# An innovative process that converts PVC waste into raw materials

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## Abstract

Recycling of PVC waste is a focus area in European environmental policy. PVC waste may hence be regarded as a potential resource instead of useless waste.

Since 1998, the Danish company RGS 90 has made a great effort to develop a sustainable method for chemical recycling of PVC waste. RGS 90 has obtained financial support from the LIFE-programme under the European Union (EU) and from Vinyl 2010. The financial support has made it possible to carry out a full-scale industrial demonstration project for chemical recycling of PVC waste into oil, salt and minerals.

The process has shown the ability to treat all types of PVC waste in full-scale tests. With a capacity of 50,000 t/y PVC waste, the plant is erected near the Danish city of Skælskør. RGS 90 has already other waste treatment facilities placed at this location, and the PVC plant is integrated with these facilities. With the industrial size pilot plant in operation, further tests will be performed to evaluate the PVC waste pre-treatment, reactor performance and product refining processes.

The combination of dechlorination of PVC by hydrolysis and the successive pyrolysis of the dechlorinated solid fraction has already shown environmental improvements creating a liquid product with low chlorine content and 100% utilisation of the PVC waste.
*Keywords: PVC waste, pyrolysis, hydrolysis, recycling.*

## 1 Introduction

Two of the major challenges to waste management in industrialised countries are the handling of polluted sludge from wastewater treatment plants and the

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handling of PVC waste. Until recently, no recycling alternative existed for wastewater sludge besides the present application on farmland, and there were limited possibilities for chemical recycling of PVC waste to industrial scale. RGS 90 has made a dedicated effort to create a concept for industrial recycling of PVC waste as well as of wastewater sludge in an industrial symbiosis. The symbiosis solves two challenges for the waste-handling sector and produces products that can be sold as merchantable goods. The result is an unusually perfect example of successful recycling of problematic waste types.

### 1.1 Development of new methods

The development of the chemical recycling of PVC waste began in 1998. The process has been tested in laboratory scale and partly in a full-scale plant. The result of this development work is that a full-scale plant will be designed and erected in the period 2002/2004 for chemical recycling of PVC into oil, salt and minerals.

The oil will be sold to the chemical industry, while the salt fraction can be reused by the PVC industry or as salt for roads. Finally, RGS 90 itself will make use of the mineral fraction as raw material for the production of Carbogrit, as the composition of minerals fits into this production and the energy from the coke will be utilized. The annual handling capacity is approx. 50,000 tons of PVC waste, resulting in 12,500 tons of oil and 21,000 tons of salt.

The development of the concept for industrial usage of wastewater sludge began in 1996. The work has resulted in completion of a large production plant in the spring of 2003. The plant processes wastewater sludge and other mineral waste products into a glass silicate, to be marketed under the name Carbogrit. Carbogrit will be used as sandblasting material. The annual handling capacity is approx. 350,000 tons of sludge and approx. 35,000 tons of mineral waste products, resulting in 70,000 tons of Carbogrit. The spent sandblasting material will be returned and utilized as raw material in the production of for instance mineral wool.

### 1.2 Location of the plants - industrial symbiosis

The process plants with pre-treatment facilities are built within an industrial site near Skælskør in Denmark. Material will be collected from all parts of Denmark as well as from the countries in the Baltic Region.

The two process plants are the first of their type in the world, and the processes can be implemented separately or combined in industrial symbiosis in other parts of Europe, subject to suitable commercial conditions.

Locating the two process plants within the same industrial site in Denmark has generated industrial symbiosis; whereby the product from one waste treatment process (PVC) is utilized as raw material for the other (Carbogrit), while at the same time excess heat and coke from the Carbogrit factory provide process heat to the PVC-process.

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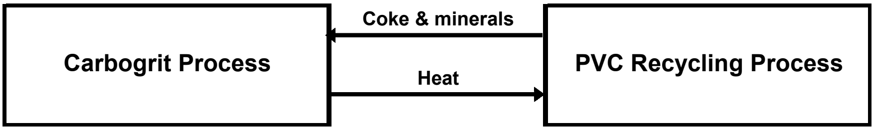


Figure 1: Synergy between the two process plants.

## 2 Chemical recycling of PVC waste

PVC waste is a priority waste stream in the European environmental strategy. As is the case for all waste, the treatment shall maximise recycling with utilization of the materials.

In the absence of the necessary recycling solutions for PVC waste, the European PVC industry has entered into a voluntary agreement to provide adequate treatment technologies, emphasising in recent years the development of new treatment technologies. One of these projects has been developed in co-operation with RGS 90, and involves removal of the chlorine from the PVC waste in order to recycle and utilize the resulting oil, salt, and coke/mineral fractions.

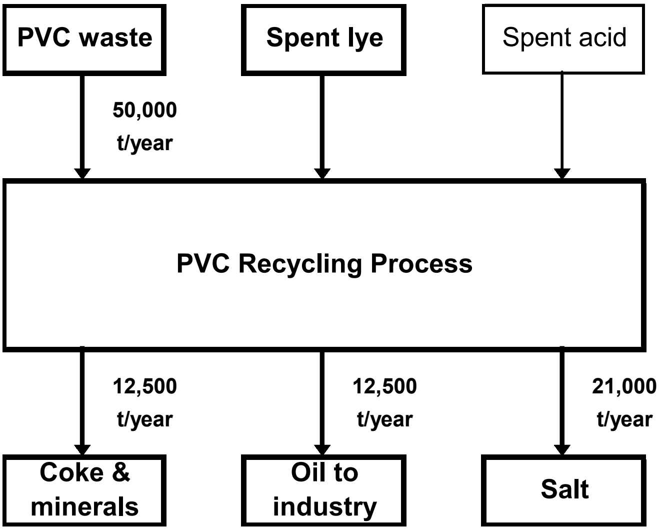


Figure 2: Main streams in the PVC recycling process.

This newly developed treatment process ensures an optimal solution both in terms of recycling of materials and of environmental protection.

The processes comprise two patented key treatment steps – first hydrolysis and second a post-heating process. The technology has been developed in a long

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series of laboratory experiments, which by the end of 2001 have been scaled up to full-scale demonstration tests of short duration.

The result is a process with utilization and recycling of all the components in any type of PVC waste. The heavy metals present in the PVC waste will, moreover, be concentrated in the filter dust from the Carbogrit plant. Tests performed have indicated that some of these metals can subsequently be recovered from the filter dust.

## 3 Challenges and results

The processes comprise a patented combination of two key treatment steps – first hydrolysis and second, a post-heating process as well as pre-treatment and intermediate treatment steps for:

- Pre-treatment of PVC-waste and mixing of feed to reactor
  - Shredding
  - Sorting and granulation
- De-chlorination by hydrolysis in a tubular reactor
- Separation of solid and liquid reaction products
- After-treatment
  - Salt water from hydrolysis plant is adjusted to pH 7 and nano-filtrated
  - Salt brine is crystallized under vacuum
- Post-heating of solids generating oil and coke.

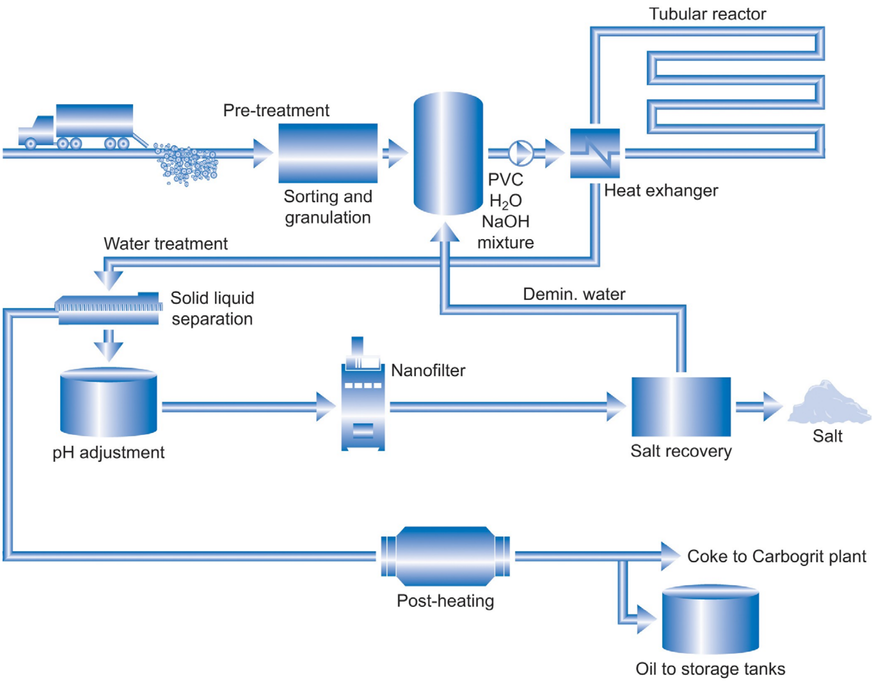


Figure 3: PVC recycling process - treatment steps.

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Some of the challenges that have been faced during the project development encompass:

- Material and energy balances
  - Optimisation of water balances, lye and acid consumption
  - Estimation of heat of reaction for the hydrolysis (full scale and laboratory tests
- Selection of construction materials appropriate for corrosive solutions
  - Short and long-term corrosion studies
- Sufficient pre-treatment to homogenize the PVC waste prior to the hydrolysis
- Design of equipment for handling of streams with a high potential for clogging
  - Flow studies for two-phase streams with lye/water and PVC particles
- Dimensioning of purpose-built heat exchanger
- Optimisation of the hydrolysis reaction
- Study of separation techniques for the hydrolysis products
- Test of nanofiltration equipment for appropriate removal of impurities
- Test of post-heating equipment for selection of operation temperatures

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As an example of some of the challenges of bringing theories and practical waste recycling together, the following figures illustrating two-phase streams with lye/water and PVC particles are presented here:

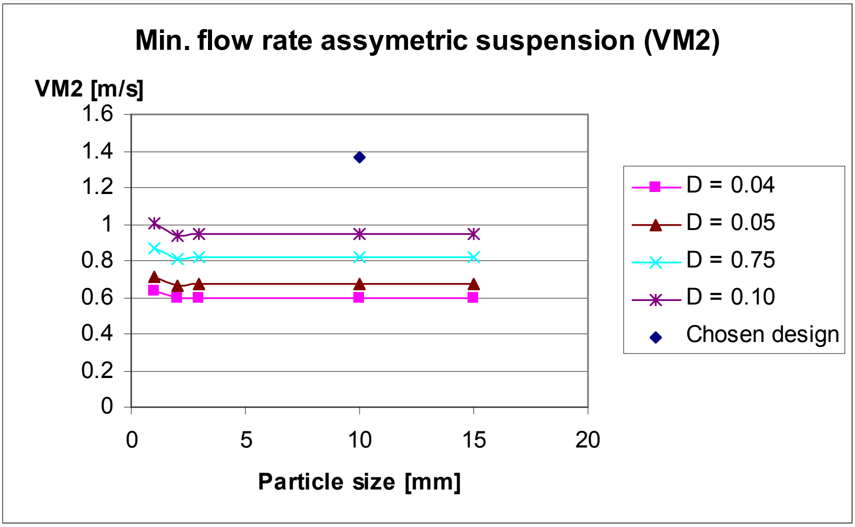


Figure 4: Minimum flow rate particles in asymmetric solution. Curves based on equation 6-145 and figure 6-33 in Perry and Green [2].

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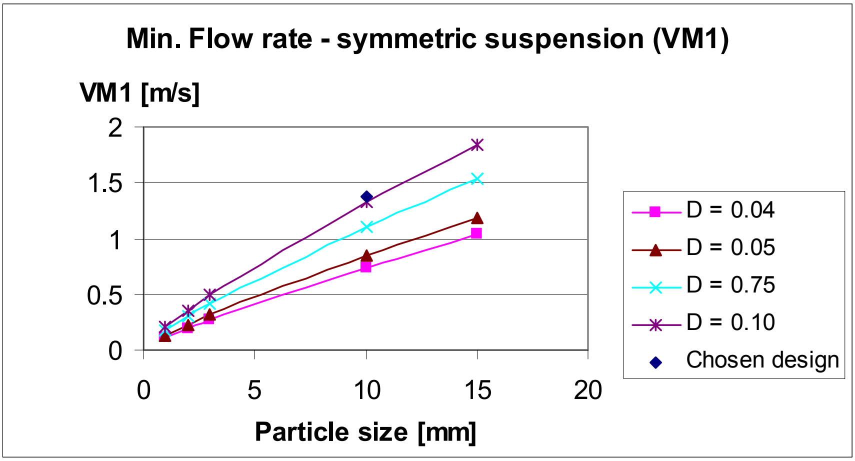


Figure 5: Minimum flow. Particles in symmetric solution. Curves based on equation 6-146 in Perry [2]. D is pipe diameter.

As can be seen from the indication of "chosen design", almost symmetric flow might be expected based on theory. In this connection, it should be noted that the equations in Perry are indicated for particles in the range of 0-3 mm.

In the figure below, a further equation from Perry (equation 5-181 [1]) has been compared with experimental data. This latter formula, showing "Deposition starts", is stated to be valid for particles greater than 2 mm:

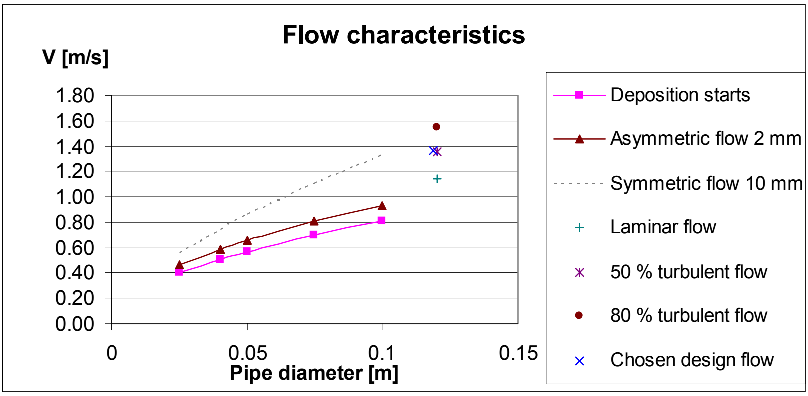


Figure 6: Flow characteristics. Comparison of theory (curves) and experiments (points).

The experiments have been carried out for a mixture of PVC waste shredded to sizes below 10 mm (i.e. 0-10 mm). The experiments also show that smaller particles will follow the flow rate of the liquid, whereas the greater particles will have a slower rate and hence a longer retention time in the reactor. The experiments show that chosen design flow of a mixture with different particle sizes is approximately 50% turbulent and 50% laminar. The chosen design flow rate reflects a compromise between homogeneous (or turbulent) flow and minimum wear of the pipe reactor, especially in bends.

## 4 Conclusion

Two of the major challenges to waste management in industrialised countries, the handling of polluted sludge from wastewater treatment plants and the handling of PVC waste, have been solved in an industrial symbiosis. The symbiosis produces products that can be sold as merchantable goods. The result is an unusually perfect example of successful recycling of problematic waste types.

## References

[1] Perry, R. H. & Green, D. W. Perry's Chemical Engineers' Handbook, sixth Edition, McGraw-Hill International Editions, 1984.
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