The use of biosolids from wastewater treatment plants in agriculture

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The global population explosion and the accompanying industrialisation have resulted, on the one hand in an increase in wastewater volumes and an almost innumerable list of constituents, and conversely, in an increasing shortage of water resources and basic food supplies, at least in some regions of the world. Current technologies enable almost all constituents to be eliminated from wastewater assuming the necessary financial resources are available, but appreciable quantities of sludge are produced. However, this handicap can be turned to advantage; sludge, when transformed into biosolids, is an ideal soil conditioner and fertilizer in agriculture. Thus the supposed threat of increasing agriculture. Thus the supposed threat of increasing agriculture. Thus the supposed threat of increasing agriculture. Thus the supposed threat of increasing agriculture. Thus the supposed threat of increasing agriculture. Thus the supposed threat of increasing agriculture. 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The use of biosolids from wastewater treatment plants in agriculture took place, mainly due to the following two reasons: artificial fertilizers were gaining ground fast; and a strongly increasing environmental awareness within the German population had led to more critical examination of sludge constituents. In this context, I would like to remind you for instance of the heated arguments over the content of dioxines in sludge during the late 1980s.

During the 1990s however, the use of sludge in agriculture grew in importance again. Over 800,000 tons of dry solid matter were employed in agriculture in reunited Germany in 1992, roughly 25 per cent of the total quantity. The areas affected cover around 500,000 hectares of arable land.

Why should sludge be utilized in agriculture?

The idea of feeding valuable organic matter, primarily nitrogen and phosphorus, back into a natural cycle forms the basis of using sludge in agriculture. One of the positive side-effects is the protection of natural resources, especially phosphorus – which will be discussed in detail.

Additionally, cost calculations have shown that using sludge in agriculture proves to be a more economical alternative than other kinds of sludge disposal.

Fertilizing value of sludge

The nitrogen, phosphorus and, in some cases, lime content of sludge, depends primarily on the kind of sewage and sludge treatment. The dewatering of sludge causes a significant decrease in the nitrogen content, along with the removal of excess water. Conversely, lime is quite frequently added in the process of dewatering – again, this results in the accumulation of valuable nutrients.

The elimination of phosphorus in the course of sewage treatment leads to an accumulation of phosphorus in the sludge. Thus, the following main combinations are possible:

1. Liquid, highly nitrogenous sludge, possibly with an increased phosphorus content.
2. Dewatered sludge, possibly with an increased phosphorus and/or lime content.
3. Dried sludge, with an increased phosphorus content.

Table I shows the average contents of nutrients in sludge as a percentage of dry, solid, matter

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>With lime</th>
<th>Without lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH(_4)-N</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>3.1</td>
<td>4.7</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>CaO</td>
<td>32.4</td>
<td>5.4</td>
</tr>
<tr>
<td>MgO</td>
<td>0.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

annum, the annual fertilizing value of the sludge sums up to 48 million DM.

Naturally, agricultural use of sludge is profitable only if there is a need for the nutrients which are included in the sludge, which are mainly nitrogen, phosphorus and lime. This need should be determined by carrying out a nutrient balance analysis of the soils on which sludge is to be applied, taking into account the kind of plants to be grown on the soil, their crop pattern, and the yield, kind and quantity of harvest residues and the use of other fertilizers.

The saving of natural resources

An admittedly pessimistic estimate of global phosphorous resources is based on the assumption that current resources will last for about another 500 years, with an annual consumption of 10 million tons worldwide. A total of 415,000 tons P\(_2\)O\(_5\) are currently used in artificial fertilizers in German agriculture. Let us further assume that the total annual sludge quantity is 3.6 million tons of dry solid matter with an average P\(_2\)O\(_5\) content of 5 per cent, equaling 180,000 tons of P\(_2\)O\(_5\) per annum. At best, if 100 per cent of these sludges were employed in agriculture, the amount of phosphorus used in artificial fertilizers could be reduced by more than 40 per cent. This is shown in Figure 1.

![Figure 1 Phosphate balance](image-url)
Naturally, this assumption is a very idealized one. Still, it clearly shows that the use of sludge in agriculture could influence the saving of natural resources significantly.

### Content of toxic substances in sludge

Owing to continuous monitoring of indirect dischargers, the sewage treatment authorities have been able to reduce the content of noxious substances in sludge significantly over the past 20 years. The present cadmium content for example, which is quite harmful to humans, has dropped to only 10 per cent of the content 15 years ago. Table II illustrates the decrease of heavy metals in sludge between 1977 and 1992/1993.

The content of organic toxic substances in sludge also remains well below the limit values. An analysis of sludge samples shows, that, on average, the adsorbable organic halogen compounds (AOX) content amount to only 30 per cent, the polychlorinated biphenyls (PCB) content to 10 per cent and the polychlorinated dioxines/furanes (PCD/PCF) content to 30 per cent of the respective limit values.

It has to be emphasized that other kinds of fertilizers such as mineral fertilizers or animal manure also contain toxic substances. Phosphate fertilizers, in particular, show an extremely high cadmium concentration compared with sludge. Depending on the origin of the phosphorus used, the type of fertilizer and the processing technology employed, the cadmium content can be as high as 300mg per kilogram of P2O5. Conversely, sludge, has an average cadmium content of only 40mg per kg P2O5.

Figure 2 shows the results of some very interesting research, carried out over a period of 30 years. No significant difference could be detected in the cadmium content of those wheats, which are highly sensitive to heavy metals.

It goes without saying that the volume of toxic substances in sludge must be reduced even further to ensure the long-term use of sludge in agriculture.

### Comparison of costs for sludge disposal

The following specifications can only be seen as a rough outline of the present situation in Germany. A more exact cost determination cannot be carried out without taking into account the local variations in costs for use of sludge, or any other disposal. The fees for disposal of sludge on landfill sites, for example, are currently between DM 150 and DM 1,500 per ton of dry solid matter.

For the use of liquid sludge in agriculture, costs between DM 200 and DM 500 per ton of dry solid matter are to be expected.

The total costs for the use of dewatered sludge in agriculture vary between DM 300 and DM 450 per ton of dry solid matter.

The disposal of dewatered sludge on a landfill site costs roughly DM 1,000 per ton of dry solid matter.

The burning of sludge, including dewatering, drying and the disposal of residues on a landfill site currently costs between DM 1,000 and DM 2,000 per ton of dry solid matter.

These figures show clearly that there is a significant cost advantage in using sludge in agriculture as opposed to alternative ways of disposal.

### Legal requirements

Previously, a numerical listing of the laws and regulations for sludge disposal that applied in Germany in the middle of 1995 was presented.

On 7 October 1996, an additional law, the “Gesetz zur Förderung der Kreislaufwirtschaft und zur Sicherung der umweltverträglichen Beseitigung von Abfällen” (Law for the promotion of recycling and for safeguarding an environmentally compatible waste disposal) came into force. It aims at saving natural resources and securing environmentally compatible waste disposal.

This requires avoiding waste as far as possible – if it cannot be avoided, it should be used to produce energy or be recycled. The fact is that sludge can hardly be avoided, as it accumulates continuously in the process of waste water treatment.

The “Decree of use of sludge in agriculture”, which came into force in 1982, and was updated in 1992, serves as a basis for the recycling of sludge. The decree aims at protecting soil, groundwater, plant, animal and human life.

The decree is built upon the following seven pillars:

<table>
<thead>
<tr>
<th>Table II</th>
<th>Average content of heavy metals in sludge, used in agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>290</td>
</tr>
<tr>
<td>Cadmium</td>
<td>21</td>
</tr>
<tr>
<td>Chromium</td>
<td>630</td>
</tr>
<tr>
<td>Copper</td>
<td>378</td>
</tr>
<tr>
<td>Nickel</td>
<td>131</td>
</tr>
<tr>
<td>Mercury</td>
<td>4.8</td>
</tr>
<tr>
<td>Zinc</td>
<td>2,140</td>
</tr>
</tbody>
</table>

Note: mg/kg dry solid matter
It limits values for heavy metals and organic toxic compounds in sludge, as shown in Table III.

Determination of limit values with regard to the previous heavy metal contamination of soils; attention should be paid to Table IV.

No more than five tons of dry solid matter may be spread per hectare within a period of three years.

The method, quantity and time for the land application of sludge should be adjusted to the nutrient need of the plants concerned, also the natural nutrient resources and organic substances within the soil as well as the specific conditions for cultivation.

The limit values specified in the decree represent the maximum allowable; actual values should be as low as possible.

The land application of sludge is only legal on appropriate arable land. It is not allowed for instance within natural reserves, national parks, water protection zones, etc.

The land application of sludge needs to be authorised and controlled by the relevant authorities.

Steps towards the realization of using sludge in agriculture

The following lists indicate the steps that should be taken to ensure the use of sludge in agriculture.

1. Preparatory Measures
   - Information campaign/awareness raising in agriculture.
   - Preselection of areas, exclusion of prohibited areas.
   - Sampling and analysing of soil.
   - Interpretation of soil analysis (heavy metals!)
   - Elaboration of manuring plan.
   - Selection of sludge, determination of quantities, fixation of date.
   - Risk management, liability.
   - Preparation of delivery notes.
   - Announcement to supervising authority
   - Determination of transport, intermediate storage, distribution modalities.
   - Balancing out of sludge demand/sludge disposal.

2. Implementation
   - Transportation/intermediate storage.
   - Distribution.
   - Monitoring.

The use of sludge in agriculture requires team-work

The main institutions concerned are listed as follows:

- the sewage treatment authority, which is responsible for the quality of the sludge;
- the farmer, who spreads the sludge on appropriate areas;
- the consultant, who influences the process technology of the treatment plant and designs the land application scheme;
- the laboratory, where the sludge and the soil samples of the areas concerned are analysed;
- the biosolids land application enterprise, which organizes the transport and distribution of sludge;
- the supervisory authority, which checks compliance with the decree of using sludge in accordance with the authorities involved.
3 Documentation
- Fill up delivery notes.
- Distribute delivery notes to all parties involved
- Cartographical monitoring of areas.
- Establish card-index, inform supervising authority

Liability
In spite of the greatest possible care and compliance with the Decree of Use of Sludge, there are a few hidden risks involved which cannot always be eliminated as early as at the stage of land application. Thus, the so-called “Waste water sludge fund” was founded in 1990 on a voluntary basis. The fund is financed by contributions from the sewage treatment authorities which amount to DM 62 million (in 1995). The fund currently has around 800 members, all of them sewage treatment authorities. The maximum possible claim for a single damage is DM 2 million.

Apart from a few goodwill cases (with a total compensation of DM 26,000 in 1995), no claims for damages have been made so far.

Conclusion
Owing to an increasing tightening-up of laws and regulations, a progressive improvement and refinement of advanced wastewater treatment technologies and - last but not least - a continuous monitoring of indirect dischargers, the sewage treatment authorities have been able to reduce the content of noxious organic and inorganic substances in sludge significantly over the past 20 years. Consequently, sludge from wastewater treatment plants can be applied in agriculture successfully and without any risk if certain standards – e.g. hygiene, previous and permissible additional soil load levels – are to be met, if suitable crops and balanced crop patterns are chosen and if an operationally efficient logistics, administration and cost management system is available.

Thus, the use of sludge in agriculture contributes quite considerably to the idea of recirculating valuable substances into nature and helps saving of natural resources.

Further reading


Leschber, R., Bannick, C.G. (1995), Schlammcharakterisierung, behandlung und verwendung (sludge characterization, treatment and use), Korrespondenz Abwasser, Heft 11, Abwassertechnische Vereinigung, Hennef, Germany.


Table III
Limit values in sludge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Light soils</th>
<th>Normal soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Cadmium</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Chromium</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Copper</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Nickel</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Mercury</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Zinc</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>PCP</td>
<td>0.2mg/kg dry solid matter</td>
<td></td>
</tr>
<tr>
<td>Dioxines/ furanes</td>
<td>100ng TE/kg dry solid matter</td>
<td></td>
</tr>
<tr>
<td>AOX</td>
<td>500mg/kg dry solid matter</td>
<td></td>
</tr>
</tbody>
</table>

Table IV
Limit values in soil (mg/kg dry solid matter)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>100</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.5 (1)</td>
</tr>
<tr>
<td>Chromium</td>
<td>100</td>
</tr>
<tr>
<td>Copper</td>
<td>60</td>
</tr>
<tr>
<td>Nickel</td>
<td>50</td>
</tr>
<tr>
<td>Mercury</td>
<td>1</td>
</tr>
<tr>
<td>Zinc</td>
<td>200 (150)</td>
</tr>
</tbody>
</table>