A Novel Waste Water Treatment Plant for The Disposal of Organic Waste from Mobile Toilets

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Abstract

The EU wastewater management industry is continuously looking for innovative technological solutions that can enter the market with a reduced environmental impact. This paper focuses on the problems associated to the disposal of human waste and on the specific market of the so-called mobile toilets. These are independent portable units equipped with sanitary tools that use chemical agents to disinfect the vessel and not connected to the sewer network. With growing awareness towards effective sanitation, mobile toilets have gained immense popularity in recent years and are now widely used at construction sites, event venues, public places, and in several other application like temporary refugee housing, migrants' camps, military missions, cases of natural disasters, airplanes, trains, campers, caravans and campsites. This paper illustrates a new process for the disposal of organic waste from mobile toilets.

Keywords: Waste Water Treatment Plants, Chemical Portable Toilets, Use of sludges in agriculture.

1. Introduction

The use of sludge in agriculture within the EU is currently regulated only by the limits of heavy metals (Cd, Cu, Hg, Ni, Pb and Zn) listed in Council Directive 86/278/EEC. This document is now more than 30 years old and most of the EU countries have introduced more stringent requirements and have adopted limits for concentrations of other heavy metals, synthetic organic compounds and microbial contamination. There is a need to update these regulations taking into account the current risks associated with the application of sludge to agricultural land. In general, sludge is characterized by considerable variability in nutrient content depending on the wastewater source and treatment process. Although nutrients are essential for plant growth, when applied excessively (especially nitrogen and phosphorus) they may accumulate in soil and can be leached and transported by drainage systems (particularly nitrogen) or can be transported by water erosion (phosphorus bound to soil particles) and pose a risk to surface water and ground water. It is then necessary to have the correct safety measures facilitating the prevention of possible leakage of contaminants into surface and ground water and to avoid toxic effects on soil, plants, animals and humans. In most cases, national authorities have implemented policies supporting the use of sludge in agriculture, as it is considered to be the best economic and environmental option to deal with the increasing quantities of sludge produced. In this context, national authorities are seeking to increase confidence in the quality and safety of products cultivated on sludge fertilised soils. In the context of uncertainties concerning the potential impacts on human health and the environment of the various disposal and recycling routes, all main stakeholders are calling for additional demonstration activities in order to increase confidence in the use of sludge in agriculture. The development of agricultural recycling depends largely on the possibilities to improve the quality of the sludge itself and increase confidence in sludge quality. This implies the prevention of pollution of the waste water at source and improving sludge treatment as well as ensuring the monitoring of sludge quality. This paper focuses on an innovative process for the treatment of a particular category of organic residues deriving from the use of chemical toilets and from agri-food industry's production process.

2. Innovative solutions for the market

The EU wastewater management industry is continuously looking for innovative technological solutions that can enter the market with a reduced environmental impact. This paper focuses on the problems associated to the disposal of human waste and on the specific market of the so-called mobile toilets (See Figure 1).

Figure 1: Portable chemical toilets.

These are independent portable units equipped with sanitary tools that use chemical agents to disinfect the vessel, not connected to the sewer network and intended for the use of a single person and temporarily placed in places where a number of people have to use them in the absence or insufficiency of fixed sanitation facilities. With growing awareness towards effective sanitation, mobile toilets have gained immense popularity in recent years and are now widely used at construction sites, event venues, public places, and in several other application like temporary refugee housing, migrants' camps, military missions, cases of natural disasters, airplanes, trains, campers, caravans and campsites. These toilets are also called "chemical toilets" because the relative waste collection tanks are usually treated with anti-fermentation and disintegrating chemical agents with caustic and disinfectant action, which are then part of the waste deriving from maintenance cleaning and emptying of the tanks themselves. There has been increasing scrutiny over the polluting chemicals currently used in mobile toilets because they are carcinogenic and harmful to the environment and to human health. UNI EN 16194 is the standard specifying the requirements for services related to the installation of the toilets and those relevant to chemicals and sanitary products, taking into account factors such as hygiene, health and safety, cleaning measures, the number of portable toilets to be provided, the locations and the cleaning and disposal intervals. Cleaning with collection of waste is the activity that must ensure the hygiene of mobile toilets in service: it consists in emptying the waste collection tank, cleaning it, restoring sanitizing liquids and consumables, and in the sanitation and disinfection of the toilet. Emptying the wastewater collection tank and its relative cleaning are carried out by loading or sucking the resulting waste into tanks mounted on specially equipped vehicles, for subsequent transport to an authorized Wastewater Treatment Plant (WWTP) within the times and in the manner established by the regulations (Figure 2)..

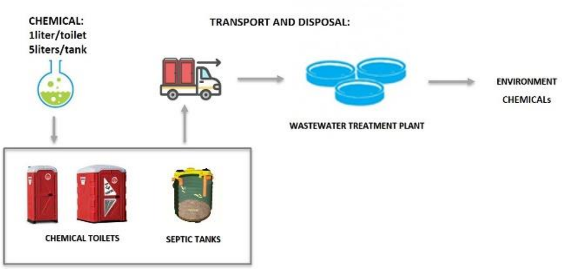

Figure 2: Traditional disposal of sludge from mobile toilets.

The mobile toilets are in general managed or owned by the same company who carries out the maintenance cleaning, who makes a specific service available to the applicant (public or private) dealing with efficiency and hygiene. From the maintenance cleaning of a portable toilet, modest quantities of waste result (tens of kilos or litres). The waste deriving from the cleaning of the toilets have the same characteristics as those deriving from the cleaning of septic tanks: in all there are chemicals, residues of cosmetics, disinfectant detergents, various types of sanitizers in addition to waste from human metabolism. This is why, as such, sludge from chemical toilets cannot be normally reused for other purposes and they are commonly sent to WWTP with significant costs and environmental consequences. The toilets must be periodically emptied with disposal intervals that depend on the specific application. On average, each chemical toilet is completely emptied of its content once a week, and every time a toilet is emptied, about 25 litres of waste are collected to be transported to the WWTP. Every time the toilet is emptied it must be cleaned and sanitized and its tank must be refilled with clean water along with chemicals. On average, the tank is filled with 10 litres of water and 1 litre of chemicals. Considering that nowadays in Europe there are about 2 million chemical toilets in circulation, it can be estimated that every week 2 million litres of chemicals are used to fill the cleaned tanks. When the toiles are emptied, this weekly huge amount of chemicals will converge in the WWTPs together with the organic materials collected. The environmental problem addressed is characterized by the current need to dispose the wastewater in the treatment plant and by the consequent environmental impact due to the presence of reactive and polluting chemical substances. Wastewater in fact, even after treatment, can end up in areas deemed sensitive to the environment and health, or affect larger populations. These wastewaters, together with those produced by septic tanks (and also by the food industry), are a significant source of pollution that can negatively affect the quality of drinking and bathing water. Furthermore, wastewater can lead to an aggravation of biodiversity reduction and hamper the achievement of the objectives set by the Water Framework Directive.

3. Use of sewage sludges in agriculture

An important issue is the possibility of using sewage sludge in agriculture. In general, sewage sludge is characterized by considerable variability in nutrient content depending on the wastewater source and treatment process. It can be suitable for complementing mineral fertilisation when used according to the rules and regulations on agriculture. Negative attitudes and concern about environmental and health hazards caused by sewage sludge have decreased the spreading of sludge on fields. The heavy metal content of sewage sludge has been considered the most significant restricting factor in the agricultural use of sludge. The problem is that heavy metals remain in the soil and many of them undergo biomagnifications in the food chain. Among the heavy metals in sewage sludge, the most hazardous ones to humans are cadmium, mercury, and lead, while copper, zinc, chromium, and nickel in high concentrations are particularly poisonous to plants. Wastewater can also contain several kinds of pathogens, including microbes, fungi, viruses, protozoa, and parasites. Although nutrients are essential for plant growth, when applied excessively they may accumulate in soil and can be leached and transported by drainage systems or can be transported by water erosion and pose a risk to surface water and ground water. It is then necessary to have the correct safety measures facilitating the prevention of possible leakage of contaminants into surface and ground water and to avoid toxic effects on soil, plants, animals and humans. Since 1986, land application of sewage sludge within the EU has been governed by Council Directive No. 86/278/EEC. It prescribes prior testing of sludge and soil, application of sewage sludge exceeding critical concentrations of pollutants to agricultural soil is prohibited, and soils exceeding permissible concentrations cannot receive sewage sludge. This Directive has been implemented into the national legislation of member states, most of which have set lower limits than that prescribed in the Directive, in order to protect soils and reduce possible emissions. There is a clear need to update these regulations because in many cases, national authorities have implemented policies supporting the use of sludge in agriculture, as it is considered to be the best economic option to deal with the increasing quantities of sludge produced. In the Northern EU countries, less than half of sewage sludge is utilised in agriculture, as well as in China, in Japan, in Korea, but also in some countries of Africa and South-America. In this context, national authorities are seeking to increase confidence in the quality and safety of products cultivated on sludge fertilised soils. In the context of uncertainties concerning the potential impacts on human health and the environment of the various disposal and recycling routes, all main stakeholders are calling for additional demonstration activities in order to increase confidence in the use of sludge in agriculture. The Italian Association of Waste Management and Remediation of Contaminated Sites ATIA ISWA considers essential to issue a new clear and organic discipline, especially in relation to the origin and codes of the sludge that may be admissible to the different forms of recovery, respecting the constraints imposed by the Community directives on waste (2008/98/EC) and the protection of the soil in case of use of sewage sludge in agriculture (Directive 86/278), fully supporting the legislative review initiative undertaken by the Italian Ministry of Environment. The development of agricultural recycling depends largely on the possibilities to improve the quality of the sludge itself and increase confidence in sludge quality. This implies the prevention of pollution of the waste water at source and improving sludge treatment as well as ensuring the monitoring of sludge quality. Following the principles of the sustainable development, recirculation of nutrients of human beings from urban areas to agricultural land represent then one big challenge.

4. The innovative prototype

An innovative process for the treatment of organic residues deriving from the use of chemical toilets, from septic tanks and also from agri-food industry's production process has been developed. The process represents the natural evolution of research activities on the use of a new biological substance named EIS that allows to fully recover water and organic materials from sewage to use them in agriculture and avoiding to introduce chemicals in the environment. The ultimate goal is a 100% valorisation of sewage from chemical toilets transforming it into water and high-quality fertilizer according to a circular economy approach. A first small-scale prototype has been **d**esigned, built and validated. The plant is able to produce, without any substantial alteration of the constituent collected substances, three different products.

These are:

- Product 1: solid fertilizer resulting from the oxidative production of the natural organic mix made of fluid and particulate solids deposited in the toilets. Such a product is biologically activated utilizing enzymes deriving from the flora and fauna specifically and exclusively present in the waste products resulting from food processing plants, thus substantially contributing to their reuse and valorisation.

- Product 2: recovered water for fertirrigation, characterized by level of BOD and COD almost equal to zero. The recovered water being rich of nitrogenous substances can be re-utilized in crops.

- Product 3: liquid concentrated fertilizer for hydroponics application.

The system is shown in Fig. 3 and consists of the following main components:

- Primary tank for collecting wastewater. The semiliquid organic material collected from the chemical toilets is discharged into this tank by gravity or using a pump directly from the vehicles. The tank has a lifting pump.
- Roto-sieve drum screens: the material undergoes a filtration process thanks to roto-sieve drum screens, which separate solid particles and fibres from liquids by screening.
- Secondary tank. In this tank the material passes through a grid for further homogenization.
- Tank for stabilization. This tank is equipped with a mixing blade and a helix shaped thickener that shreds the particles.
- Oxidation tank: in this tank the separation between the organic substance and the water takes place.
- Water tank.
- Tank for the EIS.
- Pumps.
- Oxygen meter, probe and sensors.
- Filtration tank with quartzite and activated carbon.

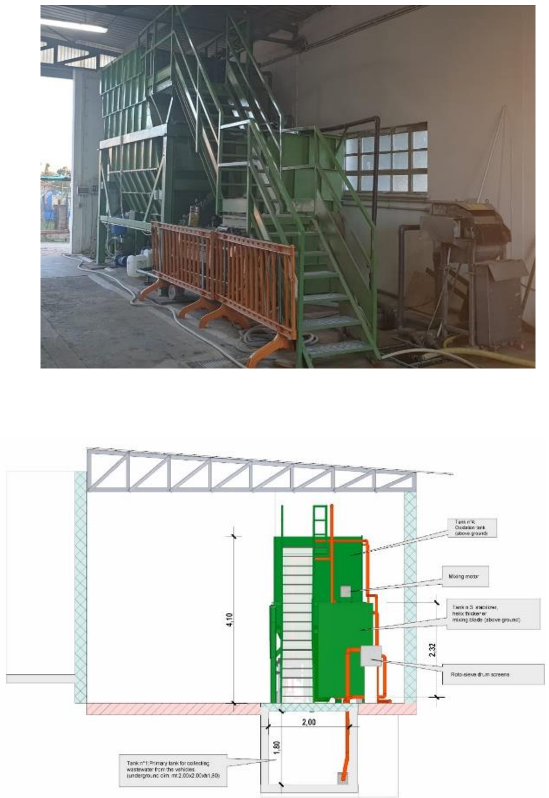

Figure 3: System prototype.

5. Experimental results

The plant has been validated in laboratory to produce fertilizer that has been used on a small experimental farm situated close the plant. The technology focus on an aerobic technique allowing to produce quality materials resulting from the oxidative production of the natural organic mix coming from the organic liquids and particulates deposited in the chemical toilets. The process is based on a new organic blend called EIS, consisting exclusively of mix of substances of natural biological origin (i.e. glycerine, ethyl alcohol, natural soap, natural fragrant sanitizer and others) that has been developed by BEB. Several tests, simulations and technical comparisons were made to analyse the possibility to replace chemicals normally used in chemical toilets with EIS. Several analyses have already been conducted on the recovered waste water in order to ensure the compliance with the national laws. The main chemical parameters are reported as follow:

- Total suspended solids mg / L = 5
- BOD5 mg O2 / L = 15
- COD mg O2 / L = 80
- Total phosphorus mg P / L = 1
- Total nitrogen mg N / L = 15
- Absence of coarse materials, heavy metals, escherichia coli and Salmonella

The plant allows to transform the waste into a completely organic and aerobically mineralized sludge that, after being pressed and dried, will be made solid and free of humidity. The solid fraction is stabilized in the aerobic phase until complete mineral oxidation of the organic residue without any harmful emissions. The liquid fraction, as well as the solid fraction, will is completely free of pollutants and rich in potassium salts, nitrates and carbonates and has been used as nourishing water for horticultural and fruit crops or for irrigation. The fertilizer produced by the prototype has been used on an experimental farm cultivated with salad, valerian, chard and horticultural crops.

The land is located in the proximity of the prototype facilitating the application of the solid fertilizer that will not have to be transported. As regards the liquid fertilizer, a system of pipes has been created allowing fertigation. Figure 4 illustrates the pipeline system. Main obtained results are shown in Table I.

Figure 4: Pipeline for fertirrigation.

Indicators	Impact	Unit
Chemicals Reduction	104000	liters/year
Waste Water Treated	2600	m3/year
Recovered water for fertirrigation	2470	m3/year
Production of solid fertilizer	10400	kg/year

Table I: Main results

6. Conclusions

The developed prototype allows to treat 10m3 of wastewater/day and transforming around 2,600 m3/year of sludges in recovered water for fertirrigation and in 10,400 kg/year of solid fertilizer. The proposed solution represents a novelty in the field of the treatment of organic waste. Future experiments will be based on hyperspectral procedures to monitor the different cultivations, to verify the productivity and quality of the products as well as the composition of soils variation in respect of nutrients contribution.

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