

**HYGIENIC ASPECTS OF BIOSOLIDS REUSE****J. Venglovský, J. Martinez**

Land application of biosolids provides agricultural benefits and presents a cost-effective method of sludge disposal following wastewater treatment. However, reuse of this product causes health concerns that must be addressed and satisfied before land application is an accepted practice. Health concerns include pathogen transmission to food or agricultural workers, contamination of ground water or surface water with faecal material from field run-off, and build-up of heavy metals or organic contaminants.

However, manures can contain pathogenic microorganisms which creates the potential for the spread of zoonoses from the farm environment into the food chain or aqueous environment. There is little quantitative information on the fate of manure pathogens during storage and following land application. This makes it difficult to assess whether current manure management guidelines, which are largely focused on reducing nutrient pollution, are appropriate for controlling the risks to food safety and water quality.

Concern has greatly increased about the potential for contamination of water, food, and air by pathogens present in manure, byproducts, and bioaerosols.

Effective sanitation of the environment, particularly of some of its special parts, which can be a source of spreading of diseases, plays an important role in prevention of infectious diseases. In this respect special attention should be paid to the disinfection of infected farm animal excrements. Sanitation of excrements should, on the one hand, ensure effective devitalization of infectious agents and, on the other hand, comply with the requirement of preserving the composition of the manure so it can be used in agricultural production.

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Pathogenic microorganisms and helminth eggs cannot be detected simply by our senses, however, their presence in the environment presents serious risk to the health of man and animals (Juriš et al., 1989, 1991; Holoda, 1998). From this point of view, excrements of sick animals can be considered important contaminants of the environment.

Survival and transport of pathogens from manure to the environment depend on a number of complex phenomena.

Chemical and microbiological changes in the composted substrate are accompanied by an increase in temperature which plays an essential role in ensuring the devitalization of pathogenic germs. Different data were presented about the causative agents of some diseases, such as mycobacteria, with regard to their survival during composting. High resistance of mycobacteria in the outer environment has been observed by Švrček et al. (1998) who reported that they survive in infected manure for 240 days.

Biowaste is known to contain pathogenic bacteria such as *Salmonella* and other microorganisms that may be a health risk for both people and animals. The biosecurity risk associated with using digested residues as fertiliser is hard to assess but this risk can not be neglected.

In recent years the fate of human and veterinary therapeutic agents as a potential pollutant of the environment has been paid increased attention. Substantial quantities of these compounds and their metabolites are excreted, flushed down the drain, discarded as waste, or left over in animal feedlots. When they enter the sewer, several of these compounds are not adequately eliminated by the methods that are currently used in sewage treatment. Substantial quantities of biosolids and livestock manure end up on agricultural land.

Four major types of human pathogens can be found in biosolids: bacteria, viruses, protozoa, and helminths. Böhm and co-workers (1999) examined a wide variety of manures, food-processing residues and household wastes for the presence of pathogenic bacteria, fungi and viruses. Table 1 gives the epidemiological importance of processed wastes and residues as well as of the resulting products.

The quality of treated sludge should be defined on the basis of risk to human, animal and plant life. The levels of pathogens in the treated sludge should not exceed their ambient levels in the environment. In practice this means that for the purposes of quality control realistic limits of defined pathogens must be set and well-established standard procedures have to be followed. A summary of the latter is given in Table 2.

Table 1. - EPIDEMIOLOGICAL IMPORTANCE OF PROCESSED WASTES AND RESIDUES AS WELL AS OF THE RESULTING PRODUCTS (Böhm, 2002)

<i>A. Direct transmission to farm animals</i>	
-	Contamination of meadows
-	Introduction of pathogens by storage and processing close to susceptible animals
-	Aerogenic transmission by spreading the materials onto farm land
<i>B. Direct transmission to humans</i>	
-	Handling of contaminated products in the household
-	Occupational exposure to contaminated products
-	Accidental transmission to immunocompromised persons
<i>C. Indirect transmission to farm animals</i>	
-	Via feed from contaminated sites
-	Via living vectors
<i>D. Indirect transmission to humans</i>	
-	Via introduction of zoonotic agents into the food-chain
-	Via food contaminated by living vectors
<i>E. Introduction into the environment</i>	
-	Generation of carriers in the fauna
-	Introduction into the microflora

Table 2. - SUMMARY OF ADVANCED TREATMENTS FOR ORGANIC WASTE (Davis et al., 2002)

Process	Parameters
Windrow composting	Batches of sludge (+/- bulking agent) to be kept at 55 <sup>0</sup> C for 4 hours between each of 3 turnings, followed by a maturation period to complete the composting process.
Aerated pile and in-vessel composting	The batch to be kept at a minimum of 40 <sup>0</sup> C for at least 5 days and for 4 hours during this period at a minimum of 55 <sup>0</sup> C. This to be followed by a maturation period to complete the composting process.
Thermal drying	The sludge should be heated to at least 80 <sup>0</sup> C for 10 minutes and moisture content reduced to < 10%.
Thermophilic digestion (aerobic or anaerobic)	Sludge should achieve a temperature of at least 55 <sup>0</sup> C for a minimum period of 4 hours after the last feed and before the next withdrawal. Plant should be designed to operate at a temperature of at least 55 <sup>0</sup> C with a mean retention period sufficient to stabilise the sludge.
Heat treatment followed by digestion	Minimum of 30 minutes at 70 <sup>0</sup> C followed immediately by mesophilic anaerobic digestion at 35 <sup>0</sup> C with a mean retention time of 12 days.
Treatment with lime (CaO)	The sludge and lime should be thoroughly mixed to achieve a pH value of at least 12 and a minimum temperature of 55 <sup>0</sup> C for 2 hours after mixing.

From the variety of bacterial pathogens *Salmonella spp.* are the most relevant since they can infect or contaminate nearly all living vectors from insects to mammals. Multiresistant bacteria are coming more and more into focus since their transmission via environment as well as the introduction of resistance genes into other bacteria may cause tremendous problems in human and veterinary medicine. From the viewpoint of environmental risks viral pathogens such as enteroviruses and rotavirus are the most relevant ones (Metzler et al., 1996). Special attention must be paid to the parasitic pathogens, not only to eggs of round- and tapeworms but to *Giardia lamblia* and especially *Cryptosporidia parvum* too, since the latter sometimes occurs in slurry from calves and cattle used in co-digestion. Nearly all gut related pathogens can be found in slaughterhouse effluents. If sludges are of plant origin or if they had been processed by using plant material, they may contain plant-pathogenic viruses, fungi, bacteria, parasites and undesired weeds. This will cause an additional phytohygienic risk if the final product is to be used in agriculture as fertilizer (Böhm 1999 a, b).

Recycling to agricultural land is an important outlet for sewage sludge and other organic wastes but it must be controlled in order to obtain agricultural benefit from the operation whilst protecting human and animal health and the environment at large. Current practices in Europe are based on the requirements of the 1986 Directive on the use of sewage sludge in agriculture (86/278/EEC). However, since that time new technologies have become available for sludge treatment, more pathogens associated with the food chain have been identified and the concerns of the public relating to acceptable risk have changed.

A wide range of phyla, genera and species are likely to be present in sludges, particularly those that contain large amounts of faecal material. The identity and numbers of pathogens in municipal wastes will be dependent upon the health of the contributing population.

According to Davis et al., 2002 *E. coli* counts in treated sewage sludge or sludge from meat processing waste released for land use should not exceed 1000 per gram (dry weight) whereas those of *C. perfringens* spores 3000 per gram (dry weight). A 4 log<sub>10</sub> reduction in numbers of added *Salmonella* should be achieved, and *Ascaris* ova should be rendered non-viable.

Of course there are some constraints on the reuse of sludges in agriculture. For example those that may contain the BSE agent should not be applied to land where animals have direct access whereas sludges from paper, vegetable and tannery waste should present no risk after mesophilic digestion or a similar treatment standard.

Table 3. - SUGGESTED CONSTRAINTS ON LAND USE OF TREATED ORGANIC WASTE (Davis et al., 2002)

Crop	Advanced treatment	Conventional treatment
Pasture	Yes	Injection and 3-week no-grazing
Forage	Yes	3-weeks no-harvest
Arable	Yes	Injection or plough-in
Vegetables in ground contact	Yes	10-month no-harvest
Fruit & vegetables eaten raw [salads]	Yes	30-month no-harvest
Fruit trees, vineyards	Yes	Injection and 10-month no-access
Parks & urban open spaces	Well stabilised and odourless	No
Land reclamation	Yes	10-month no-access

The two following figures (Fig. 1, Fig. 2) express the effects of temperature and time on some species of micro-organisms. In Figure 1 the *Safety Zone* is the area of the graph where pathogens would not survive, or the sludge would be virtually pathogen free due to a combination of time and temperature. The lowest safe temperature for the tested pathogens elimination was about 45 °C. The length of time required to maintain the sludge at this temperature was over 40 days. By increasing the temperature to 50 °C, the time required shortened to just over three days, at 55 °C to 15 hours, at 60 °C to two hours and at 70°C to seven minutes. This describes ideal conditions which are rarely achieved in full-scale treatment plants. Practical studies indicate that sludge should be held for four hours at 55 °C (Fig. 2) or 30 minutes at 70 °C to kill at least 99.99% of pathogens (Car-rington et al., 1998). The heat distribution through concentrated sludge and solid materials is more difficult to estimate; therefore the time safety margin should be observed.

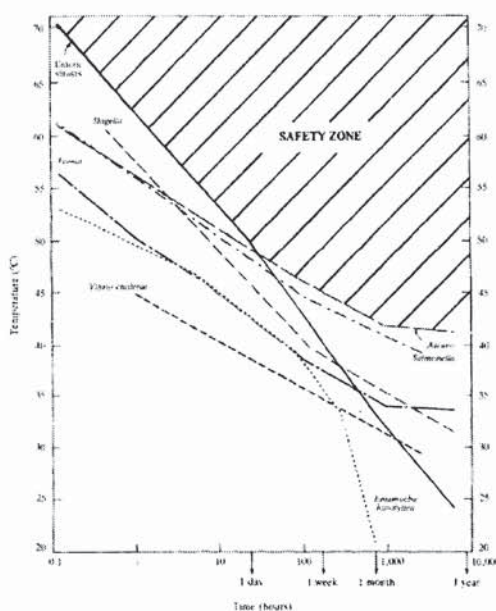
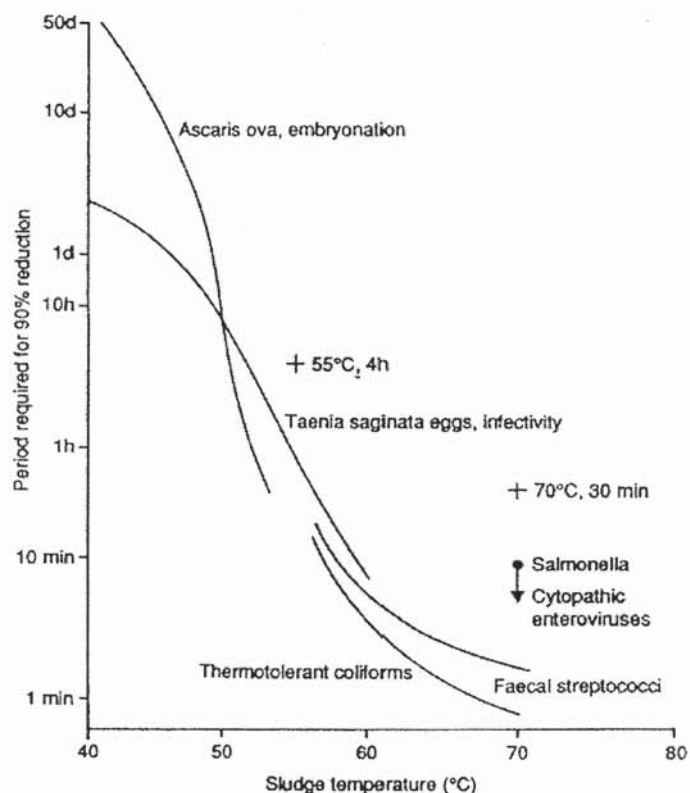


Figure 1. - TIME-TEMPERATURE REQUIREMENTS TO PRODUCE SLUDGE, THAT IS VIRTUALLY PATHOGEN-FREE. (Feachem, 1983)

Figure 2. - EFFECT OF SLUDGE TREATMENT TEMPERATURE UPON TIME FOR 90% DESTRUCTION OF VARIOUS PATHOGENS. CROSSES INDICATE TEMPERATURE/TIME CONDITIONS SPECIFIED IN CODE OF PRACTICE (DoE, 1989) (Pike and Carrington, 1986).



According to Rapp (1995) total bacterial counts as well as the numbers of Enterobacteriaceae, *E. coli* and faecal streptococci remained nearly unaffected under practical conditions (farm storage tanks), and even increased during storage for up to 185 days. The numbers (cfu) of *Salmonellae* in slurry exposed to the slurry in semi-permeable membranes were reduced by more than  $10^5$ . *Yersinia enterocolitica* was completely inactivated within only a few days whereas the eggs of *Ascaris suum* as well as the oocysts of *Cryptosporidium parvum* also lost their viability, although very slowly. 0

The study by Findlay (1972) showed that *Salmonella dublin* in cattle slurry survived storage for between 19 and 33 weeks. Similarly Larsen and Munch (1986) found that *Salmonella typhimurium* survived in pig and cattle slurry stored at 8°C for more than 10 weeks with only a small decrease in

numbers (from  $10^6$  to  $10^4$ /ml). *Yersinia enterocolitica* was eradicated by week 6 while *Staphylococcus aureus* was reduced from  $10^6$  to  $10^2$ /ml in 9 weeks. In the solid fraction of pig slurry, *Salmonella typhimurium* survived for 26 days in summer and 85 days in winter (Placha et al., 2001), and coliforms were reduced by 90% in 35 and 233 days during the summer and winter time, respectively. *Cryptosporidium parvum* oocysts required more than 90 days to become non-viable in cattle slurry stored at 4 °C while at 15 and 20 °C they were nearly all killed in 30 and 20 days, respectively (Svoboda et al., 1997). In the farmyard, manure stored at temperatures of 4 and 15 °C, 30% and 8% of oocysts, respectively, survived longer than 90 days. When composting was encouraged and temperatures in excess of 30 °C were achieved, there was no survival of oocysts after 35 days.

Concluding it can be said that with view to the threats not only of diseases virtually or potentially transmissible to animals and man but also with view to the threats of global terrorism the hygienic aspects of the production and reuse of biosolids are of utmost importance. They present a challenge that requires further sound research and surely also global cooperation and even coordination.

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## HIGIJENSKI ASPEKTI OBRADENOG GNOJA

### Sažetak

Gnojenje poljoprivrednih površina talogom odnosno muljem nakon obrade otpadnih voda iz stočarske proizvodnje je ekonomski prihvatljiviji postupak od ostalih metoda. Međutim upotreba tog supstrata može uzrokovati zdravstvene probleme koje treba uzeti u obzir prije njegova nanošenja na poljoprivredne površine. Briga za zdravlje uključuje prijenos različitih patogena u hranu ili na poljoprivredne radnike, zagađenje podzemnih ili površinskih voda fekalnom materijom ili kumulaciju teških metala i organskih komponenti. Opisane različite mogućnosti prijenosa zoonoza i epidemiološka važnost animalnog otpada. Iz rada se može zaključiti da se tretiranjem gnoja odnosno mulja ne sprječava samo pojava bolesti koje se mogu prenijeti na životinje i ljude već je njegova obrada, proizvodnja i upotreba od globalne važnosti. Stoga predstavljaju izazov za daljnja istraživanja.

Ključne riječi: gnoj, patogeni mikroorganizmi, zoonoze.

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