Incorporating waste treatment processes in systems in which residual energy can be utilized is one of the best residue management alternatives. This project is an innovative showcase of thermal drying of sewage sludge, as it allows avoiding any use of primary energy consumption and the CO₂ quota and optimizing its environmental footprint.

Construction and operation of a Sewage sludge thermal drying process at low temperature using the clinker kiln gases in Cemex Alicante cement factory

AQUALOGY

Abstract

This project is based on the complete integration of a sludge dryer within the cement factory of Cemex España in Alicante (Spain). The overall benefits include the use of dried sewage sludge as a substitute fuel in the cement kiln while the quality of the cement is guaranteed, and a reliable end-use for the sludge, as well as energy self-sufficient and 0-odour sludge drying. The paper explains these benefits, including a special emphasis on the carbon footprint balance, the benefits of coupling several sectors of the industry and water management, and technical aspects of the integration process.

The project was carried out by Aqualogy for the company CEMEX, within the framework of a collaboration agreement between the latter and the local water administration (Entidad de Sanejament de la Comunitat Valenciana). The plant was started-up on February 1st 2012, and the operation has been successful in terms of flexibility, drying performance, treatment capacity, odour control, and has demonstrated the feasibility of several innovative heat recovery features. This plant is now a key showcase for Aqualogy, as a differentiating reference as an expert low temperature dryer provider, able to comply with the client's specifications and concerns as well as contributing to climate change mitigation.
1 Introduction

Improved wastewater treatment processes and compliance with European water quality directives have led to a spectacular increase in the amount of sludge generated by wastewater treatment processes. Suitable management of sludge is therefore at present a major challenge. Competition between this type of waste and urban waste converted into compost, combined with stricter legislation, has reduced the possibilities of using sewage sludge for agricultural purposes. This fact, along with the ban on sludge direct disposal in landfills, has led to the search to optimize methods for deriving energy from sewage sludge, which, to date, have encountered economic drawbacks mainly due to energy consumption which can represent 30 % to 50 % of the total operational costs.

The emission reduction requirements established by the Kyoto Protocol pose an enormous challenge for the industrial world, and most particularly for the main industrial consumers of fossil fuels, such as, for example, the cement industry. In this type of industry, fuel costs exceed 30 % of production costs. Consequently, for several years now, most of these industries have started implementing energy optimization measures in their processes. To date, strategies have been based on the search for alternative fuels – classified as substitute fuels, e.g. sewage waste and biomass – so as to reduce the use of conventional fuels. Within this context, one of the primary objectives of this type of industry is both to make the supply and use of these substitute fuels reliable, and to search for innovative solutions that allow for the introduction of new approaches.

Within this context, Cemex Spain S.A., committed to improve the energy efficiency of its processes. In keeping with its collaboration agreement with the local water administration (Entidad de Sanejament de la Comunidad Valenciana, EPSAR), AQUALOGY was selected for the execution and operation of the BOT project (Build, Operate & Transfer).

Aqualogy is a company that integrates all its activities related to Solutions and Technologies for the water and environmental sector. Aqualogy focuses on improving efficiency under 4 main areas: Environment and Operations Technologies, Infrastructures, Management Solutions and Knowledge Technologies.

The STC thermal drying system, included in this project, is a consolidated process belonging to Aqualogy that provides experience in thermal drying of sludge at low temperature with its own technology based on the application of solutions for the utilization of waste energy and heat pump.

As the STC dryer operates at low temperature, the complete integration of both processes (namely sludge drying and cement production) is possible, resulting in significant environmental and financial synergies.

2. The collaboration framework

On November 3rd 2003, Cemex España, S.A and the Entitat de Sanejament de la Comunidad Valenciana signed the collaboration agreement for recycling residual heat from the furnace of the cement factory for the treatment of the sewage sludge produced in the wastewater treatment plants of the local region (Comunidad Valencia), and especially those from Alicante (Monte Orgegia y Rincón de León).
CEMEX contracted AQUALOGY the project of construction and operation of the plant, as well as financing by means of a BOT solution (Built, Operation & Transfert). The project was executed via the subsidiary EMARASA (Empresa Mixta de Aguas Residuales de Alicante, S.A.), of which the local government is shareholder. Several subsidiaries of Aqualogy were involved in the project, and especially Aqualogy Sistemas de Transferencia de Calor, S.A., specialized in design, manufacture and assembly of low temperature sludge thermal drying technologies.

 Procedure for permits delayed the Project 5 years, as an environmental impact assessment was required to obtain a global environmental permit from the very cement factory, as well as permits for the construction of the works including all the peripheral processes: construction, operation, energy recycling of sludge. The project finally obtained all the permits and started up on February 1st, 2012.

3. Description of the project

The plant was design to treat up to 56,000t/yr sludge. The sludge produced in wastewater treatment plants has a dry solids content of 22-25% after mechanical dewatering. It is transported by truck to the low temperature thermal drying plant located on the premises of the cement factory, the average being 10 trucks per day. The sludge is deposited in two 15m³ hoppers, and then pumped to two 200m³ storage silos.

The location for the treatment of this sludge is ideal: as shown on Figure 2 - WWTP’s location in relation to the Cement Plant, the wastewater treatment plants of the region, are located all around and close to the cement factory.

The dewatered sludge is fed from the silos into 2 dryers, which produce a final product with a dry solids content over 85%.

![Figure 2 - WWTP’s location in relation to the Cement Plant](image-url)
The heat required for the thermal dryer is recovered from the exhaust gases of the clinker cooling coil and the cyclones of the clinker furnace, by means of gas-water exchangers, thus fuelling a water circuit of 90/75ºC. These gases pass through highly efficient filter, due to its content in solid particles, before they are emitted into the atmosphere. To ensure the filtering efficiency, most filter processes require these gases to be cooled down before they pass through the filter system. The heat recovery is installed in this particular location.

The dried and granulated sludge is recovered and transported by means of conveyor belts to 3 dried sludge storage silos, each of 180m3, which include a rotating extraction device. The process is described in Figure 3 - Process flowchart.

Moreover, several other pieces of equipment and peripheral items were installed, such as: deodorisation unit of the building ventilation system, an inertization system of the dried sludge silos as well as electric connections and general civil works.

The excellence in terms of design engineering, implantation and execution were the basis to ensure the success of this robust and easy-to-run and environmentally-friendly installation.

In this case, two dry-sludge treatment final disposal routes are planned – agricultural use and energy recovery – depending on the sources of the sludge and the time of year. The energy recovery corresponds to the use of the dried sludge in the cement kiln, as an alternative fuel.

The global construction investment has been 12.5 Million €.
4. The technological basis of the project

4.1 Sludge recovery in the cement industry

According to Cembureau, in 1997 the EU cement industry produced around 170 million tonnes of cement per year. As energy consumption represents 30-40% of the total production costs, many measures aimed at process energy improvements, the industry has made a significant investment effort over the past 20 years reducing energy consumption by 30%. One of these measures has been the use of substitute fuels: this allows the cement industry to improve its competitiveness and to make savings in the use of over 2.5 million tonnes of coal per year.

Using sewage sludge and other types of waste in the cement industry offers certain widely acknowledged advantages – irrespective of whether the resulting energy production is utilized or not – due to the special characteristics of the cement production process. This explains the growing interest for this approach and its strong development over the past few years. The main advantages are:

» the use of alternative fuels reduces the use of fossil fuels in the cement production process, as well as avoiding CO2 emissions which would have been to consider if other waste management routes were used. This leads to a reduction in overall green-house gases emissions both for the cement industry and the waste management industry.

For example Cembureau calculated that burning biofuel (or solvent waste) in a cement kiln allowed a reduction by 18% (or 21%) of the emissions with respect to emissions which would have taken place if this waste had been incinerated.

» the cement kilns increased energy efficiency can be achieved by allowing waste to be introduced directly into the clinker without the need for intermediate processing. Ash and other kinds of waste are not generated since these products are then incorporate-rated in the clinker.

» the cement kiln operating conditions – mainly working temperature, residence time and oxidation conditions – maximize the retention of potential pollutants (such as heavy metals) without reducing the quality of the main raw material, cement.

All of these general advantages also apply to sewage sludge. However, sludge has a water content of around 75-80% after the mechanical dewatering system, which does not usually manage to reach more than 30% dry matter content. This water content drastically reduces the heating value of the sludge dry matter. For this reason, a prior thermal drying stage is essential for the process to be considered operational and feasible.

4.2 Sewage sludge thermal drying and The STC sewage sludge drying process

Sewage sludge thermal drying is based on the application of heat to evaporate any water that cannot be separated from sludge dry matter using mechanical methods. Given that the cost of heat energy is far higher than the cost of mechanical energy, it is crucial to optimize the prior mechanical dewatering process. Energy costs represent more than 50% of the financial cost of the thermal drying process.

What this means is that only the more heat-efficient drying processes will permit optimization of the overall treatment costs.

The main purpose of the thermal drying process is to reduce the sludge water content. The aim is to considerably reduce, if possible in situ, the amount of sludge generated in the treatment plants so as to facilitate its subsequent management. Therefore, the thermal drying process favours a final use for sludge, reducing the amount of product that needs to be managed, and stabilizing it and therefore facilitating its storage and handling, and increasing its calorific power. After thermal drying, sewage sludge has a lower heating value (LHV) of between 2000 and 4500 kcal/kg.

The STC sludge thermal drying system (Figure 5 - Flow Chart of the STC thermal drying process) is based on hot air convection at low temperature...
(65/80 °C) in a continuous closed tunnel. This system has been designed for drying sludge that has already been dewatered mechanically and for different kinds of biomass, and allows the achievement of a final content of dry solids of 80-90%.

The sludge, stored in the receiving pit or silo, must be taken to the tunnel head, where the extruder granulates and distributes it evenly along the width of the belt providing better control over the drying process (this makes it easier for air to pass through the product mass in a uniform way). Moreover, as there is no movement or friction in the drying process, no dust is generated in this stage of the process.

The system comprises two belts. These belts convey the sludge along the tunnel, in which hot dry air circulates at a temperature of 65–80 °C and perpendicular to them. This air, propelled by the ventilation system, goes through the product extracting the water by means of hygroscopic equilibrium. The returned moist hot air is condensed in exchangers inside the tunnel, eliminating the water separated from the sludge and supplying new heat energy, so that the air is recirculated and the process is maintained in a closed air circuit. It must also be noted that the low-temperature drying process prevents the stripping of other pollutants retained in the sludge, ensuring that they do not return to the water. As a result, only high quality water is obtained, with very low entrainments that depend on the kind of the sludge treated.

As an alternative for maximizing energy use and energy integration with other processes, STC has developed an approach to use residual gases from cement production processes, with a system that generates a 65/80 °C closed air circuit resulting from the exhaust gas exchange in the cement production process. Consequently, as all the energy used for the drying process comes from the cement production process, there is no need to consume primary energy, and this ultimately optimizes the overall process.

Figure 5 - Flow Chart of the STC thermal drying process

Figure 6 - Hot water pipes to dryer
5 Results

5.1 Environmental and financial benefits

This type of process offers environmental advantages for all parties: water administrations, companies managing sludge treatment plants, and the cement factory as explained in the following.

For water agency, the management process is improved in environmental terms, since there is no need to locate a new site. It is also improved in financial terms, due to more efficient overall process management costs – as the final destination for the sludge is guaranteed – and reduced operational costs due to the heat supply (since no primary energy source is required to carry out the process).

Company operating sludge treatment plants benefits from an installation with an environmental impact that is compatible with the cement production, reduced energy costs (since primary heat energy is not required), preferential electricity costs, and a guaranteed final destination for sludge. In addition, this type of process does not rule out the use of other solutions, such as agricultural use or sludge disposal in a landfill, as reductions in the quantity of product requiring handling and water content facilitate sludge management.

In the case of the CEMEX cement factory, the sludge thermal drying process allows for the overall efficiency of the production process to be improved by achieving more useful energy for the same primary energy consumption (which, moreover, implies a CO2 quota). Moreover, the combustion of sewage sludge in the production process provides an additional CO2 quota. The additional income from sludge management should also not be overlooked.

The following environmental indicators can be achieved, based on a heat content for the substituted coal of 26 GJ/t and a ratio of 93 kg of CO2 per ton of coal:

- waste energy from the cement factory used for thermal drying the sludge, implying 46 million therms gained annually, equivalent to around 18 000 t of CO2
- energy supplied by the sludge combusted in the kiln (mean calorific power of 3000 kcal/kg of dry sludge) implying 53 million therms gained annually, equivalent to 20 500 t of CO2

Figure 7 - Dryer
5.2 Feedback from the first year of operation

During the 1st year of operation, a quality management process involving seeking continuous improvements in operations and efficiency of the installation was implemented.

One of the 1st achievements to emphasize is the absence of any odour nuisance caused by the operation of the installation. This was one of the main concerns of the cement factory, not only concerning the local population, but also within the actual factory.

Another example is that of the heat recovery from the exhaust gases, which has not required any cleaning during the 1st year of operation. This is a key issue to emphasize as it is the first time this type of system is implemented on a cement factory, and includes many innovative components in its design and implantation which have all been successfully checked onsite.

Furthermore, the very drying tunnels have shown a very successful operation, even though the dried solids content of the dewatered sludge was lower than that expected (20%). The drying system even ensured a higher specific capacity than that required, and a satisfactory operation of the automation system.

During year 2012, the sludge treated was mainly that from the wastewater treatment plants of Monte Orgegia and Rincón de León, as shown on Figure 8 - Monthly sludge production. The cement factory stopped twice in 2012, which therefore induced lower dried sludge production during these periods.

The plant includes an alternative boiler system (as well as the heat recovery system) in order to be able to run even when the cement factory is not operating. However in order to reduce the environmental impact and consumables, it was agreed from the very start-up to avoid any consumption of fossil fuel, even if heat recovery was not possible. Therefore 100% of the sludge were treated using ONLY recovered residual heat. This was made possible because the dryer is very flexible, and repeated start-ups / shut-downs do not involve any risk.
6 Conclusions

Incorporating waste treatment processes in systems in which residual energy can be utilized is one of the best residue management alternatives, given that the cost of energy is usually the factor that determines the feasibility and yield of a waste recovery project. Moreover, sludge energy recovery in cement factories is the only process that does not generate final waste (in the form of ash), since this becomes part of the cement end product.

This type of process provides an important environmental improvement opportunity for cement factories, since it increases energy efficiency; in other words, a greater proportion of useful energy for the same primary energy consumption effectively pre-empts the need to purchase CO2 quotas.

Sludge with a water content of less than 20 % and acquired without primary energy consumption has an increased energy recovery potential. With an LHV of between 2000 and 4500 kcal/kg, it can be used as a standard fuel, thereby reducing primary energy consumption and the CO2 quota associated with substituted fuels. This integrated sludge drying and cement production system has been assessed as a reliable, viable route for sludge management, allowing for significant reduction of greenhouse gases emissions both for the cement industry and the sludge drying process.

References


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