ROLE OF DEWATERING IN SLUDGE TREATMENT AND MANAGEMENT

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Since many decades, the management of sludge produced by wastewater treatment plants (WWTPs) is considered a

“problem”

This is not fully true because we forget that it is the

“solution”

to the problem of the increasing availability of household running water that induces greater and greater water usage and, therefore, sludge production after wastewater treatment.
This means that sludge management is a step occurring in the water cycle necessarily following the treatment of wastewaters.

However, after its production, sludge needs to be treated to properly perform the utilization / disposal operations in a "sustainable manner".
However, sludge is often inadequately addressed in the context of the water cycle, being considered as the “last wagon” of the train.

In practice, first we produce the sludge and only after we start thinking about what we can or should do with it.

This is fundamentally wrong because the selection of the most appropriate and sustainable wastewater system is strongly driven by the final reuse/disposal option(s) consistent with the local context within the limits imposed by legislation.
So, sludge must be considered the “locomotive” of the water cycle train:

*if the locomotive does not properly work the train does not run*
Further, we have to consider that the management of sludge, and waste in general, has greatly evolved, as it has moved from solutions mainly addressed to simply dispose it to solutions addressed to more efficiently utilize or reuse sludge within the frameworks of:

**Sustainability**
(where a sustainable system means environmentally bearable, economically convenient, and socially acceptable)

**Circular economy**
(instead of a simple resource efficiency got through a linear approach)
In addition, we have not to forget that all human-operated transformations are "not perfect or fully reversible" and are subject to the "3 Laws of thermodynamics"
1\textsuperscript{st} law:  
Energy is conserved and assumes different forms some of which cannot be conveniently recovered, i.e. 
\textit{energy/material losses are always occurring} 

2\textsuperscript{nd} law:  
The Entropy, which is a measure of the disorder in an isolated system, constantly increases, thus meaning that \textit{all human processes involve a worse state than before} 

3\textsuperscript{rd} law:  
It is impossible to reach the absolute zero value by finite processes, and this means that perpetual motion, i.e. \textit{infinite recycling is impossible}
Given above considerations, from a technical point of view, crucial steps for more sustainable solutions in sludge management include:

- production of a reduced sludge amount compatible with the final outlet/destination and the best overall energy balance;
- improvement of sludge quality to reduce nuisances, health risks and handling costs;
- adoption of technologies to improve recovery of useful materials and/or energy.

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Dewatering is the process that strongly allows/contributes to fulfil the aforementioned requirements.
The fundamental role played by dewatering in a modern sludge management is demonstrated by the possibility to obtain

*higher sludge concentrations*

and/or

*less polymer/conditioning agent consumptions*

with the result of:

- lower transportation costs;
- better energy balances, thus involving a greater competitiveness of thermal processes;
- optimization of spreading techniques as occurring in agricultural utilization;
- easier handling in landfills where/when this technique is conveniently applicable.
Examples of trends in material/energy recoveries

- **Anaerobic Digestion**
  - **Thermal Drying**
  - **Dewatering**
  - **Pyrolysis – Gasification**
    - with gas utilisation and management
  - **Wet Oxidation**

- **Energy Input**
- **Energy Output**

- **Reject Water**
- **Ash**
  - P and other material recovery
  - Inert “sandy” material

- **N-recovery**
- **Effluent to be treated**
  - (N removal)
Reduction of production is a pillar for the development of sustainable systems. However, the goal is not to push to an "absolute" minimum, but to an amount "compatible" with sludge final destination and the best overall energy/material balance.

Strategies for reducing sludge mass/volume include two options:

- **reduction in the wastewater treatment stage** through appropriate technologies and operating procedures (e.g. cellular lysis, increased sludge age, ozonation, membrane technology, etc.);

- **reduction in the sludge stage** (e.g. thickening, dewatering, drying, thermal processing, etc.).
As far as mechanical dewatering is specifically concerned, conditioning (chemical or physical) is necessary for an effective reduction of water content.

In chemical conditioning, sludge particle charge is neutralized and flocculation promoted by organic reagents (polymeric macromolecular compounds) or inorganic reagents (such as iron and aluminum salts, lime).

It is to be mentioned that polymer molecular weight and charge density affect the conditioning operation as a function of the type of dewatering equipment to be used.
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<th>Description</th>
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<td>Initial adsorption at the optimum polymer dosage</td>
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<td>II)</td>
<td>Floc formation</td>
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<td>IV)</td>
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<td>V)</td>
<td>Rupture of floc</td>
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<tr>
<td>VI)</td>
<td>Secondary adsorption of polymer</td>
<td><img src="image" alt="Diagram VI" /></td>
</tr>
</tbody>
</table>

1. polymer
2. particle
3. destabilized particle
4. destabilized particles
5. flocculation
6. floc particle
7. no contact with vacant sites on another particle
8. restabilized particle
9. excess polymer
10. stable particle (no vacant sites)
11. intense or prolonged agitation
12. floc fragments
13. restabilized floc fragment

a) initial adsorption
b) floc formation
The major developments in sludge thickening process should focus on the appropriate design of gravity thickeners to intensify the generation of VFA for primary sludge, and mechanical devices, including air-flotation, for excess sludge.

One of the most significant advances in solids concentration improvement follows the development of highly effective flocculant polymers that enable sludge thickening and dewatering results, not possible in earlier decades.
In principle, various alternatives are available to reduce the sludge water content but, as told, the choice of the more adapted equipment should be primarily addressed to get a final solids concentration not less, not more than that needed depending on the intended final outlet / destination.
Mechanical dewatering can take place by **filtration** or **centrifugation** processes whose conventional schemes are shown below.
To properly perform the sludge utilization and disposal operations, correctly fulfil the legal requirements and build stakeholder and public confidence, the establishment of defined outlet procedures/routes is needed and a good sludge quality must be guaranteed, so

*Characterization*

becomes a necessary tool as it allows chemical, biological and physical properties of sludge to be evaluated, and its behaviour possibly predicted.

It follows that the definition of

**Standardized characterization procedures**

and the publication of

**Guidelines of good practice**

become a necessary support to operation and regulations.
Physical properties are often considered of secondary importance with respect to chemical and biological parameters. This is fundamentally wrong because the knowledge of physical properties allows the prediction of sludge behaviour when handled and submitted to almost all treatment and utilization/disposal operations, dewatering in particular.

For evaluation of sludge

Dewaterability

Settleability, Thickenability, Drainability, Capillary suction time (CST), Specific resistance to filtration, and Compressibility are parameters of primary importance.
The **Settleability** determination is used for calculating the rate of sludge settling and the sludge volume index, and for evaluating the performance of settling tanks, while the laboratory determination of **Thickenability** allows the amenability of sludge to further concentrate suspended solids in gravity thickeners.

**Drainability** of flocculated sludge is an important parameter for evaluating its suitability to be thickened by means of a draining process, and for giving indications on the choice of flocculant and its dosage for sludge thickening through a filtering medium.
The **Capillary suction time (CST)** is a fast and simple way to evaluate sludge dewaterability by filtration; CST should also make possible the evaluation, although only qualitatively, of sludge dewaterability by centrifugation through measurement of floc strength.

The **Specific resistance to filtration** is the typical parameter indicating suitability of sludge to be dewatered by means of a filtration process. The value of the specific resistance to filtration has great importance in dewatering processes as it can be useful for estimating the performance of full-scale filtering devices mainly pressure filters, and comparing dewaterability characteristics of sludge produced in different plants.

**Compressibility** is complementary to that of Specific resistance and gives information on the best range of pressure to be adopted in filtration processes.
However, mentioned parameters are not able to give fundamental or basic information as other parameters like:

- rheological properties
- particle and floc size
- water distribution,

are able to do.

This is particularly true in characterization of sludge dewaterability, but much work is still needed to develop reliable procedures adapted to sludge for evaluating such properties.
The rheological characterization has been widely applied in the past to the study of slurry flow, in particular to the suitability for pumping, but it has been demonstrated that rheological measurements can be used as operational guide or control technique in several processes, including conditioning and dewatering.

The **Physical consistency** is a characteristic linked to the rheological properties and is related to the physical states of sludge: liquid, paste-like, solid. Also, it is often reported in European legislation as a characteristic to be evaluated for fulfilling regulation requirements. This necessarily involves setting up methods to evaluate the limit of Flowability (border between liquid and paste-like behaviors) and that of Solidity (border between solid and paste-like behaviors).
Particle size distribution is a key parameter because it is widely recognized that particle size distribution strongly affects sludge behavior in solid-liquid separation as fine particles (1-100 µm) have a high specific area and are the most difficult to settle/filter/dewater, so any increase of particle size makes the solid-liquid separation easier.

The main problem in particle size evaluation is the difficulty of measurement because of the wide range of expression of results, measurement techniques and procedures. Measurement techniques use electrical means (electrozone sensing, electroacoustics), mechanical means (sieving, sedimentation), optical means (laser diffraction, diffusion, obscuration, photo centrifugation).
The importance of **Water distribution** is that it gives an indication of the level of forces/energy needed to break links between water and solid particles.

- **Free water** can be separated from solid particles through gravity sedimentation;
- **Surface and interstitial** ones through mechanical dewatering;
- **Bound water** only by thermal means.

Methods such as dilatometric determination, vacuum filtration expression, drying and thermal analysis, freezing allow the different water fraction to be determined.
To develop standardized methods in the field of sludge and to give the necessary support to the issue of EU directives dealing, directly or indirectly, with sludge management, the European Committee for Standardization (CEN) has established in 1993 the Technical Committee 308 (TC308) whose scope is the standardization of procedures employed for sludge characterization, including production of guidelines for good management practice.

Work at the International Organization for Standardization (ISO) started in November 2013 with the establishment of the Technical Committee 275 (TC275) aimed at harmonizing analysis procedures and good practice guidelines for sludge management in support to national regulations, taking into account recent technological innovations related to production of fertilizers, organic (biopolymers), minerals (such as struvite) and biofuels, and recovery of energy.
Summarizing, the decisional criteria for optimizing a dewatering operation are:

- Quality and quantity of sludge to be treated
- Energy consumption and costs, including transportation
- Investment and maintenance costs
- Need for space of machinery and storage
- Operator availability and skill, and infrastructure
- Specific local constraints or opportunities
Moving forward the sludge management within the frameworks of sustainability and circular economy requires the development of multiple and diversified option strategies aiming at reducing the amount of sludge without increasing the consumption of natural resources, and producing higher quality sludge to maximize material/energy recoveries, and minimize impacts on environment.

Sludge must be considered the locomotive of the water cycle train because selecting the most appropriate and sustainable wastewater system is strongly driven by the final reuse/disposal option(s) consistent with the local context within the limits imposed by legislation.
Dewatering is, together with Stabilization/Digestion, a crucial step for more sustainable solutions whose goal is not to push to an absolute minimum, but to an amount compatible with sludge final destination and the best overall energy/material balance.

Characterization is a necessary tool as it allows chemical, biological and physical properties of sludge to be evaluated, and its behaviour possibly predicted.

Establishing defined outlet procedures/routes is needed and a good sludge quality must be guaranteed to properly perform the sludge management operations, correctly fulfil the legal requirements and build stakeholder and public confidence.
MANY THANKS ...

... FOR YOUR ATTENTION