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Controlling Assessment of Disinfection by Products in Drinking Water – A Review

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Abstract

The treatment and distribution of drinking water for a safe use is one of the greatest achievements of our twentieth century. Drinking water disinfection and treatment is the most successful measurement to reduce water born and bacteria that cause many disease and it is the most effective way to protect health. Before the beginning of drinking water treatment and disinfection history, many diseases had been killed thousands of people around the world and until now many people around the world have no appropriate access to clean drinking water. According to World Health Organization (WHO), in 2012, 748 million people still relied on unimproved drinking water source. It is known that water disinfection is very important and inescapable step in water treatment process to ensure safe drinking water that is leads to the formation of disinfection -by products (DBPs). Many disinfections by products are detected in drinking water, and they are usually grouped into the following categories: Trihalomethans (THMs), Haloacetic acid (HAAS) Inorganic disinfections by- products (bromate and chlorite).

Keywords*: Disinfections, DBPs, Water, Carcinogens risks.*

1. Introduction

Disinfection of water for humans can be accomplished with several disinfectant as: chlorine, chloramines, ozone and chlorine dioxide [1],[7],[2],[8]. During the treatment process chlorine is added to drinking water as elemental chlorine (chlorine gas), sodium hypochlorite solution or dry calcium hypochlorite. When applied to water, each of these forms “free chlorine “will destroy pathogenic organisms [3],[1],[4],[2]. Most of the countries around the world using chlorine based –process for water treatment either alone or in combination with other disinfectant.

As importantly, only chlorine-based chemicals provide “residual disinfectant “levels that prevent microbial re growth and help protect treated water throughout distribution system [5],[12],[6],[18]. The risk of waterborne disease can be highly occurred where inadequate water treatment is not available, then it will be big impact on public health can be devastating. Worldwide, about 1.2 billion people lack access to safe and clean drinking water, and about twice that many lack adequate to sanitation [7],[33]. So as a result the World Health Organization estimates about 3.4 million people most of them are children die every year because of water related disease and lack disinfection of drinking water [8],[30],[9],[32]. Protecting against microbial contamination is the top priority, water system must also control the disinfection by products (DBPs), and the chemical compounds that formed unintentionally when chlorine and other disinfectant react with natural organic matter is water [10],[19]. In the early of 1970s, EPA scientist determined that drinking water chlorination could form a group of byproducts known as trihalomethanes (THMs), which includes chloroform. EPA set the first regulatory limits of THMs in 1979 [11], [12]. Despite disinfection brings about carcinogen molecules, but it is essential in water treatment and cannot ignore it [13]. Therefore, if we want to prevent the severe risk due to the presence of pathogens in drinking water, it is necessary to know very well the molecules necessary to treatments removal from water resources. Many Epidemiological studies have been carried out in order to highlight the possible excess of cancer in population drinking water treated with chlorine or ozone. High levels of these chemicals are certainly undesirable [14],[15],[16]. Coast effect methods have been conducted to reduce DBP formation are available and should be adopted where possible. However, disinfection of drinking water must be adequate and not be compromised in attempting to control byproducts. Recent EPA regulations have further limited THMs and other DBPs in drinking water [12],[17],[18],[19]. Most water Systems are meeting these new standards by controlling the amount of natural prior disinfection[20].

2. Biological function of water

Water is basic element of life of all living beings, therefore it is an essential element and a primary resource. The human body weight constitutes 60-65% of water. Water molecular formula is simple but its physicochemical characteristics (solvent, dielectric and hydrolytic power) it is involved in many biological and metabolic functions [21], [22]. Water is an excellent solvent for many compounds it regulates cellular volume and body temperature and it is a good source for minerals. Man can live for quiet long time without food but cannot avert death when the body reaches 12% dehydration which occurs in 2 or 3 days [3], [14].

3. Human Consumption for water

The Microorganism presence in water can cause many diseases such as hepatitis, cholera, typhoid, dysentery. These diseases had killed many people through a century and continue to affect life of large number of lives of human beings especially in the Third World countries. So in order to carry out the prevention of waterborne disease, disinfection has been carried out through [23]. Water disinfection for human can be considered the most significant public health success of twentieth century; in fact, it has made the control and reduces the waterborne disease in most of the countries around the world. However, there is still major problems in health [21], and still considered is the speared of disease through the use of water consumption in developing countries [15]. Water to be used for drinking and other consumption types must have some characteristics of potable water. Drinking water should have about 0.5 g/l of mineral saults and should contain neither toxic substances nor pathogens. The Italian Reference D. Lgs. 31/2001 [22] is the reference standard that, in accordance with 98/83/EC European Directive, regulates drinking water issues and also defines all analysis criteria and parameters that water samples should meet in order to be defined “drinkable”. “Drinking water or water intended for human consumption” are all waters, whatever their origin, in their original state or after treatment, that are: To provide the consumer; or used by food industries for the manufacture, preservation, processing or marketing of products or substances for human consumption and that could affect the food healthiness product.

4. Quality of drinking water

The world withdraws 3,906 cubic kilometers of water in 1995 for human use. Water withdraw is projected to increase at least by 50% by the year of 2025. Figures vary from region to another Table (1) North America withdraws seven times fresh water than Africa [11]. Access to safe drinking water is crucial and critical to maintain health, particularly for Children, but more than one billion of people around the world lack to access to safe drinking water to meet the minimum levels of health and income. The World Health Organization has its priorities that all people around the globe and whatever their stage of development and their social and economic conditions have the right to have the access of adequate water supply of safe drinking water. To achieve this the WHO published “Guidelines on Drinking Water Quality “which all countries should meet to ensure the health of their population. This Guidelines describe minimum and reasonable requirements of safe practice of drinking water to protect the health of consumers and derive numerical guideline values of water or indicators for water quality. Table (2). To define mandatory limits, it is preferable to consider the guidelines in the context of national or local environment economic, social and cultural conditions. The Italian Reference D. Lgs. 31/2001 [22] [6] is the reference standard that, in accordance with 98/83/EC European Directive, regulates drinking water issues and also defines all analysis criteria and parameters that water samples should meet in order to be defined “drinkable”.” Drinking water or water intended for human consumption” are all waters, whatever their origin, in their original state or after treatment, that are: To provide the consumer; or used by food industries for the manufacture, preservation, processing or marketing of products or substances for human consumption and that could affect the food healthiness product.

Figure 1.1 and Table 1.1, describes the guidelines within mandatory limits according to Italian References D. Legs [22] of drinking water for the consumption for humans. The water should meet the minimum criteria to be drinkable and clean for daily consumptions use and to provide all consumers with a good quality of drinking water to maintain a good health for public and also to provide the factories and industrials areas with good water quality for suitable and healthy products for consumers.

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Country	Total fresh water withdrawal(Km^3/year)	Domestic use (%)	Industrial use (%)	Agriculture use (%)	2005Population Millions
Australia	24.06	15	10	75	20.61
Brazil	59.30	20	18	62	186.41
Canada	44.72	20	69	12	32.27
Chad	0.23	17	0	83	9.75
China	549.76	7	26	68	1,323.35
Egypt	68.30	8	6	86	74.03
Germany	38.01	12	68	20	82.69
India	654.84	8	5	86	1,103.37
Pakistan	169.39	2	2	96	157.94
Somalia	3.29	0	0	100	8.23
UK	11.75	22	75	3	59.67
USA	477.00	13	46	41	298.21
Zambia	1.74	17	7	76	11.67

Fig 1.1: Fresh water withdraw by country and sector. Data from the World's water 2006-2007 (P.H. Gleick, Island Press, Washington, 2006)

Table 1.1: Guidelines on drinking water quality, 3rd Edition, Geneva. Data from WHO (2006)

Chemical	Guideline value (mg/L)	Remarks
Acrylamide	0.7 (D)	
Alachlor	0.3	
Aldicarb	0.03	Applies to aldicarb, sulxofide and aldicarb sulfone
Aldrin and dieldrin	0.03	For combined Aldrin plus dieldrin
Antimony	0.05 (P) 2	
Arsenic	0.0006	For combined Aldrin plus dieldrin
Altrazine	0.07	
Barium	0.07	
Benzene Benzo [*a*] pyrene	0.03	
Boron	0.09	
Bromate	0.001	
Bromodichloromethane	0.008	
Bromoform	0.1	
Cadmium	0.07	
Carbofuran	0.1	
Carbon Tetrachloride	0.001b	For effective disinfection, there should be a residual concentration of free chlorine of
Chlorate	0.0004 (P)	
Chlordane	0.05 (T, D)	
Chlorine	0.02 (P)	≥0.5 mg/L after at least 30min contact time at Ph <8.0
Chlorite	0.7 (D)	
Chloroform	0.3	
Chlorotoluron	0.03	
Chlorpyrifos	0.03	
Chromium	0.05 (P) 2	For total chromium
Copper	0.0006	
Cyanazine Cyanide	0.07	For cyanide as total cyanogenic compounds
Cyanogen chloride	0.07	
2,4-D (2,4 - dichlorophenoxyacetic acid)	0.03	Applies to free acid
2,4-DB DDT and metabolites Di (2 - ethylhexyl) phthalate	0.09	
Dibromoacetonitrile	0.001	
Manganese	0.008	For inorganic mercury
MCPA	0.07	For total microcystin-LR (free plus cell-bound)
Mecoprop	0.1	
Mercury	0.001b	
Methoxychlor	0.0004 (P)	
Metolachlor	0.4 (C)	
Microcystin-LR	0.002	
Molinate	0.01	
Molybdenum	0.02	
Monochloramine	0.006	Short-term exposure
Monochloroacetate	0.01	
Nickel Nitrate (as $N0_3^-$)	0.001 (P)	
Nitrilotriacetic acid (NTA)	0.006	
Nitrite (as NO_2^-)	0.07	
Pendimethalin	3	Only when used as a laryicide for public health purposes
Pentachlorophenol	0.02	
Permethrin	0.07	
Pyriproxyfen	500.2	

Selenium Simazine	3	
Styrene 2,4,5-T	0.2 (P) 0.02	
Terbuthylazine	0.009 (P)	
Tetrachloroethene	0.3	
Toluene Trichloroacetate	0.3	
Trichloroethene	0.01	
Trichlorophenol 2,4,6 – Trifluralin	0.002	
Trihalomethanes	0.02 (C)	
Uranium	0.009	
Vinyl chloride	0.007	
Xylenes	0.04	

Where P = Provisional guideline value, C = Concertation of substance at or below the health guidelines, D = Provisional guideline value because disinfection is likely to be exceeded in the guideline value.

The guidelines are intended to lead to national standards and regulations that can implemented and enforced to protect public health. This approaches may work in one country or origin will not necessarily transfer to other region or countries. So that it is essential that each country review it demand and capacity to in developing regality frame work. The quality of drinking water is always concern. They are different regulations for drinking water around the globe, like in United States, it is regulated by the Safe Drinking Water Act (SDWA) and applies to every public water system inside the country. The SDWA authorized The United States Environmental Agency to set rules and regulations for safe drinking water to protect health public against both naturally and man occurred condiments that may be found in drinking water. In Europe Directive 98/83/EC, the Drinking Water Directive (DWD), covers the Quality of water intended for human consumption. The main objective of the Drinking Water Directive is to protect the consumer public health in the European Union and make sure that water is clean and safe for human consumptions [24]. The Drinking Water Directive sets standards for the most common substances in total is 48 microbiological and chemical parameters. Those parameters are important to human health but they are also including others that related to the water treatment control.

5. Disinfection By-Products and its History (Regulations and Formations)

Many epidemical studies have been conducted to highlight the possible increase of cancer in drinking water populations that using chlorine for treatment through their water system. These studies have shown that there is a relationship between disinfection by-products concertation and in drinking water that cause prostate, intestine and anal cancer. Of all cases of prostate cancer was 9% and 15% of anal cancer are related to disinfection by- products in drinking water [26]. Disinfection defined as the process of that removes and renders inactive pathogenic microorganism. Water disinfection can be achieved through a number of treatment process that are using various combination depending on quality, type and source [30], [31], [32]. Disinfection is only effective when they are using together to provide multiple barriers to the passage of microorganism [33], [34], [35]. Disinfection chemicals using chlorine, or other oxidant provides the final barriers. Commonly Groundwater require little pretreatment before chemical disinfection while Surface water treatment includes generally process such as coagulation and filtration before the final chemical disinfect step [36], [37], [38].

Disinfection Chemicals principally using chlorine but also ozone, chlorine dioxide, and other oxidant that have been practiced for long time and has took a major role in radiation of waterborne disease around the globe [39], [40]. However, all disinfectants chemical produce either or both organic and inorganic by-products that have potential health effect on humans. For Example, the result of chlorination in the formation of trihalomethanes (THMs) naturally occurring from cursors; ozone oxidize bromide to form bromate; and chlorine dioxide react to form to chlorite which is inevitable decomposition product [12].

Since the early of twentieth century, disinfection has been practiced but it was not until 1970s was discovered that chlorination generates THMs [17]. Since then many efforts have been considered to study and identify the formation of disinfection by-products (DBPs) world –wide. Many (DBPs) have been identified yet some of which are potentially hazardous but the risk of (DBPs) considered to be small comparing to risk of inadequate disinfection [26].

5.1 Formation and chemistry of (DBPs)

Disinfections by-products principals that are forming through, chlorinationare, trihalomethanes (THMs) chloroform, bromodchloromethand, bromodichloromethane, dibromochloromethane and bromoform – so as a result of chlorination process naturally occurring organic precursors such as humic substances. Result of chlorination of naturally occurring organic precursors such as humic substances.

Chloroform normally is the dominate THM; so the brominated THMs forms as the result of oxidization of naturally present bromide acid and then reacts with precursors [27],[28]. Some of the THMs including chloroform, classified as possible carcigonioc for humans. While Chloramination produce lower THM concertation than chlorination but also produce other types of DBPs which is including cyanogen chloride [12].

Ozone can also form brominated THMs through the oxidization of bromide to form hypobromuose acid which is brominates precursors. While Chlorine dioxide does not from THMs by reaction with humic substances. The following equation generalize the formation of THMs and other halogenated DBPs:

$$HOCL + Br^{-} + NOM \rightarrow \text{THMs and Other Halogenated DBPs} \quad \text{Eq. 1}$$

Table 1.2: Disinfectant and Disinfectants by – Products

Disinfectant	Disinfectant by –Products
Chlorine (e.g. gas, sodiumhypochlorite, tablets, OSEC)	Trihalomethanes, Haloacetic Acids, Chloramines1, Chlorinated Acetic, Acids, Halogentated Acetonitriles, Chloral Hydrate, Chlorophenols, MX 2, bromate 3, chloropicrin, halofurans, bromohydrins.
Chlorine Dioxide	Chorite,Chlorat,Chloride
Ozone	Bromate, Formaldehyde, Aldehydes, Hydrogen, Peroxides, Bromomethanes
Chloramines	Dichloramines,Trichloramines, Cyanogen Chloride, Chloral Hydrate.

The Factors that Inflected DBPS formation is below: Type of used disinfection PH, Contact time, Concertation of disinfection us, Concertation of organic matter and other DBP precursors in water to be disinfected**,** Season and Temperature, Bromide concertation, Length of Distribution Network.

5.2 THM Concertation

THMs is still represent a major problem for public health in use and consumption for drinking water [12]. THMs are formed by the interaction of natural organic matter NOM, bromide and chlorine. When disinfectant (chlorine, ozone, chlorine dioxide and chloramines) react with natural organic matter, this reaction produce DBPs during the production of drinking water. THMs are very Mutagenic, very resistance, teratogenic and carcinogenic substances; chloroform is the best known and the most dangerous [23]. THMs including bromibrominedichloromethane (BDCM, $CHBrCl_2$), trichloromethane, (chloroform, $CHCl_3$), tribromomethane chlorine ($CHBr_2$ Cl) and tribromometane ($CHBr_3$).THMs is very dangerous and considering concern because they cause gastro intestinal cancers [27], [28]. Recently many epidemiological studies have also suggested that THMs may have negative acute reproductive effects, including casual abortion and birth defects [26], [17]. To minimize the risk of cancer, United States Environmental Protection Agency (U.S. EPA), the European Union (EU) and the WHO have produce the giddiness for individual THMs [12]. In 1979, the U.S.EPA fixed a Standard of 100 µg/L for THMs. Nowadays, this standard has been reduced to 80 µg/L, a level of 60 µg/L has been introduced for the sum of five haloacetic acids (HAAs) and one of 10 µg/L for bromate [29].

5.3 Basic Strategies to reduce the effect of DBPs

Changing the condition process (Removal of precursors compound which including enhancing coagulation, filtration of a membrane and granular activated carbon GAC), using alternative chemicals for disinfect using UV irradiation or membrane, air striping [10], [20],[30],[37], [40].

6. Conclusion

To reduce the disadvantages of chlorination process, many disinfection alternative techniques have been developed including: Using chemical system such as copper, silver, iodine, ferrate, hydrogen peroxide, bromine, and potassium permanganate; physico-chemical systems (e.g. titanium photo catalysis),photodynamic disinfection, electrochemical disinfection and also using other physical system such as such as ultraviolet irradiation, ultra-sonication, pulsed electric fields, irradiation, magnetic enhanced disinfection, and microwave systems. However, these techniques do not guarantee disinfection residual activity, therefore drinking water industry have performed other methods. Besides Using UV as disinfection sometimes presents free of DBP but it has potential to form hydroxyl radicals in water (as O_3 does) which can produce oxygen that contains DBPs. People every day are exposing to at least 600 not identified DBPs via inhalation, ingestion and dermal. The toxicological effects by mixtures of DBPs are largely unknown and the exposure to different DBPs has never been all studies as well as dermal. Although the different DBPs and their negative effect on Humans life and health but still the direct and immediate greater impact risk to health and life of a human is caused by the pathogenic that presence in water. Therefore, the presence of microorganism makes disinfection unthinkable to abandon the process of disinfection. The primary success and main purpose of disinfection of drinking water is to protect the human life and health from pathogens and microorganism that cause diseases. In fact, water disinfection has allowed people to have wholesome water and prevented many deadly diseases. Besides through the past 30 years' human exposure to DBPs has definitely decreased.

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References

[1] M.I. Kerwick, S.M. Reddy, A.H.L. Chamberlain, D.M. Holt, "Electrochemical disinfection an environmentally acceptable method of drinking water disinfection", Electrochimical Acta, vol. 50, 2005, pp: 5270–5277.

[2] A.S. Biryukov, V.F. Gavrikov, L.O. Nikiforova, V.A. Shcheglov, "New physical methods of disinfection of water", Journal of Russian Laser Research, vol. 26, no. 1, 2005, pp: 13-25.

[3] E.N. Whitney, C.B. Cataldo, S.R. Rolfes, "Understanding normal and clinical nutrition, 6th edition, Belmont: Wadsworth/Thompson Learning, 2002, cap. 12: Water and the major minerals.

[4] A.M. Costantini, C. Cannella, G. Tomassi, "Alimentazione e nutrizione umana. Il Pensiero Scientifico Editore., 2006, Seconda edizione cap 15. Roma.

[5] R. Sadiq, and M.J. Rodriguez, "Disinfection by-products (DBPs) in drinking water and predictive models for their occurrence: A review", Science of the Total Environment, vol. 321, 2004, pp: 21–46.

[6] E. Agus, N. Voutchkov, D.L. Sedlak, "Disinfection by-products and their potential impact on the quality of water produced by desalination systems. A literature review", Desalination, vol. 237, 2009, pp: 214–237.

[7] World Health Drinking Water Guidelines, 2011, 4th Edition, http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/.

[8] World Health Organization, 2000, Environmental Health Criteria 216: Disinfectants and Disinfectant By-products, Geneva, Switzerland.

[9] World Health Organization: Seminar Pack for Disinfection and Disinfection By-products, Geneva, Switzerland. http://www.who.int/water_sanitation_health/dwq/S04.pdf.

[10] G.N. Wogan, S.S. Hecth, J.S. Felton, A.H. Conney, L.A. Loeb, "Environmental and chemical carcinogenesis", Seminars in Cancer Biology, vol. 14, 2004, pp: 473–486.

[11] P.H. Gleick, 2006, "The World's Health Water Washington, DC: Island Press".

[12] H.A. Duong, M. Berg, M.H. Hoang, H.V. Pham, H. Gallard, W. Giger, G.U. Von, "Trihalomethane formation by chlorination of ammonium and bromide - containing groundwater in water supplies of Hanoi, Vietnam", Water Research, vol. 37, 2003, pp: 3242-3252.

[13] J. Fawell, M. Walker, "Approaches to determining regulatory values for carcinogens with particular reference to bromate", Toxicology, vol. 221, 2006, pp: 149-153.

[14] S. Sciacca, C.G. Oliveri, "Mutagens and carcinogens in drinking water", Mediterranean Journal of Nutrition and Metabolism, vol. 2, 2009, pp: 157-162.

[15] EMEP, 2006, Transboundary particulate matter in Europe: Status report 2006 (EMEP Repor 4/2006). Norwegian Institute for Air Research, Kjeller. EMEP/CCC. (2005a). *Measurements of particulate matter: Status report 2005* (Karl Espen Yttri, Ed., EMEP/CCC Report 5/2005). Norwegian Institute for Air Research, Kjeller.

[16] S.K. Golfinopoulus, "The occurrence of trihalomethanes in drinking water in Greece", Chemosphere, vol. 41, 2000, pp: 1761-1767.

[17] U.S.EPA Environmental Protection Agency, 2009 and 2010, The Provision and Quality of Drinking Water in Ireland, http://www.epa.ie/downloads/pubs/water/drinking/

[18] US EPA, 2008, Stage 2 Disinfectants and Disinfection By-Guidance Manual http://www.epa.gov/ogwdw/disinfection/stage2/pdfs/draft_guide_stage2_operationalevaluation.pdf

[19] US EPA, 1998, Fact Sheet on the Federal Register Notice for Stage 1 Disinfectants and Disinfection By-products Rule http://water.epa.gov/lawsregs/rulesregs/sdwa/stage1/factsheet.cfm
[20] American Water Works Association (2002) Disinfection of Water-Storage Facilities, AWWA Report C652-02
[21] WHO, Guidelines for Drinking-Water Quality, 2nd edition: Recommendations, Vol. 1, 1993, World Health Organization, Geneva.
[22] US EPA, 2009, National Primary and Secondary Drinking Water Standards, http://www.epa.gov/safewater /consumer/ pdf/mcl.pdf
[23] M.M. Moore, T. Chen, "Mutagenicity of bromate: Implications for cancer risk assessment", Toxicology, vol. 221, 2006, pp: 190–196.
[24] DoEHLG (2009) Circular L04/09 - Drinking Water Incident Response Plans DWI (2010). Advice for Applicants and Water Suppliers - Advice Sheet 5 - Approval of products made from recognized materials and from metals May 2010.
[25] DWI, 2010, Advice for Applicants and water suppliers - Advice Sheet 9 - Emergencies – Use of equipment and disinfectants Feb 2010DWI (2010) List of Approved Products for use in Public Water Supply in the United Kingdom. Updated May 2010 and available at http://www.dwi.gov.uk/drinking-water-products/approvedproducts/soslistcurrent.pdf.
[26] D.E. Kimbrough, I.H. Suffet, "Electrochemical removal of bromide and reduction of THM formation potential in drinking water", Water Research, vol. 36, 2002, pp: 4902–4906.
[27] HSE and the EPA, 2011, Joint Position Statement Trihalomethanes in Drinking Water, http://www.epa.ie/downloads/advice/water/drinkingwater/name,31744,en.html
[28] US EPA, 2008, Stage 2 Disinfectant and Disinfection By-products Rule Consecutive Systems Guidance, http://water.epa.gov/lawsregs/rulesregs/sdwa/stage2/upload/ guide_stage2_consecutivesystems_mar2010_v3.pdf
[29] WHO Guideline for drinking-water quality, 3rd edition, vol. 1, Geneva, 2004.
[30] H. Ryan, 2012). Technical Guidance Document on Trihalomethane Formation in Drinking Water Supplies, (Unpublished).
[31] World Health Organization, 2003, pH in drinking water, http://www.who.int/water_sanitation_health/dwq/chemicals/en/ph.pdf.
[32] S.D. Richardson, M.J. Plewa, E.D. Wagner, R. Schoeny, D.M. De Marini, "Occurrence, genotoxicity, and carcinogenicity of regulated and emerging disinfection by-products in drinking water: A review and roadmap for research", Mutation Research, vol. 636, 2007, pp: 178–242.
[33] Decreto Legislativo 2 -02-2001, N. 31 "Attuazione della direttiva 98/83/CE relativa alla qualita' delle acque destinate al consumo umano". Gazzetta Ufficiale 52, 3 marzo, 2001, Supplemento Ordinario n. 41. World Health Organization. Guidelines for Drinking-Water Quality, 2nd Edn., 1998.
[34] Water Research Centre WRc, 2011, Evaluation of Haloacetic Acid Concentrations in Treated Drinking Water, http://dwi.defra.gov.uk/research/completedresearch/reports/DWI70_2_253.pdf.
[35] R. Gori, and C. Caretti, "Experimental study on municipal and industrial reclaimed wastewater refinement for agricultural reuse", Water Science and Technology, vol. 58, no. 1, 2008, pp: 217-223.
[36] R. Herruzo, M.J. Vizcaino, I. Herruzo, "Efficacy of a new peracetic acid based disinfectant agent ('Adaspor® ready to use')", Journal of Hospital Infection, vol. 74, no. 2, 2010, pp: 192-193.
[36] EPA, 2010, European Communities (Drinking Water) (No. 2) Regulations 2007 A handbook on the Implementation of the Regulations for Water Service Authorities for Public Water Supplies USEPA (2004) Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents Module 5: Public Health Response Guide April 2004 WHO (2004) Guide to promotion of Drinking-Water disinfection in emergencies.
[37] J.E. Alvaro, S. Moreno, F. Dianez, M. Santos, G. Carrasco, M. Urrestarauz, "Effects of peracetic acid disinfectant on the postharvest of some fresh vegetables", Journal of Food Engineering, vol. 95, no. 1, 2009, pp: 11-15.
[38] L. Hébert, S. Frigerio, E. Chiesara, and S. Radice, "Effects of ozone, ultraviolet and peracetic acid disinfection of a primary-treated municipal effluent on the immune system of rainbow trout (Oncorhynchus mykiss)", Toxicology and Pharmacology, vol. 148, no. 2, 2006, pp: 122-127.
[39] L. Marabini, S. Frigerio, E. Chiesara, and S. Radice, "Toxicity evaluation of surface water treated with different disinfectants in HepG2 cells", Water Research, vol. 40, no. 2, 2006, pp: 267-272.
[40] A. Dell'Erba, D. Falsanisi, L. Liberti, M. Notarnicola, and D. Santoro, "Disinfection by-products formation during wastewater disinfection with peracetic acid", Desalination, vol. 215, 2007, pp: 177-186.

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