Bubbling bed FBC process for the conversion of paper (de-inking) residue.

LIFE project to convert a waste material into a valuable product
LIFE97 ENV/NL/00017

The recycling of waste paper produces, apart from new paper products, a significant amount of de-inking residue. In Europe, approximately 2.3 million tonnes of de-inking residue are produced per annum; a number that still rises with time. In this LIFE project we have demonstrated a new and sustainable solution for the processing of de-inking residue. This material is converted into a valuable mineral product named Top-Crete, by means of the CDEM process. The product can be used as a cementitious material, replacing cement or other binding materials. In contrast, existing thermal de-inking residue conversion processes yield filling materials of low value. Moreover, the CDEM process produces low emissions and the energy efficiency of the process is better than that of existing traditional de-inking residue combusting processes.

Key project results include:
- Realization of a full-scale conversion installation of 200,000 annual tons of deinking residue conversion capacity.
- Realization of a Top-Crete mineral product production capability of 50,000 annual tons.
- Production of high quality Top-Crete product that indeed can be sold into the binding minerals market.
- Realization of a high degree of energy recovery including applications for district heating as well as dedicated electricity production.
- A lower cost for deinking residue conversion as compared to most commercial alternatives.
- A wide and serious market interest that gives the potential to realize more deinking residue conversion projects producing a Top-Crete mineral product.

Deinking residue
Waste paper is recycled for several reasons:
- Recycling of waste paper leads to less waste because the fibres present in the waste paper are re-used.
- Producing paper from waste paper is less energy intensive than the production of new paper from wood, because fibres in waste paper have already been refined. The difference is approximately 3,600 kJ/kg fibres.
- The re-use of 1 ton of waste paper replaces the use of 10-12 mature trees.
- It is more economic/cost effective to make new paper by recycling waste paper than to use trees for this purpose, if costs for the disposal of paper recycling by-products are at an acceptable level.

A disadvantage related to the recycling of waste paper, however, is the production of a by-product called de-inking residue. De-inking of waste paper is necessary to produce
good quality recycled paper. Approximately 30 percent of the compounds present in the
dope paper end up in the de-inking residue. Ink only makes up a minor fraction of this
residue. The deinking residue is obtained as a wet sludge type of material, with a dry
solids content of typically some 50%. These dry solids in turn consist of some 50% of
organics (fibres and fillers); the other 50% are mineral fillers mainly consisting of china
clay and chalk. Currently, the four companies joined in CDEM Holland B.V. (CDEM)
produce approximately 145,000 tonnes of this de-inking residue per annum, while other
companies in the Gelderland province produce around 35,000 tonnes of de-inking like
residue per annum. This waste stream is currently being disposed of through normal
applicable waste handling channels.

Deinking residue processing
Apart from landfilling and landspreading, which are not considered to be “processing”
methods, several initiatives have been launched to process de-inking residue. Nowadays
only incineration processes are known to be operational in which de-inking residue is
converted. These processes include:
- Deinking residue incineration, which is for instance done at the Parenco paper-mill
  in the Netherlands.
- Combined incineration, which is for instance done in Scandinavia where de-inking
  residue is jointly incinerated with products like wood wastes.
- Incineration in cement ovens, which is for instance done in Germany.

The temperatures applied in these
incineration processes are
significantly higher than those
applied in the CDEM process
described below. Consequently,
these processes produce ash that at
best can be used as relatively low
valuable filling material in for
example the cement industry.

The CDEM process
The CDEM process demonstrated
in this project makes it possible to
convert de-inking residue into a
valuable product, as yet referred to as Top-Crete. This product is of significantly higher
value than the filling materials discussed in the previous paragraph. Top-Crete can be
used as a cementitious material, replacing cement or other binding materials in
constructive applications as well as in stabilizing and immobilizing applications.

The CDEM process applies
specific process conditions in a
fluidised-bed incinerator to de-
hydrates the china clay present
in the de-inking residue (about
40% of the mineral fraction),
while part of the calcium
carbonate (about 60% of the
mineral fraction) is calcined.
The organic matter is incinerated to produce energy. Proper process control warranties the production of a valuable product called Top-Crete, while improper control will result in the production of an ash-like material. The diagram illustrates the tight line between wanted materials such as meta-kaolin and unwanted low-value materials like mullite and gheleinite. At too low temperatures, the incineration of the organic matter becomes troublesome. Consequently, the CDEM process has to balance on a narrow temperature line lying slightly underneath a value of 800 °C.

Prior to the realization of the full-scale plant, studies at Twente University of Technology made clear that a fluidised bed system is more successful for conversion of de-inking residue than other thermal conversion systems. The main advantages of a bubbling fluidised bed are:

- A high energy efficiency for the thermal conversion of materials with a low caloric value, such as de-inking residue. The caloric value of the de-inking residue typically is 5.1 MJ/kg based on dry weight.
- A well defined residence time of the deinking residue to be processed, which makes them better suited for the production of the high quality mineral Top-Crete, that requires tight control of process conditions.
- Ease and low cost to build, maintain and operate.

A schematic diagram of the bubbling fluidised bed used in the CDEM process is shown in the adjoining figure.

The process conditions prevailing in the fluidised bed used in the CDEM process differ from those normally applied during the incineration of deinking residues in fluidised beds as is shown in the figure below. Traditionally, approximately 50 percent of the combustion takes place in the bed, while the other 50 percent occurs in the freeboard above the bed. Temperatures of the bed and freeboard are normally 850°C and 1100°C, respectively. In the CDEM process on the other hand, as much as 90 percent of the combustion takes place in the actual bed, while the temperature of both the bed as well as the freeboard are kept at a controlled value of approximately 780°C.
Demonstration plant
A low temperature thermal conversion installation geared towards the application of the CDEM process was built in the current infrastructure present at AVR-AVIRA. AVR-AVIRA originally had planned to build four municipal waste incinerators and realized only three, which are used at the moment. Consequently, AVR-AVIRA possessed both excess space and utilities that are now well used for the CDEM installation.

The installation has a capacity of 150,000 to 200,000 ton de-inking residue per year, to produce some 50,000 annual tonnes of Top-Crete product, which is collected from the baghouse filter of the installation and needs no further treatment.

Top-Crete product
The Top-Crete product resulting from the CDEM process has pozzolanic and hydraulic properties. Hydraulic properties mean that the Top-Crete hardens upon reaction with water, like in common cement hardening. Pozzolanic properties mean that the Top-Crete wants to react with hydroxides and water, meanwhile producing a hardened (concrete like) material. Given that common cements contain an excess of hydroxides, the pozzolanity of Top-Crete will improve the final strength of a Top-Crete / cement mixture. Top-Crete thus is a cementitious material in itself, but it is also a cement-improving additive.
Comparison of Top-Crete to Portland cement shows that the composition of Top-Crete is better defined, containing less possibly polluting compounds. The Top-Crete product thus meets the standards set by the Dutch government for construction materials as well as for reactive fillers. It even can be used to reduce leaching of nasty compounds such as sulphates from shaped (concrete) structures.

The Top-Crete quality produced from the full-scale demonstration plant was better than that produced in previous small-scale pilot plant tests, and thus exceeded expectations. The Top-Crete meanwhile is marketed at a positive price.

Apart from well-known applications in the production of bound or shaped materials (concrete), the application of Top-Crete as a sulphate scavenger is worthwhile mentioning. In this application, the leachability of sulphates from shaped materials is suppressed to a value that is lower than the Dutch leaching standards. In this way, high sulphate leaching materials (originating from for instance the demolition rubble of offices or houses) need not be disposed, but can be re-used in construction applications.\(^1\)

**Energy**

The CDEM process is exothermal, which implies that the energy produced from the organic fraction present in the deinking residue suffices for the evaporation of the water present in the deinking residue as well as for the mineral conversions required for the production of Top-Crete, after which excess energy is used to produce approximately 10 MW of thermal energy in the demonstration plant. This energy will be used by AVR-AVIRA to produce heat for district heating and/or to generate electricity. In this way optimal energy integration on the location of AVR-AVIRA is secured by the project.

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\(^1\) Just imagine, we are converting the waste that is produced upon the recycling of waste paper. The resulting product of our process can then be used to convert the waste that is produced upon the demolition of houses or offices into a product that can be used for construction purposes. Too good to be true?, no it is demonstrated in our process!
Emissions

The Top-Crete product produced appeared to have excellent flue gas cleaning characteristics. Harmful substances, such as heavy metals, are adsorbed in the CDEM process. Measurements showed that emissions of dioxins are very low. Other emissions to air are also within the Dutch and European legislations for the incineration of waste materials. The operating conditions, which were proven to be optimal for both the production of Top-Crete as well as for the cleaning of the flue gas, have been patented by CDEM in order to commercialise and further disseminate the process.

Current status

Shortly after its start-up a fouling problem in the steam boiler occurred, which could not be solved because of the absence of boiler cleanup devices, a choice (as we now know) erroneously made by TKEC, the main supplier. A program geared to install proper steam boiler cleanup devices, as well as to debottleneck the steam boiler is currently running. First results of this program are that a semi-normal operation meanwhile is possible, resulting in the processing of some 2000 tons of deinking residue and the production of some 500 tons of good quality Top-Crete. Further improvement is foreseen upon the delivery and installation of further steam boiler cleanup devices that meanwhile have been ordered for.

Cost

A successful implementation of this technology will result in a lower disposal fee for the deinking residue producers (the paper mills) when compared to their current costs of typically some 50 per wet tonne. The lower fee of the CDEM process is a result of the positive income from the production and sale of Top-Crete, as well as the good energy recovery possibilities of the CDEM process. The good energy recovery possibilities are furthermore enhanced by the fact that no flue-gas cleanup systems are needed other than a baghouse filter system meant to collect the Top-Crete product.

2 Although the CDEM installation converts a waste material (deinking residue), we consider the process to be a production process rather than a waste incineration process. The comparison to waste incineration emissions is made only to demonstrate the ability of the process to comply with these stringent demands.
The absence of additional flue gas cleanup equipment furthermore results in relatively low investment and maintenance costs.

Apart from the above-mentioned attractive cost outlook of the CDEM process, it is eminent also to mention the strategic benefit that this technology can give to the paper industry. The CDEM technology gives a solution for a waste problem that the paper industry otherwise would have solved through channels outside their control, thus leaving them vulnerable to the price-setting of a waste-conversion market that they do not control, nor are attached to.

**Key innovative results**
Summarizing from the above, we can say that the LIFE demonstration project results in:

A demonstrated process that
- uses a waste material as a well defined input
- uses an incineration process for chemical conversion rather than for energy production or volume reduction
- produces a high valuable mineral product with cementitious qualities
- is highly energy efficient
- Produces very clean off-gases

A product that
- is whiter than cement
- hardens faster than cement
- increases strength of cement products when admixed to cement
- reduces leachability from other mineral materials, especially that of sulphates

**Environmental benefits**
Summarizing from the above, we can say that the LIFE demonstration project results in:
- Prevention of landfill (reduced by 200,000 annual tonnes)
- Reduction of the use of materials (production of 50,000 annual tonnes of cementitious binder, energy production from non-fossil fuels)
- Energy reduction and re-use (production of 288 TJh from non-fossil fuels)
- CO₂ reduction (reduced by 28600 annual tonnes)
- Application of Top-Crete to immobilize (hazardous) waste materials, so that they can be re-used or at least be disposed off at lower environmental impact.
- Very low emissions to the air from the CDEM process, as compared to conventional incineration processes.

**Dissemination**
Dissemination and publicity are now speeding up, because of the almost finished full-scale start-up of the full-scale installation and the consequent wide interest from paper industry due to the fact that paper industry, (like most industries) want proven technologies. Meanwhile, about 5 paper mills have shown serious interest, and meanwhile their deinking residues have been tested with the positive outcome that they are suited for the CDEM process.
Transferability
Transfer of the CDEM process to areas outside the paper industry is hampered by the fact that this process was developed with the specific quality of this industries deinking residue in mind. Treatment of the deinking residue as if it were a production feedstock furthermore implies that mixing this material with alien substances would result in unwanted poor product quality.

Transfer of the methodology of thought applied during the development of the CDEM process however can be carried out to areas outside the paper industry. In fact several industrial waste stream contain well-defined minerals in concentrations that are similar to those in deinking residue. One could for instance consider Kieselguhr containing waste streams from beer-brewing processes, or spent catalyst streams from e.g. food production processes.

Contacts
CDEM Holland can be contacted through

Phone: +31 313 675123 (N. Voogt)
Fax: +31 313 675128
e-mail: cdem@cdem.nl
website: www.cdem.nl
Publications


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