BIOSOLIDS IN EUROPE

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Abstract
This paper surveys the biosolids situation in Europe and aims to correct some of the myths and misinformation. It reviews the legislation and the practices. Overall 37% of biosolids are recycled to agriculture but the range for different Member States (MS) extends from more than 70% to 0.006%. In some federal countries there is considerable variation between the internal States. MS have also chosen a range of measures and limits when implementing of the European Union sludge use in agriculture directive. There has been much discussion of revising this directive but revision is now regarded by the European Commission as having no priority. For the future, biogas and phosphate recovery appear to be the areas of greatest interest.

Keywords
Biosolids, land application, landfill, legislation, incineration, phosphorus recovery, recycling

Introduction
The European Union (EU) now comprises 27 independent countries with 23 official languages. The combined population is 501 million people and the land area is 4.4 million km^2 (1.7 million $miles^2$) which is 114 people/km^2. In comparison, the population of the contiguous USA is 307 million people and the area is 7.7 million km^2 (3 million $miles^2$) - 40 people/km^2. Norway and Switzerland are not members. Neither are the constituents of the former Yugoslavia but some are candidates to join along with Turkey and Iceland.

The Member States (MS) of the EU are required to enact EU Regulations and Directives into their own national legislations. Regulations must be transposed verbatim but Directives are minimum requirements that MS can elaborate on if they wish (they can make them more stringent but not less). The role of the European Environmental Protection Agency is data gathering, not enforcement. Enforcement is the responsibility of each individual MS. MS who fail to comply with EU policies can be tried by the European Court of Justice (ECJ) and may be required to pay fines for as long as they are non-compliant.

The ECJ interprets EU law with the intention that it is applied in the same way in all MS. It also settles legal disputes between EU governments and EU institutions. Individuals, companies or organizations can also bring cases before the Court if they feel their rights have been infringed by an EU institution.

The European Commission (EC) is the civil service of the EU but with the added power that has the 'right of initiative', i.e. to propose new laws to protect the interests of the EU and its citizens. It is one of the main institutions of the European Union. It also manages the day-to-day business of implementing EU policies and spending EU funds. The Commission's political leadership is provided by the Commissioners, one from each MS. Each Commissioner has a 5-year term and is assigned responsibility for specific policy areas by the President of the European Commission. The EC drafts proposals for new European legislation, which the European Parliament and the Council [of MS Ministers] of Europe debate, amend and approve

or reject. Drafting involves consultation in order to produce something that it hopes the Parliament and Council will accept.

Directives relevant to biosolids

The sludge (use in agriculture) directive (CEC, 1986), the landfill directive (CEC, 1999) and the waste incineration directive (CEC, 2000) are relevant to the fates of biosolids. Other relevant instruments are the urban wastewater treatment directive, nitrates directive, water framework directive and the hazardous substances regulations that have controlled the production and use of substances such as PCBs, brominated flame retardants, etc. These have affected the quantity and composition of biosolids. For example, by harmonizing requirements for phosphate removal during wastewater treatment, the urban wastewater treatment directive has increased the quantity of sludge produced and also its phosphate content. Hazardous substances regulations have reduced the concentrations in biosolids of the substances they regulate. The portal to EU legislation is at http://eur-lex.europa.eu/en/index.htm.

Land application

Each MS is obliged to transpose the EU sludge directive (CEC, 1986) into its national legislation. It has limit values for heavy metals in biosolids and soils and for average annual loading rates. It also addresses sludge treatment and cropping and harvest restrictions that shall apply following biosolids application. The EC worked on revising this directive and also on suggestions for a directive for biowaste from 2000 until 2004 and again from 2009 until 2011 but none of the working documents has any legal status. Work also started on a soil protection directive in 2001. In April 2004, the then Director General of the Directorate General Environment (DG ENV) concluded, from the slow progress and failure to agree, that politically, consensus was unattainable, she shelved the initiative.

Work on soil protection has continued but in a more piecemeal approach. The leader of the EC soil team hopes a proposal for a soil protection directive might reappear at some time in the future but the politics are still difficult. The importance of soil is agreed; salinization, sealing, desertification, pollution, soil organic matter, erosion and maintaining agricultural productivity and ecosystem functions are agreed in principle. The difficulty of getting agreement from the Mediterranean to the Arctic Circle, from the different cultural heritages of the MS and the different economic statuses is extreme.

The most recent suggestion for biosolids and biowaste, contemplated a single directive for biosolids and biowaste. As far as soil protection, health protection, resource utilization, etc. is concerned, a single directive for organic resources applied to land would seem to have merit but earthworms were not consulted. The MSs and other consultees could not agree what needed to be included. There was little support for regulating sludge and biowaste with the same instrument. Regarding biosolids, many MS thought that restrictions on potentially toxic elements in biosolids should be increased and that restrictions on one or more organic compounds were needed, but with no consensus on which ones. Regarding sludge treatment, the 1986 sludge directive says “sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use”. Only a minority of MS wanted revision along the lines of ‘conventional’ (Class-B) and ‘enhanced’ (Class-A) treated, which would be defined according to the indicator-organism reduction capability and/or maximum allowable

concentrations of organisms/pathogens. There was no support for the idea of banning land application.

In late 2010 work started on end-of-waste (EoW) criteria for composted materials and for digestate. Materials that satisfy EoW criteria would be treated as products and outside the requirements of waste regulations. Currently the products of composting and of anaerobic digestion are classified as "wastes" and categorization as EoW is the prerogative of MS governments, though they must be ratified by the EC.

Incineration

The EU Directive on the incineration of waste (CEC, 2000) sets strict operating conditions and technical requirements on waste incineration plants and waste co-incineration plants to prevent excessive emissions of substances that pollute the air, water and soil and have harmful effects on human health. Incineration or co-incineration plants must have a permit issued by the competent authority to carry out their activities. The permit specifies the categories and quantities of waste which may be treated, the plant's incineration or co-incineration capacity and the procedures to be used for sampling and measuring air and water pollutants. To guarantee complete waste combustion, the Directive requires all plants to keep the incineration or co-incineration gases at a temperature of at least 850°C for at least two seconds. If hazardous waste with a content of more than 1% of halogenated organic substances, expressed as chlorine, is incinerated, the temperature has to be raised to 1100 °C for at least two seconds.

The directive sets limit values for incineration plant emissions to air for heavy metals, dioxins and furans, carbon monoxide (CO), dust, total organic carbon (TOC), hydrogen chloride (HCl), hydrogen fluoride (HF), sulfur dioxide (SO_2) and the nitrogen oxides (NO and NO_2). In addition, special provisions are laid down relating to cement kilns and combustion plants which co-incinerate waste. As far as possible, heat generated by the incineration process must be put to good use.

Some MS appear to be flouting the waste incineration directive by burning sludge in facilities (notably coal fired power stations) that do not comply but nobody has brought action before the ECJ.

Landfill

The landfill directive (CEC, 1999) targets biodegradable municipal waste as a means of reducing methane leakage; most MS have included sewage sludge in their implementations even though the directive did not. Landfill gas is a major source of non-fossil, base-load energy; it is about 30% of the UK's non-fossil energy. Modern landfills are sealed and the biogas harvested but inevitably there is leakage from the working area before sealing can be completed and also inevitably there is some leakage after sealing. Irrespective of whether estimates of emissions are valid and current, landfilling of sludge is disapproved politically and legally.

Phosphate Recovery and Conservation

The EC is aware that phosphate is a matter for concern. It is essential for life and cannot be substituted. The world's reserves of phosphate are being extracted at an unprecedented rate. Today's mines will be exhausted by the end of this century. Estimates of future reserves range from 200 to 400 years at the current rate of extraction, which is not long in the history of human-kind. Urban wastewater is also the fate of much of the phosphate used in society. The EU does not yet have any legislative obligation for recovery and recycling of phosphate from urban wastewater but this must be regarded as probable. Sweden was the first MS to establish a target; by 2015 60% of phosphate will be recycled largely by increasing the rate of recycling biosolids in agriculture. Germany plans to have a target that will probably be an obligation to recover P from wastewater, land application of biosolids would count towards recovery; there is debate whether storing mono-incinerated ash for future recovery would comply or whether the P would have to be recovered from the ash.

Biosolids Practice

Table 1 shows biosolids production by EU MS. No MS bans the use of biosolids on farmland. The earlier (EU_{15}) members and the more recent ones (EU_{12}) are shown separately. The per capita production (i.e. reported production divided by total population) varies widely reflecting (a) differences in the proportions of people connected to main drainage and (b) a lack of precision in defining where the production should be measured (raw, treated, etc.). The UK has one of the highest percentages of people connected to main drainage and therefore should have one of the highest per capita production figures. It looks as if some figures are for final outturn quantities (i.e. after digestion, etc.) and others are for raw sludge.

Table 1 shows the UK as having the largest recycling percentage, and it has even increased significantly since 2006. The demand for biosolids was swelled by the steep increase in the price of mineral fertilizers in 2008 (Figure 1). For example, in 2000 mineral fertilizer delivered to farm was £0.36 /kg N, £0.26 /kg P_2O_5 and £0.19 /kg K_2O, whereas in 2011 it is £1.00 /kg N, £0.93 /kg P_2O_5 and £0.60 /kg K_2O. Prices have eased from their peak in 2008 but they have recovered to be 3 times the prices in 2000. Many water companies in UK are now charging farmers for deliver-and-spread of Class-B cake. UK companies with incinerators [all fluidized bed] are in

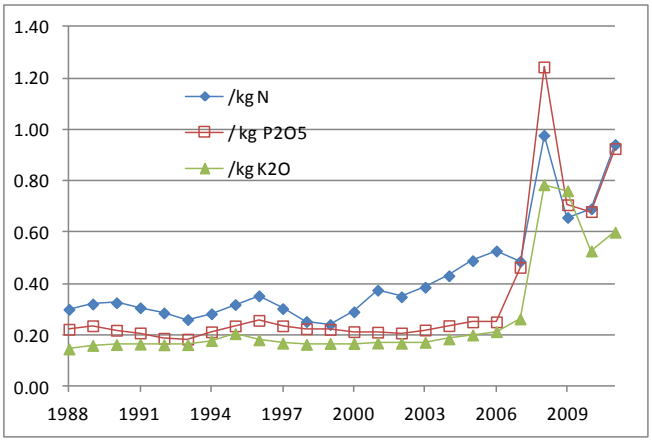

Figure 1 Index of UK fertiliser prices (1988 to 2011) on farm, in bulk (DairyCo.net)

many cases switching to recycling. There is a big push on increasing biogas yields and biogas utilization (CHP and biomethane). After trying other pretreatments, thermal hydrolysis is being installed quite widely at larger works. In 2005, 64% of sewage sludge in England and Wales was treated by anaerobic digestion, by 2015 the figure will be 85%.

Table 1 Recent sewage sludge production and quantities recycled to agriculture in the 27 EU Member States (after Gendebien, A., 2009)

Member State		Year	Biosolids production (t DS)	Biosolids use in agriculture (t DS)	Ag %	Population	gDS/cap.day
Austria	AT	2005	266,100	47,190	17.7%	8,372,930	87.1
Belgium	BE	2006/03/02	102,566	14,646	14.3%	10,827,519	26.0
Denmark	DK	2002	140,021	82,029	58.6%	5,547,088	69.2
Finland	FI	2005	147,000	4,200	2.9%	5,350,475	75.3
France	FR	2002	910,255	524,290	57.6%	64,709,480	38.5
Germany	DE	2006	2,059,351	613,476	29.8%	81,757,595	69.0
Greece	EL	2006	125,977	56.4	0.0%	11,125,179	31.0
Ireland	IE	2003	42,147	26,743	63.5%	4,450,878	25.9
Italy	IT	2006	1,070,080	189,554	17.7%	60,397,353	48.5
Luxembourg	LU	2003	7,750	3,300	42.6%	502,207	42.3
Netherlands	NL	2003	550,000	34	0.0%	16,576,800	90.9
Portugal	PT	2002	408,710	189,758	46.4%	10,636,888	105.3
Spain	ES	2006	1,064,972	687,037	64.5%	46,087,170	63.3
Sweden	SE	2006	210,000	30,000	14.3%	9,347,899	61.5
United Kingdom	UK	2006	1,544,919	1,050,526	68.0%	62,041,708	68.2
Bulgaria	BG	2006	29,987	11,856	39.5%	7,576,751	4.0
Cyprus	CY	2006	7,586	3,116	41.1%	801,851	9.5
Czech Republic	CZ	2006	220,700	25,400	11.5%	10,512,397	21.0
Estonia	EE	2005	not reported	3,316		1,340,274	
Hungary	HU	2006	128,380	32,813	25.6%	10,013,628	12.8
Latvia	LV	2006	23,942	8,936	37.3%	2,248,961	10.6
Lithuania	LT	2006	71,252	16,376	23.0%	3,329,227	21.4
Malta	MT		not reported	not reported		416,333	
Poland	PL	2006	523,674	88,501	16.9%	38,163,895	13.7
Romania	RO	2006	137,145	0	0.0%	21,466,174	6.4
Slovakia	SK	2006	54,780	0	0.0%	5,424,057	10.1
Slovenia	SI	2006	19,434	27	0.1%	2,054,119	9.5
Sub-total EU_{15}			8,649,848	3,462,839	40.0%	397,731,169	59.6
Sub-total for EU_{12}			1,216,880	190,341	15.6%	103,347,667	32.3
Total EU_{27}			9,866,728	3,653,180	37.0%	501,078,836	53.9

Yorkshire Water in UK has obtained EoW for the product of its SPT (Sludge Phytoconditioning Treatment) process from which it manufactures topsoil. Dewatered biosolids are biodried with greenwaste [composted] then laid out on beds approximately 60 cm deep. It is sown with grass and over a period of months it is dried, mineralized and sanitized.

Germany is often misreported as having little biosolids recycling but in terms of quantity recycled (613,476 tDS) it ranks number three, behind UK and Spain. Biosolids use in agriculture is subject to federal legislation and is permitted. Three Länder (States) oppose beneficial use, whereas the remaining eleven favor it. For example Monika Grashorn is the current farmer of a 100 ha family farm in Lower Saxony whose history can be traced back to 876. The farm is respected by local farmers. The soil is light. They farm arable crops and pigs. They were early adopters of biosolids from Bremen and based on their success developed a business supplying other farmers. Mrs Grashorn estimated that in 2000 biosolids reduced the farm's fertilizer bill by 130 euros/ha. In 2004 Agretech Grashorn celebrated 25 years in biosolids (Figure 2). The celebration was attended by the Minister for the Environment of Lower Saxony, Hans-Heinrich Sander, who praised the agricultural utilization of biosolids which he said was "Not only economically but also ecologically expedient". In 2008 69% of all sewage sludge in Lower Saxony was utilized agriculturally.

WILDESHAUSER ANZEIGER 10. Juni 2004

Minister: Ökologisch sinnvoll

„Agretec" 25 Jahre alt / Geschäftsführerin Monika Grashorn: „Mein Kapital sind meine Mitarbeiter"

Von Andreas Hetteler

HATTEN-TWIEST – Niedersachsens Umweltminister Hans-Heinrich Sander ließ es sich am Mittwochnachmittag nicht nehmen, Monika Grashorn, Geschäftsführerin des Entsorgungsfachbetriebes „Agretec" in Hatten zum 25-jährigen Bestehen der Firma persönlich zu gratulieren.

Im Beisein zahlreicher Gäste unter anderem aus Politik und Wirtschaft überreichte Sander ihr im Namen der Landesregierung einen kleinen Porzellanteller mit Niedersachsenpferd. „Wenn ich in 25 Jahren wiederkomme, ist der Teller bestimmt größer", scherzte Sander.

Das „Agretec" als Entsorgungsfachbetrieb für kommunale, gewerbliche und landwirtschaftliche Abfallprodukte den Vorteil einer landwirtschaftlichen Verwertung von Sekundärrohstoffen kennt und auch weiß, dass alle Aspekte des Umweltschutzes und wissenschaftliche Erkenntnisse zu berücksichtigen sind, um die landwirtschaftliche Verwertung auf hohem Sicherheitsniveau durchzuführen, stellte Sander in seinem Grußwort heraus. Eine kostengünstige Möglichkeit der Versorgung mit Grundnährstoffen sei zum Beispiel die landwirtschaftliche Verwertung von Klärschlamm. „Sie ist nicht nur ökonomisch, sondern auch ökologisch sinnvoll", so der Umweltminister.

In Niedersachsen liegt der Anteil der landwirtschaftlichen Klärschlammverwertung derzeit bei 69 Prozent. „Selbstverständlich dürfen im eigenen Interesse der Landwirte nur qualitativ unbedenkliche Klärschlämme ausgebracht werden. Diese Thematik ist ihnen als Entsorgungsbetrieb bestens vertraut", bestätigte Sander.

Zuvor hatte Monika Grashorn einen Einblick in die Firmengeschichte gegeben. Vor 25 Jahren gründeten Schwiegervater und Ehemann den Betrieb, der in zwei Wirtschaftszweigen aufgeteilt ist. In einen 110 Hektar großer landwirtschaftlicher Betrieb mit Weizengetreide-, Raps- und Hanfanbau sowie einer Putenmast und dem Entsorgungsfachbetrieb. 1979 wurden vorerst versuchsweise auf eigenen Flächen Klärschlämme der Bremer Entsorgungsbetriebe zur Düngung gebracht, begleitet durch ausführliche und intensive Beratungsgespräche mit dem Landkreis Oldenburg, der Bezirksregierung und den Landwirtschaftskammern Oldenburg und Nienburg.

Von links: Dipl.-Ing. agr. Rainer Kemmann, Minister Hans-Heinrich Sander, Monika Grashorn und Dr.-Ing. Matthias Hessling.

Foto: Hetteler

„Agretec" entsorgt nicht nur Klärschlamm mit modernsten Fahrzeugen.

Blick auf den Fahrpark von Agretec.

Figure 2 Minister endorses biosolids land application in Lower Saxony (Agretech Grashorn)

Germany has established a strict liability compensation fund to remedy any problems that might arise from land application. It was funded by a levy based on tonnes of biosolids recycled. It

was started voluntarily by some of the leading operators and later taken over by the federal government (BCB1, 1998). The fund closed when it reached a sufficient size. Payments have been minimal, just a few occasions of litter picking. The fund is not linked to any quality management system.

Germany allows co-combustion of sludge in coal-fired power stations with authorization from the authorities locally but without requiring them to comply with the waste incineration directive (WID). Nobody has yet taken Germany to the ECJ for this apparent failure to apply WID; if it did the co-firing would end because it would be uneconomic to clean up the [coal] emissions to WID limits. Germany also has a large number of incinerators (it is a major supplier of the technology). Competition to satisfy this large "grate capacity" has driven down gate fees to the extent that beneficial use is more expensive than incineration for some WwTWs (Figure 3). In anticipation of the phosphate recovery obligation, research has been undertaken into recovering phosphate from sludge before dewatering and incineration. Trials have found that removing phosphate (as struvite) before dewatering increases cake %DS compared with controls.

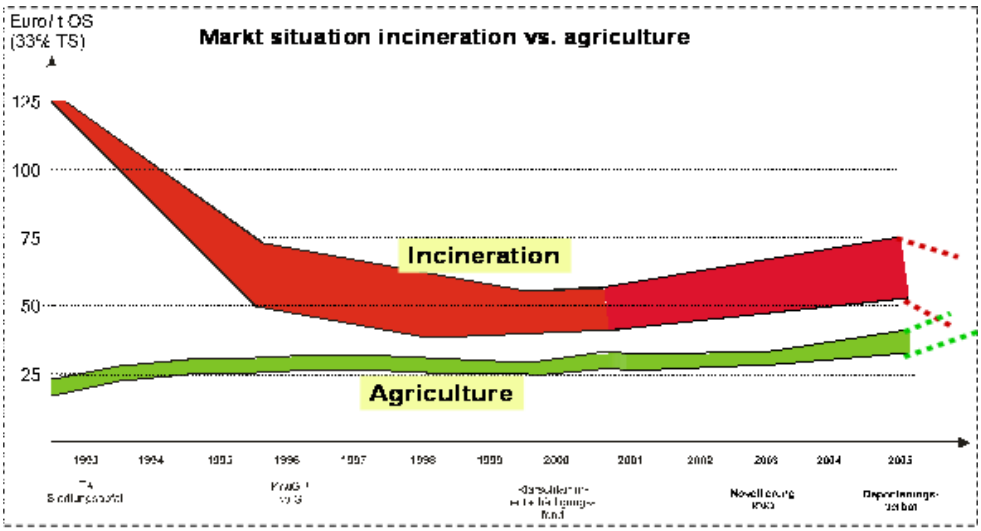

Figure 3 Approximate changes in costs (euros/tonne) for sewage sludge in Germany (Roland Wolf, EmscherGenossensschaft/LippeVerband)

In 2006 only 14.3% of biosolids were recycled to agriculture in Sweden and the proportion is increasing from a crash in 2000 that resulted from a scare about brominated flame retardants. A Quality Assurance scheme called ReVAQ has restored confidence to the stakeholders (Hugmark, 2006). Increasing land application is regarded as an important component of the phosphate conservation target. 50% (dry solids basis) of biosolids in Sweden are in ReVAQ in 2011 (Per Baumann, ReVAC Board and Euro Coop, personal communication, 2011).

France is a major agricultural country in the EU. In 2006 it recycled 57.6% of its biosolids to farmland. Like Germany, France has an indemnity fund; it is administered by the national government and it is linked to a quality assurance program, SYPREA (Syndicat des Professionels du Recyclage en Agriculture http://www.syprea.org). It was launched in 2002 following pressure from the water industry and from farmers. If there should be any adverse effects from

land-applied biosolids they will be remedied. To date payout has been negligible but the fact that there is the guarantee of indemnity based on strict-liability has given confidence to the market. Composted materials come under separate legislation, essentially compost that complies with the compost law is EoW; a substantial amount of sludge is composted with greenwaste in France and land applied as compost. Biosolids composters are in competition with [renewable] power generation for greenwaste.

Spain, Austria and Italy all use the composting route to move biosolids into a different legal status from the national implementations of the sludge directive.

The Netherlands has the lowest percentage of biosolids use in agriculture (0.006%) the reason for this is that the Ministry of Agriculture was tasked with setting the limit values for metals in sludge and, in order to keep land open to the very large quantity of livestock manure, set the limits so low that it is almost impossible for biosolids to comply. The Netherlands has a large population of people and of farm animals in relation to its area.

The Ministry of Agriculture in Finland did the same as the Netherlands and the response has been to develop biosolids products for gardening, landscaping and other green applications. In the capital, Helsinki, the Viikinmäki WwTW (serving 800,000 people) is constructed in underground rock caverns (to protect it from Helsinki's cold winters); all the sludge is anaerobically digested (with the biogas used for CHP) and then dewatered. The cake (58,000 tonnes/year) is composted with bark and peat; in Finland peat is growing faster than it is extracted. Composting started in 1982. The compost is blended with sand, crushed biotite stone (which acts as potassium source) and crushed limestone to produce Metsäpirtin Bio-Soil. Helsinki's gardeners and landscapers buy all the Metsäpirtin Bio-Soil the plant can produce (100,000 m^3/year). Long experience has shown them that they can trust Metsäpirtin Bio-Soil and that it is good for their plants and their soils.

Norway and Switzerland (neither is a MS of the EU) have contrasting positions. Norway has an official target to recycle 60% of biosolids to farmland, which was exceeded quickly; in 2008, 80% of biosolids were recycled to farmland or green areas. Switzerland, in contrast, banned the use of biosolids on farmland from 2005 (despite it being 40% of the production) because a panel of 15 experts thought the public might not favor the practice. Some Swiss biosolids are used on farms in France.

Why phosphate will change biosolids practice

Phosphate already limits the amount of biosolids that can be applied through the requirement for good agricultural practice and the requirement to protect watercourses. WwTW are also restricted on the concentration of phosphate they can discharge (or the percentage they have to remove from wastewater) under the urban wastewater treatment directive. In future there will almost certainly be an additional obligation which will be to recover phosphate from wastewater because it is a disappearing resource.

Phosphate is the most important constituent that can be recovered from urban wastewater; because it is irreplaceable. Phosphate is essential for life because it is part of DNA and cells' energy pathways. It can never be substituted. Children accumulate phosphate in their bones,

teeth, etc. but adults excrete 98% of the phosphate in their diets because they are just turning over cells. This and other phosphate ends up in urban wastewater. At the current rate of extraction, today's phosphate mines will be exhausted by the end of this century. Estimates of future reserves range from 200 to 400 years; this is not long in the history of human-kind (Rosemarin et al., 2010). Morocco and Western Sahara have the largest proportion of the world's reserves (about 60% of the total). The USA (11%) and China (3.6%) have both implemented measures to restrict exports because they realize the strategic significance of phosphate. As regards threats to the human population, phosphate depletion is on a par with climate change. As Isaac Asimov explained:

> "…life can multiply until all the phosphorus is gone, and then there is an inexorable halt which nothing can prevent…. We may be able to substitute nuclear power for coal, and plastics for wood, … but for phosphorus there is neither substitute nor replacement." (Asimov, 1974).

The total amount of phosphate in urban wastewater in EU_{27} is about 1,145,000 tonnes P_2O_5 per year. This is equivalent to 34% of the total 3,400,000 tonnes P_2O_5 per year imported by the EU_{27} (Rosemarin et al., 2010). About 595,000 tonnes P_2O_5 ends up in sewage sludge; that is 52% of the phosphate in wastewater. Overall 37% of the sludge was recycled to farmland, which is approx. 220,000 tonnes P_2O_5 per year. Thus, only 20% of the phosphate in urban wastewater is recycled, the rest is squandered by failing to capture it (48%) or by 'losing' it in landfill or ash, etc. There is considerable potential to improve capture, recovery and conservation of phosphate.

Sweden already has a recycling target and Germany will have one soon, it seems inevitable that the EU, which is already concerned about the phosphate situation, will follow. This will assuredly affect technologies and strategies. As Sweden has realized, land application is the easiest way to recycle phosphate. Recovering phosphate from dewatering liquor [or prior to dewatering] as struvite is bound to be more widespread. If, because for example there is insufficient land, sludge has to be burnt, phosphate should be recovered before or after combustion or at the very least the ash should be stored so that the phosphate can be recovered in future.

Conclusions

Overall more than half the biosolids produced in the EU are used on farmland; contrary to the myths. Landfilling of sludge is negligible. The only real alternative to land application is combustion (which should be WID compliant). Biogas utilization is extensive and increasing. Phosphate conservation is developing as a driver for policy and practice. Unfortunately many Member States have been somewhat arbitrary in the limits they have set when implementing the sludge directive so there is little coherence. There is ample science to undertake strict risk assessment but it is expensive and does not come up with the same answer as preconceptions. There will always be fecal-phobes, chemo-phobes and grubby commercial vested interests but hopefully science and conservation of resources will prevail.

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