Trihalomethane formation by chlorination of ammonium- and bromide-containing groundwater in water supplies of Hanoi, Vietnam

Duong H.A., Berg M., Hoang M.H., Pham H.V., Gallard H., Giger W., Von Gunten U.

Ctr. Environ. Technol./Sustainable, Hanoi University of Science, Nguyen Trai Street 334, Hanoi, Viet Nam; EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland

Abstract: The occurrence and the fate of trihalomethanes (THMs) in the water supply system of Hanoi City, Vietnam was investigated from 1998 to 2001. The chlorination efficiency, THM speciation, and, THM formation potential (THMFP) was determined in the water works and in tap water. With regard to THM formation, three types of groundwater resources were identified: (I) high bromide, (II) low bromide, and (III) high bromide combined with high ammonia and high dissolved organic carbon (DOC) concentrations. Under typical treatment conditions (total chlorine residual 0.5-0.8mg/L), the total THM formation was always below WHO, EU, and USEPA drinking water standards and decreased in the order type I>type II>type III, although the THMFP was >400?g/L for type III water. The speciation showed >80% of bromo-THMs in type I water due to the noticeable high bromide level (??140?g/L). In type II water, the bromo-THMs still accounted for some 40% although the bromide concentration is significantly lower (??30?g/L). In contrast, only traces of bromo-THMs were formed (?5%) in type III water, despite bromide levels were high (??240?g/L). This observation could be explained by competition kinetics of chlorine reacting with ammonia and bromide. Based on chlorine exposure (CT) estimations, it was concluded that the current chlorination practice for type I and II waters is sufficient for ?2-log inactivation of Giardia lamblia cysts. However, in type III water the applied chlorine is masked as chloramine with a much lower disinfection efficiency. In addition to high levels of ammonia, type III groundwater is also contaminated by arsenic that is not satisfactory removed during treatment. N-nitrosodimethylamine, a potential carcinogen suspected to be formed during chloramination processes, was below the detection limit of 0.02?g/L in type III water. ??

Author Keywords: Ammonium; Bromide; Chlorine exposure; Competition kinetics; Disinfection by-products; Hanoi; N-nitrosodimethylamine (NDMA); Trihalomethane formation potential; Vietnam; Water distribution system

Index Keywords: Ammonia; Bromine compounds; Chlorination; Contamination; Groundwater; Water treatment; Dissolved organic carbon (DOC); Water supply; ammonia; bromide; drinking water; ground water; organic carbon; tap water; trihalomethane; chlorinated hydrocarbon; disinfection byproduct; trihalomethane; water supply; water treatment; article; chlorination; controlled study; disinfection; evaluation; Giardia lamblia; laboratory; nonhuman; priority journal; species differentiation; Viet Nam; water supply; Ammonia; Animals; Bromides; Carbon; Environmental Monitoring; Giardia lamblia; Kinetics; Soil Pollutants; Trihalomethanes; Vietnam; Water Pollutants, Chemical; Water Supply; Giardia; Giardia intestinalis

Year: 2003
Source title: Water Research
Volume: 37
Issue: 13
Page : 3242-3252
Cited by: 30
Link: Scorpus Link
Chemicals/CAS: ammonia, 14798-03-9, 51847-23-5, 7664-41-7; bromide, 24959-67-9; Ammonia, 7664-41-7; Bromides; Carbon, 7440-44-0; Soil Pollutants; Trihalomethanes; Water Pollutants, Chemical
Correspondence Address: Berg, M.; EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland; email: michael.berg@eawag.ch
ISSN: 431354
CODEN: WATRA
DOI: 10.1016/S0043-1354(03)00138-6
PubMed ID: 14509712
Language of Original Document: English
Abbreviated Source Title: Water Research
Document Type: Article
Source: Scopus
Authors with affiliations:

1. Duong, H.A., Ctr. Environ. Technol./Sustainable, Hanoi University of Science, Nguyen Trai Street 334, Hanoi, Viet Nam
2. Berg, M., EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland
3. Hoang, M.H., Ctr. Environ. Technol./Sustainable, Hanoi University of Science, Nguyen Trai Street 334, Hanoi, Viet Nam
4. Pham, H.V., Ctr. Environ. Technol./Sustainable, Hanoi University of Science, Nguyen Trai Street 334, Hanoi, Viet Nam
5. Gallard, H., EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland
6. Giger, W., EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland
7. Von Gunten, U., EAWAG, Swiss Fed. Inst. Environ. Sci./T., Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland

References:

1. Berg, M., Tran, H.C., Nguyen, T.C., Pham, H.V., Schertenleib, R., Giger, W., Arsenic contamination of groundwater and drinking water in Vietnam: A human health threat (2001) Environ Sci Technol, 35, pp. 2621-2626
2. Singer, P.C., Reckhow, D.A., (1999) Water Quality and Treatment, a Handbook for Community Water Supplies, 5th Ed., pp. 121-1251. , Letterman RD, editor. New York: McGraw-Hill
3. Singer, P.C., Formation and characterization of disinfection by-products (1993) Safety of water disinfection: Balancing chemical and microbial risk, , G.F. Craun. Washington, DC: ILSI Press
4. Guidelines for Drinking Water Quality, 2nd Ed., 1. , Recommendations, Geneva, Switzerland, 1993
5. Miles, A.M., Singer, P.C., Ashley, D.L., Lynberg, M.C., Mendola, P., Langlois, P.H., Nuckols, J.R., Comparison of trihalomethanes in tap water and blood (2002) Environ Sci Technol, 36, pp. 1692-1698
6. Golfinopoulos, S.K., The occurrence of trihalomethanes in the drinking water in Greece (2000) Chemosphere, 41, pp. 1761-1767
7. (1988) Standards for Drinking Water, , Hanoi, Vietnam
8. Standard Methods (1995) Standard Methods for the Examination of Water and Drinking Water, 19th Ed., , Eaton AD,

Clesceri LS, Greenberg AE, editors. Washington, DC: American Public Health Association

9. Pinkernell, U., Nowack, B., Gallard, H., Von Gunten, U., Methods for the photometric determination of reactive bromine and chlorine species with ABTS (2000) Water Res, 34, pp. 4343-4350
10. Berg, M., M?ller, S.R., Schwarzenbach, R.P., Simultaneous determination of triazines including atrazine and their major metabolites hydroxyatrazine, desethylatrazine, and deisopropylatrazine in natural waters (1995) Anal Chem, 67, pp. 1860-1865
11. Gallard, H., Von Gunten, U., Chlorination of natural organic matter: Kinetics of chlorination and of THM formation (2002) Water Res, 36, pp. 65-74
12. Symons, J.M., Krasner, S.W., Sclimenti, M.J., Simms, L.A., Sorensen H.W., Jr., Speitel G.E., Jr., Diehl, A.C., Influence of bromide ion on trihalomethane and haloacetic acid formation (1996) Disinfection by-products in water treatment: The chemistry of their formation and control, pp. 91-130. , R.A. Minear, & G.L. Amy. Boca Raton, FL: CRC Lewis Publishers
13. Wolfe, R.L., Ward, N.R., Olson, B.H., Inorganic chloramines as drinking-water disinfectants - A review (1984) J Am Water Works Assoc, 76, pp. 74-88
14. Morris, J.C., Isaac, R.A., A critical review of kinetic and thermodynamic constants for the aqueous chlorine-ammonia system (1981) Water chlorination: Environmental impact and health effects, 4, pp. 49-62. , R.L. Jolley, W.A. Brungs, J.A. Cotruvo, R.B. Cummings, J.S. Mattice, Jacobs V.A. Ann Arbor, MI: Ann Arbor Science
15. Margerum, D.W., Gray E.T., Jr., Huffman, R.P., Chlorination and the formation N-chloro compounds in water treatment (1978) Organometals and organomataloids: Occurrence and fate in the environment, pp. 278-291. , F.E. Brinckman, & J.M. Bellama. Washington, DC: ACS Books
16. Kumar, K., Margerum, D.W., Kinetics and mechanism of general-acid-assisted oxidation of bromide by hypochlorite and hypochlorous acid (1987) Inorg Chem, 26, pp. 2706-2711
17. Von Gunten, U., Driedger, A., Gallard, H., Salhi, E., By-products formation during drinking water disinfection: A tool to assess disinfection efficiency? (2001) Water Res, 35, pp. 2095-2099
18. (1999) Disinfection Profiling and Benchmarking Guidance Manual, Appendix C: CT Values for Inactivation Achieved by Various Disinfectants, , EPA-815-R-99-013, August 1999, Washington, DC
19. Langlais, B., Reckhow, D.A., Brink, D.R., (1991) Ozone in Water Treatment: Application and Engineering, 2nd Ed., p. 221. , Chelsea, MI: Lewis Publishers
20. (1993) Water Master Plan of Hanoi City for the period of 1993-2001, 1. , The Social Republic of Vietnam, Hanoi People's Committee and The Republic of Finland, Finnish International Development Agency FINNIDA, Hanoi, Vietnam
21. Mitch, W.A., Sedlak, D.L., Formation of N-nitrosodimethylamine (NDMA) from dimethylamine during chlorination (2002) Environ Sci Technol, 36, pp. 588-595