

Removal of DBPs from Drinking Water: An Outlook on Green Technology

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ABSTRACT: *The major concern across the world is about the generation, surveillance and health impacts of disinfection by-products (DBPs). DBPs are contaminants of which most human beings are unprotected, since drinking water is often remediated with a chemical killing agent. The water production process has undertaken great efforts in the killing of pathogens and DBP surveillance due to the health impacts related to chlorinated water subjection and some DBPs. The widespread surveys of growing health and regulatory concerns have been undertaken. The DBPs were historically concentrated in the treatment of carbohydrate DBPs containing chlorine and bromine. The appearing DBPs include iodine containing species, including halogenated and non-halogenated nitrogen. The survey has been conducted to better understand how the wide interval of managed and emerging DBPs is monitored cost-effectively. This includes the use of sophisticated methods of remediation and killing of pathogens. This paper shows some of the latest research on these critical DBP problems. The disinfection kills waterborne microorganisms but also kills people by using toxic DBPs to drink water.*

KEYWORDS: Chlorine, DBPs, HAAs, NOM, THMs, Water Treatment.

1. INTRODUCTION

Disinfection remains the most commonly used process for demobilization of pathogens. This is an important step in the management of drinking water because it reduces the risk of waterborne diseases like typhoid and cholera. As it maintains the residual disinfectant concentrations to monitor bacteria, the production of disinfection by-products (DBPs) may increase considerably. However, it is important to emphasize that the positive public health contribution of disinfection cannot be overlooked when assessing and monitoring DBPs [1].

The efficiency of disinfection technology is affected by pH, residence period and temperature. In addition to the potential health consequences, a massive investigation was carried out on DBPs to understand the phenomena of generation throughout the remediation technique and the delivery system. Disinfectants interact in treated water and in the delivery system with natural organic matter (NOM) to form DBPs, comprising haloacetic acids (HAAs) as well as trihalomethanes (THMs). THMs and HAAs have been studied more frequently as their concentrations are very higher compared to other DBPs.

Numerous DBPs have been reported as being carcinogenic, reproductive contaminants, and mutagenic, posing a major risk to human health. Humans are exposed to DBPs through a variety of pathways, including ingestion of elevated amounts of DBP in liquids. Because of the potential dangers to human health, the United States Environmental Protection Agency (USEPA) developed thresholds for multiple DBPs in drinking water [2]. The type of killing agent of micro-organisms, physico-chemical characteristics in the groundwater, running cases in treatment plants, water temperature, and contact time in the distribution systems affect the generation and levels of DBPs in potable water. Many models were used to anticipate the capability and actions of DBP generation for WTPs and distribution systems. These models aid in reducing exposure and establishing tolerance limits and expectations in corporate decision making.

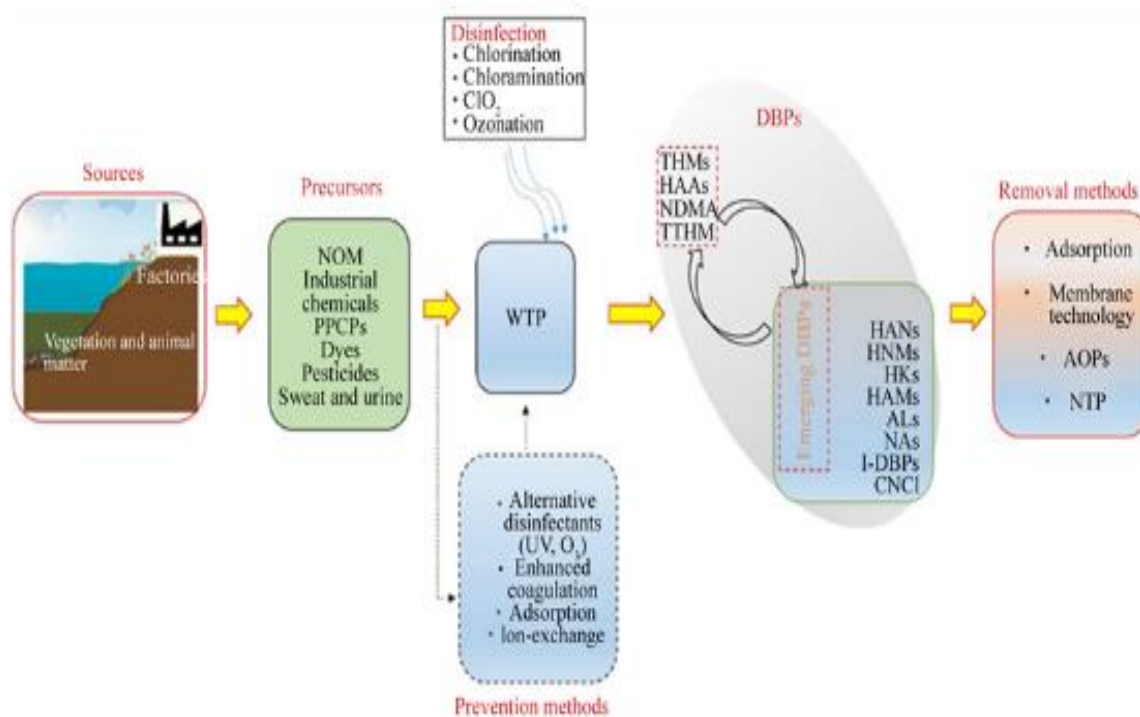


Figure 1: The diagram depicts the origins, precursors, range, and preventative and removal strategies for DBPs.

Chlorination is primarily linked to the production of DBPs. Several substitutional disinfectants have been tested to prevent this, such as chloramines, ozone and ClO_2 , the key benefit of chloramine is that it reduces the production of regulated DBPs and other chemicals that affect harmful organoleptic functions in drinking water, such as 2-methyl isoborneol and geosmin. Furthermore, the ability of chloramine to dominate biofilm formation is more effective than chlorine as biofilms penetrate it. Chloramination alternatively can guide to the development of carcinogenic N-nitrosamines (NAs). Although the ozonation method is successful, it is likely that a DBP like bromate will be generated if considerable bromide levels exist in the source water. Although the output of numerous generated DBPs is lower than chlorination by substitutional disinfectants, there are original concerns by establishing a innovative category of DBPs recognized as emerging DBPs. Additionally, emerging DBPs from the chlorination application have also been specified. This involves chemical substances such as cyanides, aldehydes, haloketones (HKs), halonitromethanes (HNMs), haloacetamids, iodinated-DBPs (I-DBPs) as well as NAs. Consequently, present studies focus mainly on the mechanisms, concentrations and dangerous influences in health of evolving DBPs to be understood. Many researches was conducted in distribution networks into the temporal and spatial existences of emerging DBPs. Technological advances in the extraction, sampling, and analytical capability have also made it possible to detect and measure new DBPs even in trace levels[3].

As shown above, in treated water DBP's are unwanted because they are extremely human carcinogenic. Those water quality and running problems in water treatment must therefore be eliminated in an efficiently manner to avoid NOM and other DBP precursors. Protective measures may use replacement disinfectants that do not produce DBP. Advanced oxidation processes (AOP), Enhanced coagulation, ion exchange, and membrane processes are few removal processes studied in this study (Figure 1). Elimination of precursors before interacting with disinfections agents is an efficient and economically viable method to monitor DBP generation in WTPs. The bromide ion remains in conventional WTPs even though organic matter (OM) can be extracted. Many WTPs have also focused on removing DBP precursors such as NOM.

W. Gwenzi et al. published a systematic analysis for NOMs present in water sources and their effect on DBP generation. Particularly, DBP output was discussed, NOM contribution to DBP generation was examined, and techniques were estimated and recommended to eliminate DBP. The key results are discussed and the authors' experiences in managing disinfection processes and DBP generation problems and strategies for removal from water are examined[4].

1.1 Sources of Water:

Both surface waters and ground waters are considered as potable sources of water supplies. Groundwater sources in the United States have nearly 53% of all drinking water and surface water supplies with residual 47%. Groundwater is drained from underground aquifers, where the water is drilled. Wells can be between ten and hundred meters deep. Groundwater is less likely than surface water to be contaminated. It usually is more protected from surface contamination and as it runs later, organic material has enough contact time for soil bacteria to degrade. The soil itself acts as a filter and fewer suspended solids are thus observed along with overflows of surface water from lakes and rivers. It also contains more suspended solids than freshwater and therefore has to be handled in order to make it safe to consume. Some motives are mostly for drinking surface waters which are typically polluted by waste, industry and recreation.

1.2 Disinfection By-Products (DBPs):

As previously mentioned, parameters such as disinfectants, water supply properties, water temperature running variables, pH, and the contact period for water in the WTP, as well as the delivery system, all have an effect on DBP output and levels in potable water. For example, coastal water sources are often exposed to saltwater contamination, increasing I-DBPs as well as brominated by-products (Br-DBPs), while chloramines or NAs are usually present in swimming pools, sewage, waste water, and potable water (Figure 2).

Other DBPs present in large concentrations in ultimate drinking water included HNMs, haloacetonitrils (HANs), haloaldehydes and iodo-THMS (I-THMs), as well as higher quantities of THMs and HAAs. Emerging DBPs are more involved in chlorinated water than controlled DBPs, given their uncontrolled nature[5].

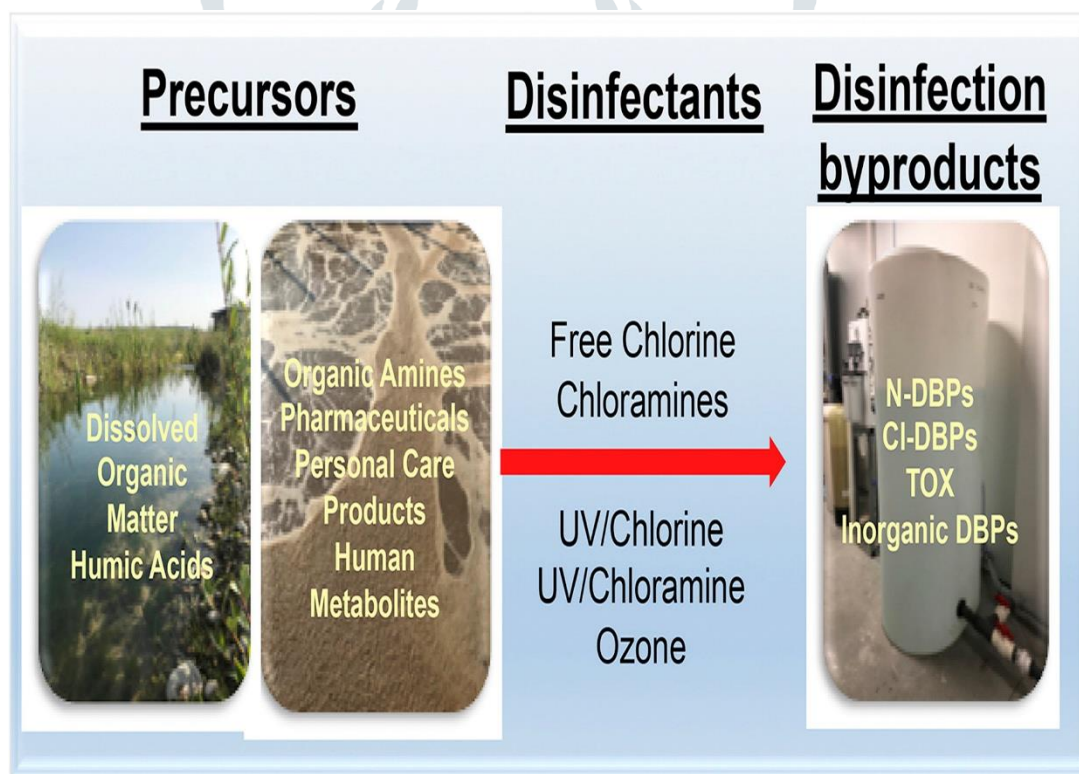


Figure 2: Layout of Disinfection By-Products. Coastal water sources are often exposed to saltwater contamination.

1.3 Emergent Disinfection By-Products (DBPs):

In the past studies, there was research interest among various scholars to find out a fresh category of unregulated DBPs. Aldehydes, HKs, NAs, haloacetamides and I-DBPs are shown (Table 1). A limited knowledge of emerging DBPs shows that in distribution systems as well as drinking water treatment is out of control.

Anthropogenic chemical contaminants are emitted from both residential drainage and industrial sectors. The various among those pollutants interact with decontaminators utilized in the treatment of water to form specific DBPs. Personal care goods, pharmaceuticals, contaminants, synthetic chemicals, estrogens, clothing dyes, antibacterial agents, and ethoxylate surfactants are among the toxins that produce DBPs when combined with decontaminators. The inorganic precursors of DBPs are the ions iodide and bromide [6].

Table 1: The details of Emerging DBPs. Aldehydes, HNMs, HANs, HKs, NAs, haloacetamides, and I-DBPs are few emerging DBPs.

Emerging DBPs	Frequent concentration intervals	Production circumstances
HNMs	0.16 - 1.50 $\mu\text{g/L}$	Produced if before chlorine or chloramine disinfection pre-ozonation is used.
HANs	0.6 - 24 $\mu\text{g/L}$	Produced with chlorination, chlorine dioxide and chloramination during disinfection of water.
Halomethanes (HMs)	1.50 - 7.0 $\mu\text{g/L}$	Generated in a water distribution system without biofilter, which hydrolyses HANs to HMs after chloramination and ozonation.
HKs	1.23 - 8.6 $\mu\text{g/L}$	HK levels shift through the distribution system.
NAs	10 - 90 ng/L	The generation of NAs is induced during chloramination. In the case of nitrosamine precursors, chlorination of nitrite forms NAs.
Aldehydes	-	Trihalogenated organisms are more likely to be formed during chlorination.
I-DBPs	0.54 - 0.9 $\mu\text{g/L}$	Appear when water in the presence of iodide is chlorinated, chloroaminated, or ozonated.

1.4 Procedures for Eliminating Disinfection By-Products (DBPs):

The removal of the NOM is due to the fact that the production of DBPs in drinking water supplied to customers is limited. In general, the treatability of Organic Matter (OM) cannot be predetermined in order to obtain the best match testing procedures. Each group of DBP produced throughout the design phase has a reaction mechanism that involves disinfection. It is therefore suggested that DBP reduction measures must focus on analyzing the precursor in each water source as well as its next generation of DBP. As a consequence, a method that reduces all DBPs is currently not special in water treatment. The use was made of alum, intermediate ozonation (iO_3), powdered activated carbon, ferric sulphate coagulation. These techniques have different efficiencies in the reduction of dissolved organic carbon (DOC)[7].

DBP elimination can be accomplished by a variety of methods, including anion exchange, biological treatment, adsorption, membrane systems, increased coagulation, and AOPs. Two wide-ranging techniques for managing DBPs can be used effectively in adsorption and enhanced coagulation.

The use of air stripping, a low-cost technology for removing THMs, especially in smaller sites or even in hot THMs in large distribution systems, also might reduce volatile DBP. The high distributor constantly improves air stripping performance in the summer when THM production is at its peak, but it is less efficient when brominated THMs are present. However, in contrast to bioactive carbon adsorption, aviation is less effective in reducing DBPs. Air stripping does not contain harmful by-products compared to chloramination and enhanced coagulation. The highest generation of HAA and THM in summer is more effective in both chloramination and enhanced coagulation.

1.4.1 Membrane Technologies Concept:

The membrane is considered as a distinguishing barrier used to isolate molecules through size exclusion and distribution pathways. Membranes are used in various orders and uses according to their characteristics. Some of the membrane methodologies are microfiltration (MF), reverse osmosis (RO), NF, as well as ultra-filtration (UF). Since each membrane methodology does have a single capacity to extract DOC, membrane selection is heavily influenced by water pollutants. DOC rejection is affected by size exclusion or electrostatic repulsion as well as by the DOC aromatic nature by membrane rejection. The major issue with NOM removal membranes continues to be membrane fouling, which limits flow and performance. Accordingly, water is often preprocessed by prior membrane techniques because the use of membrane remediation is not necessary for direct filtration. The use of membrane techniques in water and wastewater treatment has been greatly increased thanks to the benefits of modification using nanomaterials. Many studies have noted that nanoparticles embodying in membranes can minimize membrane fouling. As humic acids are injected into nanoparticles membranes, it is possible to absorb the molecules of humic acid and fill voids between nanoparticles in the surface of the membrane.

1.4.1.1 Nano-filtration (NF):

As a pressurized membrane device, NF appears as an intermediary between RO and UF techniques, with characteristics of both. NF is a low-pressure technology used to eliminate contaminants such as NOMs, organic small molecules, and DBP precursors. It can also be used to provide drinking water in impoverished countries. Similar to RO, both organic and inorganic DBP precursor is simultaneously eliminated. The membrane surface modification is not entirely effective in decreasing fouling, such as grafting hydrophilic monomers.

1.4.1.2 Reverse Osmosis (RO):

RO is indeed a high-pressure process. It is commonly used in the treatment of sewage and wastewater. RO, as is customary, is incapable of removing contaminants. However, in the case of VOCs, THMs, and a variety of other organic and inorganic contaminants, RO setups are less successful. In addition, RO settings may be used to deal with extreme or untreatable sources of water. Before RO considerable water pre-treatment is needed to remove particles as well as colloidal material in order to assure the membrane is retained.

1.4.1.3 Ceramic Membranes:

The capacity of a membrane to sustain a smooth flow and prevent fouling determines its effectiveness. The most common flaw in potable water is NOM. The biggest flaw in potable water is NOM. The flux, pH, ionic strength, hardness, and surface shear of the solution are all important considerations. In general, organic polymers have been developed for most of the membranes used for potable water treatments. However, the emphasis on membranes made from ceramic materials has increased. Ceramic membranes are less brittle than polymeric membranes, and their pathways vary. More prominently, the use of aggressive chemicals to deteriorate polymer equivalents will clean ceramic membranes. Therefore, ceramic membranes with a better efficiency than similar polymeric membranes have been developed. The elimination of the NOM from potable water is stimulated by ceramic membrane. Ceramic membranes' higher cost has restricted their use until recently [8].

1.4.1.4 Ultrafiltration (UF):

UF is a method used in commercial water treatment to save money. UF membranes are made of diverse materials, have massive pores, and have varying surface load densities. They reduce turbidity, suspended solids, and THM precursors, but they are ineffective when dealing with heavy HAA humics and THMs. Even when prepared, the UF membranes can minimize NOMs, and many NOM sections are too small to be effectively preserved by the UF membranes. Charged membranes are usually more sensitive to pH modifications than neutral membranes. Despite the fact that UF membranes can strip laboratory scale DPB precursors, the removal of assimilable organic carbon (AOC), which is usually small molecular compounds, is inefficient. The removal of NOM is easier under alkaline conditions due to the linear configuration and strong molecular ray.

1.4.1.5 Microfiltration (MF):

For highly turbid water, this procedure may be utilized as an initial-treatment stage for RO or NF, or as an independent operation. Unless it is attached to particulates. The membranes of MF are pore-sized and thus inefficient to exclude NOMs than the NOM molecules. In addition, NOM appears to connect pores and settle on a membrane surface, which ultimately causes pore obstacles. The membrane fouling of this kind can thus be managed by the pre-treatment process using coagulation or flocculation.

1.4.2 Enhanced Coagulation:

The coagulation mechanism reduces hydrophobic NOM sections of the water more efficiently due to its lower affinity, high molecular weights, as well as load density. This necessitated additional research to control the coagulation process, mostly for the elimination of total organic carbon (TOC). Particulates and organics can be removed by metal salt coagulants through two routes: charging neutralization and sweeps. Charge neutralization occurs by generating complexes with increased adsorption for multiple charges. For optimum performance, such routes need a particular pH domain. The load-neutralization promotes the connection of metal species with organic material anionic sites. Flocking happens as massive injections of mineral salt coagulants are used, resulting in massive precipitates of hydroxide. The particles are mixed in with the steep and can be "swept out of the water" during sedimentation. The course, however, is determined by the addition of coagulant and the consistency of the water.

If coagulant is applied, the pH of the water reduces, and additives, if necessary, alter the pH. For reducing turbidity, the procedure usually employs greater metal salt injection coagulants. This form of coagulation uses charge-neutralization technologies rather than sweep coagulation and is based on hydrophilic and hydrophobic NOM proportions. However, improved coagulation efficiency is a feature of the injection of the coagulant and the pH.

1.4.3 Ultraviolet (UV)-Founded Technology:

UV is mainly used to destroy and track microbial organisms in water containing protozoans including cryptosporidium and giardia. Since UV treatment cannot be maintained with long-term disinfectants, chlorine or chloramine is used in conjunction with UV radiation to ensure the delivery network's robustness. Ultraviolet disinfection system for treatment of water is shown in figure 3.

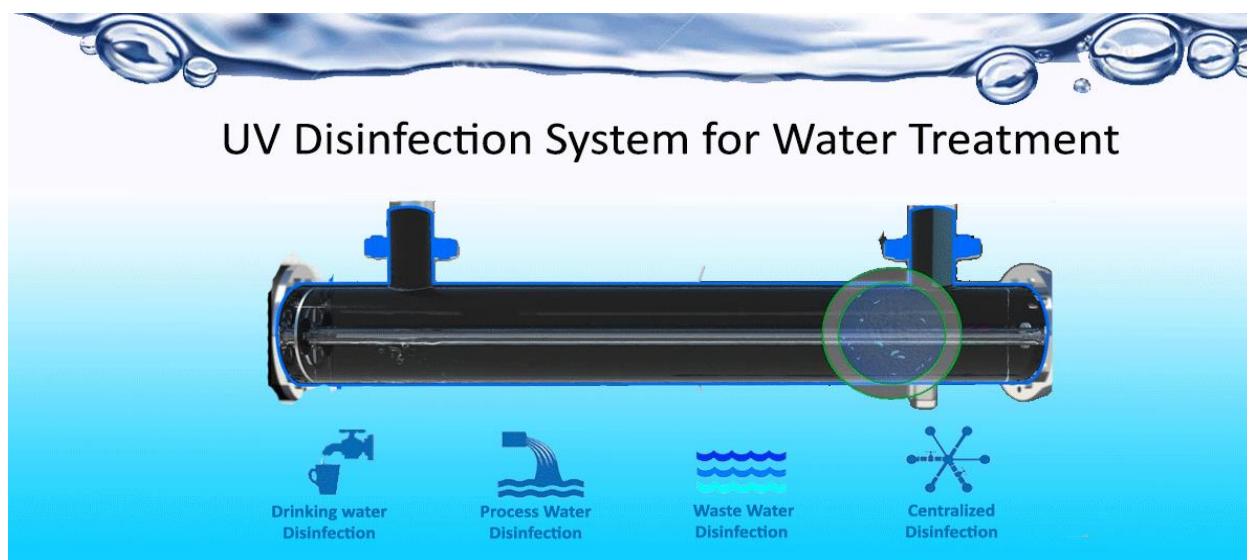


Figure 3: Ultraviolet disinfection system for treatment of water [alfaauv/ UV disinfection system for water treatment].

2. CONCLUSION

For drinking water treatment, disinfection is extremely essential. Its purpose is to destroy micro-organisms which can cause water diseases to ensure the safety of drinking water. Due to the increasing natural and artificial water pollution, the water quality of the fountain head gets worse and worse. DBPs were created to deal with NOM, anthropogenic toxins, bromide and iodide in the drinking water chain at what time disinfectants (chlorine, chloramine and ozone) interact. In addition, the controlled DBPs have been found in many other unregulated DBPs. The components of these new carcinogenic, mutagenic and teratogenic nitrosoamines are highly cancerous. Price is a crucial factor in choosing the technology for water treatment. Evaluating the precursors until they communicate with disinfectants is an effective and economical way of dominating the output of DBPs in WTPs. Balance remains to be sought among high enough remaining chlorine to control water bio-stability and low enough to minimize DBP.

The primary goal of water treatment process is to provide healthy drinking water by ensuring it is free of contaminants and toxins; the second aim is to make it a desirable drink, by removing unnecessary turbidities, tastes, colors and odors. Regarding the primary goal of making water pathogens-free and without harmful substances, it is evident that disinfection is an unmitigated compromise, as the disinfection destroys micro-organisms yet forms DBPs. Therefore, it must be avoided, even if the above cause is water disinfectant, to inject chemical products into water. Instead of chemical treatment, it is urgently required to extract contaminants and organic compounds in such techniques such as physical processes such as distillation and membrane processes.

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