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GLOBAL SLUDGE MANAGEMENT: A STATUS REPORT AND PERSPECTIVE

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ABSTRACT

Sludge management is a more and more complex problem due to increased difficulties in locating disposal works and meeting more stringent environmental quality requirements. The most recent notable developments in conventional processing systems have regarded dewatering and stabilization, which remain essential prerequisites to any disposal method. With the increasing pressure on disposal options, such as agricultural use and landfilling, there has been a resurgence of interest in incineration. New processes and alternative uses have been proposed and experienced, but most of them still require further investigations to evaluate effectiveness and reliability. In any case, it is not realistic to search for a global solution to the problem, but the best solutions must derive from local and site-specific considerations.

KEYWORDS

Sewage sludge; management; treatment; disposal; new processes; alternative uses.

INTRODUCTION

The general purpose of sewage sludge management is to solve individual sludge problems in a suitable way. Suitability would require that the solution be at a minimum cost, taking into account local factors and circumstances, including environmental considerations and the benefits obtained from the sludge disposal. The future will bring a steady increase in sludge production following new work installations and up-grading of existing facilities. This will be coupled with increased difficulties in properly locating disposal works and increasingly stringent environmental quality requirements.

The ideal solution to the sludge disposal problem would be to develop sludgeless sewage treatment systems. Assuming that this is unlikely to occur anytime soon, the first goal should be to develop cost-effective sewage treatment processes which produce less sludge, or processes which produce sludges that have beneficial use.

An example of a process that reduces sludge production is the LOSLUJ process which involves the biological filtration of finely screened unsettled sewage so that much of the suspended matter normally removed by primary sedimentation passes on to the filter to be partially destroyed by biological action. This means a sludge reduction up to 30 % compared with conventional plants (Hoyland and Ronald.1984).

Sludge is not only a difficult material to handle, due to its putrescence and moisture content, but wastewater sludge is extremely variable and complex in terms of chemical and biological composition and physical and physico-chemical behaviour. This constitutes a fundamental problem for the process designer and treatment process operator. Simpler and more reliable sludge characterization tests are needed, and better laboratory or pilot equipment is necessary to conduct these tests. A deeper knowledge of the role played by the intrinsic properties, such as water distribution and particle size distribution, is also necessary.

In the past, research has concentrated on substrate kinetics and energetics and not on solids as they appear in the influent and as they are transformed. It seems that future research should concentrate on the solids and how they form into flocs that must be separated from the water prior to its discharge as plant effluent. The flocculation of sludge solids has a great influence on the degree of solid-liquid separation that can be achieved, and this needs to be studied in some detail. Experimental techniques are required that could be used to measure the degree or flocculation. Moreover, representative sampling is essential prior to analysis since even excellent procedures cannot correct the error incurred as the result of obtaining an unrepresentative sample. This was not adequately addressed in the EC COST 68/681 program (Commission of the European Communities, 1992).

DEVELOPMENT OF CONVENTIONAL SYSTEMS

The sludge processing options are numerous, as shown in the network diagram of Fig. 1, which includes most of the common stages of treatment, with the options available for each stage. Also included are some new processes which are discussed below. As far as conventional systems for treatment and disposal are concerned, every system still has problems, even though significant developments have occurred during the past few years.

Treatment

The simplest and historically first method of solids removal is screening. And yet screening can still be ineffective and the process may result in offensive and unsightly conditions.

In primary sedimentation, the tendency of sludge to produce gas and to rise in the tank, especially during warm weather, is not an infrequent problem. This will of course result in poor consolidation performance.

Colin (1986) described a method of thickening using an electric field, thus speeding up sludge sedimentation and gravity thickening, but its practical application seems still questionable. In any case, the preferred practice is to separate thickening of primary and biological sludges in order to apply the most effective technology to each sludge type.

Although stabilization technology is well known and developed, some occasional problems still remain, including digestion inhibition due to toxic materials. A method of reliably providing operators with an early warning of any stress of the bacterial populations is needed. Excessive foaming is another problem occurring with both anaerobic and aerobic digesters. Control methods are available but are not completely satisfactory in that the cause of foaming is not fully understood.

Thermophilic aerobic digestion, as a practical method of stabilization and disinfection of sludge, has

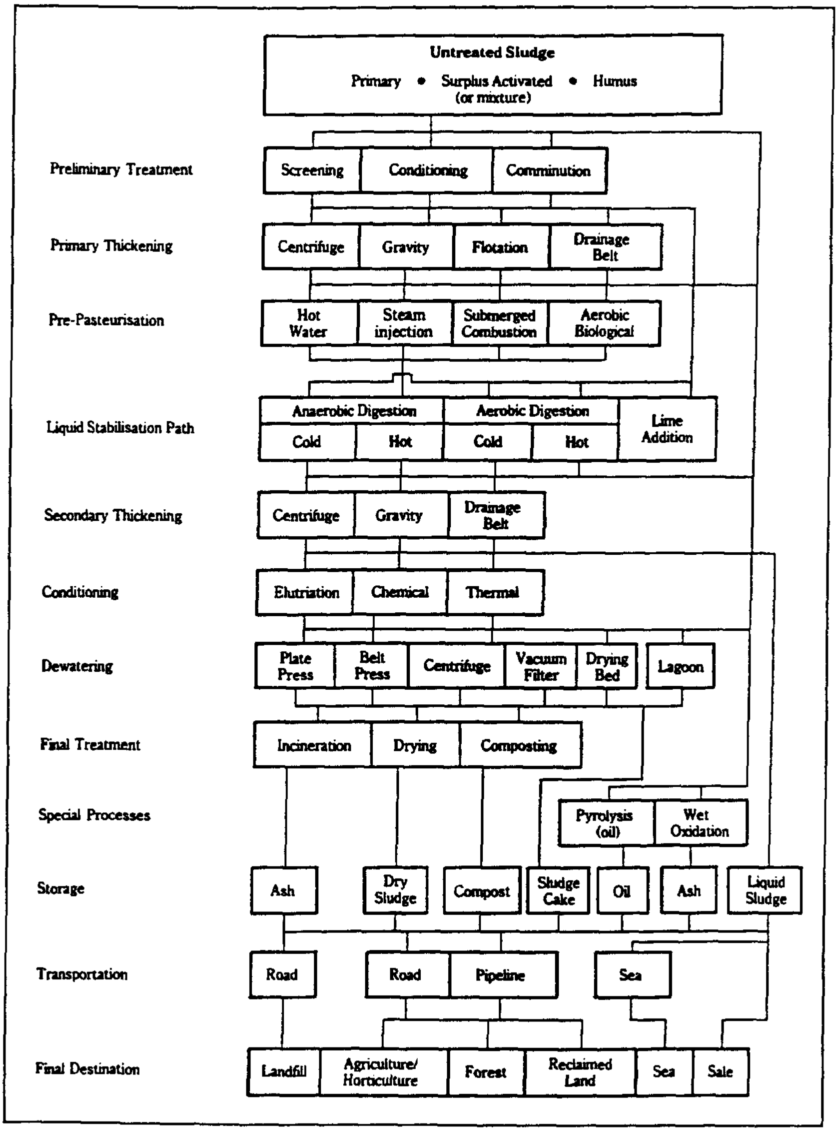

Fig. 1. Sludge processing network (Comm. of the Europ. Commun., 1992).

been perhaps the most notable development in sludge processing during recent years. This process has found several applications, especially in Germany and the United Kingdom. Its use as a preliminary stage before anaerobic digestion was also demonstrated in Switzerland. Operational problems remain, including the occurrence of foaming and a nuisance odor.

In spite of the increased use in many cases of liquid sludge in agriculture, dewatering remains an essential prerequisite to any other disposal procedure. This is due to the necessity for increasingly drier and more physically stable cakes. The major problem is the presence of large quantities of secondary sludge, particularly surplus sludge from high-rate activated sludge plants and humus from high-rate filters.

Many types of new dewatering machines designed to produce high solids concentration sludge have been developed. Such machines (Gildmeister, 1989) inevitably represent higher investment costs than conventional ones but in many cases the pay-back can be within a few years due to lower transport and disposal costs.

The increased interest in filtration under pressure caused the introduction of innovations to extenuate the inconvenience caused by the non-continuous operation and low yields of filter presses. Automation of plate movement and cloth washing allows the first problem to be somewhat solved, while new equipment is able to produce high cake solids concentrations (Continuous High Press, High Intensity Press, Burger Press). Good performance can be also obtained by screwpresses (Spinosa and Lotito, 1993a).

Several innovations have also been introduced in the field of centrifugation (Minyuan, 1987; Albertson, 1990). Increasing the available torque on the conveyor shaft together with the modification of differential speed control and regulation systems allow for operation at low differential speed without plugging risks, thus significantly improving cake solids concentration up to 30%. Further improvements include increasing bowl length with respect to diameter and using scrolls with variable pitches. This last modification, first used in oil field mud dewatering over 30 years ago, allows the centrifuge to move the sludge at variable velocity through the different centrifuge zones. Improvement can also be obtained by reducing internal turbulence by installing diffused feed port and feeding under the water surface in a concurrent flow machine.

Most of these ideas are not new and there does not seem to be complete agreement on the beneficial effects of such machine modifications. It is agreed, however, that if the centrifuge is to be able to compete successfully with other dewatering processes, it must be able to produce sludge cakes of more than 30% solids with essentially complete solids recovery.

Disposal

The conventional disposal systems include landfilling, agricultural use and incineration. In Western European Countries landfilling and agricultural use represent roughly 95% of the total sludge production, with about 50% going to each form of disposal. The information on sludge treatment in Eastern Europe is not readily available, but it can be assumed that about 80 to 85% of sludges generated in municipal treatment plants are used as soil conditioners.

In Asian Countries, landfilling or farm application is also a typical way of final disposal unless this conflicts with local environmental regulations. Land disposal is often the best choice because it represents the least expensive alternative.

Where neither landfilling nor agricultural use are feasible, incineration represents a third alternative, although this becomes more difficult due to a strict regulation and stringent public concern for pollution, especially in Japan.

For deposition in landfills, mechanical dewatering is commonly required to produce a sludge with a high solids content (>35%). However, dry solid matter is often not the most significant sludge property in landfilling. Sludge placed in land that has to be worked and covered requires that heavy equipment be able to move in the sludge/soil mixture, and the sludge physical nature, as described by the shearing strength, becomes a governing parameter. Typically sludges need to have shearing strengths in the range of 15-20 kPa.

Advantages can be obtained by co-landfilling municipal solids waste and sewage sludge. This results in a higher refuse compactability and better water balance, especially in dry climates. Adding sludge to a municipal landfill results in faster anaerobic degradation and a more rapid decay of the organic matter in refuse, allowing for quicker reuse of the landfill for municipal refuse disposal. Adding sludge to landfills will increase the leachate production and this can be a problem if an excessive amount of sludge is added to refuse (Spinosa and Lotito, 1993b). The placement of sewage sludge in refuse landfills can be considered to be an economical way of recycling organic matter back into the environment and reducing the need for new landfill space.

In agricultural applications, the principal benefit of sludge lies in its nitrogen content. Applications on land can, however, lead to several environmental problems which include surface runoff, leaching of nitrate into groundwater, volatilization of ammonia, possible dissemination of pathogens, persistence of toxic organic contaminants, heavy metal leaching and uptake by plants, and threat to human health due to pathogenic microorganisms. Much is known about potential environmental problems associated with sludge utilization and how they can be avoided, but more information is needed.

The EC Directive 86/2278/EEC provides guidance on limits for metals for European Member Countries. More stringent and detailed regulations may be set by Member Countries and local communities. The United States Environmental Protection Agency recently promulgated sludge disposal regulations which limit the amount of metals that can be placed on productive land.

Composting still finds quite limited use in Europe, North America and in Japan, mainly due to the very limited market for such a product. However, the situation could change in the future if reliable methods for determining the maturity of compost and maintaining quality control are developed.

Also, in this case, co-composting with municipal solid waste would allow an optimal C/N ratio to be obtained (20-30) provided that C/N ratio for sewage sludge is low. While nitrogen can be lost as ammonia gas during composting, slower operations can yield composts with high nitrogen content. By carefully managing the moisture content, a lower consumption of the bulking agent and a better quality product result (Spinosa and Lotito, 1993b).

With the increasing pressure on disposal options such as agriculture and landfilling, and the reduction in the costs of energy, there has been a resurgence of interest in the thermal treatment of sludges, especially incineration. It, however, requires significant capital investment, produces an ash that requires disposal, and emits pollutants into the atmosphere and is therefore not applicable to all localities.

There has been considerable improvement in incinerator design in the last decade, especially in fluidized bed technology (Frost, 1990). Improvements have been made in the effectiveness of emission cleaning systems and in energy efficiency. Improved heat recovery and more effective dewatering and drying before burning have been able to achieve autothermicity.

A lower energy consumption is often the result when sludge is co-incinerated with municipal refuse. However, higher capital costs are involved for the necessary adjustment of equipment and pollution control, and the system must be accurately designed in order to take into account the higher production of particulate in the emissions (Spinosa and Lotito, 1993b).

NEW PROCESSES AND ALTERNATIVE USES

Treatment

Two new systems of processing sludge have come to the fore during recent years: deep-hole wet oxidation and low-temperature pyrolysis to produce oil.

Wet oxidation by deep-hole technology has been developed in The Netherlands. It consists of a set of vertical tubes, drilled vertically into the ground for about 1,500 m where high pressure is obtained by the sludge column and heat is generated by the process itself after start-up. Pure oxygen has to be added to start the process. After separation of the ash, the off-gases and the liquid, dewatering of ash takes place as gases are afterburned and the liquid biologically treated. This form of emissionless incineration has attraction but there is still a long way to go to demonstrate its economic viability. Clearly, it is inappropriate for use in some geological conditions (De Bekker and Van den Berg, 1988).

The main thrust for the development of oil production from sewage sludge using temperature pyrolysis has come from Canada, but the original work on this process really started in Germany. The dried sludge is heated to 300-350°C in an oxygen-free environment for about 30 minutes. It is postulated that catalyzed vapor phase reactions convert the organics to straight chain hydrocarbons, much like those present in crude oil. Analysis of the product confirmed that aliphatic hydrocarbons are produced in contrast to all other pyrolysis processes, which produce aromatic and cyclic compounds regardless of the substrate. The economical attraction of the process is strictly linked to oil production, but it also has merits in its own right as it reduces the mass of material and concentrates the energy in liquid form, thus making the product more easily storable (Campbell, 1989).

Innovative research has shown that the inefficiency of dewatering gelatinous and fine-particle sludges can be overcome by mechanical dewatering enhanced by electro-osmosis and electro-acoustical fields. The first system consists of a feed box, a horizontal belt gravity dewatering section and an electro-osmotic section, where sludege is squeezed between to belts made of electrically conductive material which constitute the electrodes Osmollen, 1993). The effect of ultrasound is based on radiation pressure, agglomeration of particles, cavitation and transformation of viscosity, while that of electric field is based on motion of charge particles and ions and on chemical reaction (VTT, 1993). Their applications allow blinding of filter media to be markedly reduced and significant reduction in polymer consumption obtained.

Disposal

Frost and Campbell (1986) reviewed possible alternatives for using sludges. They found that many possibilities exist in addition to the conventional uses, including chemical feedstock, animal feedstuff, and source of metals, building material and energy. However, most of these alternative uses have not found favour in practice.

In Japan, sludge disposal is practised with three governing characteristics: 1) the sludge should require the least possible disposal volume, 2) no leakage of heavy metals or other toxics into the environment is allowed, and 3) the sludge must be disposable or saleable all year round.

One option in Japan is the manufacture of light-weight aggregate from sludge incinerated ash. The product is used for the production of porous paving material, acoustic panels, ornaments, pottery, and light-weight furniture. The aggregate can be incorporated into asbestos-fiber to provide strength and lightness. In normal acidity environments, leakage of metals is minimal. An experimental full-scale production plant with a capacity of 12 t/d of light-weight aggregate has been installed in Tokyo.

Manufacturing bricks from incinerated ash as raw material is rather simple. At present, two plants are in operation in Tokyo, each with a capacity of 3,800 bricks from 10 t/d of ash. Bricks are widely used for pavement of paths, driveways and plaza floors. Roughly one brick is made from 100 persons' daily discharge.

When reduction of volume and immobilization of heavy metals are the first requirement, solidification of dewatered undigested sludge cake is an answer. The end product (slag) has a volume of only 4% of the initial volume is a marble-like mineral of semi-crystalline structure. It can be used for concrete aggregates, interlocking tiles, water-permeable tiles, and even jewelry. Since 1990, a full scale slag plant has operated in Tokyo with capacity of 13 t/d of slag from 160 t/d of sludge cake.

Costs to manufacture the above products are not cheap, but not too expensive when compared with landfilling of the incinerator ash.

CONCLUSIONS

Sludge continues to be a global problem. It is curious that while technological advances have solved problems such as the production of vaccines for many infectious diseases, heavier than air flight at speeds exceeding the speed of sound, and the manipulation of genes, we have as yet to solve the problem of sludge disposal. There is a tendency to be embarrassed about the sorry state of global sludge management.

And yet, it is not realistic to search for a global solution to the sludge problem. The best solutions are local and site-specific. Installing a sludge incinerator in a developing country and then making jewelery out of the ash is utter nonsense. Likewise, spreading sludge on farmland in Hong Kong is foolishness. Each community must determine what is best for it. What we in the business of solving the sludge problems for our communities must do is to search for the most effective solution for us.

Accordingly, sludge research should be multifaceted, searching for means of removing metals and pathogens from sludge so it can be disposed of on farmland, as well as seeking ways to remove water so the solids can be used for oil production, as an energy source, or many other alternatives. In a way, the search for solutions to the sludge problem is like the search for a cure for cancer. There will never be one single solution and the successes will come with time and with patience. And as this paper shows, there have been many significant advances in sludge technology. Perhaps we need not be embarrassed after all.

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