

# Sewage Sludge: Fertilizer or Waste?

The use of sewage sludge as an agricultural fertilizer is at the center of an intense debate. The primary benefit of using sewage sludge as a fertilizer is the recycling of valuable plant nutrients from the consumer back into the agricultural system. But this benefit is offset by the risk posed by the introduction into the environment of potentially harmful chemicals contained in the sewage sludge. The benefits and the risks must be weighed against one another. In the short term, we should use only the highest quality sewage sludge; in the long term, we need to develop systems and techniques that satisfy criteria for both sustainability (nutrient recycling) and precaution (environmental protection).

Sewage sludge is produced by centralized wastewater treatment plants and is classified as a waste fertilizer (see box) according to the Swiss Regulations on Chemicals (StoV) and the Regulations on Fertilizers (DüBV). In 1999, the 979 wastewater treatment plants in Switzerland produced a total of 209 000 tons of sewage sludge (dry weight), 40% of which was used in agriculture (Tab. 1). The bulk of the remaining sludge was used for fuel in industrial furnaces designed for sludge incineration, in cement production, and in waste incineration plants. A small portion of sewage sludge was once deposited in landfills, but this practice was banned in 2000. Utilization and disposal methods for sewage sludge vary strongly among the cantons: in JU, GL, FR, TG and UR, almost the entire volume of sewage sludge is used in agriculture, while GE, BS and AI used virtually none of their sewage sludge as fertilizer.

## Sewage Sludge Contains Both Nutrients and Pollutants

Despite the fact that most European countries use at least some portion of their sewage sludge as agricultural fertilizer, this practice is presently the topic of an intense debate. On one hand, the recycling of nutrients contained in sewage sludge satisfies the sustainability principle; on the other hand, sewage sludge may contain a number of undesirable chemicals so that its use as a fertilizer poses a risk to both the environment and human health, thereby contradict-

ing the principle of precaution. It is our task to weigh the benefits against the risks.

## Benefits of Sewage Sludge Utilization

**Source of Nutrients, Fertilizer:** On a dry weight basis, sewage sludge contains on average 45 % organic matter, 5.8 % calcium, 4.4 % nitrogen, 2.7 % phosphorus, 0.5 % magnesium and 0.3 % potassium. In addition, it usually contains sulfur and trace elements like cobalt, copper, molybdenum, nickel and zinc. Compared to the total amount of nutrients from farm manure and mineral fertilizers (see box), the contribution from sewage sludge is relatively small (Tab. 2). It counts only for 7.1 % of phosphorus, 2 % of nitrogen, and 0.1 % of potassium from the totally deposited amount of fertilizer [1]. Omitting nutrient input from internal farm sources (dung, manure, etc.) and considering only the nutrient input from external sources (deposition, mineral fertilizers, animal feed), however, sewage sludge may account for as much as 34 % of the phosphorus and 9 % of the nitrogen output from

Fertilizers are nutrients for plants. There are three groups of fertilizers:

1. Waste fertilizers
  - Sewage sludge: product of wastewater treatment
  - Compost: decayed plant and animal material
  - Undecayed plant material, e.g., waste from apple juice production
  - Products from mineral or animal waste, e.g., horn chips, ground leather
2. Farm manure: e.g., liquid manure, solid manure, manure drainage, silo drainage
3. Mineral fertilizers: mostly chemical products

	Nutrient load in 1000 t		
	N	P	K
Farm manure	128	20.5	162
Mineral fertilizer	53	7.4	27
<b>Sewage sludge</b>	<b>3.7</b>	<b>2.2</b>	<b>0.25</b>
Compost	2.9	0.74	1.8
Other wastes	1.5	0.57	1.5
<b>Total</b>	<b>189</b>	<b>31.4</b>	<b>192</b>

Tab. 2: Comparison of nutrient loads from different fertilizers in Switzerland for the year 1999.

	1974	1980	1984	1989	1994	1999
Number of communal WWTP's	430	710	855	930	977	979
Population served (%)	46	70	81	88	91	95
Total sewage sludge production (1000 t dry matter)	90	170	176	213	211	209
Amount used in agriculture (%)	80	65	50	50	55	40

Tab. 1: Number of wastewater treatment plants (WWTP's), population served, total production and agriculturally utilized sewage sludge volumes for Switzerland.

agricultural production (plant and animal products) [2, 3].

#### Preservation of Global Nutrient Reserves:

According to current estimates, phosphate mineral deposits accessible by current technologies (12 billion tons of ore) will be depleted within the next 80 years. Additional phosphate reserves, estimated at approximately twice that volume, are at the bottom of the oceans or contain heavy metals and can, therefore, be utilized only to a limited degree or at a high cost. The situation is less critical for nitrogen and also the potassium reserves should last for the next 300 years [1].

#### Improvement of Soil Characteristics:

The introduction of organic matter and lime improves the physical, chemical and biological properties of the soils when fertilized with sewage sludge. Field studies have documented an increase in humus content, soil pH, biological activity (soil respiration, nitrogen mineralization, enzymatic activity) and microbial biomass. These improvements were found down to a 1 m depth [4]. The increased soil pH has a secondary effect on adsorbed and dissolved heavy metals in the soil: an increase in soil pH reduces the amount of dissolved (i.e., bio-available) heavy metals in the soil, with the result that plants on soils fertilized with sewage sludge exhibit lower cadmium and nickel concentrations than plants grown on unfertilized soils or soils amended with liquid manure (Stadelmann et al. 1988, cited in [1]).

**Benefits to the National Economy:** Fertilization with sewage sludge (at 1999 levels) can save fertilizer and nutrient costs of 7 million CHF per year. In addition, the use of sewage sludge in agriculture saves approximately 34 million CHF annually of incineration costs [1].

### Risks in the Use of Sewage Sludge

**General Risks:** Long-term use or inappropriate application of sewage sludge can lead to contamination of surface waters (due to run-off or erosion), ground and spring water. Contaminants may also accumulate in the soil, which leads to reductions in soil fertility (reduction of diversity and activity of soil organisms), crop quality, and crop yield. At

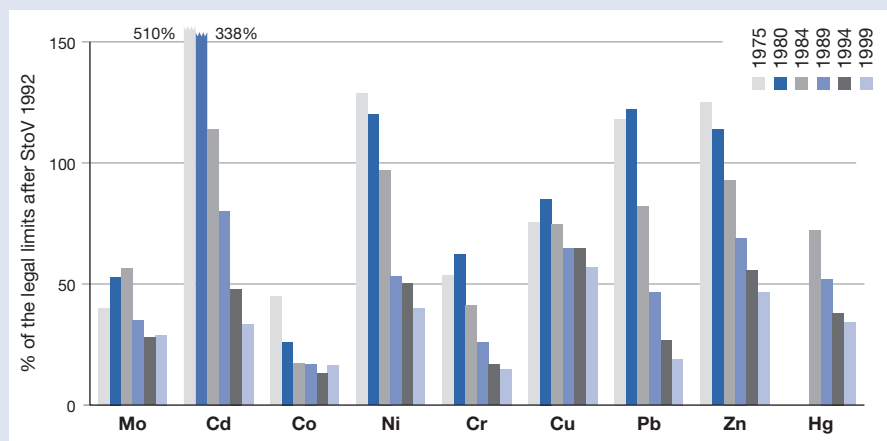


Fig. 1: Average utilization of heavy metal limits for sewage sludge in Switzerland, according to the Regulations on Chemicals (StoV 1992) (after Külling 2001, cited in [1]).

the same time, contaminants may enter the food chain and cause negative effects on the health of livestock and humans [1].

**Heavy Metals:** Repeated fertilization with sewage sludge causes heavy metals to accumulate in the soil. Increased levels of dissolved heavy metals (e.g., cadmium, zinc, copper) result in a reduction in biological activity in the soils [5], lower crop yields, and increased heavy metal concentrations in the crops. The threat from heavy metals to livestock and human health, however, is generally considered to be minimal [1]. Since 1975, heavy metal concentrations have been generally dropping. The quality of the sewage sludge used in agriculture has never been as good as it is currently, and contamination levels are clearly below the levels set by the StoV (Fig. 1). This is reflected in improved heavy metal-nutrient values (HMN) and heavy metal-phosphorus values (HMP), two parameters that are commonly used in Switzerland to assess and compare the quality of different sewage sludges (Tab. 3) [1]. The lower the two values, the higher the quality of the sewage sludge.

**Organic Contaminants:** Sewage sludge may contain a number of organic contaminants (see box), mostly in the range of  $\mu\text{g}/\text{kg}$  dry weight [1]. The organic compounds can vary over a wide range in their chemical characteristics, i.e., persistent, lipophilic, toxic or carcinogenic properties. Persistent compounds, such as PCBs, can accumulate in agricultural systems and food chains

(Fig. 2). Most organic contaminants show only minor toxicity towards plants and usually are absorbed by the plant to a negligible degree. If the plant takes up the contaminant, it is often at least partially degraded during the plant's metabolism. The problem for livestock and humans, however, is the surface contamination of meadows, pastures and soil surfaces as a result of sewage sludge application. If dairy cows, for example, ingest plants and soil particles that are contaminated on their surfaces, the contaminants may end up in the milk and, therefore, in the food chain. For this reason, Germany, Sweden and Norway have strict bans on the use of sewage sludge in feed crops.

**Pathogens:** Sewage sludge is a potential carrier of a number of pathogens, such as bacteria (e.g., *Salmonella*), viruses (e.g., Hepatitis B), protozoa (e.g., *Entamoebae*) and roundworms (e.g., *Ascaris*) [1]. If sewage sludge is sanitized, for example by heat, the number of pathogens can be significantly

#### The dominant organic contaminants in sewage sludge are:

- chlorinated aliphatic and aromatic hydrocarbons
- chlorophenols
- polycyclic aromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- polychlorinated dibenzodioxines and dibenzofuranes (PCDD/F)
- di(2-ethylhexylphthalate) (DEHP)
- organotin compounds (TBT)
- tensides and tenside metabolites (LAS, NP)
- bisphenol A
- chlorparaffines
- polybrominated diphenylethers (PBDE)
- polychlorinated naphthalene (PCN)
- organochlorine pesticides
- musk compounds and drugs (including antibiotics and hormones)

	1975	1980	1984	1989	1994	1999	AG <sup>99</sup>
Total of heavy metals	378	653	534	467	375	321	140
HMN	6.39	4.43	1.99	1.44	1.15	0.96	0.85
HMP	21.46	11.78	4.48	4.27	3.26	2.68	2.37

Tab. 3: Heavy metal loads in sewage sludge (t/year) and heavy metal-nutrient (HMN) and heavy metal-phosphorus (HMP) values for Switzerland [1]. AG<sup>99</sup>: Metal load introduced into agriculture via sewage sludge for 1999.

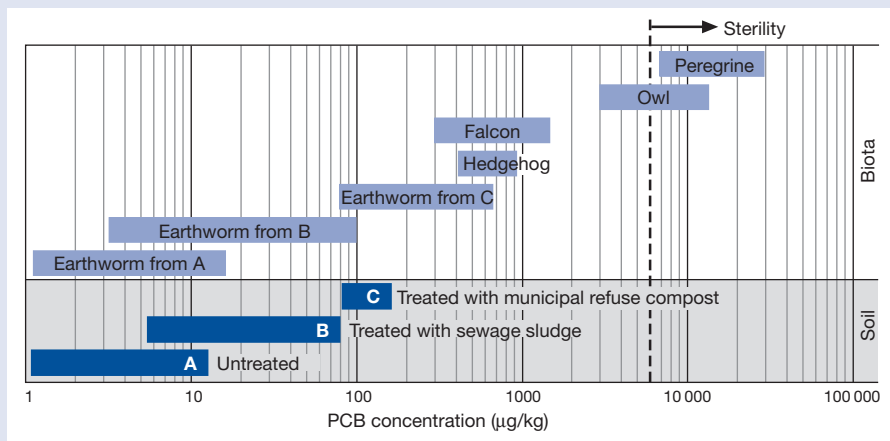


Fig. 2: Accumulation of PCBs in agroecosystems in Switzerland (after Tarradellas et al. 1985, and Becker van Slooten 2001, cited in [1]). PCB concentrations in soils are based on dry weight, in animals on wet weight.

reduced. The use of heat-treated sewage sludge as a fertilizer in agriculture, therefore, poses a very low risk to human and animal health.

**BSE and GMO:** Only a minimal fraction of infectious material (e.g., BSE infectious particles) is found in the waste water, provided that appropriate methods of slaughtering and meat processing are used, good hygiene is practiced, and all solid materials from filtration and floatation processes in meat processing plants that could pose a risk are collected. Sewage sludge, therefore, presents a minimal contamination risk for BSE. In the case of genetically modified microorganisms (GMOs), spreading of these organisms via sewage sludge is possible, in principle, particularly in sewage sludge that has not been sanitized [1].

## Sewage Sludge is Only One of Several Risk Sources

Chemical pollutants, pathogens and GMOs are released into the environment also by processes other than those related to sewage sludge. Only about 12% of the heavy metals in Switzerland are released into the soil from sewage sludge; 38% come from farm manure, 25% from atmospheric deposition, 14% from mineral fertilizers, 6% from fungicides, 4% from compost and 1% from ash (wood burning) [1]. The situation is similar for many organic contaminants. For PCBs, for example, annual amounts released into agricultural soil are estimated at about 1000 kg from deposition, 70 kg from farm manure, 8 kg from sewage sludge, and 3 kg from compost [1]. In a rough evaluation of the total risk by multi-criteria analysis [1] assessing nutrient stock (availability), soil structure, heavy metal content, organic contaminant concentrations, pathogens, BSE, GMOs, disposal costs and marketing/image, sewage sludge was rated

the worst. Better ratings were given to wood ash, waste from lumber processing, farm manure, compost, waste from food processing and mineral fertilizers. What is generally acknowledged, however, is that any use of fertilizer carries certain risks.

## What Has to Be Done?

Generally, we cannot evaluate the benefits and risks of using sewage sludge as a fertilizer isolated from other aspects. First, we need to reduce the contaminant load in sewage sludge; secondly, we need to improve both the methodology and practicality of risk management.

In the short to mid-term, we need targeted measures to minimize risks and optimize benefits, such as:

- solid waste separation in meat processing (BSE risk), improved monitoring of hygiene and targeted selection of sewage sludges with low HMN and HMP values;
- prevention/reduction of the ingestion of sewage sludge by livestock on pastures;
- introduction of additional criteria in the Regulations on Fertilizers (DüBV) for organic contaminants and re-evaluation of current limits for heavy metal concentrations and recommended fertilizer volumes as set in the Regulations on Chemicals (StoV);
- phasing out of sewage sludge applications in agriculture in case of a ban (grassland before arable crops).

The long-term goal in the context of a closed agricultural system and resource management is to recycle nutrients from human waste and other usable sources. We need to put increased effort into the conceptual development of alternative sewage systems that allow us to separate domestic waste water, industrial process water and run-off. We also need to advance technologies dealing with the extraction of nutrients from waste water and sewage sludge.

Nature does not produce waste, but only valuable nutrients that need to be utilized. Expressions such as waste, waste water and waste heat are out of place. Our primary goal should be to simultaneously satisfy the principles of sustainability and precaution.



Franz X. Stadelmann, natural scientist, member of management and leader of the product area "Environmental Resources/ Environmental Protection in Agriculture" of the Swiss Federal Research Station for Agroecology and Agriculture (FAL) in Zurich-Reckenholz.

### Coauthors:

David Külling, environmental scientist, research scientist in the Waste group within the product area "Nutrient System/Water Protection" at FAL in Zurich-Reckenholz.

Ulrich Herter, agronomist, until August 2001 head of the Waste group within the product area "Nutrient System/Water Protection" at FAL in Zurich-Reckenholz.

[1] Herter U., Külling D. (eds.) (2001): Risikoanalyse zur Abfalldüngerverwertung in der Landwirtschaft. Teil 1: Grobbeurteilung. Bericht der Eidg. Forschungsanstalt für Agrarökologie und Landbau FAL, Zurich-Reckenholz, 271 p.

Document available as pdf-file from:

[www.blw.admin.ch/themen/hstoffe/pbm/d/texte.htm](http://www.blw.admin.ch/themen/hstoffe/pbm/d/texte.htm)

[2] Spiess E. (1999): Nährstoffbilanz der schweizerischen Landwirtschaft für die Jahre 1975 bis 1995. Eidg. Forschungsanstalt für Agrarökologie und Landbau, Zurich-Reckenholz, Schriftenreihe der FAL 28, 46 p.

[3] Stadelmann F.X. (2000): Landwirtschaftlicher Umweltschutz – eine spannende Aufgabe: Erfahrungen und Überlegungen aus schweizerischer Sicht. Veröff. Bundesamt für Agrarbiologie Linz/Donau 22, 13–52.

[4] Stadelmann F.X., Furrer O.J. (1985): Long-term effects of sewage sludge and pig slurry applications on microbiological and chemical soil properties in field experiments. In: Williams J.H., Guidi G., L'Hermite P. (eds.) Long-term effects of sewage sludge and farm slurries applications. Elsevier, London, 136–145.

[5] Stadelmann F.X., Gupta S.K., Rudaz A., Santschi-Fuhrimann E. (1984): Die Schwermetallbelastung des Bodens als Gefahr für die Bodenmikroorganismen. Schweiz. Landwirtschaftliche Forschung 23, 227–239.