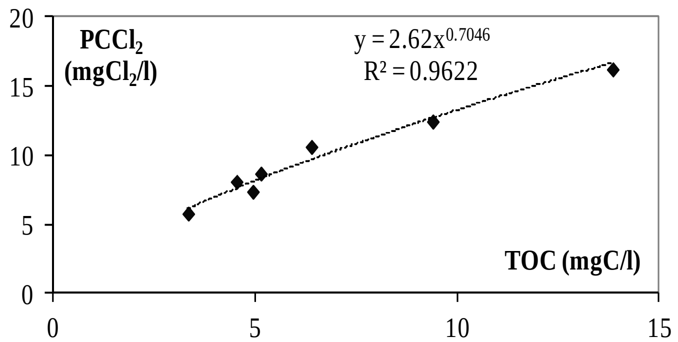

Figure 2: Relationship between chlorine consumption and organic matter of some dam waters in Eastern Algeria (Achour et al, 2009)

Table 7: Chlorine consumption and chlorination by-products formation potentials of dam waters in Eastern Algeria (Achour et al., 2009)

Barrages	**$PCCl_2$** ($mgCl_2/l$)	**PFTHM** (µg/l)	**PFTOX** (µg Cl^-/l)
Beni Zid	7,58	67	493
Ain Dalia	9,35	46	489
Hammam Debagh	10,46	62	860
Hammam Ghrouz	9,90	81	608
Mexa	12,48	112	822
Fontaine des gazelles	6,00	45	450
Beni Haroun	16,22	78	985

In addition, chlorine residual levels and contact periods now employed for disinfection may not adequately remove pathogens since preliminary chlorination tests are not always carried out. The increased dosage used to produce a free chlorine residual in the water will intensify residual toxicity and increase the quantity of chlorinated organics released to drinking waters.
The unlikely, but conceivable, formation of halogenated organic compounds that are potentially toxic to man, from chlorination of waters, is an area of special public health concern. The use of high chlorination doses for breakpoint chlorination may result in the production of significant amounts of halogenated

organics which, although they are usually unstable, may be detrimental to people health. However, high levels of THMs and residual of chlorine appear to be largely a consequence of the use of high chlorine dosage for the disinfection of drinking water. A high dosage of chlorine resulted nevertheless to a good microbiological quality. In Algeria, pathogenic microbes continue to be a major cause of waterborne disease globally. In contrast, epidemiological investigations indicate an increase in the incidence of cancer (Allem, 2014). But none of these studies attempt to correlate this increase with chlorination practice and produced THMs. The risk of illness and death from chemicals such as DBPs seems mostly low to in Algeria and many developing countries.

Comparison of chlorination to other water disinfection methods

While chlorination remains the most commonly used disinfection method by far, water systems may use alternative disinfectants, including chloramines, chlorine dioxide, ozone, and ultraviolet radiation. No single disinfection method is right for all circumstances, and in fact, water systems may use a variety of methods to meet overall disinfection goals at the treatment
plant. However, in Algeria, chlorine may be considered an almost ideal disinfectant, based on its proven characteristics:
• Effective against most known pathogens
• Provides a residual to prevent microbial re-growth and protect treated water throughout the distribution system
• Suitable for a broad range of water quality conditions
• Easily monitored and controlled
• Reasonable cost
Breakpoint chlorination should be a highly effective method for pathogen inactivation but may intensify the potential hazards of halogenated organics. This requires above all avoiding uncontrolled and indiscriminate use of chlorine for disinfection. In-plant modifications to provide proper contact periods, with accurate residual monitoring and control, should eliminate many of the operational and toxicity problems associated with present chlorination practices. Whether chlorination continue being the only disinfection method in Algeria, water system managers just must design unique disinfection approaches to match each system's characteristics and source water quality.
Alternate means of disinfection may possess certain advantages that favor their use in some instances, but a correct evaluation of the ecological-health-resource trade offs should proceed the selection of anyone method of disinfection.
The use of ozone, bromine, iodine and potassium permanganate can reduce the problems associated with toxicity of residual chlorine, but the interactions of these disinfectants with organic matter have not been completely revealed. Thus, little is known about either the short or long-term health or ecological

effects of reaction products formed during use of these disinfecting agents (USEPA, 2011). Ultraviolet irradiation of water may also initiate undesirable side reactions resulting in the formation of compounds that have adverse effects on drinking water quality.
The use of lime for disinfection may be feasible if provisions can be made to handle the large quantities of sludge that would be formed by this treatment. In fact, the use of alternative disinfectants should be evaluated on a case-by-case basis for any water treatment plant.
Water pretreatment may moreover be employed to enhance disinfection by chlorine. Step optimization upstream of the final disinfection is crucial to removal organic precursors and turbidity from water. Several studies show deficiencies in the optimization of clarification steps at the Algerian treatment plants. In particular, doses of coagulant are seldom adjusted to the water quality. The clarified water then contains significant levels of organic matter and suspended solids. Optimization of pretreatment steps may be necessary for proper disinfection and may be also required for the majority of alternate disinfection processes.

CONCLUSION

There are a number of appropriate methods for drinking water disinfection, each with advantages and disadvantages.
The choice of a given disinfection process is not only a function of the water quality parameters but also other factors such as technical, economical and healthy criteria. So, the state regulators, water professionals, and researchers must be involved in substantial work toward development of disinfection system optimization and assessment programs over the coming years. Chlorination is the most widely used method of disinfection practiced throughout the world. Chlorination is a relatively simple and cost effective process which does not require extensive technical expertise and which is capable of dealing with supply systems of varying size by altering dosing systems or storage for chemical contact accordingly. However, chlorination of water rich in organic material is known to produce a complex mixture of organohalogenated compounds, including mutagenic and carcinogenic substances. Disinfection must also be recognized as a unit operation for which the degree of upstream pretreatment is vitally important. In many developing countries, chlorine will nevertheless continue to be one of the most popular options for its low cost and residual disinfection. Though, the technology of alternate methods of disinfection should be rapidly developed. Current and future research should provide parameters for practical process design of technologies such as ozonation, and ultraviolet light facilities. However, cost

and complex implementation of these methods can be a deterrent. In addition, a greater understanding of their disinfection by-products is required.
Regarding Algeria, there is no doubt that chlorination has been successfully used for the control of water borne infections diseases over recent decades. However, identification of chlorination byproducts and incidences of potential health hazards could create a major issue on the balancing of the risk the chemical species and risk from pathogenic microbes in the supply of drinking water. The amount of drinking water toxicity and mutagenicity can be reduced through changing water treatment practices without compromising the microbiological quality drinking water. In addition, Information concerning the potentially adverse affects on public health from toxic reaction by-products must be developed.
Water treatment designs and operators have only alternatives either limit the formation of disinfection by-products by innovative chlorination strategies or optimization of treatments upstream disinfection. In-plant, modifications should be used to develop good mixing of chlorine and drinking water with adequate contact periods and chlorine dosage to improve existing chlorination processes. In Algerian areas where protection of distribution system of concern, chlorine residuals should be precisely monitored and maintained about 0.1 to 0.2 mg/l in the tap water at all times. In areas where microbiological contamination and halogenated organics pose a threat to public health, the use of alternate disinfectants should be considered, based on a proper evaluation of the trade offs associated with acute toxic effects (waterborne diseases) versus chronic toxic effects (cancers and mutagenic effects).

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