Sludge Management, Processing, Treatment, and Disposal

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Current sludge regulations limit sludge disposal alternatives based on the treatment level provided, pathogen removal, and metals content. At the same time, practical disposal options for sludge involve some form of reuse of the product, whether by direct land application, stabilization, composting, or pelletizing. Much of the sludge from South Florida is stabilized and used on sod farms in the central part of the state, then later returned to South Florida in the form of sod. As a result, the focus of "reuse" of wastewater products should not be solely limited to the use of reclaimed water, but also to the process by products.

As defined by EPA in 40 CFR Part 503, sewage sludge is any "solid, semisolid, or liquid residue generated during the treatment of domestic sewage in a treatment works." Generally, these byproducts consist of microorganisms and detrital matter from the treatment process, but they may also include domestic septage, scum, or solids removed in primary, secondary, or advanced wastewater treatment processes, and any material derived from sewage sludge (WEF 1998). Sewage sludge is one of the principal products of municipal wastewater treatment. Drawing from the successes of wastewater treatment effluent reuse, the following is a review of some available options for beneficial use and reduction of sewage sludge.

Beneficial Uses of Biosolids

Disposing of biosolids by shipment to landfills is considered a beneficial use only when such disposal includes methane gas recovery for fuel. However, methane operations are relatively rare. Alternative beneficial uses are receiving greater attention because of a decline in available landfill space and an interest in conserving nutrients, and utilizing soil conditioning properties and other recoverable qualities of sewage sludge. Thus, land application for soil conditioning and fertilization is the primary beneficial use of biosolids.

Biosolids applications to agricultural lands utilize recyclable components of wastewater in the production of crops. Biosolids recycling and reuse programs not only create savings for local and state governments through lower disposal costs and sales of biosolids-derived products, but they also add nutrients and improve soil characteristics (Evans 1989). Biosolids provide the essential plant nutrients, moisture content, and organic matter necessary to improve a soil's physical condition and render it more productive. Biosolids contain all the elements essential for the growth of higher plants, and since nitrogen and phosphorus are the most abundant major plant nutrients in biosolids, they can be used effectively as a supplemental source for fertilizer manufacturers. Biosolids also contain most of the essential plant micronutrients, with the possible exception of potassium (Linden 1995; NRC 1996).

As with land application of other organic materials, such as hay and animal manures, biosolids addition improves the physical properties of soils. This, in turn, exerts a beneficial influence on water penetration, soil porosity, bulk density, strength, and aggregate stability (O'Connor 1996; Sastre et. al 1996; WPCF 1989). The effects of biosolids application to crops is an issue of public scrutiny, but consider that in Spain's Andalusian region, cherry wine produced with biosolids continues to outsell the wine produced using conventional fertilizers in taste tests, even when the wine grown in biosolids was identified prior to tasting (Andrades, Gomez, and de Castro 1998).

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Dewatered treated sludges have also been used successfully for producing building materials, such as concrete and bituminous mixes, and also as a road subsoil additive utilizing chemical fixation processes (Aziz and Koe 1990). The chemical fixation process involves combining treated sludge with stabilizing agents, such as cement, sodium silicate, pozzolan, or lime, to chemically react with or encapsulate sludge particles (Metcalf & Eddy 1989). Final residuals of incineration or other thermal process have also been used to generate road subbase material or concrete aggregate (Takeda et. al 1989). Pulverized sludge ash and dewatered sludge/clay slurries have been used successfully in lightweight concrete applications without influencing the product's bulk properties (Tay and Show 1991). Sludge-based concrete has been deemed suitable for load-bearing walls, pavements, and sewers (Lisk 1989). Imagine: sewer pipes made from sludge — that would be the ultimate in recycling schemes.

Sludge has also been used in cement manufacturing. This industry is highly energy intensive; however the large energy costs of creating clinker at 1500°C can be offset by utilizing biosolids as a low-cost and readily available supplemental energy source. Furthermore, biosolids can be injected into the exhaust gas chamber to eliminate NOx emissions using the thermal energy of the hot exhaust gases combined with ammonia contained in the biosolids to convert NOx to nitrogen gas (Kahn and Hill 1998).

Sludge enriched by heavy metal content has been incorporated into the production of biobricks. In this approach, incinerator sludge ash is used as a clay substitute during the manufacture of bricks. The process improves the ceramic properties and product strength of the resulting construction materials (Anderson et. al 1996). Biobricks do not release metals during firing or weathering (Alleman et. al 1990). Benefits of biobrick technologies also include volume reduction and substantial savings on water and fuel consumption as well as treatment costs. Biosolids have also been used as a carbon source for odorous gas treatment via adsorption and for flue gas treatment via desulfurization, albeit both with limited results (Krogmann et. al 1997). Palasantzas and Wise (1994) investigated the possibility of producing calcium magnesium acetate using residual biomass from sewage sludge. Reportedly, this production mechanism would generate a cost savings of 68% over conventional disposal costs.

A technique called "sludge-to-fuel" (STF) involves a process that converts sludge organic matter into an incinerable oil using a solvent, atmospheric pressures, and temperatures in the range of 200-300°C (Millot et. al 1989) or, alternatively, high pressures in the range of 10 MPa combined with high temperatures (Itoh et. al 1994). One system uses a hydrothermal reactor to convert mechanically dewatered sludge to oil, char, carbon dioxide, and wastewater. The char, making up 10% of the product, is sent to a landfill, while the gaseous emissions are treated and released to the atmosphere. The produced oil has approximately 90% of the heating value of diesel fuel and can be sold to offsite users or refineries (Hun 1998).

Other processes produce oils from sludge by employing activated alumina pyrolysis of digested, dried sludges, or tolueneextracted sludge lipids (Abu-Orf and Jarnrah 1995). In either case, sludge-associated metals seem to bind to the residuals, with final product conversion efficiency being dependent on the sludge particle size, temperature, and process heating rate (Takeda et. al 1989). Conversion to oil traps heavy metals in the residual and destroys organochlorine compounds that survive treatment within the POTW (Bridle et. al 1990). Liquid fuels produced with the STF technology have the potential to be used as a diesel fuel substitute, a heating fuel, or a chemical feedstock (Konar et. al 1994).

Another innovative use for wastewater sludge involves accelerated phytoremediation of sites contaminated with 137Cs. After the Chernobyl incident, field experiments were conducted in Finland in which radioactive wastes were remediated through land application of wastewater sludge to barley, straw, and spring wheat fields. This resulted in a minimum of 2-12 times higher concentrations in the crop than in control plots (Puhakainen and Ylaranta 1992). Following along this precedent, brownfield treatment has also been accelerated using the application of biosolids (Sajad 1998).

Reduction of Biosolids

Minimization of sludge produced during treatment seems like a simple way to cut biosolids disposal costs. However, it is not so easy. For example, it should be noted that increased mineralization leading directly to a decreased sludge yield, and the associated increase in aeration costs and detention times, results most often from increased oxygen consumption (Sinollen 1999). A balance must be struck between biosolids production, treatment plant size, and operating costs to achieve maximum efficiency. Nevertheless, some innovative methods for reducing the amount of sludge generated during processing are available.

During the aeration phase of wastewater treatment, for example, the production of secondary sludge can be decreased by 60-80% by manipulating the microbial consortium so that the bacterial cell mass produced during treatment is consumed by protozoa and metazoa (Lee and Welander 1996).

Sludge acidification to a pH less than 2.5 with sulfuric acid is another technique that was found to result in significant sludge reduction (WPCF 1989).

In Germany, a novel approach to reducing sludge production involved the use of an agitator ball mill to disintegrate bacterial cell walls, thereby releasing an external carbon source for biological denitrification (Krogmann et. al 1997). Utilizing this method, sludge production was reduced by 65% with a small energy cost; however, the simultaneous release of phosphorus and trace metals are issues that remain unresolved. Furthermore, dewatering was adversely affected, necessitating a greater polymer demand.

Future Developments

According to Mike Cook in the EPA Office of Wastewater Management, a nationwide survey of POTWs showed that 54% of all biosolids production in the United States is currently being reused (1998). This is consistent with the new approach to wastewater treatment as a biosolids production facility as opposed to an effluent disposal facility approach. With legislation banning ocean disposal, restricting the release of contaminants to the environment, and requiring more intensive treatment of wastewater, the volume of sludge produced has increased. Regulatory concerns about air and water quality have further restricted available options for ultimate disposal of wastewater residuals Furthermore, increased regulation of manure and other animal products is on the way (Bastian 1997a; Bastian 1997b; Cook 1998) and will force POTWs to become more competitive and creative when it comes to markets for their residuals (Nelson and Wemsdorfer 1994). EPA has made it clear that it will continue to change the sludge treatment and disposal regulations to further reduce undesirable environmental impacts of domestic sewage sludge on communities and public health (Bastian 1997a). Accordingly, there has been a move away from landfilling and incineration and toward beneficial uses such as land application (Wang 1993). The regulatory changes that will be made to further encourage recycling practices, while at the same time protecting the public health and risks to the environment, will require new and innovative treatment processes capable of effectively dealing with the variable and diverse nature of wastewater treatment biosolids, and it is up to the wastewater industry to adopt environmental management approaches and encourage beneficial use and reuse of biosolids as a valuable resource.

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