Sustainability in sludge management: a combined approach to meet future needs

Due to be published next year, the second edition of 'Wastewater sludge: a global overview of the current status and future prospects' will provide further information on wastewater sludge developments. The book's editor, **LUDOVICO SPINOSA**, discusses in this article the three areas that need to be taken into consideration when developing or implementing a sustainable approach to wastewater treatment – environment, economy and society – and looks at different wastewater treatment situations around the world.

Recovering energy by gasification. Credit: Professor Masaki Takaoka, Kyoto University.

The term 'sustainability' and its associated forms are today widely used when speaking of the development of human activities, especially in the environmental field, including sludge management.

Since 1987, when a United Nations (UN) conference defined sustainable developments as those that 'meet present needs without compromising the ability of future generations to meet their needs', a range of other definitions have been proposed, but the general conclusion that can be drawn is that sustainability is related to the statement that 'the quality of life in a community relates to the economic, social and environmental systems that make up community, which provide a healthy, productive, meaningful life for all community residents, in the present and the future'.

The three above-mentioned systems are strongly interconnected to one another and cannot be considered separately when achieving effective sustainability, as clearly shown in Figure 1, which demonstrates that sustainability is the confluence of three constituent parts of fundamental importance:

- The environmental element (environmentally robust, and supported by consistent and applicable normative and legal requirements)
- The economic element (economically affordable, technologically feasible, operationally viable)
- The social element (socially desirable, culturally acceptable, psychologically nurturing)

An 'unsustainable situation' occurs when the total sum of natural resources is used up faster than it can be naturally replenished. In this situation, long-term environmental degradation has to be expected, thus involving the inability to sustain human life.

On the contrary, a 'sustainable situation' follows consumption of renewable resources less than, or at least equal to, nature's ability to replenish them.

However, although the sustainability concepts have in theory a 'unique' meaning, their transferral to practice is a difficult task because solutions need to be specifically tailored to each field of activity and the starting point, i.e. the specific social, economic and technological level of the involved community.

So, in the case of sludge management, the question is: How can those systems fulfil sustainability requirements?

Sustainability in sludge

At present, sludge management systems are often inefficient and unsustainable, mainly because no single process or treatment when used alone is able to address all three environmental, economic and social aspects, which are needed for an entirely sustainable system. Therefore, a change toward more sustainable procedures must be promoted through an integrated approach, including the:

- Better use of current technologies
- Innovative and new planning procedures
- Development of self-sustaining energy systems, or systems with a low energy impact
- Maximization of the production of materials, to be usefully reused for different purposes
- Better adaptation to the local specific context and situations

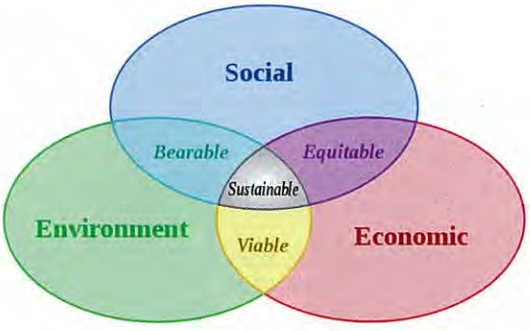

Figure 1: Interconnection of elements affecting sustainability (Adams, 2006).

A strategy for the recovery and reuse of valuable products has, therefore, become of greater concern. As well as this, the conventional and more traditional recycling options, like direct utilisation in agriculture and other land uses, are being progressively restricted and in some cases banned, which also drives the push toward searching for new solutions.

Therefore, it is to be concluded that the development of correct and sustainable sludge management procedures should mainly be addressed towards reducing the amount of sludge to be disposed of, applying reuse options that are aimed at recovering useful products or energy instead of simple disposal ones, developing integrated systems that are self-sustaining from the energy point of view, producing materials to be safely

handled from an environmental point of view and conveniently marketed, and developing operational systems appropriate to local circumstances, including social ones, i.e. interactions with the public through informing them about sustainability efforts, and encouraging them to participate.

Strategies for reducing sludge mass / volume include the minimization of sludge production in the wastewater treatment stage, by adopting appropriate technologies and operating procedures, and minimization in the sludge stage itself in a preceding wastewater treatment stage. Methods can range from increasing sludge age, ozonation and using membrane technology, through to methods specifically reducing sludge volumes by removing water, e.g. thickening, dewatering and drying, and finally incineration, gasification, and many other combined processes.

Possibilities for material recovery include production of organic matter, nutrients, carbon source, coagulant, bricks, pumice, slag, artificial lightweight aggregate and Portland cement. The nutrient content of sludge is also of interest, especially phosphorus, which has to be regarded as the most valuable product in the sludge as it is not an endless resource. It is estimated that in 100 years the apatite mines will be empty and we will have no reliable phosphorous sources left, but phosphorus can be recovered from sludge through anaerobic digestion or from incinerated ash, while nitrogen can be recovered mostly from sludge treatment reject waters, e.g. from dewatering.

As far as possible energy recovery from sludge is concerned, several alternatives are available, from anaerobic digestion to thermal processing technologies, including pyrolysis and gasification. Enhancement of pyrolysis / gasification processes, through more efficient dewatering and drying processes, should allow for the production of quality products for material and / or energy utilisation to be improved. Other advantages of high temperature processes include reduction of volume and weight of waste, and destruction of toxic organic compounds. However, overall energy balances have to be carefully evaluated to avoid the entire system consuming energy instead of recovering it. This evaluation should also consider transportation aspects with the aim to minimize trip lengths. In addition, a fully sustainable system should have the capacity to preferentially produce one or more materials depending on the specific local situation.

In conclusion, the correct management of sludge requires the development of multiple and diversified option strategies, which is a combined challenge common to city administration, citizens and industry. These groups should first aim at reducing the amount of sludge to be disposed of, and secondly at producing higher quality sludge.

Therefore, for optimal sludge management decisions, a case-by-case solution has to be found by determining what is the best solution based on local and site-specific considerations, and then, once the optimal disposal / use practice has been chosen, by defining the treatment(s) necessary to optimize the entire system, as a whole.

Examples of alternative approaches

Several examples demonstrate how local situations affect decisions on approaches adopted for the development of more sustainable sludge management systems.

Routes planned in Italy, especially in Northern Regions, are aimed at increasing the reliability of sludge disposal routes, as sludge quality may not always comply with the quality requirements needed for agricultural reuse, reduce the environmental impact due to landfilling, as biogas and leachate leakage in the long-term pose serious problems of social acceptance and environmental impact, minimize the economical impact of sludge management, as disposal costs to landfills in Northern Italy have increased to about twice those for sludge drying and incineration, and recover energy and materials, minimizing or even reducing to zero the final residues. Other alternatives, such as pyrolysis, are not considered as yet to be a fully developed, reliable and economical alternative.

In Portugal, current waste and energy policies are in favour of sustainable end outlets and associated renewable energy production.

Enhanced production and utilization of biogas could be one of the anticipated trends in sludge management of Eastern Europe. There are experiments taking place of anaerobic co-digestion of wastewater sludge and municipal solid wastes. Methods of sludge treatment with energy recovery through anaerobic digestion, incineration or other thermal treatment have also begun to be very promising in Eastern Europe.

In Turkey, treatment technologies minimizing the quantity of sludge are being researched. Further, it is planned to developed regional sludge management action plans for each region.

In Toronto, Canada, a quite unexpected event occurred at the city's largest wastewater treatment plant. The existing thermal oxidation facility was considered environmentally unsustainable and replaced with a dual system (thermal multi-shelf indirect driers for 50% of the anaerobically digested solids and direct land application of dewatered mesophilically digested solids), but almost immediately after the thermal oxidation facility was decommissioned the drier caught fire and became non-functional while the county that was supposed to receive dewatered biosolids refused that service. This forced Toronto to truck its dewatered solids, for several years, across the border to a landfill in USA. Backlash against importation of Canadian solids led the city to rethink again the option of thermal oxidation.

In Japan work is underway to

New updated and expanded edition

Wastewater Sludge - A Global Overview of the Current Status and Future Prospects: Second Edition

Editor: Ludovico Spinosa

Following a successful first edition published in 2007, the follow-up 2011 edition of 'Wastewater sludge – a global overview of the current status and future prospects' will present an updated and expanded perspective on developments in relation to wastewater sludge around the world.

Sludge arising from wastewater treatment represents a serious environmental issue, requiring technological and management solutions to ensure it is processed in a safe and economically efficient manner.

The 2011 edition of this report provides a strategic overview of the wastewater sludge market around the world, based on regional and country contributions. These look at the current situation in terms of sludge generation, legislation, technology applied and management approaches. These will then look at anticipated developments over the short- / medium-term, including expected developments in terms of legislation and the technology and management solutions to be implemented. These will also be complemented by longer-term perspectives.

The report has been prepared for the Market Briefing Series of the International Water Association's magazine *Water21*, with input from IWA's network of wastewater sludge experts around the world.

IWA Publishing, March 2011. 60pp. Paperback. ISBN: 9781843393887.
Price: £79.00/US$142.20/€106.65. IWA members price: £59.25/US$106.65/€79.99.
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reduce greenhouse gas emissions and dependence on limited resources; energy-independent wastewater treatment plants that do not use fossil fuels should be established. Eventually, energy independence will be realized by using biomass and natural energy as resources. The co-management of sewage sludge and other organic wastes is very important from the perspective of global warming. It is necessary to develop more effective co-treatment technologies to produce energy and to save natural resources.

In Korea the critical issue is the application of alternative methodology for sludge disposal instead of dumping it into the ocean. In general, the majority of produced sludge will be either solidified or processed for energy recovery. Carbonization of sludge for use as supplemental fuel will be a growing market in this country.

Sludge treatment and disposal planning is at the beginning stage in China, and only some big cities or provinces in developed regions have integrated sludge management plans, but other regions have also put sludge management on their agendas. According to the governmental policies and situations in China, sludge treatment and disposal technology applied in future should be low-carbon, energy-efficient, environment-friendly and easy to maintain. There is still a long way before China can achieve the sustainable management of sludge, but sludge management is attracting more attention from government, inhabitants, the water industry and investors.

Recovery of nutrients through utilisation of sludge in agriculture. Source: Sludge into Biosolids: Processing, Disposal, Utilization. PA Vesilind and L Spinosa (Ed.), IWA Publishing, 2001.

In Australia beneficial reuse of biosolids is the preferred strategy, and its success will be driven by the opposing influences of regulatory pressure and economic forces. Beyond this, approaches may be taken to recover valuable components such as phosphorus, oils and energy individually or even in a combined step. In addition, governments on both state and federal levels are adopting increasingly stringent regulations for biosolids management. Under such a political climate, biosolids producers should develop multiple long-term strategies for reuse of biosolids to avoid being caught defenceless in the changing waves of policies.

More detailed information on current situation and anticipated evolution of management approaches in different parts of the world will be given in the new updated edition of the book 'Wastewater sludge: a global overview of the current status and future prospects' (see box). ●

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