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EDITORIAL

Water, sanitation, pollution, and health in the Arctic

Pernille Erland Jensen[1] · Thomas W. Hennessy[2] · Roland Kallenborn[3,4]

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Editorial

Recent developments such as urbanization, increased consumption of modern goods, global climate change, population growth, and economic development in sectors such as tourism, resource extraction, and transportation are rapidly altering the physical and societal environment in the Arctic. This ongoing development creates new challenges in relation to waste and wastewater handling, pollution control, human health, management of contaminated land and protection of the water supply.

A recent survey on the status of water and sanitation in the circumpolar Arctic reports a significantly higher prevalence of incomplete services for the Arctic region compared to the overall national status (Bressler and Hennessy 2018). Households without running water and sewer service are primarily found in communities that do not have any type of centralized water supply and sewer system (piped or water and wastewater covered haul infrastructure), but also in communities where the existing water/sewer infrastructure does not include all homes. In addition, there are many homes and municipal infrastructures connected to centralized water supply and sewer which are experiencing long-term failure due to age, defective infrastructure, harsh weather conditions, climate effects such as thawing permafrost, and the high costs of operation.

As a consequence, the lack of sanitation infrastructure will ultimately pose serious health threats and environmental problems due to uncontrolled exposure to contaminated water. Recent health studies conducted in the North American Arctic and Sub-Arctic have shown a direct correlation between clean water in sufficient quantities and significant reductions in the occurrence of illness and hospitalizations due to infectious disease (Hennessy et al. 2008, Thomas et al. 2016, Wenger et al. 2010). These studies show that skin infections, respiratory tract infections, and severe invasive bacterial infections, such as meningitis, are more common in communities lacking centralized and well-maintained water and sewer service. Hospitalization rates for respiratory infections in rural Alaska Native infants and children are the highest in the USA (Foote et al. 2015). In Greenland, a high incidence of respiratory infections is also documented (Koch et al. 2002), while no studies have been made so far to reveal relations between this observation and the status of water and sanitation systems in this part of the Arctic region. The health threats impose costs that impede socioeconomic development (Hennessy and Bressler 2016).

In places with sanitation systems installed, challenges with the performance due to climatic and infrastructural conditions are observed, due to use of technologies not sufficiently adapted for harsh Arctic conditions. Recent research indicates that disinfection and removal of human pathogens in some Arctic wastewater stabilization ponds may be inadequate (Huang et al. 2014). The risk of human exposure to inappropriately treated wastewater adds to the already high rates of infections, such as tuberculosis and methicillin-resistant *Staphylococcus aureus* (MRSA), in Alaska, Greenland, and Canadian indigenous populations (Meyer et al. 2008; Vandenesch et al. 2003, Byrd et al. 2009, Bourgeois et al. 2018). Furthermore, the continuing environmental change in the Arctic could significantly influence the fate of pathogenic microorganisms discharged from wastewater treatment systems into marine and freshwater environments, posing

Responsible editor: Philippe Garrigues

✉ Pernille Erland Jensen
pej@byg.dtu.dk

[1] Arctic technology Centre, Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

[2] Arctic Investigations Program, Division of Preparedness and Emerging Infections, National Center for Emerging and Zoonotic Infectious Diseases, US Centers for Disease Control and Prevention, Anchorage, Alaska, USA

[3] Faculty of Chemistry, Biotechnology and Food Science, Norwegian University of Life Sciences (NMBU), Ås, Norway

[4] University Center in Svalbard (UNIS), Arctic Technology, P.O. Box 156, NO 9171 Longyearbyen, Svalbard, Norway

increased human health risks (Dudley et al. 2015; Hueffer et al. 2011; Parkinson et al. 2014).

In addition to pathogens, presence of excessive levels of nutrients (nitrogen and phosphorus) in wastewater effluents can lead to unwanted eutrophication of receiving water bodies, resulting in algae blooms, anoxic conditions, fish death, and loss of traditional fishing and shellfish harvesting areas. As the climate changes, these effects may increase. Furthermore, inadequately treated waste and wastewater contains a large variety of anthropogenic chemicals originating from commercial and household activities, i.e., substances that can be harmful for the environment as well as for human health. Those substances include industrial chemicals, synthetic oil, grease, pesticides, industrial chemicals, flame-retardants, and residues of pharmaceuticals and personal care products. Studies have shown negative ecological effects on benthic invertebrates in areas around marine town outfall sites of untreated wastewater in the Arctic (Bach et al. 2010). The lack of disinfection may also have consequences for the development of antibiotic resistance in the local microbial communities exposed to a variety of pharmaceutical residues at high concentration levels, including antimicrobial agents (Gunnarsdóttir et al. 2012), further imposing an increased health risk for the local population.

Mineral extraction and military activities already left a number of sites in the Arctic with long lasting pollution issues. It is expected that climate change will open the Arctic region further to increased industrial development and commercial ship transportation, thus making it necessary to investigate the risk of exposure to and uptake of pollutants into the food web, and the subsequent potential hazardous effects on human health and the environment (Kallenborn et al. 2011).

The capital cost and operational costs of centralized sanitation systems in the Arctic and Sub-Arctic is extremely high. Rural households typically spend a much higher percentage of their income on water and sewer user fees than urban households (Eichelberger 2010). Due to remoteness, harsh weather conditions, climate change, and the high cost of fuel, many rural Arctic and Sub-Arctic communities are hard pressed to keep their systems running. Because of the relatively high costs and technical challenges associated with centralized and commercial systems, development of less expensive technologies, or adaptations to existing technologies fit for the Arctic conditions is needed.

In recognition of these potential threats to human and environmental health, many local governments have a keen interest in developing waste and wastewater treatment options that are suitable for the Arctic and sustainable for the foreseeable future. For instance, an Intergovernmental Panel on Climate Change (IPCC) report on climate change highlights the tremendous potential for low-cost decentralized technologies such as ecological toilets and separation of greywater from blackwater to provide viable treatment strategies where community acceptance is garnered (Bogner et al. 2007), and bench scale experiments with different commercial systems have been made in two different municipalities in Greenland recently (P.E. Philbert 2014, N.K Søndergaard 2015).

The purpose of this issue is to collect contributions from two international conferences held in 2016: "Sanitation in Cold Climate Regions", which took place Sisimiut, Greenland 12th–14th of April 2016 http://www.artek.byg.dtu.dk/english/about_artek/aic-artek-international-conferences/artek_event2016, and "Water Innovations for Healthy Arctic Homes", held in Anchorage, Alaska 18th–20th of September 2016 http://dec.alaska.gov/water/water-innovations-for-healthy-arctic-homes/. Both conferences were part of the Arctic water, sewer and health (WASH) initiative of the Arctic Council's Sustainable Development Working Group, which aims to characterize the extent of WASH services in Arctic nations, the related health indicators and climate-related vulnerabilities to WASH services (Hennessy and Bressler 2016). The initiative included an assessment of the current status of water and sanitation services in the Arctic and the two scientific meetings focused on addressing the region's unique sanitation issues. More than 100 delegates gathered for each event and the significant participation by community professionals, educators, and students ensures the long-term local impact of the conferences. Beyond the presentations, the conferences were great occasions for launching new collaborative actions and networks to better face the challenges of the Arctic.

Nineteen papers have been collected constituting todays scientific status and visiting the various topics on water management from various angles. Thus, seven articles are presented on drinking water supply and related health issues, seven articles are on wastewater contamination, three articles on environmental contamination and remediation technology, and finally two on infrastructural system analysis.

We thank each author and congratulate them on the published papers. We also want to thank the editor-in-chief of the Environmental Science and Pollution Research Journal, Professor Phillippe Garrigues (University of Bordeaux, France) and the Springer editorial team for their editorial support during the production of this special issue and for help during the reviewing process.

Compliance with ethical standards

Disclaimer The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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Pernille Erland Jensen , PhD is Associate Professor at the Department of Civil Engineering of the Technical University of Demark (DTU), and Head of Studies for the Arctic Engineering B.Eng. program taught partly in Greenland and partly in Denmark with the ambition to educate young Greenlanders to engineer their own country.

She teaches both undergraduate and graduate courses on Arctic Environmental Engineering topics in Greenland and Denmark, and has developed several courses including field work courses in Greenland and E-Learning courses and modules. She was affiliated to at the Arctic technology Centre (ARTEK), now Arctic DTU, since 2006, and heads the centers research area on Arctic Environmental Engineering where her foci have been on technologies for safe domestic wastewater handling in remote Arctic communities, and on safe and sustainable management of residuals from the dominant industries in Greenland including fish production and mining. Pernille was a member of IACORDS (International Association for Cold Regions Development Studies) since 2013, and heads the University of the Arctic (UARCTIC) thematic network on Arctic WASH. Pernille has authored more than 60 scientific journal papers, supervised 9 PhD students, and participated in numerous national and international research and development projects.

Tom Hennessy, MD, MPH is the Director of the Arctic Investigations Program (AIP), CDC's field station for infectious diseases in Anchorage, Alaska. The Program includes a microbiology and molecular diagnostics lab, teams of epidemiologists and biostatisticians, and a biorepository with specimens from human research dating back to the 1960's. Their work focuses on reducing infectious disease threats among peoples of the Arctic region, with special emphasis on the indigenous populations. Successful outcomes include the elimination of hepatitis A and B transmission, a 95% reduction in childhood bacterial meningitis among Alaska Native children, and progress in addressing underlying health disparities such as water/sanitation services and indoor air quality. Dr. Hennessy has served in the US Public Health Service since 1990. He is a graduate of Antioch College, the Mayo Medical School, and Emory University's School of Public Health. He is trained in Family Medicine and Preventive Medicine, and is a graduate of the CDC Epidemic Intelligence Service. He is a member of the US Interagency Arctic Research Policy Committee, which developed the US Arctic Research Plan. He is also the US Representative for the Arctic Human Health Experts Group, a multinational advisory group to the Arctic Council.

Roland Kallenborn , Norwegian University of Life Sciences/ University Centre in Svalbard, Norway

Is a Professor in Organic Chemistry at the Department for Chemistry, Biotechnology and Food Sciences (IKBM) at the Norwegian University for Life Sciences (UMB) in Ås, Norway. In addition, he holds an adjunct Professor position (20%) at the University Centre in Svalbard (UNIS), Spitsbergen, Norway. Previously, he worked as senior research scientist at the Norwegian institute for Air Research (NILU), department in the Polar Environmental Centre in Tromsø (Norway). For 2005–2008, Kallenborn was employed as Professor and Head of Department (Arctic Technology) at the University Centre in Svalbard (Longyearbyen/ Svalbard). Currently, his work focuses mainly on the development of new methods and strategies for the interdisciplinary scientific linkage between trace analytical organochemical technology and bioeffect methods for elucidation of ecotoxicological potential of organochemical xenobiotics. His is author/co-author of ca. 100 peer reviewed scientific publication, 1 monograph and has presented more than 170 oral or poster presentations on international scientific conferences/ workshops and seminars. His recent research interest focuses mainly around three major research topics:

Evaluation of environmental fate and properties of currently identified contaminants (e.g., perfluorinated alkylated substances, brominated flame retardants, pharmaceutical residues and personal care products).

Assessing global long range processes of sparsely investigated anthropogenic contaminants.

Pollution issues in polar regions including risk assessment

Development of new versatile methods and tools for multidisciplinary environmental risk evaluations.