



SEWAGE SLUDGE: FROM RESIDUE TO FUEL AND RAW MATERIAL

BIO MILL GRINDS SLUDGE GRAINS INTO FUEL AND RAW MATERIAL

We have known for many decades now that government bodies, companies and individuals must take care of the environment and make effective use of energy and natural raw materials. The need to really make sustainable use of the resources available to us is gaining ever-wider recognition. There is not only an ecological, but also an economic background to this.

When the needs of ecology and economy converge, the results are beneficial in several ways: for example, when a surplus of residue and demand for energy and raw materials complement one another, and the environment and the water consumer both profit. The BioMill plant at cement producer ENCI's site at the foot of the Sint Pietersberg in Maastricht is an inspirational example of such a meeting.

Sustainable Energy in the Netherlands

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SEWAGE PURIFICATION SLUDGE— RESIDUE WITH VALUE

Thanks to all manner of reuse, most residual materials are no longer useless. Sewage purification sludge is one such residual material, consisting of organic (vegetable and animal) and inorganic or inert material, such as sand and chalk. When used in a clinker oven – in which Portland cement clinker (or clinker) is made, a semi-manufactured product used in cement production – it appears that this previously useless residue can be given a useful application. The organic part (biomass) burns and the heat created can be used, and the inert part is incorporated as a raw material in the clinker process.

Sewage purification sludge

Sewage purification plants purify domestic and industrial waste water. Alongside clean water, this produces a sludge (sewage purification sludge or sewage sludge), a wet mud-like substance that until recently was dumped or used in agriculture.

Unfortunately, this sludge contains components harmful to the environment. In addition, it can cause odour nuisance. For this reason, its use in agriculture has been banned since January 1998. At present, there are great demands made of the processing of this sludge. The dumping of sewage sludge is subject to strict legal restrictions.

The water is always first removed from the sewage sludge to make it suitable for transport and processing. Part of the sludge is then composted or dried. Approximately half of the sludge is incinerated in purpose-built sludge incinerators. Following incineration, only \pm 20 percent of dry matter remains in the form of fly ash and slag that must be processed separately.

The primary objective of the processing methods is to reduce the volume of the sewage sludge. There is little or no really useful application.

However, when sewage sludge is burned in a clinker oven, such as those of Dutch cement producer ENCI in Maastricht, this produces a high energetic yield. In this process, the heat is used to 'burn' the (Portland cement) clinker whereby the solid elements of the sludge bind with the clinker. This method therefore leaves no waste.

The Limburg Purification Board (Dutch: Zuiveringschap Limburg or ZL) has 18 sewage water purification plants, which each year process an average of 170 million cubic metres of waste water from more than 1.1 million people and some 35,000 companies. Once most of the water has been removed from the remaining sludge by sedimentation and mechanical drying, the damp mass is transported to one of the Purification Board's own thermal sludge dryers. Here, it is dried further for processing and transport, initially to the above-mentioned sludge incinerators, but since March 2000 largely to the BioMill plant at the ENCI site in Maastricht.

View of the BioMill plant



The processing of this sludge accounts for approximately forty percent of the total cost of sewage purification. Furthermore, the amount of sludge to be processed is expected to increase in the coming decades by 25 to 30 percent. A sludge surplus is looming, making the need for alternative forms of processing all the more acute. Sustainable solutions are preferred.

ZL decided at an early stage not to choose to export its sludge, nor did it want to wait for other processing options to be developed. ZL was and remains of the opinion that its own residue should be processed at the lowest possible cost, sustainably and within its own area – in accordance with Dutch government policy.

Limburg seeks a responsible solution

During the early 1990s, the Province of Limburg, Industrial Bank LIOF (Limburg Investment and Development Fund) and a number of large industries set up the Environmental/Economic Steering Party (Dutch: Stuurgroep Milieu-Economie). The processing of purification sludge is seen as one of the problem areas in terms of the environment.

The idea of processing dried sludge from the province by cement producer ENCI was met with enthusiasm by the steering party. On the basis of this idea, the working party Sludge Synergy (Dutch: slibsynergie) was established. The Province of Limburg, the LIOF, sludge producers DSM, SAPPi and ZL participated in this, along with prospective customer/processor ENCI. The aim of the working party was to investigate the best means of processing purification sludge from an economic and environmental point of view. An Environmental Impact Report (EIR, Dutch: MER), carried out within the context of the Provincial Waste Substances Plan for Limburg, demonstrated that the use of the sludge in ENCI's clinker oven was the most environmentally responsible solution within the province of Limburg.

To investigate the feasibility of this application, tests were carried out in 1996 and 1997 with paper sludge (SAPPi), industrial sludge (DSM) and purification sludge (ZL). On the basis of the results obtained, ENCI continued its cooperation with SAPPi and ZL, with the objective of processing 12,000 tonnes of paper and purification sludge per year.

ENCI B.V. has its head office in 's-Hertogenbosch and three production companies, in Maastricht, IJmuiden and Rotterdam. ENCI is the only cement producer in the Netherlands with annual production of approx. 3.3 million tonnes of cement and is the cement branch of ENCI Holding N.V. ENCI Holding is part of Heidelberg Cement Group.

The plant in Maastricht has a quarry in the Sint Pietersberg, from which it obtains the marl (limestone). From this, the semi-manufactured product Portland cement clinker, or clinker, is produced. This semi-manufactured product is the base material for cement.

ENCI strives for sustainable development in general and in particular in its production processes, by working to reduce its energy consumption, increase its use of secondary fuels and raw materials and reduce the amount of clinker in its cement. The use of biomass – in particular sewage sludge – is a good example of this, bringing savings in both fuel and raw materials.

Benefits of using sludge for ENCI

Burning sewage sludge in ENCI's clinker oven offers a sustainable processing method from both an environmental and economic viewpoint.

Environmental benefits:

- Use of sludge as a secondary fuel saves burning fossil (primary) fuels and thereby reduces CO₂ emissions, which means a reduction in contribution to the greenhouse effect;
- heavy metals present in the sludge are largely absorbed by the cement clinker;
- the inorganic part of the sludge fits into the process' raw materials requirement and means a saving on the primary raw material, marl;
- this alternative raw material can be used without the need for extra transport;
- the entire process takes place without residue, as all solid components are bonded within the clinker and thereby absorbed into the cement. Only a small amount of relatively volatile metals such as mercury is emitted. These mercury emissions remain well within Dutch and European standards and within the boundaries of ENCI's environment permit.

Economic benefits:

- the Purification Board (ZL) saves on processing costs as the use of sludge by ENCI is cheaper than other solutions;
- processing within the region saves on transportation costs;
- for ENCI, using sludge represents a saving on more expensive primary fuels;
- as well as a (modest) saving on the use of the raw material marl.

Grinding purification sludge is pioneering work

In practice, burning sludge with other ingredients in ENCI's clinker oven turned out to be not without some teething problems. This was a completely new application that had never been tried before anywhere. So those involved were pioneers in this area. Unexpected problems arose during the long period of research and development that followed. It transpired that the dried sludge was not suitable for incineration without being prepared. Its grainy form had a destabilising effect on the burning processes in the oven. So the sludge grains had to be ground before incineration.

Grinding tests revealed that purification sludge behaves differently from most other (additive) substances in cement production. Wear on the machinery proved particularly great owing to the high concentrations of sand in the sludge. Common grinding machines such as ENCI's own ball mills were not adequate. This setback marked the initiation of the BioMill project, a cooperation between ZL and ENCI (see the box 'Organisational Renewal').

Project aim

ENCI's aim was to change the fuel package in its clinker ovens: more secondary and sustainable, less primary fuel. However, high demands are made of the fuels used by ENCI. The project therefore had to satisfy two strict requirements: the quality of the cement clinker produced could not be compromised and the total emission of residual substances could not increase.

For the production of 1 million tonnes of cement clinker per year, a clinker oven consumes some 3.5 petajoules (PJ, 10¹⁵ Joules) of energy per year.

Before the BioMill plant was taken into use, fuel consumption in the clinker oven was as shown in Figure 2, with the primary fuels being cokes, brown coal, shale and natural gas. With 40,000 tonnes of purification sludge per year going into the BioMill project, the aim was to cut back the demand for fossil fuels by approx. 20%.

THE GRINDING PROCESS

A considerable part of the lead up to the realisation of the BioMill consisted of research into the 'grindability' and combustion properties of the sludge.

Research into the specific grinding behaviour of dried purification sludge led to the following conclusions:

- purification sludge is heavily abrasive, which causes a great deal of wear to the grinding machinery;
- the sludge is (extremely) poorly grindable owing to the compressibility of the material;
- depending on the humidity and duration of storage, among other factors, under certain circumstances sludge can spontaneously combust. In air, ground purification sludge can cause (dust) explosions.

Wear, grindability and safety therefore played a decisive role in the final choice of the grinding system. Eventually, the vertical roller mill turned out to be the best choice.

This was an expensive option, however. In addition, being the first of its kind, this project had considerable technical (and therefore financial) risks. A subsidy from the Novem's (Netherlands Agency for Energy and the Environment) EWAB (Energy Generation from Waste and Biomass) programme reduced the financial risk to an acceptable level.

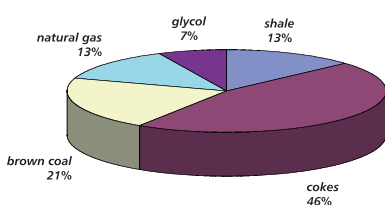


Figure 2: Traditional fuel package, ENCI clinker oven (8).

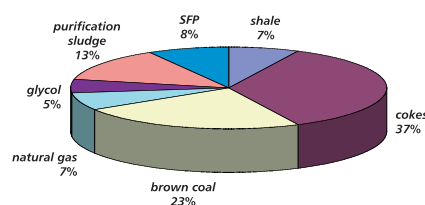


Figure 6: The fuel package of ENCI following the taking into service of the BioMill plant.

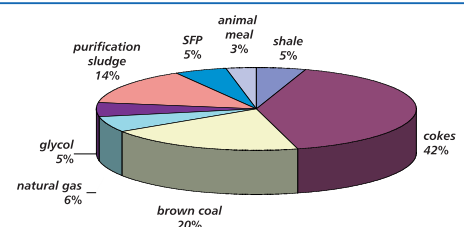


Figure 7: Composition of the fuel package of 2002.

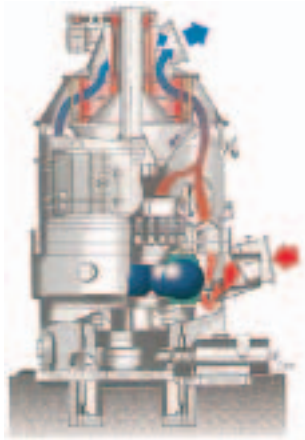


Figure 3: Grinding principle of the vertical roller mill.

Vertical roller mills

A vertical roller mill grinds the material, which is entered from the top, on a grinding table, using grinding balls or grinding rolls; see Figure 3. The ground material is then taken to a separator, which separates the coarse material from the fine product. The coarse material is returned to the mill and ground again. The fine product is taken by an airflow to the storage silos and then to the incinerator of the clinker oven.

The grinding balls, lower and upper rings are of a 'wear-resistant' material. Nevertheless, the wear caused is still considerable. BioMill chose grinding balls rather than grinding rolls as the grinding capacity of grinding balls remains the same, even though wear makes them smaller and smaller.

The supplier of the mill, BMH Claudius Peters, conducted tests with sewage purification sludge from ZL. The wear to the grinding balls was great but not insurmountable. Application of 'High Cr abrasive parts' guaranteed an operating life of 7000 hours. The optimum fineness (15% at 90(M)) of the powder was achieved with the minimum necessary grinding capacity. A slightly coarser grind (17% at 90(M)) gave adequate grinding capacity. At 40 kWh/tonne, the specific energy consumption was relatively low.

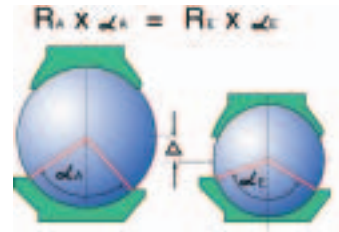


Figure 4: Constant grinding capacity of grinding balls with decreasing size.

Use of vertical roller mill

The use of the vertical roller mill made a number of changes to ENCI's production process necessary. Figure 5 shows the new grinding plant plus the other essential changes.

The major changes and innovations were:

- the grinding machinery itself, the separator and two pneumatic pumps that maintain the air flow for the material transport within the plant;
- alterations to two fuel storage silos for the storage of unground purification sludge;
- the realisation of a new pneumatic transport pipe from the grinding plant to the fuel day silo;
- a new fuel day silo plus transport and dosing equipment for taking the ground sludge to the incinerator of the clinker oven.

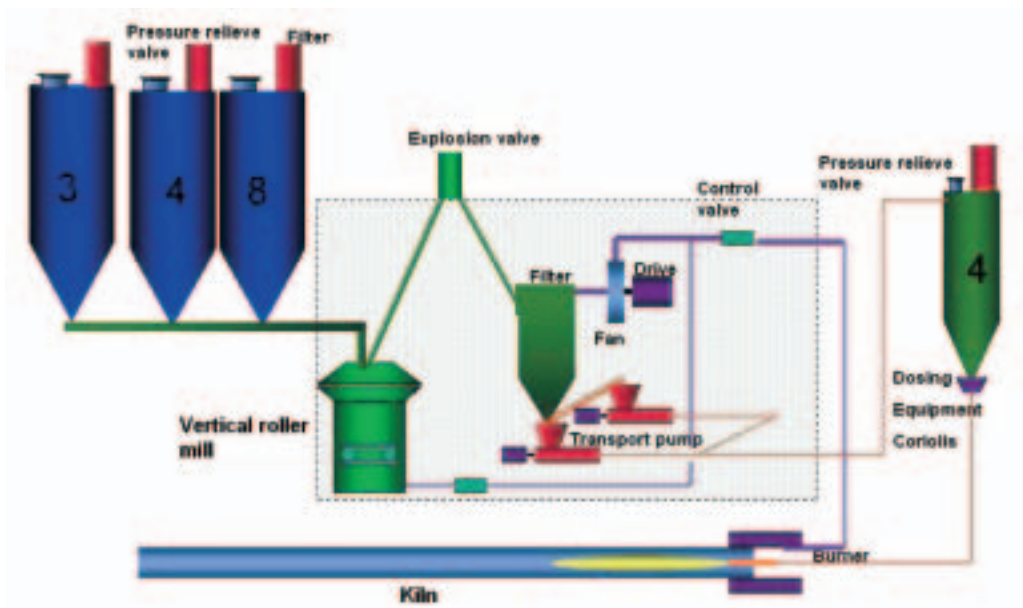


Figure 5: Process chart BioMill Installation.



New starting points

During the run-up and construction phases of the BioMill plant, a series of potential risks had to be avoided. The major obstacles were: long oven stops, vibration, variable sludge composition and varying calorific values, as well as potential noise and odour nuisance.

The cooperation with ZL led to the following joint starting points for the new grinding system to be constructed:

- Grinding capacity: more than 40,000 tonnes per year = 6 tonnes per hour
- Storage capacity: 600 tonnes (to bridge oven stops of four days)
- Fineness of product: 15% sieve residue at 90 µm

RUN-UP PHASE AND RESULT

In March 2000, the plant was taken into use. Owing to problems with the pneumatic transport, during the first year of operation the expected capacity was not achieved. Each alteration then had consequences that had to be further investigated and this resulted in new modifications. All this time, ENCI worked together with the supplier, Claudius Peters, to improve the performance of the BioMill.

The biggest problem was the material transport within the roller mill itself. The air flow was not strong enough to take the material from the mill up into the separator. Furthermore, the transport pipes to the fuel day silo became clogged.

The following alterations were made to solve these problems:

- a bigger fan;
- an altered Düsenring (used to blow air along the lower ring in the mill);
- more power for the pneumatic transport.

However, these alterations resulted in a higher noise level, which was resolved by installing a new silencer.

In spite of these alterations, half way through 2001 the plant was still operating at only 85 percent of its design capacity. For this reason, an oven stop was introduced. Once again, the fan was enlarged and the air ducts replaced with ones with a larger diameter. For safety reasons, the explosion hatches in the plant were enlarged. A larger Düsenring was installed to keep the pressure drop even. Finally, measures were taken to after burn the exhaust gasses from the BioMill in the clinker oven, thereby preventing odour nuisance.

All of these alterations finally resulted in the BioMill plant working at its design capacity from the end of 2002. 40,000 tonnes of purification sludge were ground each year in the BioMill and burned in ENCI's clinker oven. As intended, this led to a reduction of approx. 20% in the consumption of traditional, fossil fuels, or 0.6 PJ of primary energy, predominately brown coal, and to a lesser extent shale. In terms of CO₂ emissions, the project led to a reduction in these emission of 44,000 tonnes of CO₂ per year. Figure 6 shows ENCI's fuel package after taking the BioMill plant into service.

BioMill is not the only instrument ENCI is using in its aim to make the fuel package in its clinker oven sustainable.

In 2001, the secondary fuel plant (SFP) project was taken into service, in which paper sludge, Rofire pellets and later shredded (iron-free) car tires can be used as fuel. This project also makes 12% of the primary fuels redundant, although only half can be seen as sustainable. Since 2002, dried animal remains have also been used. Figure 7 shows the fuel package in 2002.

In 2002, preparations started for the construction of BioMill II. Alongside purification sludge from ZL, this improved copy of the first plant will also burn sludge from other parts of the country. This will double the capacity of the sludge processing.

The availability of purification sludge in the future seems guaranteed. Purification Boards from other parts of the Netherlands have also shown interest in having their sludge processed by ENCI. In fact, the BioMill I plant already uses 40% third-party sludge. This makes purification sludge one of the more reliable sustainable (energy) resources for ENCI in the future and makes the construction of BioMill II a solid investment.

Organisational renewal: the BioMill joint venture

Two very different organisations, the public body ZL and the private company ENCI, came together in a joint solution to each's objectives. One sought an economical but sustainable way to process its residue. The other was seeking to save fossil fuel without creating a greater burden on the environment. Together, both parties were able to achieve their goals by building a grinding plant that made the dried purification sludge from ZL suitable for burning in the ENCI oven.

The close cooperation between the two parties led in 1999 to a highly unusual legal construction for two such different organisations: the establishment of the joint venture BioMill. ENCI and ZL have an equal share in this, much to their mutual satisfaction.

Henk van Alderwegen, chair of the Limburg Purification Board (ZL)

now, following some initial doubts, commends BioMill as a particularly successful form of socially responsible business.

"When I joined ZL and was confronted by this project (the joint venture ZL-ENCI was still being set up at the time), I wondered what the energy return would be. To make the sludge suitable for processing by ENCI, ZL first has to thermally dry it, and this takes 'clean' natural gas. What's more, ZL had to build two driers to achieve the required capacity. This demanded a relatively large investment. However, the EIR report convinced me totally of the usefulness of this project. Burning sludge in the ENCI oven turned out to be the most environment-friendly solution. ZL had to invest in primary energy (natural gas) to finally save ENCI primary energy in its clinker oven. This allowed us to look beyond our own organisation. The dried purification sludge that ZL supplies consists of 50% organic material that is converted into energy. From 2003, this will be almost 40,000 tonnes of dried sludge per year.

Another benefit is that the inorganic residue fits in so well with the production of clinker: sand, minerals and chalk, exactly what you need when making clinker. The impurities in the sludge consist primarily of germs and heavy metals, which are normally difficult to process. The metals are virtually entirely bonded into the clinker matrix during the sintering process; the germs burn. So I am actually very proud of the system we have chosen. It is a nice example of recycling.

The joint venture between a public body such as ZL and industry in the form of ENCI was slightly uneasy in the beginning. But BioMill was realised very quickly, and now we are carrying on as a team."

Theo Pluijmen, director of ENCI Maastricht:

"The BioMill grinding plant is a separate, independent company that consists of two equal partners. ZL and ENCI share the risks and benefits. This also means that the citizens of Limburg also profit: they pay the lowest water purification charges in the Netherlands. This is to a considerable extent a result of the lower sludge processing costs for ZL thanks to the BioMill. ZL saves on processing costs, and ENCI can buy an alternative fuel at lower price. ENCI was quick to see the strategic importance of cooperating with a public organisation such as ZL: this meant we were not acting alone as a company in applying an alternative fuel. In addition, the structure chosen offers commercial stability in the longer term.

The processing of residues will play an increasingly important role in determining the future of our industry. As we as a company are future-oriented and wish to operate in a prudent manner, we not only applied for the necessary permits but also instigated an Environmental Impact Report. The outcome of this was highly favourable: the combination of thermal drying and incineration in a clinker oven (or power plant) leads to the smallest burden on the environment of all the alternatives examined. An additional benefit of this option compared with conventional burning is that the clinker oven doesn't create any waste. This is included as a raw material in the clinker matrix. By communicating this to local residents and interested parties, we were able to obtain permission to build the BioMill. The German company Claudius Peters then helped us with the research into solutions for all manner of technical problems, such as an extremely high degree of wear to the grinding grinding balls and problems with the pneumatic transport. All of this required a considerable investment on the part of ENCI. The fact that Novem granted us a subsidy was a significant stimulus. Without this subsidy, the whole project would probably not have happened. The other conclusion is that the direct partnership with ZL proved to be the best way of realising this project."

NOVEM, THE NETHERLANDS AGENCY FOR ENERGY AND THE ENVIRONMENT

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