

SURBHI TAK

Postdoctoral Researcher

Department of Energy & Environment

Sejong University, Seoul, South Korea

E-mail: surbhitak92@gmail.com Phone: +91-9760899996 DOB: 30/07/1992

Education:

| Degree | Field | University | Institute | Year | CGPA/% |
|---------------|--|--------------------------|--------------------------------|------|--------|
| Doctorate | Environmental Engineering | IIT Roorkee | IIT Roorkee | 2020 | - |
| M.Tech | Environmental Management of Rivers & Lakes | IIT Roorkee | IIT Roorkee | 2015 | 8.78 |
| B.Tech | Biotechnology | DCRUST, Murthal, Haryana | DCRUST, Murthal, Haryana | 2013 | 8.55 |
| Intermediate | 12 th | CBSE | D.A.V. Centenary Public School | 2009 | 88.0 |
| Matriculation | 10 th | CBSE | D.A.V. Centenary Public School | 2007 | 91.1 |

Areas of Interests:

- Environmental science & engineering
- Drinking water and wastewater treatment
- Analytical Environmental chemistry
- Emerging contaminants: Analysis and removal
- Environmental monitoring & assessment
- Environmental biotechnology
- Environmental sustainability & management

Work Experience:

1. **Postdoctoral fellow**, Department of Energy & Environment, Sejong University, Seoul, South Korea (Feb 2021-present)
2. **Research Intern**, Department of Biotechnology, PGIMS Rohtak, India (May–Aug 2012)

PhD Research:

Title: Natural and effluent derived organic matter removal using synergy of advanced oxidation and biofiltration processes

Supervisor: Dr. Bhanu Prakash Vellanki, Department of Civil Engineering, IIT Roorkee, Uttarakhand, India

Abstract:

Disinfection of treated effluent water is a critical final step in any drinking water treatment plant. The reaction of the widely used disinfectant, chlorine, with the natural organic matter and effluent organic matter (NefOM), from anthropogenic activities around the catchment, leads to formation of unwanted disinfection byproducts (DBPs). Major fraction of the DBPs are trihalomethanes (THMs), which are regulated in drinking water. Many studies have reported their carcinogenicity. NefOM, which are precursors to DBP formation, can be partially oxidized by advanced oxidation processes (AOPs), followed by degradation of the simpler and more biodegradable compounds by biological activated carbon (BAC) treatment, allowing for economical treatment.

Masters Research:

Title: Analysis of disinfection systems for wastewater treatment with special reference to trihalomethanes

Supervisor: Prof. Arun Kumar, Department of Hydro and Renewable energy, IIT Roorkee, Uttarakhand, India

Abstract:

Apart from numerous other well-known drawbacks of chlorination, viz., onsite operational hazards, residual chlorine toxicity, trihalomethanes (THM) formation is the major factor that came into limelight in the last 40 years, primarily in drinking water treatment industry. Treated effluent from wastewater treatment plants are also chlorinated and then discharged, indirectly coming in human contact, so there is need to consider THM as a potable as well as wastewater parameter. In this study, THMs were identified in seven sewage treatment plants (STPs) in North India. STPs were selected based on treatment technology employed viz. up-flow anaerobic sludge blanket (UASB), activated sludge process (ASP), sequential batch reactor (SBR) and oxidation pond (OP). THM concentrations obtained at all the seven STPs were below BIS standards of drinking water (0- 40µg/L). UASB plant shows considerably higher concentration of THM. UV followed by chlorination is suggested as an alternative to chlorination. Per MLD capital and operation & maintenance (O&M) cost of UV Disinfection was analyzed revealing decreasing

per MLD capital cost of UV with increasing plant capacity. The comparative annual O&M cost analysis of chlorination, de-chlorination and UV disinfection shows that there is up to 63% reduction of the total annual O&M cost by UV in comparison to chlorination, whereas in the case of chlorination followed by de-chlorination, total reduction is 71%.

Technical Skills and knowledge

- Environmental science: Potable water and wastewater treatment, characteristics and microbiology of wastewater, unit processes, biological wastewater treatment; advanced oxidation processes
- Environmental Engineering: Wastewater engineering and design; environmental impact assessment; aquatic ecology, water resource engineering and management, environmental planning, and management
- Environmental Chemistry: Analytical environmental chemistry, chemical processes occurring in environmental system, emerging contaminant analysis and removal.
- Introductory Biology: Basics of biology, microbiology, genetics, cell biology, biochemistry, bioprocess engineering, immunology, molecular biology etc.
- Environmental Biotechnology: Biofiltration for the removal of emerging chemical as well as biological contaminants
- **Instrumental Expertise and Lab development:** Gas chromatography-Mass spectrometry (GC-MS), Ion chromatography (IC), Total organic carbon (TOC) analysis, High pressure liquid chromatography (HPLC), QToF- MS, UV spectrometry, Fluorescence spectroscopy, FEEM-PARAFAC, FTIR etc.

List of Publications:

Publications in SCI-indexed Journals/Book Chapters:

1. **Tak, S., Han, S.J., YK Lee., Cho, J., & Hur, J. (2021).** Exploring applicability of end member mixing approach for predicting environmental reactivity of dissolved organic matter. *Environmental Pollution* (**SCI, Q1, IF:8.1**).
2. **Tak, S., & Vellanki, B. P. (2020),** Comparison of O₃- BAC, UV/H₂O₂-BAC, and O₃/H₂O₂-BAC treatments for limiting the formation of disinfection byproducts during drinking water treatment in India, *Journal of Environmental Chemical Engineering*, 104434. (**SCI, Q1, IF: 5.9**)
3. **Tak, S., & Vellanki, B. P. (2019).** Applicability of advanced oxidation processes in removing anthropogenically influenced chlorination disinfection byproduct precursors in a developing country, 186, *Ecotoxicology and Environmental safety*. (**SCI, Q1, IF: 6.3**)
4. **Tak, S., Tiwari, A., & Vellanki, B. P. (2020).** Identification of emerging contaminants and their transformation products in a moving bed biofilm reactor (MBBR)-based drinking water treatment plant around River Yamuna in India. *Environmental Monitoring and Assessment*, 192, 1-23 (**SCI, Q2, IF:2.5**).
5. **Tak, S., & Vellanki, B. P. (2018).** Natural organic matter as precursor to disinfection byproducts and its removal using conventional and advanced processes: state of the art review. *Journal of Water and Health*, 16(5), 681-703. (**SCI, Q2, IF: 1.7**)
6. **Tak, S., & Kumar, A. (2017).** Chlorination disinfection by-products and comparative cost analysis of chlorination and UV disinfection in sewage treatment plants: Indian scenario. *Environmental Science and Pollution Research*, 24(34), 26269-26278. (**SCI, Q1, IF: 4.2**)
7. **Tak, S., & Kumar, A. (2018).** Trihalomethanes Occurrence in Chlorinated Treated Effluents at Sewage Treatment Plants of North-Indian Region. In *Advances in Waste Management* (pp. 279-288). Springer, Singapore.
8. **Tak, S., Vellanki, B.P. & Ahuja, S. (2020).** A review on disinfection and disinfection byproducts. In *Contaminants in Our Water: Identification and Remediation Methods*. January 1, 2020, 105-117.

Conference Publications

1. **Tak, S., & Vellanki, B. P. (2019).** Reduction of chlorination disinfection byproduct precursors by the synergy of advanced oxidation and biofiltration processes. AGUFM, 2019, H43L-2212.
2. **Tak, S., & Vellanki, B. P. (2019, March).** Identification of disinfection byproducts and its precursors in River Yamuna in India: First case study of the situation. In *Abstracts Of Papers Of The American Chemical Society* (Vol. 257). 1155 16TH ST, NW, Washington, Dc 20036 USA: Amer Chemical Soc.
3. **Tak, S., & Vellanki, B. P. (2018)** Identification of trihalomethanes (THM) in Indian drinking water treatment plants and their relationship with NOM characteristics, International Conference on desalination, NIT, Trichy, India.
4. **Tak, S., & Kumar, A.** Trihalomethane occurrence in treated effluents of sewage treatment plants, International conference on waste management, Recycle, 2016, IIT Guwahati, Guwahati.

Conference Presentations

1. **Tak, S., & Vellanki, B. P. (2019)** Reduction of chlorination disinfection byproduct precursors by the synergy of advanced oxidation and biofiltration processes, *AGU Fall Meet 2019*, 9th-13th Dec 2019, San Francisco, CA, USA
2. **Tak, S., & Vellanki, B. P. (2019)** Identification of disinfection byproducts and its precursors in River Yamuna in India: First case study of the situation” *ACS National meeting and exposition*, 31 March - 4th April 2019, Orlando, Florida, USA
3. **Tak, S., & Vellanki, B. P. (2018)** Identification of trihalomethanes (THM) in Indian drinking water treatment plants and their relation with NOM characteristics, *International Conference on desalination, NIT, Trichy, India. (Best paper award)*.

4. **Tak, S., & Vellanki, B. P. (2018)** Trihalomethane identification and NOM characterization in Indian drinking water treatment plant. *ACS on campus*, IIT Roorkee, India.
5. **Tak, S., & Vellanki, B. P. (2017)**, Trihalomethane identification in Indian drinking water treatment plants and removal of natural organic matter using UV based advanced oxidation processes, *IUVA Symposium: UV Technology Advancement for Water Environment at NUS, Singapore*.
6. **Tak, S., & Kumar, A (2016)**. Trihalomethane occurrence in treated effluents of sewage treatment plants, International conference on waste management, *Recycle, 2016, IIT Guwahati*, Guwahati. (**Best paper award**)
7. **Tak, S., & Kumar, A (2015)**. Analysis of disinfection system for wastewater treatment with special reference to trihalomethanes formed during chlorination. *National seminar on Ganga rejuvenation*, NIH, Roorkee (December, 2015).

Research Projects:

1. **Removal of disinfection byproducts from drinking water treatment plants in India** (Jan 2016-Jun2018), sponsored by NBCC, India (Research fellow)
2. **Fate and management of emerging contaminants:** Analysis of emerging contaminants (>300) in Agra and Mathura water treatment plants. (Research fellow)
3. **Analysis of trihalomethanes in wastewater treatment plants** supported by National Ganga River Basin Authority (NGRBA), Govt. of India and Central Pollution Control Board (CPCB), Govt. of India. (Jul-Dec 2014) with Prof. Arun Kumar, Department of Hydro and Renewable Energy, IIT Roorkee (Student Research associate)
4. **Conservation of water in Industries** (Aug-October 2014) (Student Research associate)

Awards and Achievements:

1. Received **CSIR student travel grant** for attending AGU Fall Meet 2019.
2. Received **AGU student travel grant award** by American Geophysical Union.
3. Received **IITR Dean of Resources and Alumni Affairs (DORA) Travel support** for attending *ACS National Meeting & Exposition 2019*.
4. Won the **Best Paper award 2018**, at InDACon, NIT Trichy.
5. Won the **Best Paper award 2016**, at Recycle, IIT Guwahati
6. GATE: AIR 367
7. **MHRD** Scholarship for MTech and PhD
8. Laureate certificate by DAV college management committee March 2007

References:

Dr. Arun Kumar PhD
Professor and MNRE Chair Professor,
Department of hydro and renewable energy,
Indian Institute of Technology Roorkee, Roorkee - 247 667,
Uttarakhand, India
Phone : Off.(+91 1332) 285821; Res. 285051,Fax : (+91 1332) 273517, 273560 E-mail : aheciitr.ak@gmail.com,
arun.kumar@hre.iitr.ac.in

Dr. Bhanu Prakash Vellanki PhD
Assistant Professor,
Department of Civil Engineering
Indian Institute of Technology, Roorkee, Roorkee-247667,
Uttarakhand, India
Phone: Off.(+91 1332 28 4832) E-mail:
bhanuprakashv@ce.iitr.ac.in;
bhanuprakashvellanki@gmail.com

List of Publications

Publications in peer reviewed SCI-indexed Journals:

1. Tak, S., Han, S. J., Lee, Y. K., Cho, J., & Hur, J. (2021). Exploring applicability of end member mixing approach for predicting environmental reactivity of dissolved organic matter. *Environmental Pollution*, 290, 118044. **SCI, Q1, IF:8.1**
2. Tak, S., & Vellanki, B. P. (2020). Comparison of O₃-BAC, UV/H₂O₂-BAC, and O₃/H₂O₂-BAC treatments for limiting the formation of disinfection byproducts during drinking water treatment in India. *Journal of Environmental Chemical Engineering*, 8(5), 104434 (**SCI, Q1, IF: 5.9**).
3. Tak, S., Tiwari, A., & Vellanki, B. P. (2020). Identification of emerging contaminants and their transformation products in a moving bed biofilm reactor (MBBR)–based drinking water treatment plant around River Yamuna in India. *Environmental Monitoring and Assessment*, 192, 1-23 (**SCI, Q2, IF:2.5**).
4. Tak, S., & Vellanki, B. P. (2019). Applicability of advanced oxidation processes in removing anthropogenically influenced chlorination disinfection byproduct precursors in a developing country. *Ecotoxicology and environmental safety*, 186, 109768. (**SCI, Q1, IF: 6.3**).
5. Tak, S., & Vellanki, B. P. (2018). Natural organic matter as precursor to disinfection byproducts and its removal using conventional and advanced processes: state of the art review. *Journal of Water and Health*, 16(5), 681-703. (**SCI, Q2, IF: 1.7**).
6. Tak, S., & Kumar, A. (2017). Chlorination disinfection by-products and comparative cost analysis of chlorination and UV disinfection in sewage treatment plants: Indian scenario. *Environmental Science and Pollution Research*, 24(34), 26269-26278. (**SCI, Q1, IF:4.2**).

Book Chapters:

1. Tak, S., & Kumar, A. (2018). Trihalomethanes Occurrence in Chlorinated Treated Effluents at Sewage Treatment Plants of North-Indian Region. In *Advances in Waste Management* (pp. 279-288). Springer, Singapore.
2. Tak, S., Vellanki, B. P., & Ahuja, S. (2020). A Review on Disinfection and Disinfection Byproducts. In *Contaminants in Our Water: Identification and Remediation Methods* (pp. 105-117). American Chemical Society.

Conference Publications/proceedings

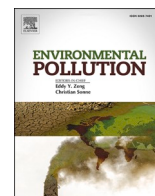
1. Tak, S., & Vellanki, B. P. (2019). Reduction of chlorination disinfection byproduct precursors by the synergy of advanced oxidation and biofiltration processes. AGUFM, 2019, H43L-2212.
2. Tak, S., & Vellanki, B. P. (2019, March). Identification of disinfection byproducts and its precursors in River Yamuna in India: First case study of the situation. In *Abstracts Of*

Papers Of The American Chemical Society (Vol. 257). 1155 16TH ST, NW, Washington, Dc 20036 USA: Amer Chemical Soc.

3. Tak, S., & Vellanki, B. P. (2018) Identification of trihalomethanes (THM) in Indian drinking water treatment plants and their relation with NOM characteristics, International Conference on desalination, NIT, Trichy, India.
4. Tak, S., & Kumar, A. Trihalomethane occurrence in treated effluents of sewage treatment plants, International conference on waste management, Recycle, 2016, IIT Guwahati, Guwahati.
5. Tak, S., & Kumar, A (2015). Analysis of disinfection system for wastewater treatment with special reference to trihalomethanes formed during chlorination. *National seminar on Ganga rejuvenation*, NIH, Roorkee.

Conference Oral/poster Presentations

1. Tak, S., & Vellanki, B. P. (2019) Reduction of chlorination disinfection byproduct precursors by the synergy of advanced oxidation and biofiltration processes, *AGU Fall Meet 2019*, 9th-13th Dec 2019, San Francisco, CA, USA (Poster)
2. Tak, S., & Vellanki, B. P. (2019)) Identification of disinfection byproducts and its precursors in River Yamuna in India: First case study of the situation” *ACS National meeting and exposition*, 31 March - 4th April 2019, Orlando, Florida, USA (Oral)
3. Tak, S., & Vellanki, B. P. (2018) Identification of trihalomethanes (THM) in Indian drinking water treatment plants and their relation with NOM characteristics, *International Conference on desalination, NIT, Trichy*, India. (Oral, **Best paper award**)
4. Tak, S., & Vellanki, B. P. (2018) Trihalomethane identification and NOM characterization in Indian drinking water treatment plant. *ACS on campus*, IIT Roorkee, India (Poster).
5. Tak, S., & Vellanki, B. P. (2017), Trihalomethane identification in Indian drinking water treatment plants and removal of natural organic matter using UV based advanced oxidation processes, *IUVA Symposium: UV Technology Advancement for Water Environment at NUS, Singapore* (Poster).
6. Tak, S., & Kumar, A (2016). Trihalomethane occurrence in treated effluents of sewage treatment plants, International conference on waste management, *Recycle, 2016, IIT Guwahati*, Guwahati. (Oral, **Best paper award**)
7. Tak, S., & Kumar, A (2015). Analysis of disinfection system for wastewater treatment with special reference to trihalomethanes formed during chlorination. *National seminar on Ganga rejuvenation*, NIH, Roorkee (Oral).



Exploring applicability of end member mixing approach for predicting environmental reactivity of dissolved organic matter[☆]

Surbhi Tak, So-Jeong Han, Yun-Kyung Lee, Jinwoo Cho, Jin Hur^{*}

Department of Environment & Energy, Sejong University, Seoul, 05006, South Korea

ARTICLE INFO

Keywords:

Dissolved organic matter
Trihalomethane formation potential
Pyrene binding
Membrane resistance
Biodegradation
Mineral adsorption
Fluorescence spectroscopy

ABSTRACT

Despite the wide applications of end member mixing analysis (EMMA) for assigning the sources of dissolved organic matter (DOM) in aquatic environment, there was no study attempting to test the applicability of EMMA for predicting environmental reactivity of DOM. This study aimed to explore the feasibility of EMMA, or the concept of ideal mixing behavior of end members, for describing several well-known DOM reactivities using two DOM end member sources (i.e., soil and algae) at varying mixing ratios. The selected DOM reactivities were trihalomethane formation potential (THMFP), mineral adsorption amount, pyrene binding, membrane resistance, and biodegradation potential. Among the tested DOM functions, all were found to follow the ideal mixing behavior, presenting the linear relationships between the source mixing ratios and the tested reactivity with the R^2 value of >0.80 . The ideal mixing behavior of the DOM functions was more pronounced than that based on several spectroscopic indicators derived from UV absorption and fluorescence spectroscopy. This study provided insight into potential applicability and limitation of EMMA approach in monitoring and predicting environmental functions of DOM in aquatic systems where identified DOM sources are mixed and vary dynamically with the mixing ratios.

1. Introduction

Dissolved organic matter (DOM) is a complex mixture of components with a wide array of different molecular weights, sizes, and chemical properties (Lamsal et al., 2011; Tak and Vellanki, 2018). DOM is ubiquitous in nature and can be broadly divided into two classes based on the sources (i.e., autochthonous and allochthonous origins). Allochthonous DOM is derived mainly from terrestrial sources, which is external to the aquatic system, while autochthonous DOM is generated within the given system and typically algae serves as the primary source (Berggren et al., 2015; Bertilsson and Jones, 2003; Li et al., 2020; Pagano et al., 2014; Wershaw, 2004). Allochthonous DOM is mainly dominated by high molecular weight (HMW) hydrophobic fractions whereas autochthonous DOM is characterized by low molecular weight (LMW) hydrophilic fractions (Matilainen et al., 2011; Shafiquzzaman et al., 2020; Wershaw et al., 2005; Zhou et al., 2018). Identifying DOM sources along with the variations in the mixing ratios has already proven effective in understanding the apparent chemical properties of the DOM samples (Derrien et al., 2018a; Hur et al., 2006; Lee et al., 2020; Lee et al., 2018; Wang

et al., 2021). However, there is little to no focus on understanding changes in environmental reactivity of DOM based on the variations in the sources.

Dissolved organic matter, as an important component in the biogeochemistry and ecosystem of any aquatic environment (Zhuang and Yang, 2018), possess many environmental functions including metal binding, adsorption onto minerals, oxygen depletion via biodegradation, trihalomethane (THM) or disinfection byproduct (DBP) formation upon chlorination (Galeron et al., 2018; He et al., 2016; Lee et al., 2020; Lourencetti et al., 2012). Hydrophobic organic contaminants (HOC) binding property of DOM is another important DOM function, which affects the fate and the toxicity of HOCs like Pyrene (Chen et al., 2018; Hur and Lee, 2011). The adsorption of DOM onto minerals may also modify the mineral's surfaces and alter the fate and the functions of the minerals in aquatic environment (Phong and Hur, 2015; Zhang et al., 2012). Many studies have provided insight into the relationships between the origins of DOM and their subsequent environmental reactivity (Baker et al., 2008; Chen et al., 2019; Gondar et al., 2008; Hu et al., 2019; Malik et al., 2020; Thacker et al., 2005; Xu et al., 2018; Zhang

[☆] This paper has been recommended for acceptance by Baoshan Xing.

^{*} Corresponding author.

E-mail address: jinhur@sejong.ac.kr (J. Hur).

Natural organic matter as precursor to disinfection byproducts and its removal using conventional and advanced processes: state of the art review

Surbhi Tak and Bhanu Prakash Vellanki

ABSTRACT

Natural organic matter (NOM) is ubiquitous in the aquatic environment and if present can cause varied drinking water quality issues, the major one being disinfection byproduct (DBP) formation. Trihalomethanes (THMs) are major classes of DBP that are formed during chlorination of NOM. The best way to remove DBPs is to target the precursors (NOM) directly. The main aim of this review is to study conventional as well as advanced ways of treating NOM, with a broad focus on NOM removal using advanced oxidation processes (AOPs) and biofiltration. The first part of the paper focuses on THM formation and removal using conventional processes and the second part focuses on the studies carried out during the years 2000–2018, specifically on NOM removal using AOPs and AOP-biofiltration. Considering the proven carcinogenic nature of THMs and their diverse health effects, it becomes important for any drinking water treatment industry to ameliorate the current water treatment practices and focus on techniques like AOP or synergy of AOP-biofiltration which showed up to 50–60% NOM reduction. The use of AOP alone provides a cost barrier which can be compensated by the use of biofiltration along with AOP with low energy inputs, making it a technoeconomically feasible option for NOM removal.

Key words | AOP, biofiltration, disinfection byproducts, drinking water treatment, trihalomethanes

Surbhi Tak (corresponding author)
Bhanu Prakash Vellanki
Environmental Engineering Laboratory,
Department of Civil Engineering,
Indian Institute of Technology,
Roorkee, Uttarakhand 247667,
India
E-mail: surbhitak92@gmail.com

INTRODUCTION

Providing safe drinking water is essential for sustaining human life on earth. With the growing demand for water, it is becoming difficult for drinking water industries to meet the quality needs, both chemically and microbiologically. The chemical aspect refers to chemical contaminants in water sources that are a direct threat to human life. One such contaminant is disinfection byproducts (DBPs) which are formed as a result of disinfection of the water in the treatment process itself. Disinfection is crucial for maintaining the microbiological safety of water, i.e. it aids in inactivating microbial pathogens (bacteria, virus, protozoa etc.) that can cause various water-borne diseases (Gomez-Alvarez *et al.* 2016). One such disinfectant is chlorine and it is the most widely used across the globe. DBPs are generally formed by

the reaction of disinfectants such as chlorine with organic precursors present in source water; these organic precursors are mainly called natural organic matter (NOM) and NOM acts as a forerunner to DBPs. Some of the chlorination disinfection byproducts are shown in Table 1. Trihalomethanes (THMs) are the major class of DBPs formed. Though THMs is not a regular water quality parameter, various studies have reported their occurrence in water systems across the globe and stringent guidelines have been imposed for controlling THM levels in water supply systems (Golfopoulos 2000; Rodriguez *et al.* 2003; Ivahnenko & Zogorski 2006; Wang *et al.* 2007; Kumari *et al.* 2015). THMs constitute four main volatile organic compounds (VOCs): trichloromethane (chloroform), bromodichloromethane (BDCM),



Identification of emerging contaminants and their transformation products in a moving bed biofilm reactor (MBBR)–based drinking water treatment plant around River Yamuna in India

Surbhi Tak · Aman Tiwari · Bhanu Prakash Vellanki

Received: 3 July 2019 / Accepted: 21 April 2020
© Springer Nature Switzerland AG 2020

Abstract The prevalence of emerging contaminants of concern in water regimes is very common these days. High anthropogenic intervention is leading to occurrence of various types of microcontaminants of concern in drinking water systems. Their removal using conventional form of treatment systems employed in water treatment plants is not widely researched upon. Their fate in the conventional as well as advanced water treatment system needs to be focused upon for efficient and safe water disposal. Some compounds may leave the system unchanged or some might transform into much more toxic byproduct. Moreover, understanding level of occurrence of these emerging contaminants in source water bodies is also quintessential for assessing their fate in treatment plant itself as well as in the final treated water. Here in this study, the occurrence and removal of various classes of emerging contaminants were investigated in a moving bed biofilm reactor (MBBR)–based advanced drinking water treatment plant (ADWTP) alongside one conventional drinking water treatment plant, both of which use River Yamuna as the source of water. Non-target analysis utilizing high-performance liquid chromatography combined with time of flight (HPLC-QToF) identified more than

300 compounds. Pharmaceuticals accounted for a major fraction (58%) of the identified compounds, followed by plasticizers and insecticides. Nine parent compound and their transformation products were additionally identified using solid-phase extraction followed by analysis using gas chromatography mass spectrometry and HPLC-QToF. The degradation pathway of the parent compounds in MBBR-based ADWTP was also analyzed in depth. The efficiency of each unit process of MBBR-based drinking water treatment plant was studied in terms of removal of few emerging contaminants. Pharmaceutical compound like diclofenac supposedly was persistent, even, toward the end of the treatment train. Semi-quantitative analysis revealed ineffective removal of pyridine, hydrochlorothiazide, and diethyl phthalate in the outlet of ADWTP. ADWTP was able to remove a few emerging contaminants, but a few were recalcitrant. Likewise, it was established that although some parent compounds were degraded, much more toxic transformation products were formed and were prevalent at the end of the treatment.

Keywords Emerging contaminants · Yamuna River · Mass spectrometry · Drinking water treatment plant · Identification · Non target analysis

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10661-020-08303-4>) contains supplementary material, which is available to authorized users.

S. Tak (✉) · A. Tiwari · B. P. Vellanki
Department of Civil Engineering, Indian Institute of Technology,
Roorkee, Uttarakhand, India
e-mail: surbhitak92@gmail.com

Introduction

Nowadays, the most crucial challenge for water treatment industries is to supply potable water to consumers, which is biologically as well as chemically risk free.

Chlorination disinfection by-products and comparative cost analysis of chlorination and UV disinfection in sewage treatment plants: Indian scenario

Surbhi Tak¹ · Arun Kumar¹

Received: 3 April 2017 / Accepted: 24 October 2017 / Published online: 3 November 2017
© Springer-Verlag GmbH Germany 2017

Abstract Apart from numerous other well-known drawbacks of chlorination, viz. on-site operational hazards and residual chlorine toxicity, trihalomethane (THM) formation is the major factor that came into limelight in the last 40 years, primarily in drinking water treatment industry. Treated effluent from wastewater treatment plants is also chlorinated and then discharged, indirectly coming in human contact, so there is need to consider THM as a potable as well as wastewater parameter. In this study, THMs were identified in seven sewage treatment plants (STPs) in North India. STPs were selected based on treatment technology employed, viz., up-flow anaerobic sludge blanket (UASB), activated sludge process (ASP), sequential batch reactor (SBR), and oxidation pond (OP). THM concentrations obtained at all the seven STPs were below BIS standards of drinking water (0–40 $\mu\text{g L}^{-1}$). UASB plant shows considerably higher concentration of THM. UV followed by chlorination is suggested as an alternative to chlorination. Per million liter per day (MLD) capital and operation and maintenance (O&M) costs of UV disinfection were analyzed revealing decreasing per MLD capital cost of UV with increasing plant capacity. The comparative annual O&M cost analysis of chlorination, dechlorination, and UV disinfection shows that there is up to 63% reduction of the total annual O&M cost by UV in comparison to chlorination,

whereas in the case of chlorination followed by dechlorination, total reduction is 71%.

Keywords Disinfection · Chlorination · UV disinfection · DBPs · Wastewater · Trihalomethanes · Cost analysis

Introduction

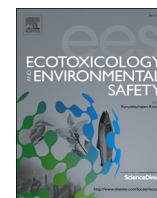
Disinfection is a significant piece of wastewater treatment framework that inactivates the water-borne microbial pathogens, seed to water-borne infections influencing human wellbeing. Disinfectants apart from focusing on pathogens react with natural organic matter (NOM) present in the water offering ascend to new genera of mixes called disinfection by-products (DBPs) (Rook 1974). The other important source of DBP is wastewater-derived organic matter or effluent-derived organic matter (EfoM). EfoM tends to have completely different properties from NOM (Krasner et al. 2009; Yang et al. 2014; Doederer et al. 2014). The aromatic moieties present in EfoM are of completely different origin than those in NOMs. EfoM especially from biologically treated wastewater consists of biodegradation products and soluble microbial products (SMPs) (Jarusutthirak and Amy 2007). Therefore, the quantity and quality of DBPs expected in wastewater treatment plants will vary differently from potable water treatment plants. The term DBP is not new in India considering drinking water treatment, but rather for wastewater treatment, their implication and comprehension is very restricted. Chlorination is the most winning type of disinfection in India and different nations as a result of its entrenched practices, wide range germicidal effectiveness and minimal effort of chlorine (Yang et al. 2005). As per Central Pollution Control Board (CPCB), New Delhi, India, report, chlorination is as yet not utilized at each sewage treatment plant (STPs) across the

Responsible editor: Philippe Garrigues

✉ Surbhi Tak
surbh.dce2015@iitr.ac.in; surbhitak92@gmail.com

Arun Kumar
aheciitr.ak@gmail.com

¹ Indian Institute of Technology, Roorkee,
Roorkee, Uttarakhand 247667, India



Applicability of advanced oxidation processes in removing anthropogenically influenced chlorination disinfection byproduct precursors in a developing country

Surbhi Tak^{a,*}, Bhanu Prakash Vellanki^b

^a Environmental Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology, Roorkee, Uttarakhand, 247667, India

^b Department of Civil Engineering, Indian Institute of Technology, Roorkee, Uttarakhand, 247667, India

ARTICLE INFO

Keywords:

Drinking water treatment
Disinfection byproducts
Trihalomethanes
Advanced oxidation processes
Effluent derived organic matter

ABSTRACT

The studies on occurrence of contaminants of emerging concern in drinking water treatment plants or even wastewater treatment plants in developing country like India, are very limited. Trihalomethanes (THMs) is one such contaminant of concern in drinking water treatment sector. THMs are the major disinfection byproducts (DBPs) formed during the widely used chlorination process. Their identification and removal is of utmost importance in developed as well as developing nations. This study is first of its kind to assess the removal of mixture of urban run-off driven organic matter, agricultural run-off driven organic matter, untreated sewage effluent driven organic matter and little natural organic matter (NOM) (altogether NefOM) (major DBP precursors) using advanced oxidation processes (AOPs) in the Indian region. Since, NOM vary geographically, this study will add up to applicability of generally utilized AOPs for removal of site explicit (Indian) NefOM. Trihalomethanes at a conventional water treatment plant at Mathura and a moving bed biofilm based non-conventional water treatment plant at Agra were monitored over a year, demonstrating the inability of the water treatment plants to limit formation of DBPs from Yamuna inlet water at any time of the year. Various AOPs (UV-H₂O₂, O₃-H₂O₂, O₃) and UV (ultraviolet) photolysis were assessed for their ability to decrease the trihalomethane forming potential (THMFP) by degrading the contaminants in the waters of Yamuna. Kinetic studies were conducted to evaluate the selected AOPs based on their ability to mineralize dissolved organic carbon (DOC), and decrease UV₂₅₄ at various pH, UV intensities, and ozone and hydrogen peroxide concentrations. UV-L/H₂O₂ at an intensity of 47 mJ/cm²/min, pH = 7, and at hydrogen peroxide concentration of 0.5 mM provided an optimum reduction of DOC (64%) and UV₂₅₄ (87%). Fractionation studies indicated that treatment by UV-L/H₂O₂ leads to the most significant decrease in the hydrophobic fraction of the water, while further study indicated that UV-L/H₂O₂ also showed maximum attenuation of THMFP.

1. Introduction

Trihalomethanes (THMs), a significant group of chlorination disinfection byproduct (CDBP), usually occur in water due to the reaction of natural organic matter (NOM) present in water with the chlorine. NOM is highly versatile in nature and varies with the site and season. Four main compounds of THMs are chloroform (CHCl₃), bromodichloromethane (BDCM, CHCl₂Br), dibromochloromethane (DBCM, CHClBr₂) and bromoform (CHBr₃). These compounds have been reported as a probable human carcinogen (Group B2 and Group C) by the International Agency of Research on cancer (IARC) (USEPA, 1999). Some animal toxicity studies have indicated that the site of tumour formation in animals was liver, kidney, thyroid, and intestines (Sharma

et al., 2009). Various epidemiological studies have reported a link between long term exposures to CDBP and potential human health effects (WHO, 2011; Zhang et al., 2018). Most carcinogenic effects were in terms of the colon, rectal and bladder cancer (Genisoglu et al., 2019; Villanueva et al., 2004). More than 600 disinfection byproducts (DBPs), which are carcinogenic and mutagenic have been detected in drinking water systems (Abbasnia et al., 2018). Other adverse effects related to THMs consumption includes problem in respiratory functions, asthma as well as reproductive effects (Abbasnia et al., 2018; Hamidin et al., 2008; Lourencetti et al., 2012; Nickmilder and Bernard, 2007). Various bodies across the globe are regulating the occurrence of THMs. United States Environmental Protection Agency (USEPA) has given The Stage 1 Disinfectant and Disinfection Byproducts Rule (DBPR) to reduce the

* Corresponding author.

E-mail addresses: surbhitak92@gmail.com, stak@ce.iitr.ac.in (S. Tak).



Comparison of O₃-BAC, UV/H₂O₂-BAC, and O₃/H₂O₂-BAC treatments for limiting the formation of disinfection byproducts during drinking water treatment in India

Surbhi Tak^a, Bhanu Prakash Vellanki^{b,*}

^a Environmental Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology, Roorkee, Uttarakhand, 247667, India

^b Department of Civil Engineering, Indian Institute of Technology, Roorkee, Uttarakhand, 247667, India

ARTICLE INFO

Editor: Zhang Xiwang

Keywords:

Disinfection byproducts
Natural organic matter
Emerging contaminants
Advanced oxidation processes
Biofiltration
River Yamuna

ABSTRACT

Natural organic matter (NOM) acts as a precursor to toxic disinfection byproducts (DBPs). Recently it has been established that a mixture of natural and effluent derived organic matter (NefOM) leads to very high concentration of DBPs. Both conventional and non-conventional/advanced ways of drinking water treatment do not remove NefOM sufficiently. Advanced oxidation processes (AOPs) have been shown to oxidize dissolved organic carbon (DOC) effectively but entail high energy inputs. Therefore, combining AOP as a pre-oxidation step with an economical system like biological activated carbon (BAC) filtration is a more economical solution. In this study, BAC was developed from virgin granular activated carbon (GAC) with river Yamuna water, which has the highest levels of DOC in the world, as influent water. Two columns were used, with one of them as a control. For the development of BAC from GAC, Empty bed contact time (EBCT) of 12 min was found to be effective. Steady-state was achieved after 90 days of continuous operation of the columns. After the steady-state was achieved, EBCT of 16 min was found to be optimum for the diffusion of organic molecules inside the biofilm and mineralization by the attached biomass on the surface of BAC.

The percentage DO consumption and, DOC/UV₂₅₄ reduction was found to be constant from $t = 90$ to $t = 120$ days, after which the column was assumed to be acting as a BAC column. To optimize the AOP dose for AOP-BAC experiments, biodegradable DOC (BDOC) was measured after various doses of individual AOP treatments. The maximum increase in biodegradability was observed in case of O₃/H₂O₂ with BDOC of 3.43 mg/L at an ozone dose of 5.44 mg/L and 0.5 mM H₂O₂. All three AOP treated water were passed through BAC columns and change in BDOC, DOC, hydrophobic fraction of DOC and UV₂₅₄ were observed. The maximum DOC, hydrophobic fraction of DOC and UV₂₅₄ reduction was observed with O₃/H₂O₂-BAC, as expected from BDOC results. The primary reason is enhanced biodegradability after optimum O₃/H₂O₂ treatment and thus better utilization of simpler organic molecules by microbes in the BAC column. Maximum trihalomethane formation potential (THMFP) reduction was also observed in the case of O₃/H₂O₂-BAC treatment.

1. Introduction

Natural organic matter (NOM) is ubiquitous in aqueous systems and acts as precursors to carcinogens like trihalomethanes (THMs). The formation of THMs and other disinfection byproducts (DBPs) depends on the characteristics of NOM, which vary with time and geography. Due to increasing anthropogenic, the characteristics of organic matter in surface waters are changing. Surface waters in developing countries now have a significant fraction of organic matter from anthropogenic sources. Such mixed organic matter can be referred to as effluent derived or

anthropogenically influenced organic matter and mixture is called natural and effluent derived organic matter (NefOM) [1]. The source of NefOM can be industrial effluents, treated and untreated sewage, and agricultural and urban-runoffs [1]. The current water treatment systems are not equipped to remove high levels of NefOM. Removal of NefOM is essential due to established adverse consequences like membrane fouling, colour, odour and taste problems and more significantly DBP formation on reaction with a disinfectant like chlorine. DBPs especially THMs have proven carcinogenic nature [2–9]. The conventional processes of water treatment, viz., coagulation, sedimentation, filtration or

* Corresponding author.

E-mail addresses: surbhitak92@gmail.com (S. Tak), bhanuprakashv@ce.iitr.ac.in (B.P. Vellanki).

<https://doi.org/10.1016/j.jece.2020.104434>

Received 18 July 2020; Received in revised form 23 August 2020; Accepted 26 August 2020

Available online 2 September 2020

2213-3437/© 2020 Elsevier Ltd. All rights reserved.