May 2021

Briefing note

EurEau

Waste water treatment – sludge management

A regulatory framework is needed to support sustainable and resilient sludge management, incorporating a broader scope for risk assessment and strict sludge quality control.

The UWWTD revision is an opportunity to establish policies that will enable sustainable and long-term investment decisions to be made for sludge management by waste water services. EurEau members want a circular future for valuable bioresources, built on good risk assessment and risk management techniques, where climate change targets form part of the risk assessment along with citizens' views.

Summary

This briefing note details the current arrangement for the management of sludge that comes from waste water treatment. It will inform the reader of the existing solutions for sludge and gives a sound vision of the future and appropriate directions. It is based on EurEau members' experience as waste water operators.

We refer to 'sewage sludge' or 'sludge' as the existing regulatory framework uses this terminology. However we note that the term 'sludge' does not reflect the full opportunities, which this paper explores.

The current regulatory framework for sludge is set across a number of different instruments at EU level, which tend to focus on the waste dimension rather than on the reuse of the valuable resources. Waste water operators already render the valuable resources found in sludge to be reusable. However, a regulatory framework is needed to support sustainable and resilient sludge management, incorporating a broader scope for risk assessment and strict sludge quality control.

Approximately 20-25kg of dry solids (DS) are continuously produced per person per year all across Europe annually as a result of the waste water treatment process. The quality of sewage sludge needs to be protected at source to ensure the reuse of this important bioresource.

At this moment and in the context of the revised Urban Waste Water Treatment Directive, we need policies that will enable sustainable and long-term investment decisions to be made for sludge management by waste water services.

EurEau members want a circular future for these valuable bioresources, built on good risk assessment and risk management techniques, where climate change targets form part of the risk assessment along with citizens' views.

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1. What is sludge?

The water used by households is collected and conveyed away from the population to a waste water treatment plant (WWTP) where it is treated to remove organic matter and nutrients. This water typically comprises urine, faeces, and other domestic water from our sinks and drains. On the journey towards the WWTP, it may mix with surface water run-off, and in some countries, with industrial water. This combination of water is commonly referred to as 'waste water'.

Untreated waste water contains micro-organisms and other substances that may be polluting or harmful to people and/or the environment. It is therefore necessary to treat it before it reenters the water cycle.

The raw sewage sludge is the matter resulting from the treatment of waste water and consists of water, organic matter and nutrients. It contains valuable resources (carbon (C: 25–35% in dry solids (DS)), nitrogen (N: 4–5% in DS), phosphorus (P: 2-3% in DS), oxygen (O: 20-25% in DS) and residuals (trace elements, metals, etc)).

Every one of us contributes to the production of 70-100kg of dewatered sewage sludge per year which represents around 20-25kg of dry solids annually[1].

Some technical terms:

~ **Raw sludge** is captured during the waste water treatment process.
~ **Treated sludge** has undergone processes to be prepared for use.
~ **Dry solids** (DS) is what is leftover when all the water is removed from raw sludge. It is the metric to compare quantities produced.

2. Where does the sludge come from and where does it go?

A WWTP produces about two litres of raw sludge per person per day. This a continuous process at all WWTP across Europe.

EurEau carried out an extensive survey amongst its members in 2020 to explore where treated sludge goes.

Total European production of sludge: 8.7 Million tonnes DS/y.

<u>Sludge destinations</u>:

~ Agriculture: 4.1 Mt DS/y
~ Incineration: 2.4 Mt DS/y
~ Recultivation/land reclamation: 0.7 Mt DS/y
~ Landfill: 0.5 Mt DS/y
~ Other destinations: 1 Mt DS/y

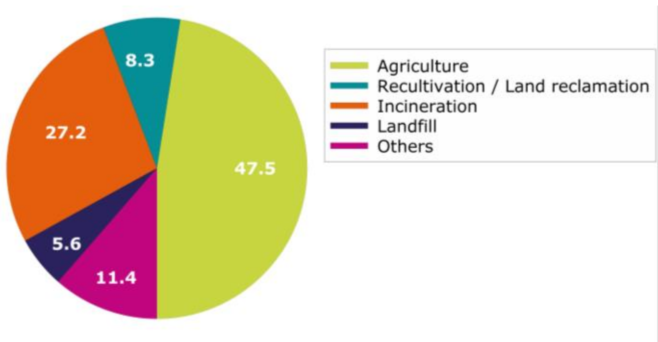

Figure 1: Sludge destination in percentages according to the 2021 EurEau Survey 'Europe's Water in Figures'.

[1] Environmental, economic and social impacts of the use of sewage sludge on land, Milieu, WRc and RPA, 2010.

Each country manages their sludge according to their own priorities, local needs and opportunities. For example, countries in the south of Europe often need organic matter, so sludge is used in agriculture. By contrast, in other locations, eutrophication of waters, excess of manure, or concerns about the quality of sludge may drive a preference for incineration (e.g. there is a ban on the recycling of sludge in Flanders and the Netherlands, while Germany and Austria require the recovery of phosphorus in certain-sized WWTP). Figure 2 presents the sludge destinations per country, showing huge variations between Member States:

- Agricultural recycling are the main options in **Cyprus, Denmark, France, Ireland, Norway, Portugal, Slovakia, Spain and the UK.**
- Incineration is the only option in **Flanders and the Netherlands.**
- Land reclamation is a very important solution in **Finland and Sweden.**
- **Germany, Wallonia, Czech Republic, Poland use a** mix of options**.**
- Landfill remains the principal option in **Malta and Romania.**

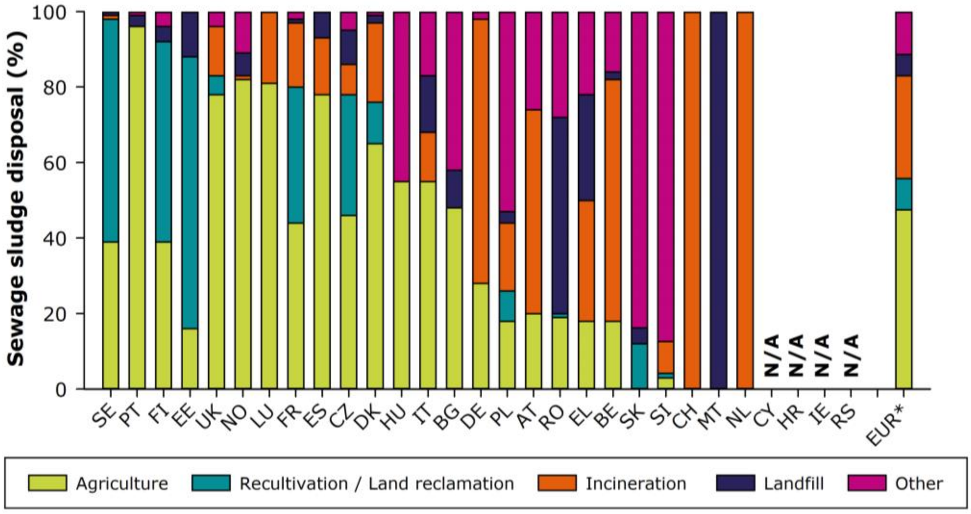

Figure 2: Sludge destination per country in % according to EurEau Survey (2017)
N.A.: No answer available from that member country at the time of the survey.

3. Sewage sludge characteristics

3.1. Types of sludge

Once in the WWTP, waste water is subject to several processes leading to different types of sludge:

- **Primary sludge** results from a first mechanical settlement of the raw waste water or rain water entering the WWTP. It mainly contains organic matter. This type of sludge has a high energy content that can be used, for example, to produce biogas. Primary sludge is only produced by WWTP equipped with a primary settler.

- **Secondary sludge** (or biological sludge), results from the biological treatment of waste water. During this treatment, micro-organisms grow and multiply through the degradation of organic matter by different biological processes. The excess of the biological sludge has to be removed during the treatment process to maintain the stability of the cycle.
- **'Chemical' sludge** comes from the addition of some chemicals to bring about a specific treatment (e.g. the addition of $FeCl_3$ - ferric chloride - to enhance phosphorus removal). It contains both biological sludge and some residual chemical products. It usually represents a very small part of sludge production.

Depending on the design of the WWTP, the different types of sludge can be produced in one WWTP and they can be further processed separately or together.

3.2. Possible treatments to prepare for onward uses

The fresh sludge is liquid (containing up to 1% DS and 99% water). It is usually thickened and dewatered on site or nearby (up to 20-35% DS) so that it can be processed and transported more easily. There are four common treatments to reduce water content and achieve better hygienical quality:

~ **Digestion** aims to stabilise the sewage sludge anaerobically while allowing energy recovery (biogas) that can be used on-site or exported (Annex III).
~ **Lime treatment** (stabilisation or conditioning) is used to hygienise and/or dewater sludge to prepare it for reuse.
~ **Composting** is an easily scalable and reliable aerobic biological process to decrease the presence of pathogens. It can also be used to produce more mature biosolids which are suitable for landscaping purposes.
~ Solar or thermal **drying**.

3.3. Sludge quality

Sludge composition is mainly influenced by the type of waste water that enters a WWTP and the treatment process applied. The quality of sludge determines the possible reuses. This becomes even more important in the context of the circular economy so as to maximise its reuse potential or the reuse of its nutrients, as well as ensuring its safe disposal. Co-composting sludge with green waste contributes to carbon sequestration in soils[2] and the local circular economy may reinforce their interest in high quality compost with good agricultural value.

Pollutants and pathogens that are present have to be managed. Chemical substances (heavy metals, pharmaceuticals, microplastics, other chemicals) that are not degraded by

[2] 4p1000.org

biochemical reactions will accumulate in the sewage sludge. Existing sludge treatment methods cannot remove all unwanted chemical pollutants and this is why **EurEau strongly supports source control** (Annex I).

As waste water carries and contains different kinds of pathogens from human waste, all operations must ensure the health and safety of the operators and users of the resources coming from the waste water, including sewage sludge. For operators, this includes using Personal Protective Equipment (PPE) and other protective measures at the WWTP. For product users, other risk management measures must be in place, like hygienic quality criteria or restrictions for use, or a combination of these. We often find that national or regional quality standards are set for the hygienisation of sludge, to ensure it is suitable for onward use.

The prevalence of micropollutants in sewage sludge is usually low and existing data suggests that the nature and concentration of pollutants mean that the human health and environmental risks remain at a very low level. Micropollutants like cadmium (Cd) and mercury (Hg) can be found at concentrations of 1mg/kg DS, and others are even lower.

Some pharmaceuticals may have an affinity for water and therefore remain in the aqueous phase. They have lower probability to end up in sludge and the extent of pharmaceutical accumulation in sludge is currently being researched.

However, data suggests that microplastics, zinc and copper might appear in the range of 0.3-1 g/kg DS (0.03 to 0.1% DS). In general, WWTPs effectively remove microplastics (80% to 99% in mass) which will partially end up in sewage sludge. Some preliminary results show that the difference of microplastic concentrations between treated and untreated sewage sludge is not very great but further research is needed to understand the impacts of microplastics in soils. Nevertheless, with good risk management practices, sewage sludge can currently be safely used in the context of the circular economy.

Additional requirements to protect receiving waters may have a positive or negative effect on the WWTP's capacity to recycle sludge. Any cost-benefit analyses conducted to increase requirements for water treatment should also consider the impact on the quality of sludge so the decision is taken with a global picture of the consequences.

4. Policy framework for sludge

A European policy framework for the monitoring and quality control of sewage sludge treatment, transportation and reuse already exists, and is illustrated in Figure 3 below. However, this policy framework straddles a number of different legislative instruments. In addition, sludge does not automatically fit into existing definitions of 'waste' as it may be intended that sludge is **not** discarded, but instead re-used.

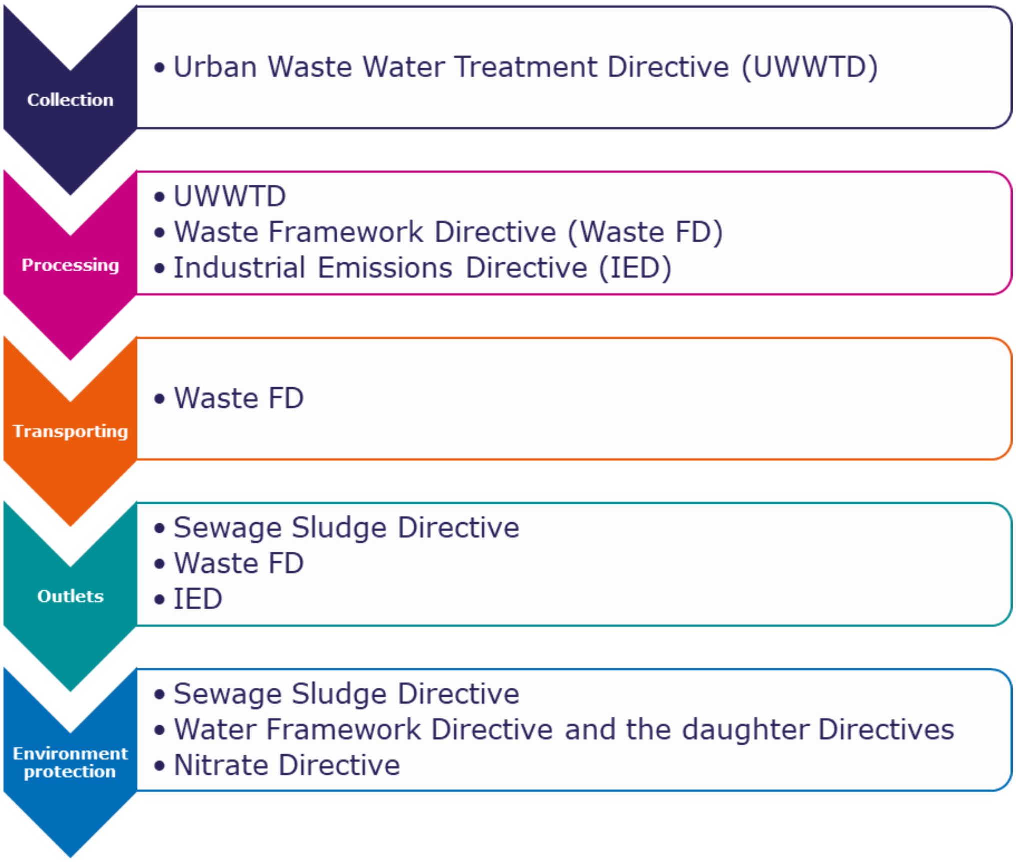

Figure 3: Graphical overview of EU legislation relating to sewage sludge.

4.1. Collection

The **Urban Waste Water Treatment Directive 91/271/EEC** (UWWTD), is the principal instrument responsible for the generation and collection of sewage sludge. It bans the dumping of sludge in the sea and **encourages the recycling of sludge** without giving any details about how this should be done.

4.2. Processing

The processing of sludge, its treatment and recovery are governed by two main European directives.

Directive 2008/98/EC on waste **(Waste Framework Directive):** this establishes the framework requirements for the management of waste and the main provisions relating to sludge management (although waste water is specifically excluded from its scope). The main provisions are the requirements that the collection, transport, recovery and disposal activities for waste do not harm human health or the environment.

Directive 2010/75/EU (Industrial Emissions Directive/IED): is the main EU instrument regulating pollutant emissions from industrial installations. Certain sludge handling installations (large-scale plants/sites/processes for sludge) above the volume thresholds identified may be subject to IED requirements. Sludge management practices vary across the EU and this is reflected in the varied application of IED to sludge. Additionally, this directive covers the anaerobic digestion of **waste** as a regulated activity but includes a rather ambiguous statement that it **does not apply** where the activity is covered by UWWTD. This leaves much to the interpretation by the individual Member State.

The UWWTD plays a role in the processing of sludge but it does not provide any details of how it should be done. However, where all processing is handled within the confines of a WWTP, the IED does not apply and additional licensing requirements under the Waste Framework Directive would be a duplication of the UWWTD; so in some instances, the UWWTD is the only directive covering sludge processing on some sites. However, the UWWTD is silent on some of the intended outlets relating to the protection of human health and the environment so, in its current form the UWWTD does not set out the equivalent level of protection as the IED.

4.3. Transportation

The Waste Framework Directive is clear that all waste must be transported in a way that does not impact on human health or the environment, cause nuisance or odours or affect the countryside or places of special interest.

4.4. Outlets for sludge

Sludge is treated so that it is ready for its intended outlet (treatment may include: dewatering, thickening, pasteurising/sanitising (for the control of pathogens), pelletising), but there are many potential treatment possibilities, depending on the outlet for the sludge. For example:

- if sludge is incinerated, it is often highly dewatered or may be dried and pelletised for energy generation through combustion. Incineration of waste is covered by the **IED**. Energy can then be recovered during the incineration process.
- if sludge is intended for energy generation, it is thickened and digested to produce biogas. The installation can be covered by the **IED**.
- if sludge is intended for use in agriculture, it is treated to comply with the requirements of the **Sewage Sludge Directive 86/278/EEC** on the protection of the environment, and in particular, of soil. This directive defines under which technical requirements sludge can be used in agriculture, without the need for a specific waste authorisation. It sets quality standards for sludge relating to heavy

metals and the requirements for the soil that is receiving the sludge. In some countries, more stringent requirements have been included in national legislation, particularly relating to microbiological conditions which are required for sludge before it is used in agriculture. Additionally, some countries have very detailed quality assurance schemes for sludge used in agriculture (Annex II).

➔ **the nature of the treatment and the quality achieved by treatment depends on the eventual outlet/s for the sludge. Many resources can be recovered and only a few are directly intended for discarding (see section 2). The varied uses for sludge reflect the fact that sludge is a resource – a bioresource - with multiple potential uses.**

In order to promote the circular economy, legislation regarding the **recovery of materials** from sludge may be required. The Fertiliser Regulation is being amended to allow certain products recovered from sewage sludge to be authorised on the EU market.

The JRC report proposing criteria for '**STRUBIAS**' materials (**STRU**vite/recovered phosphate salts, **BI**ochars/pyrolysis materials, **AS**h-based products) was published in 2019 and is the basis for new component material categories (CMCs). These new CMCs will be approved in 2021 and then added into the Fertiliser Regulation annexes. Except for biochar, which is not permitted from sewage sludge, struvite and ash-based products will be authorised as ingredients for EU fertilisers. This will allow WWTP operators to potentially enter this market through phosphorus recovery technologies.

4.5. Protection of the Environment

A set of policy instruments allow for the use of treated sludge while protecting the environment. The Water Framework Directive and its daughter directives (the Groundwater Directive and the Environmental Quality Standards Directive) establish a framework for the protection of surface waters and groundwater, while the Nitrates Directive sets the requirements to protect waters from pollution caused or induced by nitrates from agricultural sources. In certain countries, the level of protection has been reinforced for other pollutants that are not necessarily regulated at EU level and regarding specific and local considerations.

5. Good practices for sludge management

There are many good practices for the management of sludge. This section highlights the best managements from the EurEau perspective:

~ Control at source – by implementing control at source, we can reduce the amount of contaminants that end up in sludge thus improving its recycleability and reuse potential – details in Annex I.
~ Biosolids - exploring the potential for additional use of biosolids on land will not only improve soil quality but help mitigate climate change - details in Annex II.1.
~ Assurance schemes - certification to assure quality standards will help protect human and environment health– details in Annex II.2.

- Risk Assessment - risk assessment and risk management can be legislated at national level to further protect human and environmental health– details in Annex II.3.
- Energy production: switching to sustainable energy such as biogas will encourage investment in biogas production from WWTP – details in Annex III.
- Incineration - sludge incineration (either mono- or co-inceration) is another means to generate energy if land application is not feasible – details in Annex IV.
- Resource recovery - recovering phosphorus and nitrogen from sludge makes a significant contribution to the circular economy – details in Annex V.
- Innovation - innovation will drive new possibilities. New technologies such as pyrolysis (the burning of sludge without oxygen to preserve the carbon) and gasification have proven to be environmentally safe and economically feasible solutions for sewage sludge treatment. Furthermore trials with ozonolysis demonstrated its effectiveness in reducing and stabilising sludge. Hydrothermal liquefaction technology (HTL), mineralisation and Gas-to-liquid technology (GTL) are also being used– details in Annex VI.

Operators are choosing their preferred management options according to their local needs to comply with local environmental regulations, available markets and opportunities and the requirements to keep the water tariff affordable.

6. The future of sludge management

6.1. Future situation – expected growth in sludge quantities

Currently, 46.2 million p.e. do not yet meet the performance requirements of secondary treatment according to the evaluation report of the UWWTD[3]. Full compliance with the current directive would produce an additional 1.1 Mt DS per year, reaching a possible amount of 10.3 Mt DS per year. With more stringent requirements on phosphorus or suspended solids and a growing population, this amount could increase significantly.

Consequently, waste water service operators need to continuously keep various options available for their sewage sludge outlets in order to maintain sustainability and resilience to the management of waste water services.

6.1.1. Public perception

Public perception (including policy makers, food retailers, food processors, farmers) is not always aligned with risk assessment for the recycling of nutrients. The general public is not familiar with sewage sludge and may fear the contamination of soil or crops or food, even if biosolids are well managed and controlled. It is a challenge to communicate that the reuse of bioresources can contribute to the circular economy and overcoming perceptions of sludge is a key challenge for the future.

[3] Evaluatuion of the Urban Waste Water Treatment Directive, European Commission, 2019.

6.1.2. Technology

A wide range of technologies for sludge treatment are in use across Europe. Where some of them are quite simple and easy to manage, others are more advanced, demanding more energy and skills to operate and manage. Several new technologies are being developed, but in many cases these are unfortunately not sufficiently mature to be developed at a large scale, and need to be framed by appropriate legislation (e.g. to secure the use of phosphorus recovered on the market). In addition, investments must be secured, and workers will need to adapt to these new technologies.

6.2. The language of sludge

At present we refer to 'sludge' because this is the term used within the current regulatory framework. But sludge could be named differently to better reflect all the resources we can extract from it. Sewage sludge is a byproduct from waste water treatment. Using a term like 'waste water treatment sludge' already gives a better idea that this results from a treatment and not directly from faeces. The vocabulary used needs to represent the value and the variety of uses. We already talk about **bioresource** (the potential value within sludge) and **biosolids** (treated and ready for use in agriculture or on land). This vocabulary is more general and presents the positive value that can come from sewage sludge.

6.3. The reality of sludge management is circular

Currently, the choice of sludge management for WWTP operators depends on multiple factors: the quality of the sludge, the control at source measures used, the market and interest of farmers for the use of biosolids in agriculture, the existing capacity for incineration, the costs associated with sludge management etc. However, certain solutions are increasingly under pressure. In order to be able to continue collecting and treating waste water for the health of humans and the environment, it is vital that waste water operators consider strategies/drivers to maintain different solutions available for the resilience of the future management of sludge.

6.3.1. Circular economy

The circular economy should be an important driver for development. However, the necessary paradigm shift to enter into a real circular economy has to be planned. The enabling regulatory framework needs to be developed to support the new Circular Economy Action Plan[4]. Recovery and reuse of nutrients (Integrated Nutrient Management Plan[13]) and materials from waste water and from drinking water treatment is already taking place, and new solutions are being developed. Innovative business models for recovered materials, legislation that accepts recovered material from the water industry, and a level playing field are needed to improve cost-effectiveness, without adding unnecessary administrative burdens on water services (creating a well-functioning EU market for secondary raw materials[4]). To allow the circular economy to fully develop, the legislative

[4] COM(2020) 98: A new Circular Economy Action Plan For a cleaner and more competitive Europe.

framework needs to support a change of mindset of operators, to move from managing sludge towards taking actions to produce secondary resources. To achieve this, operators need to be supported by both a strong chemical authorisation process and flexible discharge permits to control the release of substances into sewers that could threaten the circularity of the sewage sludge. In that sense the zero pollution ambition[5] of the European Commission should really look at the downstream consequences of putting products and substances on the market for the circularity of the sewage sludge. And finally, the movement (transport) of the secondary raw material needs to be facilitated across Europe within the single market.The European Green Deal should foster the development of solutions, accompagnied by the financial tool/s to secure investment, that will allow to close the cycle for nutrients.

6.3.2. Climate Change

The water sector has a role to play in reaching the ambitious and necessary objective of making the EU carbon neutral by 2050. The carbon footprint of the sector's operations must therefore be an integral part of all plans for future development and solutions. This includes considering energy use and generation, as well as the direct emission of methane and nitrous oxide. However, the management of biogenic carbon, being considered as carbon neutral, captured in the waste water treatment process and embedded in the existing infrastructure should be considered as well.

The different sludge management options have different carbon footprints that must be taken into account for the choice of sludge management solutions. The question of the treatment of contaminants of emerging concern in waste water is growing. Treating those contaminant requires processes that are currently highly energy demanding, which would put more pressure on the carbon footprint of the sector. In order to compensate, low carbon footprint solutions should be maintained. Furthermore, despite scientific evidence on the limited risk for the environment (see section 3.3), the presence of these contaminants in waste water is also threatening the use of sewage sludge in agriculture. If this threat outclasses scientific evidence, alternatives (e.g. incineration, phosphorus recovery, etc.) will have to be implemented. This will require investment and new infrastructure (incinerators) to be able to manage the 62% of sewage sludge that are used on land. Building and operating these new infrastructures will generate new GHG emissions.

Reaching the objective of carbon neutrality will require following both the carbon captured during the treatment process and the carbon embedded in the existing infrastructure and decide on the best overall option to limit the GHG emissions linked to sewage sludge management. The use of sludge in agriculture allows for keeping carbon emissions low. The carbon sequestration is possibly helping to decrease the use of higher carbon footprint synthetic fertilisers. Alternatively producing green energy from incineration can be considered as carbon capture as well. Life Cycle Analysis could become a key tool to help decision makers to make good choices. Finally, the period until 2050 should be considered

[5] COM(2019) 640: The European Green Deal.

as a transition phase toward carbon neutrality, when it is possible to trial new technologies and solutions to reach carbon neutrality according to the local constraints.

6.3.3. Finance and costs

The OECD report for the European Commission related to the UWWTD evaluation identified the remaining financial gap for the full implementation of the UWWTD in all EU Member States as being €253 billion by 2030. EurEau understands that this amount does not cover sludge management as the multiple solutions and local contexts made the projection difficult. However, sludge management has been identified as one of the main cost drivers for the implementation of the UWWTD. We anticipate that the financial gap will be even bigger once sludge management is included. The cost of sludge management has to be taken into account in any revision of the regulatory framework of waste water collection and treatment.

New technologies and new routes for sludge treatment/valorisation/recycling need investment and will generate operating costs. All these costs have to be recovered either through the water bill or through revenue from the recovered energy or materials. This means that clients need to be identified with a willingness to pay and regulations have to be established to support the development of new markets.

6.3.4. Future regulations

Section 4 presented the legislative landscape that relates to sewage sludge management. From this analysis, some gaps can be identified.

With respect to sludge, there are indirect ways of protecting the quality of sludge through the EU's REACH legislation. However, there is no clear line of sight between the protection of sludge quality and source control legislation. This is a major gap, given the direction on circular economy and the range of reuses for sludge.

With the exception of the Fertiliser Regulation, it should be concluded that there does not appear to be any legislation at EU level setting out the standards for recovered materials from sludge. The question remains on the extent to which standards for recovered materials are required in future.

With the emphasis on the circular economy, sludge is a bioresource with multiple uses. This status has not been acknowledged as an opportunity in the public domain, even though the reuse of sludge as agricultural fertiliser or soil improver or as ashes to extract phosphorus are preserving precious natural resources. Public awareness drives the development of sound legislation and increases trust, which, in turn, supports the market as well as acceptance. With this in mind, the fact that sludge is legally a waste is certainly not supported.

The future legislative framework related to bioresources and the circular economy needs to provide the necessary arrangements for the protection of human health and the environment and for monitoring, reporting and quality control, for the different possible sludge re-use options. A future framework, being visible and well communicated, will enable citizens to have confidence in bioresources.

7. Conclusion

Sewage sludge is inherent to the waste water treatment and also a valuable by-product of this process. The future of sludge management will depend on what policy makers are ready to put in place to protect the quality of this byproduct and the regulatory framework to support a wide variety of reuses.

There is a need for a paradigm shift around sludge that starts by not considering it as waste but starting to see it as a bioresource on its own. This is moving the attention towards what is valuable and how we can protect it, instead of looking at how to get rid of it. This requires a different regulatory approach and moving away from the linear, traditional waste hierarchy.

In future, greater use could be made of risk assessment and risk management techniques in order to better control the sludge management itself. Sustainable and resilient sludge management options are crucial to ensure the continuity of waste water treatment services. A broader scope for risk assessment and management, broader than strictly sludge quality control, needs to be taken up by the regulatory framework.

EurEau members want a circular future for bioresources, built on good risk assessment and risk management techniques, where climate change targets form part of the risk assessment and the solutions along with the views of citizens. In this way, sustainable and long-term investment decisions can be made for waste water services.

Annex I
Control at source

Micropollutants can directly or indirectly enter the water cycle through many means. Once in the water cycle, they can pose a risk to the water environment, ecosystems and to the possibilities of a circular economy.

EurEau has consistently advocated for a control at source approach to micropollutants as well as for the implementation of the Precautionary Principle in environmental policy as the most sustainable way to protect water resources. In fact, EU legislation is built on the Precautionary, Control at Source and on the Polluter Pays Principles as enshrined in Art. 191(2) of the Treaty on the Functioning of the European Union, stating that "the Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay." These principles constitute the underlying philosophy behind the Water Framework Directive and cutting-edge and far-reaching European chemical legislation such as the REACH Regulation, the Plant Protection Products Regulation, the Biocides Regulation and cosmetics legislation.

In the UWWTD, it is also stated in Annex 1 that:

"C. Industrial waste water

Industrial waste water entering collecting systems and urban waste water treatment plants shall be subject to such pre-treatment as is required iun order to: […]

— ensure that the operation of the waste water treatment plant and the treatment of sludge are not impeded

[…]

— ensure that sludge can be disposed of safety in an environmentally acceptable manner."

As noted above, thet quality of sludge is a product of the society which generates it. The amount of contaminants ending up in the sludge can be influenced by working systematically with control at source in various ways. Water utilities have run campaigns to raise awareness of connected industries but also ordinary customers to teach the right practices for waste management e.g. related to the waste disposal of paints, solvents and pharmaceuticals. Firstly, stringent requirements for the authorisation of substances under REACH Regulation is crucial to avoid harmful substances entering the water cycle. Secondly, adequate pre-treatment of industrial effluents is essential. The main responsibility lies with the industry but a clear regulative framework and practices between industry, authorities and water utilities are necessary to implement this. Quality assurance systems described in Annex II.2 also have an important role in the holistic control of harmful substances. Sustainable storm water management practises can help to manage both the quality and quantity of waters entering sewers. Apart from the various measures water utilities are able to do, it is crucial that the wider EU-level legislative framework supports and demands effective source control measures and limits the use of harmful substances.

Annex II
Use of sewage sludge on land

1. Biosolids

'Biosolids' are the result of the refining processes of sewage sludge in order to apply it on land. Several processes can be used to achieve the required quality (see section 3). For agricultural use, the main objective is to have biosolids that improve the soil quality, have carbon and nutrient value, are stable and easy to transport and convenient to spread on fields.

Organic matter and carbon are of vital importance to European soils. Some 45% of soils in Europe have a low or very low organic matter content. This is particularly evident in many southern European countries, but it is also the case in some other countries[6]. Carbon is also needed to enable soils to be resilient to more frequent and intense droughts or rainfall events. Sewage sludge has a role to play in the transition to circular agriculture, where fields are harnessed as carbon sinks.

Many decades of innovation have constantly improved treatment technologies to sustainably produce good quality fertilisers that comply with high quality standards.

Local conditions and practices define which method will be the most applicable to produce biosolids. **Co-treatment** of various raw materials either in co-digestion or co-composting units is usually the most technically and economically feasible solution. Regional units commonly collect organic materials and process organic waste from industries and municipalities together with sewage sludge.

At the moment biosolids are widely used in agriculture and landscaping. However, it still has unexplored potential, like in forestry.

2. Certification of biosolids

Whereas European and national legislation provides the baseline, the risk management and quality work of water utilities is supplemented with voluntary Biosolid Assurance Schemes in many countries. The purpose of such schemes is to provide food chain stakeholders and consumers with transparency and reassurance that certified biosolids can be safely and sustainably recycled to agricultural land. Quality assurance systems are audited by an independent third-party certification body to ensure that participants conform with the scheme standard. Examples of national assurance systems are presented below.

In Sweden, **Revaq** is operated by Svenskt Vatten (the Swedish Water & Wastewater

[6] JRC, 2012.

Association) in close co-operation with the Federation of Swedish Farmers (LRF), the Swedish Food Federation and the Swedish Environmental Protection Agency. Almost 5 million people (50% of the population), producing about 100,000 tons DS are connected to a Revaq waste water treatment plant. Revaq requires all certified waste water treatment plants to be committed to the source control work and includes target values for pollutant concentrations, a phase-out list for chemical compounds not possible to use in connected industries and traceability via digital GIS. [7]

In the UK, the **Biosolids Assurance Scheme (BAS)** is owned and operated by Assured Biosolids Limited, which is a not-for-profit company set up by 11 UK water and sewerage companies. Assurance schemes cover transportation and storage, monitoring and analysis, treatment, rules for application to agricultural land and risk assessments.[8]

In Germany, the **Bundesgütegemeinschaft Kompost e.V. (BGK)** is the carrier of the RAL quality labels for compost, digestate, sewage sludge and sewage sludge compost. The system includes the RAL GZ 258 for AS Humus compost (sewage sludge compost) and the RAL GZ 247 for AS Düngung (sewage sludge for fertilisation) for sewage sludge. The BGK has defined a general quality standard for each RAL quality label and established a nationwide system for external monitoring of composting and digestion plants and of compost and digestion products. In 2014, eleven composting plants for sewage sludge compost and 59 sewage sludge treatment plants took part in the quality assurance system.[9]

Another quality assurance system in Germany is the **QLA-System, a quality assurance system for the agricultural utilisation of sewage sludge and other organic waste**. It was founded in 2003 by DWA (the German Association for Water, Wastewater and Waste) and VDLUFA (the Association of German Agricultural Analytical and Research Institutes), mainly to establish a system that guarantees high requirements for soil and groundwater protection and thus increases confidence and acceptance of sewage sludge utilisation in agriculture. The system has three categories: 1. Input, 2. Product, 3. Utilisation. All three categories are under external supervision with stronger requirements than the legal national legislations. In 2013 about 60,000 tons DS were used on land under the QLA-system (12% of sewage sludge used as a fertiliser in agriculture in Germany). Due to new restrictive legal requirements (waste **and** fertiliser regulations), the agricultural utilisation of sewage sludge has declined sharply in Germany during recent years. Sludge quantities certified by QLA have also decreased to around 30,000 tons of dry matter in 2018.

In Austria **Kompost & Biogas Verband Österreich** (**KBVÖ**) is in charge of quality assurance systems for compost. Quality assurance systems are based on legislation and national compost standards (ÖNORM S2200).

In France, sludge compost used for agricultural application can move out of waste status by complying with **NFU 44-095** normative standards according to their characteristics. In

[7] www.svensktvatten.se/vattentjanster/avlopp-och-miljo/kretslopp-och-uppstromsarbete/revaq-certifiering/.
[8] assuredbiosolids.co.uk/about-us/.
[9] www.compostnetwork.info/wordpress/wp-content/uploads/Presentation-BGK-2014-03-12.pdf.

this case, traceability is no longer mandatory and compost has become a finished product that can be traded. Composts from sewage sludge cannot be used in organic farming because they are not listed in Annex IIA of Regulation No. 2092/91, specifications for organic farming.

In Estonia and in Finland, quality assurance systems for biosolids are at the initial stage.

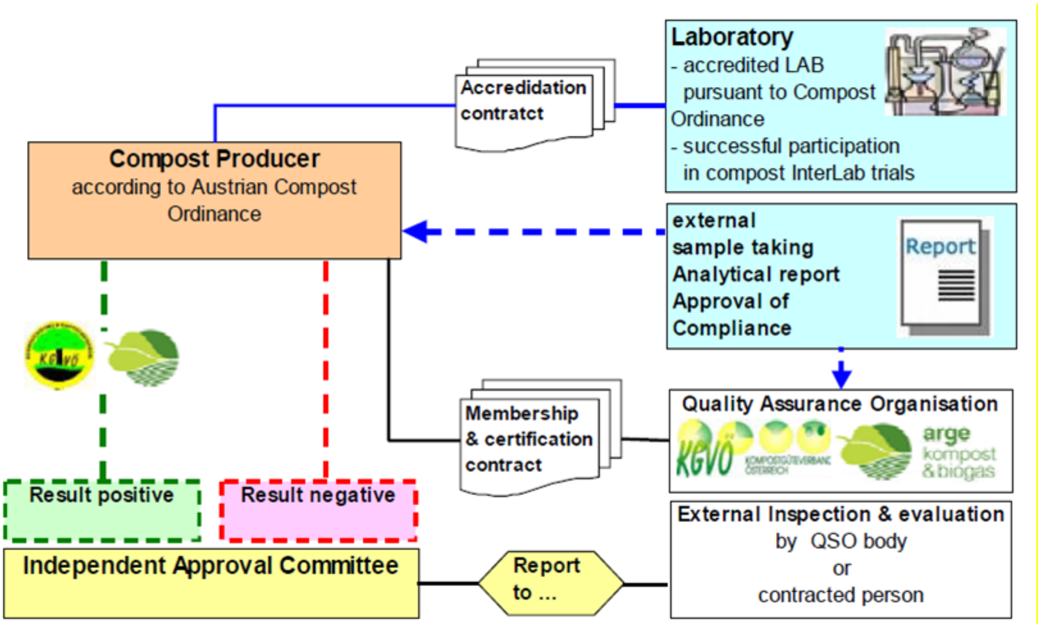

Figure 4. Austrian compost quality assurance system principles. Quality assurance systems everywhere follow similar policies.

3. Risk management and risk assessment

As already said in section 1, waste water from households, storm water runoff and industrial waste water contains traces of pollutants. During the waste water treatment process many of these pollutants are removed from the water and incorporated into the sewage sludge. Recognising this is a precondition to managing risks and assuring that biosolids are safely used.

The most prominent instrument in **risk management** is national legislation, where requirements for the quality and use of biosolids are defined. National legislation considers, for example, heavy metals, hygienical quality, organic pollutants, phosphorus loads to fields and maturity of biosolids. Unwanted accumulation of substances as well as nutrients in the soil is limited by substance-specific limits for the amount per hectare. The volume of biosolids to the fields is determined by these limitations and can vary between countries.

In France, sludge agricultural valorisation has been regulated since 1998. The aim of this regulatory framework was to protect the soil and the environment against exposure to metals and particularly toxic organic pollutants by setting threshold values for sludge valorisation in agriculture. Sludge can be applied :

a. as long as one of the contents of metallic or organic pollutants (cadmium, chromium, copper, mercury, nickel, lead, zinc, polycholorinated biphenyl (PCB), fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene) does not exceed one of the limit values defined;
b. if the pollutant loads accumulated in the soil over a period of 10 years does not exceed the limit for at least one of these component elements brought by the sludge
c. If the levels of metallic pollutants (cadmium, chromium, copper, mercury, nickel, lead, zinc) in the soil do not exceed one of the limit values defined. Soil limit values are between four and ten times lower than limit values for sludge.

Analyses for the characterisation of the agronomic value of sludge (Nitrogen, organic matter, phosphorous, potassium, calcium, magnesium, bore, iron) have to be made according to the load of dry material (tons of dry solids/hectare) applied (from 4 to 48 times per year).

Risk management is supported by **risk assessments** which have been carried out both EU wide and nationally. The main concerns studied in a risk assessment were organic micropollutants, heavy metals and pathogens. A Norwegian (2009) risk assessment evaluated that the use of sewage sludge is not expected to constitute a significant risk to the aquatic environment nor to food producing animals. Both Norwegian[10] (2009) and Finnish[11] (2018) risk assessments concluded that the risk associated with the use of sewage sludge in agriculture is not significant for the general population via dietary intake or drinking water. A recently published (2020) Swedish Phosphorus enquiry[12] included a literature study and confirmed the outcome of various previous studies. The Inquiry noted that current research on the spreading of sewage sludge with the quality requirements applied in Sweden for agricultural use has not shown adverse effects on either health or the environment.

In some risk assessment for some matrices - mainly soil ecosystems - the potential risk caused by substances of emerging concern was identified[13]. Further research is needed to get a reliable and comprehensive basis for conclusions and to decide if follow-up source control measures are required. In this context it would be useful to assess and compare the environmental benefits and disadvantages of biosolids use.

[10] 2009 VKM.
[11] 2018, Vieno et al.
[12] 2020 SOU 2020:3, p 42.
[13] 2018, Vieno et al.

Annex III
Energy recovery

Anaerobic digestion is the preferred stabilisation step in the sewage sludge treatment process for medium and large WWTPs. During the digestion process biogas is produced, which is a valuable renewable energy source. Biogas from sewage sludge has a high methane (CH_4) content, with a typical range of 63–67 % CH_4 while the rest is mainly carbon dioxide (CO_2).

The technology is mature and widely used, especially in relation to land application. In Europe many WWTP bigger than 50,000 p.e. are already equipped. In 2016, the EU28 countries produced 1.4 Mtoe (million tones oil equivalent) of biogas, coming from sewage sludge, (BIOGAS BAROMETER, 2017). This is 8.7% of the total biogas production from any feedstock (16.1 Mtoe). Germany contributes 33% of this. The biogas produced can be used in several applications that are described below.

Biogas can be used in several applications:

- to **replace fossil gas** for heating.
- in gas engines (CHP/combined heat and power) **to produce electric energy and heat**. As a general rule, it can supply 30-50% of the electricity demand and 80-100% of the thermal energy demand of WWTPs. Complete heat sufficiency is already being achieved in many plants . Higher levels of energy production can be achieved with energetic optimisation of WWTPs.
- the biogas can be **injected in the municipal grid** after further purification **to comply with the requirements of the natural gas network**. The purification process consists of removing hydrogen sulphide, water, volatile organic compounds and CO_2. Several such plants are in operation in France and Finland (Strasbourg WWTP (1 M p.e.) produce 450 Nm^3/h of bio methane injected into the Strasbourg natural gas network, as Marseille WWTP (1,8 M p.e.), Lyon La Feyssine WWTP (300 000 p.e.), Versailles WWTP (340 000 p.e.), Angers WWTP (285 000 p.e.).
- The biogas can be **upgraded to natural gas** standards and used as fuel in vehicles. This is common in Sweden, where, for example, in Stockholm, both Bromma sewage treatment works and Henriksdal sewage treatment works produce vehicle biofuel. Filling stations for biogas can be found in the whole Sweden except the most northern parts. A network is also developing in Finland, for example, in Suomenoja WWTP biogas is purified and utilised as a vehicle fuel. In Oslo, Norway, the Bekkelaget waste water treatment plant produces biogas out of sewage sludge which is refined and used as biofuel for waste trucks and buses. A biogas vehicle or a hybrid is required for transportation running on biogas. Biofuel from biogas is one way to forward fossil free transportation. Mixing requirements and national incentives can support the development of biofuel production and use.
- Biogas can be **stored in smart grids** for use during peak demand or low solar and

wind energy production.

Meistrazheim WWTP (France) treats the waste water of 27,000 p.e. and the effluents of local sauerkraut producers (equivalent to peak flow of 140,000 p.e.). Thanks to cogeneration, biogas can be used to produce the heat needed for the digester, or the heating of the operating building and of the tap water. The extra biogas can be converted into electrical energy injected into the municipal electrical grid. Some similar examples are located in Bordeaux Louis Fargues WWTP (470,000 p.e.) and Morillon-Samoëns (50,000 p.e.).

Figure 5:Anaerobic digestors in the APA NOVA WWTP (RO) and Oslo buses using biomethane.

Annex IV
Incineration

1. Mono-incineration

Mono-incineration of sewage sludge (no mixing with other waste) is the optimal solution for reducing mass and thus minimising costs for transport and/or landfill for final sludge disposal. Consisting of a high-temperature incinerator (between 850°C and 950°C), sometimes directly preceded by a thermal dryer, it allows dewatered or partially dried sludge to be fed into the combustion chamber.

The burning of the sludge produces a mixture of ashes and gases that must be treated. Nitrogen oxides (NO_x) is the most crucial emission formed, while nitrous oxide (N_2O) is an important greenhouse gas which has around a 300 times stronger impact on the climate than CO_2. The treatment is done in two stages. A first step (electric filters, cyclone separation or bag filters) separates 80 to 95% of the ash, which can be recovered or landfilled. A second step is done in a reactor, to remove all acidic gases (SO_2, hydrochloric acid, hydrofluoric acid, etc.), and capture volatile metals and fine particles, in order to meet the most stringent discharge requirements.

The use of mono-incineration could be part of an overall environmental strategy and offers new opportunities in energy saving. Sludge incineration is an option chosen in several cases :

- if the use of sludge in agriculture is not possible because of the strong pressure on agricultural soils already very rich in nitrogen and phosphorus or because national legislation bans sludge use on land (eg in Flanders and The Netherlands, in Germany for WWTPs bigger than 50,000 p.e. from the year 2029);
- if the sewage sludge does not meet the quality requirements for agricultural use.
- if there is an accumulation of heavy metals in soil that does not allow for land application. In this case mono-incineration can also be chosen if the heavy metal content of sewage sludge is at the limit of the requirements.
- if the recovered phosphorus from ashes is more bioavailable than from the direct application on land for the crop considered.

The heat of the incinerator - about 2.5 MWh/tDS for the new generation of mono-incinerators - can be recovered, on the one hand, for the heating of the incinerator itself and on the other hand for operating buildings heating or sludge drying.

Another possible solution is to consider a loop between the furnace and a methanisation platform, each of which can feed the other, which would make the most of the energy potential of sewage sludge.

Many facilities are equipped with mono-incinerators in Europe (20 WWTPs in France, 22 WWTPs in Germany, Belgium, Netherlands, Poland).

2. Co-incineration

Co-incineration, by definition, means that a flow of dewatered, partially or totally dried sludge is added to the feed stream of an existing incinerator dedicated to another primary application. This addition is currently made if there is available capacity and if an economic synergy exists.

Co-incineration concerns four cases :

~ co-incineration with special industrial waste (DIS) in incineration furnaces;
~ co-incineration in thermal power plants;
~ co-incineration in cement kilns;
~ co-incineration with household waste.

The treatment of dried/dewatered sludge in thermal power plants is typical in Germany. In Germany, more than 25% of the whole sewage sludge is incinerated in coal-fired power plants (ca. 0.5 Mt DS/a).

The incineration of sewage sludge in cement kilns is becoming increasingly interesting worldwide. Dried sludge can be used as a fuel and, depending on its composition, replace a significant portion of fossil energy resources such as coal. Sewage sludge, after drying at a dry matter content over 90%, usually has energy values of 10-12 MJ/kg. For co-incineration in cement kilns, there is an additional constraint related to impurities in mineral substances which may affect the behaviour and quality of the clinker produced. However, the inorganic part stays in the clinker and there is no ash to manage. Several examples are already available in Switzerland, in Germany, in France (Cannes WWTP), in Greece (Athens WWTP) and in Sweden.

The most common form of co-incineration of sludge is with household waste. This co-treatment can be done either with dewatered sludge (there are 26 waste incinerators co-incinerating in France) or with pre-dried sludge (totally or partially) with a Net Calorific Value similar to rubbish.

Except for co-incineration in cement kilns, co-incineration generates ashes that have to be disposed of, generally in landfill. A disadvantage of co-incineration as compared to mono-incineration is that it does not allow for the further recovery of phosphorus from ashes due to the dilution of the phosphorus content.

Annex V
Recovery of sludge components (N, P, C)

1. Phosphorus recovery

Phosphorus is an important nutrient with limited geological reserves. There is a growing interest to develop and start implementing technologies to recover phosphorus from different secondary/waste materials, such as sewage sludge, and thus replace virgin raw phosphorus. Different technical solutions exist for phosphorus recycling from waste water. Phosphorus can be recovered from different parts of the waste water or sludge treatment processes. Points for a possible recovery are presented in Figure 6.

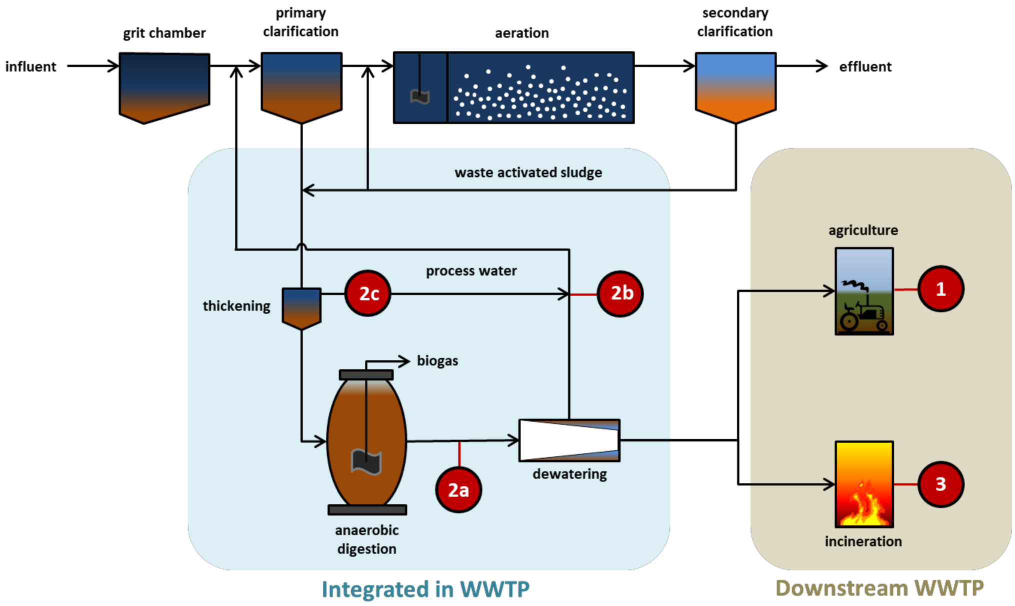

Figure 6: Hotspots for phosphorus recovery from the waste water stream (simplified)[14]

The most common method for phosphorus recovery from waste water or sludge is **struvite crystallisation**. Struvite is formed when orthophosphate (PO4-P) crystallise in the presence of sufficient ammonia (NH_3/NH_4^+) and magnesium ions (Mg^{2+}). Controlled struvite formation has been advantageous since uncontrolled precipitation in pipes and structures and demand for maintenance can be avoided which gives savings. Benefits are achieved along with better sewage sludge dewaterability properties and reduced sludge volume. Phosphorus recovery as a struvite is a mature technology and commercial solutions are available and widely in use already. Use of struvite precipitation is limited by the fact that struvite can only be recovered when the waste water treatment plant has

[14] https://www.vesiyhdistys.fi/wp-content/uploads/2019/12/GWRCPhosphorusCompendiumFinalReport2019-March-20.pdf.

biological phosphorus removal and digestion. With struvite precipitation, from 10 to 50% of phosphorus can be recovered. The situation related to the markets for struvite seems to vary depending on local circumstances. It is expected that the EU Fertiliser Regulation will soon be updated to include struvite as an ingredient for EU fertilisers.

Mono-incineration of sewage sludge (see Annex IV.1) results in **ashes** from which up to 80% of phosphorus can be recovered through various technologies. The first full-scale plants for phosphorus recovery from ashes are supposed to start operation in the near future (under construction in Hamburg WWTP, Germany). Existing technologies are very sensitive to the product concentration and therefore water balance within the system is a key performance factor. Evaporation consumes a lot of energy which has also a substantial impact on the operational cost.

A wide range of other solutions for phosphorus recovery have been tested and developed as well. Many of these technologies are still under development or at the pilot testing phase. Most prominent and already applied concepts for phosphorus recovery and recycling from sewage sludge are presented in Figure 7[15].

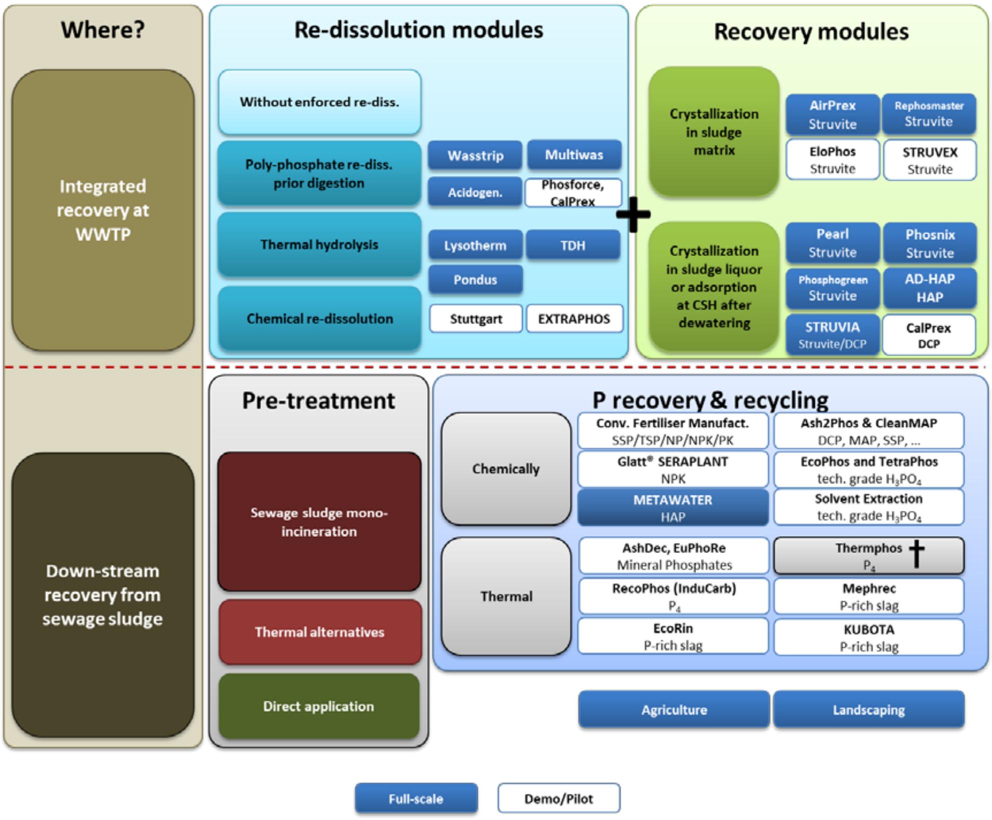

Figure 7:. Most prominent and already applied concepts for phosphorus recovery and recycling from sewage sludge

Phosphorus recovery is not more widely utilised because the cost for recovered phosphate greatly exceeds the cost for phosphate rock. As a result, most of the recovered materials are given away for free or at very low prices.

[15] Kabbe, C. 2019. Global Compendium on Phosphorus Recovery from Sewage/Sludge/Ash.

Environmental impacts of phosphorus recovery have been studied in some projects[16]. The different phosphorus recovery technologies vary in emissions and energy demand[17]. When new phosphorus recovery technologies become mature and reach full-scale solutions, environmental impact and lifecycle assessments should be reviewed.

2. Nitrogen recovery

Nitrogen is another important nutrient and there are efforts to recover it from sewage sludge. One case is the recovery of nitrogen by VEAS in Oslo (WWTP, 650,000 p.e.), in cooperation with Yara. A substantial fraction (12-15%) of the total nitrogen load entering the VEAS plant is recovered from the sludge - after anaerobic digestion (AD), lime conditioning and filter pressing stages – via ammonia stripping and subsequent capturing (scrubbing) of the ammonia gas (NH_3) with a concentrated nitric acid solution. This stripping and scrubbing treatment yields an industrially reusable ammonium nitrate (AN – NH_4NO_3) side stream. Some 350–500 Mt of nitrate/year is recovered from the waste water. Another example is in Turku (FI), where Gasum produces ammonia water by evaporation and steam stripping from reject water.[18]

[16] Pradel, aissani, 2019.
[17] Aman et. all, 2018.

Annex VI
New technologies

Sludge management is facing numerous challenges. In the future, it may require different innovative sustainable solutions to complement the use of sludge on farmland.

Therefore, WWTP operators are developing and testing a lot of new technologies in order to:

- **reduce the amount of sludge produced during the treatment process**
  (new waste water treatment technologies e.g. Anammox-process, Nereda process; new sludge treatment methods e.g. disintegration techniques or advanced oxidation processes such as ozonolysis). These technologies may lead to new products from sewage sludge, e.g. Dutch Kaumera Nereda® Gum that is a new bio-based raw material extracted from the sludge granules formed during the Nereda® purification process.
- **recover and produce energy from sludge more efficiently**
  (increase the digester gas-production by preliminary disintegration of the sludge feed, new gas-engines with higher efficiency, new incineration techniques with better heat reuse e.g. for sludge drying or electric energy production, solar drier for using renewable energy).
- **exploit sludge as a resource for nutrients, particularly phosphorus or other raw materials**
  (Recovery of phosphorus and nitrogen with enhanced struvite precipitation, new incineration techniques for a better ash quality – less heavy metals, better plant-availability of phosphorus, recovery of bioplastics, VFA (volatile fatty acids),…)).
- **reduce transportation of the sludge** (utilise sludge where it is produced or close to it, or reduce the liquid content as much as possible).

A lot of new technologies are available, but these must be safe to operate and they must offer a valuable return on investment. Both objectives are difficult to fulfil and in many cases, operational experiences are missing. Regulation should allow technology to emerge but should not push in one direction because of promising results that are not yet proven nor tested on a large number of full-scale projects.

Below we present some of the new technologies that are being developed. These are examples and the list is not exhaustive.

1. Pyrolysis

Recently, new technologies such as pyrolysis and gasification have proven to be environmentally safe and economically feasible solutions for sewage sludge treatment.

Pyrolysis is a thermal process where the organic matter in sludge is burnt with no oxygen so the carbon is not consumed. It usually converts dewatered or dried sewage sludge into usable oil and gas (syngas), forming a stabilised residue (biochar) as a by-product. Processes like hydrothermal carbonisation (HTC) can be applied to wet sludges. However, the gas cannot be upgraded and transported because of impurities. Therefore, its energy can only be recovered on site. Furthermore, it should be noted that the biochar produced from sewage sludge is unfortunately not allowed as an EU fertiliser.

Some technology providers also look to produce activated carbon from biochar. This project develops and tests technology for cost-effective improvements to the environmental sustainability of waste water treatment by upcycling residual sludge into activated carbon. Residual sludge will be transformed into high value activated carbon to be applied on-site while simultaneously reducing greenhouse gas emissions and environmental impacts related to organic pollutants and micro plastics.

Two pyrolysis plants are under operation in Germany: Linz-Unkel WWTP and Homburg WWTP.

2. Gasification

Gasification is a more recent process composed of two steps. In the first step, dried sewage sludge is transformed to a flammable lean gas at 850–880°C composed of hydrogen (H_2), nitrogen (N), methane (CH_4), carbon monoxide and dioxide (CO/CO_2) and hydrocarbons (tars). In the second step, the hydrocarbons are decomposed by partial oxidation to synthesis gas (CH_4, CO, H_2) that is then incinerated in a CHP plant.

Three plants are implementing the process in Germany: Balingen WWTP, Mannheim WWTP, Koblenz WWTP, and one in France (Valenton WWTP: 3,6 M p.e.). However, it seems that the technologies remain difficult to be mainstreamed. The final by-product is not permitted as a fertiliser even if it contains a large amount of phosphorous and biochar.

3. Hydrothermal liquefaction technology (HTL)

The HTL technology produces bio oil from sewage sludge. This bio oil is refined to be used as fuel for heavy transport. Aalborg University and Aalborg Utility in Denmark are working on this pilot project. The next step is to scale up to full size pilot.

4. Mineralisation

By mineralising in green houses, many more micropollutants will be degraded, and the resultant sludge product will be of a higher quality. Fors Utility (DK) is testing this.

5. Gas-to-liquid technology (GTL)

This technology produces aviation fuel from feedstocks of biogas, CO2 and sustainable hydrogen. Different types of this technology are already a reality in Qatar, Nigeria, Malaysia and South Africa. The University of Southern Denmark (SDU) is working on this.

About EurEau

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