INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 26, No. 3, p. 49-56, 2025
http://www.innspub.net

REVIEW PAPER OPEN ACCESS

DBP levels in India: A review of available data and challenges in monitoring

Monika Yadav[1], Vivek Singh[*1], Amit Kumar Singh[2]

[1]*Department of Botany, Shri Jai Narain Mishra PG College, Lucknow, Uttar Pradesh, India*

[2]*Department of Botany, Lucknow University, Lucknow, Uttar Pradesh, India*

Article published on March 08, 2025

Key words: Water, Disinfection, Chlorine, Disinfection, By-products, India, Challenges

Abstract

Disinfection by-products (DBPs) are the result of the chemical reactions that take place between the disinfectants such as chlorine, chloramines, or ozone and the inorganic reactants in the water during the water treatment processes. One the one hand, disinfection is an important process in killing waterborne pathogens while on the other, the unintended creation of DBPs has turned out to be a serious obstacle to the achievement of water quality and safety goals. The most common DBPs are trihalomethane (THM), haloacetic acids (HAAs), chlorites, and brominated compounds. Each group of these chemicals has a separate formation pathway, yet they are regulated mostly by three factors namely water temperature, pH, and the concentration of chloride, bromide or iodide ions. THMs are the first chemicals which were classified as DBPs followed by HAAs which are equally serious disinfection by-products. The issue of DBPs become an agenda of discussion right from the early 1970s when exposure to chloroform (THMs) was reported to lead to cancer formation in some rats. DBPs are the most likely of the pollutants to exhibit negative health effects in various parts of the body, which includes tumor formation, liver injury, nephropathy as well as reproductive toxicity. To minimize the spread of these pollutants, governmental institutions such as USEPA and WHO have set standards concerning the contamination levels with disinfection by-products in safe drinking water. This review paper takes off with an overview of the DBPs studies in India and ventures into the complications in proper monitoring of DBP levels in India.

***Corresponding Author:** Vivek Singh ✉ viveksingh_2@yahoo.com

Introduction

Chlorination of drinking water contributes enormously to the reduction of associated morbidity and mortality from the diseases due to environmental water source.

Trihalomethanes (THMs) were the first identified chlorinated by-products found in drinking water (Rook, 1974). It is generally thought that a variety of disinfection by-products (DBPs) are produced via reaction of chlorine with organic materials found naturally in water, including fulvic and humic acids. The powerful disinfectant, chlorine, is successful in the inactivation of waterborne pathogens. Water disinfection is an essential process for eliminating pathogenic bacteria and viruses from drinking water, preventing waterborne diseases like cholera and typhoid, and providing the general population with safe drinking water.

The reaction of disinfectants with NOM in treated water generates hundreds or thousands of disinfection byproducts (DBPs). The disinfectant characteristics (e.g., dosage and contact time with water) and the water source properties (e.g., pH, temperature, NOM content, micro-contaminants, and inorganic ions) will affect the type and quantity of DBPs and thereby to the type and quantity of DBPs formed. Furthermore, climate change (e.g., increasing temperature) and the rapidly increasing human population (greater demand for purified drinking water) have led to the intensification of DBPs formation.

Studies show that long-term exposure to DBPs, leads to significant health risks, since they are extremely cytotoxic, mutagenic, and carcinogenic (Clark *et al.*, 1986). Many studies have linked long-term exposure to higher rates of cancer, reproductive problems, and developmental disorders (Costet *et al.*, 2011). DBPs can be divided into three main classes: - aliphatic, alicyclic and aromatic, depending on their chemical structure. DBPs are well-studied, but the details of how they form in treated drinking water remain very much a field of active research. These findings underscore the need to further study DBP's risks — and keep them under control in drinking water.

DBPs generally included the following classes of compounds identified in chlorinated water which could be haloamines, THMs, HAAs, haloacetonitriles (HANs), halodiacids, haloaldehydes, haloketones (HKs), haloamides, halophenols, halobenzoquinones and nitrosamines (Richardson *et al.*, 2010; Chowdhury *et al.*, 2014; Teo *et al.*, 2015). Manasfi *et al.* (2016) reported DBPs in swimming pool of freshwater and seawater and also performed their genotoxicity assessment. A new DBP i.e. 2-bromo-6-chloro-1,4-benzoquinone was reported to be formed by Hu *et al.* (2022) under similar conditions. Long-term exposure to high concentrations of DBPs has been associated with various health risks, including eye, skin, and respiratory irritations (Fantuzzi *et al.*, 2010), reproductive effects (Hinckley *et al.*, 2005), and bladder cancer (Villanueva *et al.*, 2007). Sapone *et al.* (2016) described these changes in the xenobiotic metabolism in *Dreissena polymorpha* exposed to surface water that was treated with different types of disinfectants.

Status of worldwide DBP research

A study in Italy by Righi *et al.* (2011) checked out the amounts of disinfection byproducts (DBPs) in water. They found that trihalomethanes (THMs) were always there, but in small amounts. On average, they saw 2.04 µg/L, with the highest being 26.9 µg/L. Bromate ranged from 2 to 14 µg/L. Chlorite only showed up when chlorine dioxide was used to treat the water, and it varied quite a bit, from 28 to 523 µg/L. Chlorate was the most common DBP, popping up in over 85% of the samples, with levels between 1 and 399 µg/L.

In South Korea, a study by Shin *et al.* (1999) showed that DBP amounts in tap water were usually less than 50 µg/L. THMs made up the biggest chunk (60%) of the total DBPs, with haloacetic acids (HAAs) at 20%, haloacetonitriles (HANs) at 12%, haloketones (HKs) at 5%, and chloropicrin (CP) at 3%. Chloroform surfaced as the most common THM (77%), followed by bromodichloromethane (BDCM, 18%) and bromoform (BF, 3%). A French study from 2000 to 2020 (Lafontaine *et al.*, 2024) saw typical yearly amounts of total THMs at 15.7 µg/L and nitrate at 15.2 mg/L. In Nigeria, Benson *et al.* (2017) checked THM amounts in tap water using gas chromatography. They detected amounts from zero in untreated water to 950 µg/L in disinfected water. In Barcelona, Spain, Redondo-Hasselerharm *et al.* (2024) checked tap water for chlorate, THMs, HAAs, and HANs. They found them in almost every sample (98–100%), with typical amounts of 214, 42, 18, and 3.2 µg/L, respectively. In a U.S. study, Krasner *et al.* (2006) checked 12 water treatment plants and found over 50 important DBPs, including iodinated THMs, haloacids, and other halogenated things. In China, Hu *et al.* (2013) mentioned DBP levels in raw water from 14 to 100 µg/L.

Limits of various DBPs have been changing around the world with changes in their levels and discovery of newer chemicals. Since 1979, the U.S. EPA has had a THM limit of 100 µg/L under the Safe Drinking Water Act, which was later lowered to 80 µg/L. Other limits are 60 µg/L for haloacetic acids and 10 µg/L for bromate (Wang *et al.*, 2024). Canada's THM guideline, which is now 350 µg/L, is being looked at, and they might lower it to 50–100 µg/L (Health and Welfare Canada, 1992). These amounts are close to Australian guidelines of total allowed DBPs limits of 250 µg/L (Australian Water Association, 2021). In Europe, DBP limits are strict. For example, Germany has a THM guideline of 10 µg/L, and the EC's standard of 100 µg/L is being reviewed now.

Status of DBP levels in India

Compared to other countries, India is just starting to keep tabs on DBPs (disinfection by-products) levels. THMs (trihalomethanes) are the DBPs that are most talked about in India, with HAAs (haloacetic acids) coming in second. Most DBP studies have been done in north India. Since we do not have much data from other areas, it's hard to comment on the commenality between DBPs all over India. Back in 1996, Thacker *et al.* reported DBPs in the drinking waters of big cities such as Agra, Ahmedabad, Bombay, Calcutta, Delhi, Goa, Guna, Kanpur, Madras, and Nagpur. Then, in 1997, Srikanth looked into Chloroform levels in Hyderabad's city water. He also studied the Residual Chlorine in water and established a negative correlation between distance of supply and concentration of available free chlorine.

In 2002, Thacker *et al.* published a study which they had conducted from 1995 to 1996 in Mumbai for 4 water treatment plants. They have reported values of Trihalomethane Formation Potential (TFP) to be as high as 254 µg /L. Sharma and Goel (2007) presented their finding for Gangtok in Sikkim and reported much lower values of DBPs than other cities of India. In Uttar Pradesh, Kanpur showed a highest level of 259.64 µg /L (Mishra and Dixit, 2013), Lucknow reported a highest value 74.12 µg /L (Singh et al, 2012) whereas Tak and Vellanki (2019) obtained the levels of Chloroform and other Tri Halo Methanes in WTPs of Mathura and Agra between the range of 52.4 and 107 µg /L.

One thing that was common in studies of various water treatment plants was that the concentrations of DBPs reached their highest values in post monsoon tests. Clearly, a heavier dose of chlorination was used to control water borne diseases in and after the monsoon season (CPCB, 2011). Similar results were obtained by different researches, e.g., in 2011, Mishra and coworkers, found DBP levels as high as 594 µg/L in Jharkhand and West Bengal water plants. Kumari et al, saw levels of 511 µg/L in 2015 in Eastern parts of the country.

Nisha and coworkers checked Gwalior's water in 2013 and their DBP levels ranged from 0.13 to 16.2 µg/L. High DBP levels have been reported by various workers from time to time, e.g., New Delhi (377 µg/L) by Hasan *et al.* (2010), Ranchi (236 µg/L), Dhanbad (503 µg/L), and Durgapur (255 µg/L) by Minashree (2014), Bokaro (594 µg/L) by Mishra *et al.* (2014), Varanasi (380.9 µg/L) by Kumari and Gupta (2014), Raipur (324.3 µg/L), Bhubaneswar (319.7 µg/L), and Kolkata (466 µg/L) by Mahato and Gupta (2020).

Studies of Basu *et al.* (2011) and Kumari and Gupta (2015) have compared the tap water and river water for concentration of DBPs like Chloroform. Where the chloroform concentration values in the tap water were 3.92 and 533 µg /L, the river water data was between 223–461 µg /L. This proved that in most cases surface water has higher concentrations of DBPs than ground water. A comparative study done by Furst *et al.* (2019) also concluded that upon equal chlorination, surface waters develop higher amounts of DBPs than ground waters. Singh *et al.* (2012) attribute this observation to higher levels of pre-existing organic matter in surface water which produces higher levels of DBPs than ground water.

Besides Haloacetic Acids and Tri Halo Methanes, other DBPs have also been reported by some workers, e.g., Selvam *et al.* (2018), has reported 4-bromo-2-chlorophenol in the municipal water Tiruchirappalli. Similarly, Furst *et al.* (2019) have detected the presence of Halo Acetyl Nitriles, Halo Acetyl Methanes and Haloacetaldehydes in the water samples collected from Jaipur and Jodhpur.

Challenges for DBP monitoring in India

Ineffective guidelines and gaps in monitoring requirement

Firstly, there are no stringent laws that make it mandatory, for industries as well as water treatment facilities, to monitor Disinfection By products like other chemicals, heavy metals and microbiological load. It is evident that most countries of the West have formulated strict limits for various DBPs. This regulatory framework is mostly lacking in Indian setup. Bureau of Indian Standards (BIS) has established limits of only a few common DBPs but even those seem to be out-dated or comprehensively inadequate for majority of DBPs. Serious gaps in these regulations, often allow concerned agencies to overlook DBP levels while addressing water quality issues. Monitoring of DBP levels is still not a mandatory requirement for majority of industries and water treatment facilities. Thus, in absence of any legal binding, these chemicals are not regularly checked. This saves a lot of money and time and is therefore favourable option for most. The consumers are also mostly unaware of the high risks that these chemicals are posing to their health and often do not care about them.

Lack of standardized protocols

Since there are no set limits for most of the DBPs except a few, standard protocols for their testing are also non-existent. Methods and protocols borrowed from the west are still much in use for academic purposes only. However, these protocols also do not serve the exact position as the conditions of formation, precursors and types of DBPs may be very different from other countries. Thus standardization to suit the local needs has to be there. Even in case of common DBPs like THMs and HAAs, the testing is often not done, given the absence of advanced testing equipment and expert personnel are unavailable.

Cost and infrastructure for detection of DBPs

In countries like India, cost of advanced analytic techniques required for DBP testing poses a major challenge. Purchase and maintenance of equipment like High Performance-Liquid Chromatography (HPLC), Gas Chromatography-Mass Spectroscopy (GC-MS) and Biosensors is beyond the budget of most government water treatment facilities. Together with this required chemicals and trained manpower is also difficult to acquire in an already fund scarce setup. While some bigger cities have better water testing facilities, smaller cities and towns still lack even basic water testing facilities leave alone DBP testing. Government is still trying to provide safe drinking water to vast majority of population where disinfection seems to be the only solution. Stringent laws on DBPs would make this task even more difficult. This reluctance causes gaps in effective monitoring of DBP levels across India.

Large number of DBPs

At present, there are more than 700 types of DBPs that have been discovered. Each of these needs a specific methodology of detection and removal. A single test that can fit all is not possible and testing water for 700 types of chemicals is also not a feasible option especially in countries like India. It is however a proven fact that the biggest chunk of DBPs, are only a few one but this does not exempt others as safe. Some DBPs like nitrosamines can be highly carcinogenic even at very low levels while some can be much less damaging even at higher concentrations. Thus without sufficient data, it will be difficult to prioritize different DBPs for proper monitoring. Lastly, India is a diverse land in terms of temperature, seasons, humidity; microflora etc. so different regions may have difference in levels of various DBPs. Hence any policy cannot be treated as a perfect fit for all areas. It has to be developed on local basis and after sufficient data availability.

Conclusion

Disinfection By-Products pose a serious concern in the government effort of providing safe drinking water to the entire population of India. Given the history of water borne disease in India, Chlorination appears like a panacea for making the water safe for drinking. But discovery of the DBPs and the fact that they can have serious health risks has put a question mark on the safety levels and quality of water being supplied to public. Whatever data is available on the levels of DBPs in India, has mostly been collected by researchers on the basis of random researches. A systematic data for the entire country for a long period is needed for proper formulation of directives. This is impossible without government initiatives.

It can also be seen that in majority of cases the levels of DBPs in reported data is much less than that of the West. This is perhaps a case of poor monitoring and faulty data collection and analysis techniques. This lack of confidence in the available data is major hurdle in planning of a comprehensive DBP management programme in India. Adding to the problem are new and emerging DBPs which are often in low concentrations but have been reported to highly toxic, e.g., Nitrogen and Bromine based DBPs.

An effective strategy in management of DBPs focuses on removal of precursor compounds from water before disinfection. Monitoring is also very essential at all levels of water treatment like pre-chlorination, chlorination, filtration, post-chlorination etc. This will enable us to understand the mechanism of formation of all types of DBPs and allow us to formulate efficient strategies for treatment.

India is vast and so are its challenges including water quality. Besides so many other pollutants which are easier to detect and remove, DBP detection and removal is much more difficult. Obsolete testing facilities, extreme seasonal variation, poor water quality, heavy pollution load and indiscriminate use of disinfectants like bleaching powder and chlorine make it challenging to control DBPs. India has to strike a balance between microbial disinfection and safety from chemicals. There is no way except to invest in advanced technologies and ensure source water protection. Use of better disinfection methods like UV sterilization and ozonation may also be considered as alternatives for Chlorination.

Finally, a multi-faceted approach can help India in tackling the issue of DBPs. Building up of a strong regulatory framework, introducing innovative disinfection methods, enforcing mandatory monitoring, provision of infrastructure for monitoring as well as public awareness, are prerequisites in this task. This integrated strategy can help India ensure its commitment for safe drinking water to all its citizens.

Acknowledgements

One of the authors (Ms. Monika Yadav) is thankful to UGC-CSIR for providing financial assistance to her in form of Junior Research Fellowship.

References

Basu M, Gupta SK, Singh G, Mukhopadhyay U. 2011. Multi-route risk assessment from trihalomethanes in drinking water supplies. Environmental Monitoring and Assessment **178**, 121-134.

Benson NU, Akintokun OA, Adedapo AE. 2017. Disinfection byproducts in drinking water and evaluation of potential health risks of long-term exposure in Nigeria. Journal of Environmental and Public Health **2017**, 1-10.

Bureau of Indian Standards. 2012. Indian standard: drinking water—specification (Second Revision) IS 10500.

Chowdhury S, Alhooshani K, Karanfil T. 2014. Disinfection byproducts in swimming pool: Occurrences, implications and future needs. Water Research **53**, 68–109.

Clark RM, Goodrich JA, Deininger RA. 1986. Drinking water and cancer mortality. Science of The Total Environment **53**, 153-172.

Costet N, Villanueva CM, Jaakkola JJK, Kogevinas M, Cantor KP, King WD, Lynch CF, Nieuwenhuijsen MJ, Cordier S. 2011. Water disinfection by-products and bladder cancer: is there a European specificity? A pooled and meta-analysis of European case-control studies. Occupational Environmental Medicine **68**(5), 379–385.

Edition F. 2011. Guidelines for drinking-water quality. WHO Chronicle **38**, 104-108.

Fantuzzi G, Righi E, Predieri G, Giacobazzi P, Mastroianni K, Aggazzotti G. 2010. Prevalence of ocular, respiratory and cutaneous symptoms in indoor swimming pool workers and exposure to disinfection by-products (DBPs). International Journal of Environmental Research on Public Health **7**, 1379–1391.

Furst KE, Coyte RM, Wood M, Vengosh A, Mitch WA. 2019. Disinfection byproducts in Rajasthan, India: Are trihalomethanes a sufficient indicator of disinfection byproduct exposure in low-income countries? Environmental Science Technology **53**(20), 12007-12017.

Hasan A, Thacker NP, Bassin J. 2010. Trihalomethane formation potential in treated water supplies in urban metro city. Environment Monitoring & Assessment **168**, 489-497.

Hinckley AF, Bachand AM, Reif JS. 2005. Late pregnancy exposures to disinfection byproducts and growth-related birth outcomes. Environmental Health Perspectives **113**, 1808–1813.

Hu SY, Chen X, Zhang BB, Liu LY, Gong TT, Xian QM. 2022. Occurrence and transformation of newly discovered 2-bromo-6-chloro-1,4-benzoquinone in chlorinated drinking water. Journal of Hazardous Material **436**, 129-189.

Hu X, Shi W, Wei S, Zhang X, Feng J, Hu G, Chen S, Giesy JP, Yu H. 2013. Occurrence and potential causes of androgenic activities in source and drinking water in China. Environmental Science Technology **47**, 10591–10600.

Krasner SW, Weinberg HS, Richardson SD, Pastor SJ, Chinn R, Sclimenti MJ, Onstad GD, Thruston AD. 2006. Occurrence of a new generation of disinfection byproducts. Environmental Science & Technology **40**(23), 7175-7185.

Kumari M, Gupta SG. 2014. Factors influencing the formation of trihalomethanes in drinking water supplies. In: Strategic Technologies of Complex Environmental Issues - A Sustainable Approach, 225.

Kumari M, Gupta SK. 2015. Modeling of trihalomethanes (THMs) in drinking water supplies: A case study of eastern part of India. Environmental Science and Pollution Research **22**, 12615-12623.

Lafontaine A, Lee S, Jacquemin B, Glorennec P, Le Bot B, Verrey D, Goldberg M, Zins M, Lequy E, Villanueva CM. 2024. Chronic exposure to drinking water nitrate and trihalomethanes in the French CONSTANCES cohort. Environmental Research **259**, 119-157.

Mahato JK, Gupta SK. 2020. Modification of Bael fruit shell and its application towards natural organic matter removal with special reference to predictive modelling and control of THMs in drinking water supplies. Environmental Technology & Innovation **18**, 100666.

Manasfi T, De Méo M, Coulomb B, Di Giorgio C, Boudenne JL. 2016. Identification of disinfection by-products in freshwater and seawater swimming pools and evaluation of genotoxicity. Environmental International **88**, 94–102.

Mishra ND, Dixit SC. 2013. Trihalomethanes formation potential in surface water of Kanpur, India. Chemical Science Transactions **2**, 821-828.

Nisha U, Jain RK, Saxena AK, Shrivastava PK, Mahesh P. 2013. Study on formation of trihalomethanes (THMs) in potable treated water of Gwalior City, Madhya Pradesh, India. Journal of Engineering, Computers & Applied Sciences **2**(11), 10-13.

Redondo-Hasselerharm PE, Cserbik D, Flores C, Farré MJ, Sanchís J, Alcolea JA, Planas C, Caixach J, Villanueva CM. 2024. Insights to estimate exposure to regulated and non-regulated disinfection by-products in drinking water. Journal of Exposure Science & Environmental Epidemiology **34**, 23–33.

Richardson SD, DeMarini DM, Kogevinas M, Fernandez P, Marco E, Lourencetti C, Balleste C, Heederik D, Meliefste K, McKague AB, Marcos R, Font-Ribera L, Grimalt JO, Villanueva CM. 2010. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. Environmental Health Perspectives **118**(11), 1523–1530.

Richardson SD, Ternes TA. 2011. Water analysis: emerging contaminants and current issues. Analytical Chemistry **83**(12), 4614-4648.

Righi E, Giacobazzi P, Predieri G, Mastroianni K, Fantuzzi G, Aggazzotti G. 2011. Occurrence of disinfection by-products (DBPs) in drinking water in different Italian northern regions. Epidemiology **22**, 91-110.

Rook JJ. 1974. Formation of haloforms during chlorination of natural waters. Journal of Water Treatment Examination **23**, 234–243.

Sapone A, Canistro D, Vivarelli F, Paolini M. 2016. Perturbation of xenobiotic metabolism in *Dreissena polymorpha* model exposed in situ to surface water (Lake Trasimene) purified with various disinfectants. Chemosphere **144**, 548–554.

Sharma RN, Goel SUDHA. 2007. Chlorinated drinking water, cancers and adverse health outcomes in Gangtok, Sikkim, India. Journal of Environmental Science and Engineering **49**, 247.

Shin D, Chung Y, Choi Y, Kim J, Park Y, Kum H. 1999. Assessment of disinfection by-products in drinking water in Korea. Journal of Exposure Science & Environmental Epidemiology **9**, 192–199.

Simpson KL, Hayes KP. 1998. Drinking water disinfection by-products: an Australian perspective. Water Research **32**(5), 1522-1528.

Singh KP, Rai P, Pandey P, Sinha S. 2012. Modelling and optimization of trihalomethanes formation potential of surface water (a drinking water source) using Box–Behnken design. Environmental Science and Pollution Research **19**, 113-127.

Srikanth R. 1997. Chloroform levels in the drinking water of Hyderabad City, India. Environmental Monitoring and Assessment **2**, 195-199.

Tak S, Vellanki BP, Ahuja S. 2020. A review on disinfection and disinfection by-products. In: Contaminants in Our Water: Identification and Remediation Methods. ACS Symposium Series, 105-117.

Teo TLL, Coleman HM, Khan SJ. 2015. Chemical contaminants in swimming pools: occurrence, implications and control. Environmental International **76**, 16–31.

Thacker NP, Kaur P, Rudra A. 2002. Trihalomethane formation potential and concentration changes during water treatment at Mumbai (India). Environmental Monitoring and Assessment **73**, 253-262.

Thacker NP, Vaidya MV, Sipani M, Kaur P, Rudra A. 1996. Water systems and organohalide contaminants. In: 22nd Water Engineering and Development Center Conference, New Delhi, September 9–13, Proceedings **2**, 361–362.

Villanueva CM, Cantor KP, Grimalt JO, Malats N, Silverman D, Tardon A, Garcia-Closas R, Serra C, Carrato A, Castaño-Vinyals G, Marcos R, Rothman N, Real FX, Dosemeci M, Kogevinas M. 2007. Bladder cancer and exposure to water disinfection by-products through ingestion, bathing, showering, and swimming in pools. American Journal of Epidemiology **165**(2), 148–156.

Wang J, McNally MG, Ulibarri N, Gim C, Olson VA, Feldman DL. 2024. State-level regulation of disinfection by-products in the United States. Water Policy **26**(10), 1056–1068.