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Hygienic Problems in Using Permafrost Soils for Organic Waste Disposal

By Manfred Bölter[1] and Christiane Höller[2]

Summary: This paper reviews the risks on hygienic problems in the northern environments by reindeer slaughter and related waste disposals. Such risks are evident from anticipated possible changes in the socio-economic structure in this region and changes in land use and animal keeping. There are several problems going along with different pathogens and their infection ways. Precautions have to be taken especially for those organisms which can live for long times under dormant stages or which form spores.

Zusammenfassung: In diesem Beitrag wird eine Zusammenschau hygienischer Probleme in der Arktis gemacht. Insbesondere wird auf die Schlachtung von Rentieren eingegangen und auf die damit verbundene Abfallbeseitigung. Risiken entstehen durch Änderungen in der tradionellen Viehhaltung und dem Landgebrauch. Besondere Probleme entsehen durch die verschiedenen Infektionsquellen und deren Wege. Vorkehrungen sollten getroffen werden hinsichtlich solcher Keime mit langen Überlebenszeiten oder bei Sporenbildnern.

1. INTRODUCTION

The discussion on Climate Change and Global Warming shows that there will be greatest effects in northern environments. This will not only have consequences on global CO_2 fluxes or other general impacts on earth's ecology but will also influence the socio-economic features of these landscapes. Agriculture and land-use will become important facts. Concomitantly, there will arise problems with new settlements and related factors, such as sewage disposal and waste management.

Northern environments have been described as fragile in different ways. Flora and fauna are poor and adapted to cold and low nutrient state of soils. This, for instance, prevents the rapid degradation of introduced organic matter. On the other hand, cold environments may serve as a fridge which keeps introduced microorganisms alive, and thus keeping them for long time as a potential hazard for men and animals. Thus, special care has to be taken on hygienic aspects to prevent diseases and epidemics – as just shown for poultry infections in Antarctic penguins (GARDNER et al. 1997).

Despite the anticipated global warming, soils will stay cool for a long time of the year. Although the warming of these areas is slow, changes in environmental properties with positive effects are probably slower than human demands. Hence, there will arise conflicts between nature and man. In this paper, we will consider hygienic problems of organic waste disposals and their possible danger to man and environment.

2. REVIEW OF RELEVANT DATA

2.1 *Soils and vegetation in the Arctic: Environmental constraints.*

The European part of the Arctic is governed by arctic and boreal plant communities which are partly located on permafrost soils. Permafrost and patterned ground features predominate in many Arctic tundra areas. Alpine environments in northern Scandinavia show permanent permafrost soils, lowlands at the Kola Peninsula have discontinuous permafrost. We can observe several transition stages in ecosystems especially with changing altitude in combination with increasing continental influences to the east. The variability of soil properties is large and related to local vegetation and climatic patterns. Most northern environments are only poorly vegetated with low contents of available nutrients whereas more southerly taiga areas with stands of *Pinus* sp. generally show enriched soils with Arthropods and Enchytraeids as main soil faunal components.

Soil temperature and seasonal dynamics of soil thawing and freezing influence not only soil processes but the entire ecosystem. Late soil thawing promotes the establishment of big shallow tundra lakes, which serve as freshwater environments for many birds and insects, especially mosquitos. Many bacteria are hampered by these acid soils and decomposition of organic matter is dominated by fungi. Wet areas, however, favour anaerobic conditions and nutrient depletion due to hydrologic transport. This is a wide-spread phenomenon in the Arctic. Most soils are nutrient deplenished and the lack of phosphorous and especially nitrogen prevents the growth and establishment of other vegetational components.

Vertebrate organisms, i.e., lemming, fox, arctic hare, elk, reindeer as well as birds can mainly be regarded as effective feedback organisms in the regulation process on spatial and temporal changes in vegetation patterns. Microbiologically, they can be regarded as vectors for naturally occurring or introduced microorganisms.

[1] Dr. Manfred Bölter, Institut für Polarökologie der Christian-Albrechts-Universität zu Kiel, Wischhofstr. 1–3, D-24148 Kiel.

[2] Dr. Christiane Höller, Klinikum der Christian-Albrechts-Universität zu Kiel, Institut für Hygiene und Umweltmedizin, Brunswiker Str. 4, D-24105 Kiel.

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2.2 *The natural microflora of tundra and taiga soils*

The microflora of northern landscapes is a result of various effects. Supply of organic matter and its state of availability, physical and chemical soil properties have influences on soil organisms and their activities. Along with the great variety of soils and local peculiarities, the only general feature seems to be the low temperature and low nutrient status. Due to the mostly acid soil reaction and the high C/N ratios, there is a considerable amount of filamentous fungi and yeast. Their abundances, however, vary in relation to the organic matter and environmental factors (Holding 1981, Hayes & Rheinberg 1975). Classifications have shown the occurrence of *Penicillum* sp., *Cladosporium* sp. *Chrysosporium* sp., *Syctalidium* sp., *Trichoderma* sp. and *Phoma* sp. beside many sterile mycelia (Hayes & Rheinberg 1975, Dowding & Widden 1974). Mycelium length was found between 800 and 10000 m g^{-1} d.wt. (Collins et al. 1978).

Bacterial plate counts reveal also wide ranges for soils of the northern tundra soils, surface samples show numbers between 620 x 10^3 and 343 x 10^6 g^{-1} d.wt. (Holding 1981). Taxonomically, the bacterial community shows similarities with those from other regions and no types unique to tundra regions have been recognized (Dunican & Rosswall 1974). Collins et al. (1978) stated that the proportion of Gram-negative bacteria increases with depth.

2.3 *Soil pollutions from human activities*

There are different kinds of wastes which may enter soils with human activities. We want to focus on fresh and undecomposed organic wastes of different origin. The main problem of waste disposals in the northern climatic region is related to the actual soil status and climatic properties. Significant parts of the land mass are occupied by poorly drained organic and mineral soils. The water table governs its aeration and thus potentials for decomposition. The breakdown of organic materials which leads to the release of ammonia proceeds at slower rates under anaerobic conditions. Microbial conversion of ammonia to nitrate, phosphorous fixation and nitrogen removal (immobilization) by plants and microorganisms is hampered. Partly digested material, proteins, amino acids, fatty acids will stay for long time in the affected area, or it will be washed out to rivers and lakes. There it will change the nutrient stage and increase organic and inorganic pollution.

During winter until late spring most watersheds are frozen and have snow-covered surfaces. Run-off of nutrients is limited or practically non-existent and accumulation of wastes occurs until thawing in spring results in increased pulses over short time spans. Nitrogen and phophorous will enter lakes at concentrations above the usually accepted threshold value (0.01 mg P l^{-1}) for algal growth and cause ecological disturbances for long periods. As the assimilative capacity of a soil or a limnetic environment is related to the microbial, chemical and physical properties, one can assume that this capacity is finite. This means, that an overload by organic wastes will have negative feed-backs not only in the natural environment but also cause further economic problems.

2.4 *Microorganisms as pollutants*

Municipal sewage wastes and animal manures contain several disease agents. Organic wastes of (domestic) animals inevitably contain pathogens. Fresh sewage may contain all bacterial and viral pathogens, such as salmonellas and enterobacteria as well as various viruses (Möller et al. 1985). Generally, the return of organic wastes to the land is part of the natural cycle. Whether such contamination presents a significant hazard depends on the primary conditions under which such wastes are treated and the basic environmental conditions. This frame will decide whether there is a potential hazard for men or animals.

Microbiological pathogens can be classified according to their impact and their risk to the surrounding community. This includes the severity of the induced disease, the virulence, the need of vectors, their general resitance to agents etc. Beside the well known pathogenic bacteria, *e.g.*, *Salmonella* sp., *Bacillus anthracis, E. coli, Clostridium* sp., *Shigella* sp. , we also have to consider viruses, *e.g.*, *Poliovirus, Enterovirus, Hepatitis A,* and prions (Creutzfeld-Jacob), as well as intestinal parasites, *e.g.*, *Entamoeba histolytica*, *Cryptosporidium* sp., or cysts and eggs of roundworms and tapeworms, *e.g.*, *Ascaris lumbricoides*, *Taenia saginata*.

Strains of the above-mentioned bacteria are widespread and their numbers are subject of several hygienic monitorings of sewage plants. Some of those pathogens can be found in high amounts on plants as they may grow – not only survive – under favourable conditions of humidity and temperature. This was shown for *Pseudomonas aeruginosa* which was detected in 24 % of soil samples from vegetable growing areas in California (Green et al. 1974). Recently, strains of the genus *Mycobacterium* have been isolated from soils at Svalbard (Rakusa-Suszczewski, pers. comm.). However, to trace for human pathogens in arctic regions is difficult. As such, Falckh (1987) re-examined the cause of death of a member of the 1912 South Pole expedition and found that this was probably due to an anthrax infection from contact with ponies or their equipment. As anthrax is found among cattle, sheep, goats, horses and swine, it also may be found in other ruminants, such as reindeer. Another source for this anthrax desease might have been found in the sleeping bags, which were mainly from reindeer skin (Stonehouse, pers. comm.). Tab. 1 gives a short overview of some bacterial induced diseases, their causative agents and their way of transmission.

Viruses are sources of several human diseases. They are transmitted mainly from person to person and by ingestion, but also aerosols from soils and surface water have been implicated. They are responsible for e.g., poliomyelitis (Poliovirus), meningitis (Poliovirus, Coxsackievirus A, B, ECHOvirus), skin diseases (Coxsackievirus B, ECHOvirus), diarrhea (ECHOvirus), hepatits (Hepatitis A, B, C, D, E, and G virus). They can be found in different types of soils, water and on surfaces of vegetables and fruits (WEKERLE 1987). It was shown by WELLINGS et al. (1976) that they associate readily with solids of wastewater and soils.

bility and nutrients, although they can show viability at reduced rates of activity at low temperatures for long periods of time (OLIVER & WANUCHA 1989) or show the potential of recovery at higher temperatures after resting times (RAVEL et al. 1995).

Krankheit *Disease*	*Organismus* *Causative Agent*	*Übertragungsweg* *Mode of transmission*
Anthrax	*Bacillus anthracis*	Contact, inhalation, ingestion
Brucellosis	*Brucella* sp.	Contact, ingestion
Campylobacteriosis	*Campylobacter jejuni*	Contact, ingestion
Diarrhea	*Enterobacteria*	Contact, ingestion
Salmonellosis	*Salmonella* sp.	Contact, ingestion
Sepsis	*Streptococcus* sp.	Contact
Tuberculosis	*Mycobacterium tuberculosis*	Contact, inhalation, ingestion
Tetanus	*Clostridium tetani*	Bite, soil contaminated contact
Wound infection	*Staphylococcus* sp.	Contact

Tab. 1: Some deseases and ways of transmission in relation to animals and soils of the Arctic.

Tab. 1: Einige Krankheiten und deren Übertragungswege in Beziehung zu Tieren und Böden in der Arktis.

2.5 *Reactions of pathogenic microorganisms in soils*

The so-called self-cleaning of natural environments plays an important role in this discussion. Environmental processes work to destroy any non-adapted, allochthonous organisms. Their survival depends on resisting killing or inactivation. This growth/survival inhibitory effect of soils is called soil microbiostasis (HO & HO 1985). In top soils introduced bacteria have to cope with changing temperature, UV-radiation, desiccation and low concentrations of available nutrients (TREVORS et al. 1989) or die out during competition (FLINT 1987). Results of survival studies of *Campylobacter jejuni* and *C. coli* in freshwater environments gave similar indications (KORHONEN & MARTIKAINEN 1991). The original, autochthonous microflora will attack them or inhibit their growth by excretion of various toxins (CHAO et al. 1988), especially when soils are dominated by fungi or actinomycetes or pseudomonads. Generally, the sum of these factors will reduce the pathogen population. It should also be born in mind that the self-cleaning process of ground water may render difficult under permafrost conditions and in non-compact sediments.

With pathogens, however, we have to cope with the problem of the dosage. A fact which holds especially true for pathogenic organisms, i.e. their infection units. The minimum concentration of human pathogens which is necessary to cause an infection varies, but is often very low, especially in viruses and parasites. Under „normal" conditions, these microbes will be removed as they are under strong competition with the better adapted original soil flora. Another factor, described for limnetic environments is the predation by protozoans (GURIJALA & ALEXANDER 1990). The concern is that pathogenic bacteria or other parasites may escape these destructive process of the soil or just survive it long enough to complete the cycle back to man or animal hosts. Pathogens have high demands on temperature sta-

At waste deposits these organisms are able to outcompete the original soil flora as they find appropriate conditions with high amounts of organic matter and even a better temperature environment due to fouling processes. The fouling process at mesophilic conditions does not inactivate the enterobacteria and enteroviruses in sewage sludge, although there are changes in relation to its primary composition (MÖLLER et al. 1985, IBIEBELE et al. 1985).

Beside temperature and nutrient content, water is another crucial factor for survival of bacteria in soils. Most enterobacteria do not tolerate desiccation and only small fractions of inocula remain viable after rewetting, in contrast to the total heterotrophic culturable bacteria (PEDERSEN & JACOBSEN 1993). Forecasts or models about the distribution of organisms into a soil are difficult or even impossible as currently used models are too simple to describe the complex nature of field sites.

2.6 *Hygienic long-term risks*

Under the circumstances of northern environments, there can be found several points which counteract the just mentioned population decrease of pathogens. Spores of Bacilli, *e.g.* from *Bacillus anthrax*, are well known to survive for decades in all pasture lands. After years and passage of long distances, they may cause disease and death among new hosts. FALCKH (1987) reviews several cause for the spread of anthrax in Great Britain and U.S.A. in the middle of this century. Many of these organisms show special strategies to survive unfavourable conditions, and several features of northern ecosystems just favour their survival. This holds especially true for freshwater sediments, to which effluents of waste disposals may flow and cause further sanitary problems. Increasing water temperature in summer will lead to contributions of bacteria to the free water. FISH & PETTIBONE (1995) showed that *Salmonella* sp. and *Escherichia coli* could survive at high densities for nearly two months at 18-20 °C.

Species of *Campylobacter* can survive in streamwater at low temperature (4 °C) for more than four months. Even the nonculturable state holds serious epidemiological implications (ROLLINS & COLWELL 1986, HAZELEGER et al. 1995). These results show that *Campylobacter* is able to remain viable though not necessarily culturable at low temperatures and that culturability and virulence is regained after passage through animal hosts such as cuttle. Similar results were shown in agricultural surface water for *E. coli* and *Yersinia enterocolitica* (TERZIEVA & MCFETERS 1991), where survival was found at high cell numbers for at least 2 weeks. FLINT (1987) reported the survival of *E. coli* in filtered river waters for up to 260 days at temperatures between 4 and 25 °C, these times were shortened using unfiltered water. The extended survival of human pathogens has been observed in freshwater sediments and subsequent recontamination of the overlaying water column has been shown to create an additional health hazard (BURTON et al. 1987). There are also observations that *E. coli* shows a prolonged survival in unfiltered river water at temperatures below 20 °C, the survival, however, decreases at temperatures below 5 °C.

Viruses are known to use host cells for their survival and reproduction. They were found in fully digested sludge after 60 days still keeping their virulence (WELLINGS et al. 1976). Viruses act more like soil organic matter and adsorbe to particles. Thus, there may occur a competition between viruses and other organic substances for adsorbtion sites on soil particles. Investigations of SCHAUB & SORBER (1977) and WELLINGS et al. (1975) have demonstrated that viruses can travel through soil horizons at considerable depth and reach groundwater where they can desorb and contaminate the groundwater (LANDRY 1980).

IBIEBELE & INYANG (1986), however, showed a movement of faecal coliforms and streptococci near Oklahoma from top soils to deeper layers (30 cm) after 90 days of sewage application and their survival for a period of at least another 150 days. This indicated that appropriate conditions in the soil environment may serve as a reservoir for faecal bacteria and that it may contaminate the water supply. REDDY et al. (1981) noted half-lives for fecal coliforms amended to a variety of soils of 2–150 hours, for *Salmonella* sp. 2–185 hours, and for polivirus 7–416 hours.

MÖLLER et al. (1985) showed that the use of sewage sludge may pose an epidemiological risk in agricultural use. Several pathogens are capable of extravital reproduction and accumulations. Prolonged survival could be demonstrated also for enteroviruses, which could be isolated 13 months after the contamination of sandy soils in northern Germany. The most effective way of their destruction and inactivation seem to be solar radiation and high temperature (WEKERLE 1987), whereas low temperatures may favour their survival (STRAUB et al. 1992). This becomes of special importance in waste dumps with shallow groundwater. Here, an enhanced virus translocation after depletion of adsorptive sites could cause groundwater contamination (KOWAL 1982, SCHAUB et al. 1982).

Uncontrolled deposits are subject to climatic influences. Strong winds will dry out surfaces and erosion will carry aerosols or sprays after rewetting. These aerosols may carry infectous units of viruses, bacteria or cysts and eggs of parasites over long distances. Both, dusts and aerosols may be inhaled and thus serve as vectors to people. This way of infection is most important for viruses (EVANS 1976) . Waste disposals are also well known for their attraction of big and small vertebrates or arthropods, which also can act as vectors for pathogenic material.

3. CONCLUSION

Disposals of animal or human wastes into natural environments carries the hazard of spreading diseases to men or animals. The invasion of pathogens into soil and water becomes critical when these sources are used to cultivate crops or as reservoirs of drinking water, respectively. The nature of many microoganisms or parasites to survive in dormancy forms under adverse conditions makes them a long term contaminant and health risk in many regions. The true extent of diseases is generally greater than reported. Infections may occur by consuming contaminated water or food (raw products, inclusive untreated milk and raw meat), by aerosol inhalation or contact with contaminated objects.

The extent to which an actual health risk exists depends on a number of local factors which need to be considered under the actual circumstances. Among these, most important are the nature of the pathogen, climatological, demographic and geographical factors (WHO 1981). Risks are not only related to microorganisms and viruses, but also to zoonoses, e.g., infections with *Taenia* sp., nematodes and others. An EC directive on the agricultural use of sewage sludge (EC 1986) allows this use only if it is immediately injected or ploughed into the soil. Regarding viruses, a recommendation of the WHO (1979) was that drinking water should be used only carefully in the vicinities of sewage treatment plants.

Prevention of infections needs the knowledge of individual life cycles and barriers of infections by the way of studying their epidemiology with special respect to cold regions. This holds especially true for food animals of these regions and needs special epidemiological studies. The effect that pathogens may have prolonged virulence under cold conditions becomes of special importance when considering their possible spread into natural environments. It is more useful to observe the rules of infection barriers and to follow guidelines with specific treatment processes rather than reliance on self regulation.

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