Gypsum reprocessing for a cleaner environment

Since the late 1970s, OMV (Pty) Ltd has been reprocessing a waste gypsum dump created by a phosphate fertiliser plant in Potchefstroom. *MechChem Africa* visits this now modernised plant and talks to OMV mechanical engineer, Marinus van den Berg and the company's MD, Oscar Goudriaan.

From its mining history in natural gypsum, limestone and iron ore, OMV has grown into the leading supplier of gypsum in South Africa and a specialist in the reprocessing of chemical gypsum derived from phosphoric acid fertiliser production.

"We mined gypsum in Namibia and in the Northern, Eastern and Western Cape and were natural mining experts for 40 years. But in the 1980s we switched over to phosphogypsum recycling, taking the waste from the fertiliser plant over the road and processing it into industrial grade gypsum for the cement industry," Goudriaan tells *MechChem Africa*.

"Natural gypsum (calcium sulphate) is typically between 75 and 85% pure, while the 'waste' chemical gypsum we start with contains 95% $CaSO_4 2H_2O$, making it chemically purer.

"But included in the contaminants are phosphates and fluorides, which react negatively with setting cement and plaster. Our target purity window, therefore, is 0.01% phosphates and fluorides and we now apply very strict quality control on these," he says.

While natural gypsum does not have these contaminants, the ones that do have, are not removed. Although this does not directly affect final product performance, these passive contaminants mean less active powder in every bag, so more is needed to achieve required results.

"Synthetic gypsums such as ours are now generally preferred by the building industry and by manufacturers of dry wall, plasterboard and ceiling board products," adds Van den Berg.

Describing the shift from mining natural gypsum to reprocessing waste, Goudriaan says that it all started in Potchefstroom in the late 1970s: "Gavin Coulson's father Trevor Coulson, who was CEO of Blue Circle Cement at the time, came to my father, Klaas Goudriaan and asked him to build a reprocessing plant to supply gypsum to his Lichtenburg cement factory.

"At that time, we were on an exclusive cost-plus contract to Blue Circle Cement. It was then taken over by Lafarge who wanted a commercial contract, so we negotiated volume-based commercial contracts with Lafarge and all of the other cement producers," says Goudriaan.

"The cement factories used to mine gypsum from the Western Cape was transported inland by the railways; but in the 1990s, the rail network began to deteriorate and our location as an alternative gypsum producer became very attractive. Demand started to increase steadily, from around 6 000 to 7 000 t per month in the 1990s up to 40 000 t/month today. We now supply all major cement houses in South Africa.

"In total we supply about 60% of South Africa's gypsum demand, with 10% still being imported and the remainder coming from remaining mines or other chemical sources," notes Goudriaan.

Moving onto the chemistry of gypsum itself, he explains that industrial gypsum comes in three crystal forms. The raw form of gypsum is dihydrate, $CaSO_4 2H_2O$, which occurs naturally and has two water molecules bound in each crystal. "The second form is hemihydrate gypsum, ($CaSO_4 2H_2O$), which is the form we need for cement and plaster. When hemihydrate gypsum is mixed with water, each crystal absorbs water molecules and recrystalises back into a strong and hard dihydrate form." he explains.

The starting point of reprocessing chemical gypsum is reclaiming the gypsum from the dump and conveying it into the neutralising and washing plant.

The third form is anhydrite gypsum, which has no water at all. "We do not produce this, but market it from another source," Goudriaan adds.

The modernised reprocessing plant

Taking us through the reprocessing cycle used by OMV Gypsum Potchefstroom, Marinus van den Berg says that from the 6 000 t/month being supplied in the 1990s, production had ramped up to 20 000 t/month by 2007 when he joined the company. "Due to an undersupply of resources from the Western Cape, cement producers could not supply local demand, which was a serious problem for producers, one which we saw as a big opportunity.

"The initial task I was given was to balance supply and demand by raising capacity to meet market demand for dihydrate in the cement industry," he informs *MechChem Africa*.

The original process involved reclaiming the gypsum from the dump and then neutralising and washing it. The product was then dewatered down to 30% free moisture on a belt filter before being spread out on the floor outside to be sun and air dried, which took it down to 20% free moisture.

The neutralisation process involves dosing a gypsum slurry with quick lime (CaO). The slurry is then aggressively agitated for several hours until neutralisation is complete. "This causes dissolved phosphates and fluorides to precipitate out of solution as insoluble calcium fluorides: CaF_2 and calcium phosphates: $Ca_3(PO4)_2$. The degree of neutralisation is determined by testing the pH which is an indicator. The upgrade allows testing of radical phosphates and radical fluorides in the slurry.

"Dosing used to be done manually and, to ascertain the quality, only the final product was tested. Lumpy lime was added into a tank to produce milk of lime, which was pumped into the gypsum slurry before entering the agitation tank. Belt filters dewatered the slurry down to about 30% free moisture and only then was the pH measurement taken.

"If out of specification, we would send the whole batch back for reprocessing. At that time, cement plant operators were able to compensate for a very wide pH range, so we were supplying gypsum with a pH of between 7 and 11 with a standard deviation (SD) of 3," Van den Berg recalls.

The first steps OMV implemented to improve production volumes and quality was to automate the dosing process. "We have now installed Endress and Hauser pH sensors into the agitation tanks to continuously monitor and optimise neutralisation. This gives us in-process pH and fluoride/phosphate control.

"Now, before dosing, we measure the gypsum quality entering our system. In a small well we mix gypsum with water. We then take a pH measurement and, via a computer-based mathematical formula, determine the exact amount of lime needed to neutralise this slurry. Then we use a screw conveyor to add the exact amount of powdered lime needed. With the continuous flow of product, lime is added every three minutes and discharged into the first agitator tank," Van den Berg explains.

"To keep the process continuous, we transfer the contents of the full tanks into second and third tanks further down the line so that retention times can be raised without stopping product flow. We continually take measurements after agitation and neutralisation and these values are passed back to the dosing control system.

"Using pre-dosing together with the post agitation feedback control loop, we are now able to maintain a pH at 7.5 with a standard deviation of just 0.3," he tells *MechChem Africa*.

What happens to the calcium fluoride and calcium phosphate precipitates? "We used to wash out the fluorides and phosphates, but we ended up with an acid solution as a waste product, which again posed disposal problems with environmental risks," Goudriaan responds. "As non-reactive precipitates in very low concentrations, the precipitates have no detrimental effects on the end products. They simply end up being trapped into the cement as tiny particles," he says adding that OMV's

Above: The new automated dosing system takes a pH measurement of a small amount of gypsum entering the system. A computer-based formula is then used to determine the exact amount of lime needed to neutralise this slurry.

Right: Mixer motors at the top of each tank agitate the slurry to ensure complete neutralisation. To keep the process continuous, the contents of each full tank are transferred into second and third tanks further down the line.

Bottom: Neutralised product is dewatered down to 30% free moisture on one of two belt filter lines.

An additional gypsum drying kiln reduces the moisture content of OMV's 20% (post air drying) dihydrate to 10% free moisture.

is a true zero net-waste process. "We strive to use and reuse everything!"

Further improvements were achieved by close scrutiny of the sun drying process. The 30% free moisture product needs to be spread outside in the sunshine for air drying. This makes rain, in particular, a significant risk. "Artificial drying makes no sense with respect to carbon footprint or energy input costs," says Goudriaan.

Van den Berg continues: "Deliveries to cement plants are usually done on a just-in-time (JIT) basis, which means that every time it rained we were unable to meet demand and cement production had to stop."

Product is transferred outside for sun and air drying down to 20% moisture required by cement plants.

The first mitigation step was to install a drying kiln to enable some of the 30% free moisture product off the belt filter to be taken down to the 20% required by cement plants. "This can't sustain full production, though, so we also added undercover storage for 30 000 t of production, approximately three weeks of finished gypsum. This is used in the rainy season to stockpile the 30% free moisture product until the rain stops, and when the sun shines again, we go back to spreading outside.

"In the last rainy season, using stockpiles here and at client sites, along with preferential delivery methods, we were able to ensure that none of our clients experienced run-dries," Van den Berg says.

Extending the product range

"In addition, we have installed an additional kiln to reduce the moisture content of our 20% (post air drying) dihydrate to 10% free moisture. This reduces the transportation weight of the gypsum for those using it in this form," Van den Berg continues.

"About 70% of our current sales are at 20% moisture directly off the air drying floor, but we are already selling 30% of our produce at 10% moisture levels. It makes economic sense to remove the moisture before transportation, which reduces the transport costs because each delivery effectively contains 10% more gypsum.

There is another advantage for industrial clients, however, in that in taking the free moisture levels down to zero, they save on the input energy costs for evaporating that additional 10%. "We do this at a much lower cost than they can, because of our modern optimised kiln," Van den Berg suggests.

OMV has also added a complete hemihydrate line to produce final product for direct use in the manufacture of dry walling and plasterboard ceilings.

"In 2017, we started designing an efficient calcining process with the idea of taking our phosphogypsum waste resource all the way to hemihydrate plaster in a single manufacturing process. We have our own MetaCote finishing plaster brand, which we are now packaging for sale straight off the end of our line, completing the whole value chain," he reveals.

With total control of all of the inputs and the timing, delays and waste are all removed making the process highly efficient and very cost effective.

"We are first in the southern hemisphere to use a combination of fluidised bed and kettle process, which is more efficient than the current technology being used by our competitors. Energy consumption is also kept low by keeping product flow continuous. We first dry our gypsum, then we mill it and calcine off the crystal water in subsequent processes, without needing to cool it down between each stage – and we are currently putting about 8% of our production into this plant.

Three hot chambers fuelled by light-cycle oil are used for the process, each with air being bubbled up from underneath to keep the gypsum crystals in permanent suspension. The first chamber gets rid of most of the bound moisture by bubbling it through the heat exchanger.

Prior to the calciner, the material passes into a hammer mill which eliminates all free moisture by taking 10% free moisture dihydrate to a 0% free moisture dihydrate. This material is fed into the fluidised bed. The fluidised bed has three stages, the first removes the bulk of the bound moisture, the second controls the bound moisture accurately and the third is a cooling stage with a controlled cooling profile.

"The calcining temperature is higher than the hammer mill temperature and as this temperature is the most important factor, it must be controlled to within 4 °C. Too low, and calcining won't take place and if the temperature is too high, there is a risk of producing anhydride, which is not suitable for our end product," says Goudriaan. "It is a very delicate process that involves cracking open the dihydrate crystal to release some of the water and then immediately reforming hemihydrate crystals before the H_2O molecules are extracted.

"Because our whole process uses fewer natural resources, and lower residence and contact times for drying and calcining are required, our end product is as green as it can possibly be. Also, our source material has an unmodified longitudinal crystal form, so we can achieve a higher flexural strength and a smoother finish. Post grinding in our ball mill gives our hemihydrate very fine particle sizes, 90% at less than 63 µm," he says.

*OMV's new Fluidised bed Calcining plant for the manufacture of finished products such as its Metadynamics MetaCote finishing plaster (**Inset**).*

Replicating this success in Richards Bay

Goudriaan says that negotiations are at an advanced stage to replicate this model in Richards Bay, where a 700 000 to 1 300 000 t/annum of dihydrate resource is available. "This fertiliser plant used to pump their waste into the ocean, but this is no longer acceptable, so we have plans to establish a similar operation there," he says.

"We can now solve this problem by creating a genuine zero waste value chain from agricultural fertilisers all the way to high quality, modern building materials. The market for dry walled construction is fast becoming more popular because it is more environmentally friendly and uses much less water. Our process also mitigates against the need for mining, which comes with its own environmental hazards

"South Africa is still walking in baby shoes with respect to environmental issues, but we at OMV believe we have a moral responsibility to look after our planet to the best of our ability and to go well beyond obligatory environmental laws," Goudriaan concludes. ❑