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A review of wastewater handling in the Arctic with special reference to pharmaceuticals and personal care products (PPCPs) and microbial pollution

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ABSTRACT

Treatment of wastewater is often inadequate or completely lacking in Arctic regions. Wastewater contains different kinds of substances that can be harmful for the environment and human health, including residues of pharmaceuticals and personal care products. Bioaccumulation and biomagnifications of chemicals in the food web are of concern. This can affect fishery that is a significant industry in many Arctic coastal regions. Wastewater from human settlements may also contain antibiotic resistant bacteria and pathogens that can cause negative impacts on human health and the environment. In the Arctic, especially, the direct release of untreated sewage may have severe consequences for the receiving environment due to low biological diversity, low ambient temperatures and consequently high vulnerability of the Arctic ecosystem to environmental contaminants.

Bucket toilets are common in remote settlements but are also used in towns. In settlements having inadequate sanitary facilities the risk of contracting diseases, such as hepatitis A, is unacceptably high. Conventional centralized wastewater collection systems and treatment plants are a challenge to build in the Arctic and expensive to operate. Thus alternative methods are needed. Possible solutions are improved dry or low flush toilets with collection of toilet waste at the household level and subsequent centralized treatment by dry composting or anaerobic digestion. Both treatment methods facilitate co-treatment of wastewater along with other organic waste fractions and provide a by-product that is environmentally safe and easy to handle. Combining the above with decentralized greywater treatment will reduce the costs for expensive infrastructure.

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1. Introduction

It is challenging to design, construct and operate wastewater collection systems in the Arctic because of permafrost conditions, hard rock surfaces, freezing, flooding in the spring, limited quantity of water, high costs of electricity, fuel and transportation, as well as a settlement pattern with limited accessibility, especially in the rural parts of the Arctic. The cold climate influences the efficiency of biological treatment processes in particular, but also chemical processes (Smith and Low, 1996). The most important present types of wastewater collection systems in the Arctic are listed in Fig. 1 (Smith and Low, 1996).

Bucket toilets are still widely used in many of the northern communities, such as in Canada's northern areas and some parts of Alaska and Greenland. This particular toilet solution has been considered a problem for many years with respect to uncontrolled spreading of nutrients, diseases and potential pollution issues. As indicated in Fig. 1 the hauling of waste from bucket toilets is either done individually or collectively. The health and convenience level is considered being low when hauling is done individually due to limited water usage and varying individual disposal practices (Smith and Low, 1996). Those factors are improved when the hauling is done collectively by municipal or private organized operators. The initial construction costs of sanitation systems consisting of bucket toilets are low whatever hauling system is selected, and so is the operational cost of individual hauling, while the cost of collective hauling can be high, dependant on the usage rates. Flush toilets provide high inhouse health and convenience level. The selection of sewer pipe system depends on i.a. the topography; gravity systems can be used in gently sloping terrain, while vacuum systems can be

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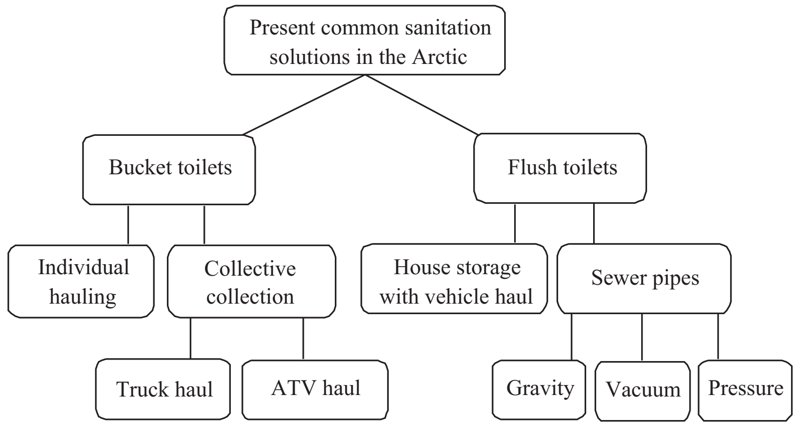

Fig. 1. The main types of wastewater collection systems in the Arctic. *Abbreviation*: ATV: All Terrain Vehicle.

used in level to gently sloping terrain. The advantage of pressure sewer is that it can be used under every topographical situation. The gravity systems require the least maintenance but flushing of low-use lines may be required. The pressure and vacuum systems use smaller diameter pipes and the water requirement is low for the latter one (Smith and Low, 1996).

The main options for drinking water systems in cold regions are (Smith and Low, 1996):

- Self-haul systems
- Vehicle-haul systems
- Piped systems

The volume of wastewater from each dwelling depends on the water supply system; i.e. households with self-haul drinking water systems produce much less wastewater than those on piped water.

In many Arctic regions wastewater treatment is inadequate or even completely lacking. Greenland is an example of an Arctic region where no treatment of industrial or domestic wastewater exists. In the Greenlandic towns the residents have pressurized in-home drinking water. The dwellings have either traditional water flush toilets or bucket toilets. Those who have water flush toilets in the larger towns are either connected to a sewer or the blackwater (wastewater from toilets) is stored in a holding tank outside the residence while the greywater is led out directly to the terrain. In the small settlements of Greenland some dwellings have pressurized in-home drinking water while other residents have self-hauled water, typically obtained from a community water point. Bucket toilets are used in almost all settlements in Greenland where approx. 8500 out of a total population of approx. 57,000 inhabitants lived in 2012 (Statistics Greenland, 2012). Routine collection of the bags from the bucket toilets and pumping of the holding tanks is organized by the municipalities or local companies, but individual haul is also done in some settlements. Handling of wastewater from tourist huts in Greenland is another challenge since they do not have running water supply and are often remotely located.

In indigenous people's communities in Alaska five levels of service have been established to categorize the different methods to dispose of human sewage (U.S. Congress, 1994). These are summarized in Table 1.

Level A is the most rudimentary service, and the health and convenience level of this service is considered low due to limited water use and different individual disposal practices (Smith and Low, 1996). Regarding level D septic tanks only work in regions with well-drained soil above the seasonal water table. Level E is considered to provide the highest technical and safety level and includes flush toilets and piped sewerage. However, construction of these systems is often difficult and expensive due to the remoteness of the villages and the harsh environment. For levels D and E a year round water supply for flushing must be supplied (U.S. Congress, 1994).

In Canada municipal wastewater effluents are considered being one of the largest threats to the quality of the water (Environmental Signals, 2003). There is a great difference in the level of wastewater treatment between Canadian municipalities that discharge to coastal versus fresh inland waters. In 1999 most of the coastal municipalities served by sewers had primary or no wastewater treatment and only a minority had secondary treatment (Environmental Signals, 2003). On the contrary about 84% of the inland municipalities served by sewers received secondary or tertiary wastewater treatment while 15% received only primary treatment (Environmental Signals, 2003). In large urban areas in Canada, such as Victoria in British Columbia, wastewater is not treated before discharged into the Pacific Ocean (Colt et al., 2003).

In 1990 wastewater from approx. 5% of the inhabitants in Iceland was treated, while in 2002 that number had increased to over 60% (UST, 2003). However, this was mainly in the capital Reykjavík, where 62% of the inhabitants lived in 2002. In other parts of the country more than half of the wastewater was discharged untreated to the recipients. The treatment method mostly used outside the capital city was septic tanks (UST, 2003). Fig. 2 shows the division of treatment methods used in Iceland in 2002.

In Iceland one step treatment includes mechanical and/or chemical treatment to lower the content of suspended particles, e.g. by precipitation or filtration. Two step treatment includes an initial precipitation or filtration step and a second step that includes biological treatment of the wastewater, often succeeded by precipitation (UST, 2003). In Iceland it is allowed to use one-step treatment when discharging wastewater from 10,000 to 150,000 person equivalents (PE) in coastal areas categorized as being less sensitive, and from 2000 to 10,000 PE when discharging to estuaries (UST, 2003). However, it is allowed to use one-step treatment for more than 150,000 PE when discharging to less sensitive areas if it can be shown that more developed treatment methods do not improve the environmental status of the recipient. Sludge from septic tanks and treatment plants is landfilled in most cases as there is no tradition for using sludge in agriculture in Iceland. However, treatment plants for sludge have been built in certain parts of the country where the sludge is mixed with lime with the purpose of being used as fertilizer (UST, 2003).

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