

## WATER REDUCTION AT SKORPION ZINC AND THE IMPACT ON THE ENVIRONMENT

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### **Abstract**

Skorpion Zinc, a world class zinc producer in the South of Namibia faced challenges after commissioning with solution balance. The water intake exceeded the outlet, resulting in an increase in inventory and intermittent overflow of the evaporation ponds into earth dams.

Flow meters were installed on all raw water off-takes, enabling management of water usage. Strict control of gland seal, Solvent Extraction bleed, reagent make-up and other users was implemented. A steady head water supply to the residue belt filter lubrication water was installed, resulting in a reduction of 1100 m<sup>3</sup>/day water consumption. Cooling Tower and Reverse Osmoses blow down water were recycled for flocculent make-up, belt filter lubrication and gland seal water. This further reduced raw water intake into the refinery.

A total reduction of ~20% in raw water intake, equivalent to N\$2.2 million per annum was achieved. This relates to an approximate 5.5 years payback on the N\$11.5 million investment and an Internal Rate of Return (IRR) of ~ 14% (over a 10 year investment period). Though not a lucrative investment, the investments to reduce water consumption is paid off by itself.

This paper describes the sensitive solution balance of Skorpion Zinc Refinery and shares details of the actions taken to the broader industry. Cognisance of gland seal and lubrication water needs to be taken during design of hydrometallurgical plants and significant reduction in raw water consumption can be achieved by recycling of blow down water.

### **1 Introduction**

Approximately 1.3 billion people worldwide lack access to safe and clean water, and 2.2 billion people lack access to sanitation facilities. As global competition for clean water increases, major users will increasingly have to demonstrate efficient use and sound custodianship of water resources. Water is fundamental to the continuation and expansion of existing mines and the development of new mining operations. However, many of the Anglo American Plc's operations are located in water scarce areas. For example, the Mantos Blancos and Mantoverde copper mines in Chile lie in the Atacama – the world's driest desert.

In 2007 Anglo American Chief Executive Cynthia Carroll stated: "There has never been a time when water-resource challenges have been more evident or urgent. Water is inherent in everything we are and everything we do. It is fundamental to our business." Against a backdrop of climate change, water scarcity and increasing environmental

pressures, Anglo is committed to minimising water use and to reusing and recycling the water we do use, with the ultimate goal of zero discharge.

In line with Anglo American's Sustainable Development Policy and the drive to conduct business responsibly, Skorpion Zinc (located in the Namib desert) assessed the challenges it has faced with solution balance in the refinery. The raw water intake into the refinery was more than what the outlets could handle. This resulted in an intermittent overflow of solution to earth dams where solution is contained. A careful review of the solution balance was undertaken and corrective actions implemented to reduce the raw water consumption by 20% stopping overflows into the earth dam.

The challenges faced by Skorpion Zinc are not unique to this Zinc Refinery. The same unit operations are present in other Hydrometallurgical plants. This document firstly describes the Skorpion Zinc solution balance and the challenges faced. The corrective actions implemented are then outlined with the benefits achieved. This knowledge will enable Anglo American and the industry to apply the learning of Skorpion Zinc in future plant design and operation.

## **2 Skorpion Zinc Process Flow**

In contrast to the majority of zinc deposits world-wide, which contain zinc primarily as the sulphide mineral sphalerite, Skorpion Zinc is a primary oxide/silicate/carbonate zinc deposit, present in Smithsonite, Sauconite and Hemimorphite, the zinc minerals can therefore not be concentrated by flotation. The ore is leached directly in dilute sulphuric acid to produce zinc sulphate. It is not possible to directly electrowin zinc from the sulphate solution due to low Zinc concentration in solution and high chlorine and fluorine levels and other metal impurities contained in Skorpion ore. A solvent extraction circuit is incorporated in the process flow to provide a buffer against chlorine and fluorine and effectively prevents any carry-over of other metal impurities into the electrolyte solution. The use of solvent extraction for zinc simplifies the overall treatment route by comparison with conventional concentrating and subsequent roast-leach-electrowinning. A process flow diagram is presented in Figure 2.1.



selective for zinc over iron. Co-extraction of iron with zinc will yield high levels of iron in the loaded organic, which would be co-stripped with zinc into the loaded electrolyte. Iron levels in loaded electrolyte, in excess of 5-10mg/l are known to reduce zinc current efficiency, thereby increasing energy consumption. The neutralisation stage, incorporated to deal with silica, is also effective for ferric iron removal to levels below 1-2mg/l by precipitation of ferric oxides and oxy-hydroxides, such as goethite.

Aluminium is also removed during the neutralisation stage as aluminium hydroxides, and aluminium fluoride (AlF<sub>3</sub>) depending on fluorine levels in solution.

After neutralisation, the neutralised slurry is thickened to produce an overflow solution containing 30g/l Zn (pregnant liquor) and an underflow pulp, containing leach residue and precipitates formed during neutralisation. The residue is filtered and washed by belt filtration with two steps of counter current washing. The residue will be deposited as a filter cake.

## **2.2 Bleed and effluent treatment**

Copper, cobalt, nickel and cadmium are also partially leached but not co-extracted with zinc during solvent extraction and are recycled with aqueous raffinate to the leach circuit. In order to control impurity levels and the overall water balance, zinc free solution is bled from the BZS circuit. Zinc is recovered from secondary filtrate solution by conventional precipitation of basic zinc sulphate by neutralisation to a pH of 5.9 with limestone and lime in the BZS plant. The precipitated basic zinc sulphate is separated from the impurity containing bleed solution by thickening and filtration. The overflow solution from the basic zinc sulphate is partly re-used for filter cake washing, with the remainder sent to the effluent treatment plant where the remaining impurity elements are precipitated at a pH of 9.5 and filtered. The filter cake reports to tailings and the filtrate is transferred to the evaporation ponds.

During the precipitation of basic zinc sulphate, copper is completely and nickel, cobalt and cadmium partly precipitated and therefore recycled to the neutralisation step. The bleed treatment system does therefore not provide an outlet for these elements (particularly copper) and dedicated copper and cadmium removal is required to prevent build-up in the circuit. In addition to this, it is necessary to produce a copper depleted solution for milling to eliminate the risk of copper cementation onto mill steel and the corresponding accelerated corrosion of mill steel. Copper and cadmium removal will be done through cementation with metallic zinc dust.

## **2.3 Solvent extraction**

The process takes place in three stages in which organic raffinate flows counter current to pregnant liquor from Neutralisation. During extraction a delta zinc of 20g/l is achieved in the aqueous stream, yielding an aqueous raffinate stream at 10g/l zinc and 30g/l sulphuric acid.

During the extraction stage, minor amounts of aqueous phase remains entrained in the loaded organic and vice-versa. Entrained organic phase is removed from the aqueous raffinate by carbon filters, before returning the raffinate to the leach circuit. The aqueous phase entrained in loaded organic must be removed to prevent the transfer of impurities to the electrowinning circuit. Also, minor amounts of calcium are extracted with zinc, which must be removed to prevent the formation of gypsum in the electrowinning circuit. This is done, by a three stage washing process. The washing process uses a mixture of demineralised water and spent electrolyte (from electrowinning). The washing process is both physical and chemical and removes entrained aqueous phase as well as calcium.

After washing, the loaded organic is brought into contact with spent electrolyte from electrowinning to strip zinc from the organic, producing loaded electrolyte and organic raffinate. As with raffinate, entrained organic are removed from the loaded electrolyte by carbon columns. The loaded electrolyte is then pumped to the electrowinning cell house. The stripped organic (organic raffinate) is returned to the extraction stage, completing the organic cycle. Organic make-up is added to this stream to compensate for minor losses due to evaporation, entrainment and crud formation.

Iron is co-extracted with zinc, even at low levels of iron in the pregnant leach solution. Minor amount of iron is stripped from the organic into the electrolyte which is detrimental for electrowinning. Iron that is not stripped from the organic in the stripping settlers has to be removed from the organic raffinate in a regeneration step, using 6M hydrochloric acid. The FeCl<sub>3</sub>-containing HCl solution from the organic regeneration is sent to an HCl regeneration step, using sulphuric acid and salt to produce regenerated HCl.

#### **2.4 Electrowinning, melting and casting**

Conventional zinc electrowinning is used to produce special high grade (99,995% Zn) cathodes. Finally, a number of special high grade ingots (25kg) is produced in melting and casting.

### **3 Skorpion Zinc Water Balance**

The raw water addition to the refinery is described below as in the beginning of 2006 before any changes were made to the circuit.

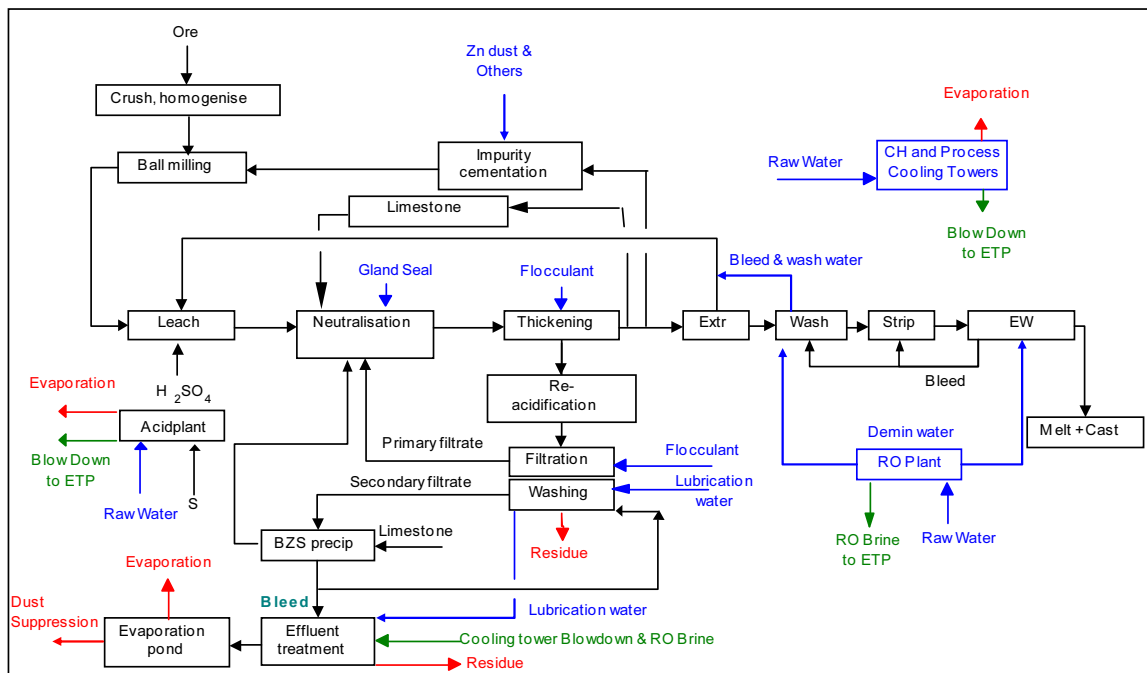


Figure 3.2: Water addition and outlets

Water is added to the refinery at various stages as illustrated in Figure 3.2 (blue lines). To prevent an impurity built up in the electrolyte, electrolyte is bled out from the electrowinning (EW) circuit to the Solvent Extraction (SX) at a rate of 440m<sup>3</sup>/day. This electrolyte is used with demineralised water (1590m<sup>3</sup>/day) to scrub the organic. Evaporative cooling is also used in electrowinning to control the temperature of the electrolyte. On average, 1125m<sup>3</sup>/day of water is lost through these cooling towers. The total addition of water to the electrowinning is therefore 1566m<sup>3</sup>/day. Both the bled electrolyte and demineralised water used for washing in SX, is discharged to the leach circuit via the aqueous raffinate from the extraction stages in SX. SX and EW together is one of the major consumers of water in the refinery. It must be noted that all water consumed in Electrowinning and Solvent Extraction is demineralised water, supplied by a Reverse Osmoses (RO) plant. Ultra pure solution is required to ensure electrolyte remains free of contaminants, enabling the plating of zinc. The RO plant operate at a recovery of ~80% of water. The remaining 20% (790m<sup>3</sup>/day) of water is discarded as brine to the Effluent Treatment Plant.

A total of 1390 m<sup>3</sup>/day of raw water is fed to the Acid Plant. The majority of the water (~1200m<sup>3</sup>/day) is lost through evaporative cooling and acid production. Approximately 200m<sup>3</sup>/day is bled from the cooling tower (blow down) to control chloride and salt built up. The blow down water is discarded to the Effluent Treatment Plant (ETP).

Raw water enters the leach circuit through reagent addition and gland seal water. Gland seal water to the circuit (Communitation and Leach) is significant at 960m<sup>3</sup>/day. Approximately 550m<sup>3</sup>/day of raw water enters with flocculant addition to the various thickeners and the residue belt filters. Other reagents (Milk of lime, zinc dust) and various smaller units introduce 590 m<sup>3</sup>/day.

Two smaller cooling towers, one for cast house and one for the residue belt filter vacuum pumps and HCL plant, consumes 573m<sup>3</sup>/day of raw water. Of this amount, most is evaporated and a small quantity of blow down is disposed to ETP to control salt build-up.

The residue belt filter consumes 1100m<sup>3</sup>/day lubrication water which finally is disposed to ETP. Table 3.1 summarises the solution intake of the refinery

|                                    |                          | <b>Actuals</b> | <b>Design</b> |
|------------------------------------|--------------------------|----------------|---------------|
| <b>Total Raw Water to Refinery</b> | <b>m<sup>3</sup>/day</b> | <b>8,495</b>   | <b>7,957</b>  |
| Thick Flocc                        | m <sup>3</sup> /day      | 323            | 306           |
| Filter Flocc                       | m <sup>3</sup> /day      | 228            | 162           |
| Acid Plant                         | m <sup>3</sup> /day      | 1,390          | 1,884         |
| Residue belt filters lubrication   | m <sup>3</sup> /day      | 1,100          | 432           |
| Cooling Towers                     | m <sup>3</sup> /day      | 573            | 749           |
| Zn dust                            | m <sup>3</sup> /day      | 46             | 48            |
| RO Plant                           | m <sup>3</sup> /day      | 3,285          | 2,688         |
| Gland Seal Water                   | m <sup>3</sup> /day      | 960            | 613           |
| Zn dust & others                   | m <sup>3</sup> /day      | 589            | 1,075         |

**Table 3.1: Skorpion Zinc Water Consumption**

Outlets for the water in the refinery are through evaporation from various cooling towers, moisture within the tailings (red lines Figure 3.2) and dust suppression to Mining. The refinery is designed with a dry tailings disposal, containing 40% moisture. This allows for an outlet of ~3200m<sup>3</sup>/day. Table 3.2 listed order of magnitude numbers for water outlet from the refinery.

The evaporation ponds receives cooling tower blow down, process bleed, RBF lubrication water and process solution overflows. The evaporation ponds were designed to accumulate water over winter seasons when evaporation rates approaches zero and during summer months accumulated water and new water bled to the ponds is evaporated. Intake of solution exceeded evaporation rates, causing the ponds to overflow intermittently.

Before water saving initiatives was implemented, the impact on the environment was reduced by diverting RO plant brine and ETP bleed (treated water) directly to the Earth Dams. This prevented the evaporation ponds from overflowing process solution to the Earth Dams.

|                           |                          | <b>Actuals</b> |
|---------------------------|--------------------------|----------------|
| <b>Total Water outlet</b> | <b>m<sup>3</sup>/day</b> | <b>8,495</b>   |
| Moisture with tailings    | m <sup>3</sup> /day      | 3,215          |
| Cooling tower evaporation | m <sup>3</sup> /day      | 2,696          |
| Evaporation from ponds    | m <sup>3</sup> /day      | 840            |
| Evaporation from process  | m <sup>3</sup> /day      | 295            |
| Mining dust suppression   | m <sup>3</sup> /day      | 693            |
| Overflow to earth dams    | m <sup>3</sup> /day      | 756            |

**Table 3.2: Skorpion Zinc Water outlets**

#### **4 Challenges with solution management and water balance**

Table 3.1 displays the design quantities together with the actual water consumption. The difference between actual and design values would clearly had a significant consequences on the water balance and solution management. The challenges can be grouped in four significant issues around the water balance and solution management that had to be addressed:

##### **4.1 Process solution overflows due to excess water intake**

Inlet of raw water to the leach circuit exceeded the design. The outlet of solution is either via moisture contained in the residue filter cake, after the washing stage, or alternatively via bleed from the Basic Zinc Sulphate precipitation plant (BZS) to the Effluent Treatment Plant (ETP). Tonnage outlet of the plant is determined by the zinc contained in the plant feed. Moisture content of the residue cake cannot be increased due to design limitations of the dry tailings disposal system. Excess solution therefore could only be taken out of the plant via bleed from BZS to ETP. The bleed of process solution to the ETP was not designed to handle the additional water. This resulted in process solution tanks overflowing to the evaporation ponds, contaminating 'clean' solution in the evaporation ponds.

##### **4.2 Excess lubrication water**

Lubrication water is used at the Residue Belt Filters to lubricate wear strips carrying the rubber vacuum belt. Reduced or no lubrication water flow results in the wear belts burning off, resulting in extended downtime on the belt filter. Lubrication water spills to the bund from where it is pumped to the ETP circuit. Excess water from ETP is discharge to the evaporation ponds. The lubrication water together with process solution that overflows to the evaporation ponds exceeded the evaporation capacity of the evaporation ponds. This resulted in intermittent solution overflows to earth dams below the evaporation ponds as illustrated in Figure 4.1.



***Figure 4.1: Filled evaporation pond and overflow to earth dams***

#### **4.3 Process solution overflows due to solution management challenges.**

Process design did not take solution transfer into account when plant modules are taken off line. Stock tanks were designed to hold limestone and milled ore slurry, sufficient buffer to supply Leach, when either of the milling circuits were off line. However – if this stock is drawn down, there were no holding capacity for the volume of solution within the circuit – resulting in overflows of the tanks. Consider Figure 4.2.

The first solution loop to consider is the Pregnant Leach Solution (PLS) / Raffinate circuit. (blue lines in Figure 4.2) PLS is stored in PLS storage tanks. When these tanks (6000m<sup>3</sup>) are full, the raffinate tank (4000 m<sup>3</sup>) should be empty. If the Leach circuit is stopped, it allows the SX to continue operation till the raffinate tank is filled and the PLS tanks are drawn down to 2000 m<sup>3</sup>. This circuit could be managed with careful control.



#### 4.4 Reduction in water consumption.

The internal target set by Skorpion Zinc was to operate with a zero discharge of effluent, but to reduce the water consumption beyond this. Though the corrective action will bring water consumption in line with design, a stretched target was set to reduce the raw water consumption below design numbers.

### 5 Corrective action and final results

Each of the deviations from design (Table 3.1) was scrutinised and evaluated to understand the root cause to the deviation. Corrective actions were implemented to address the challenges most effectively as described below and illustrated in Figure 5.1.

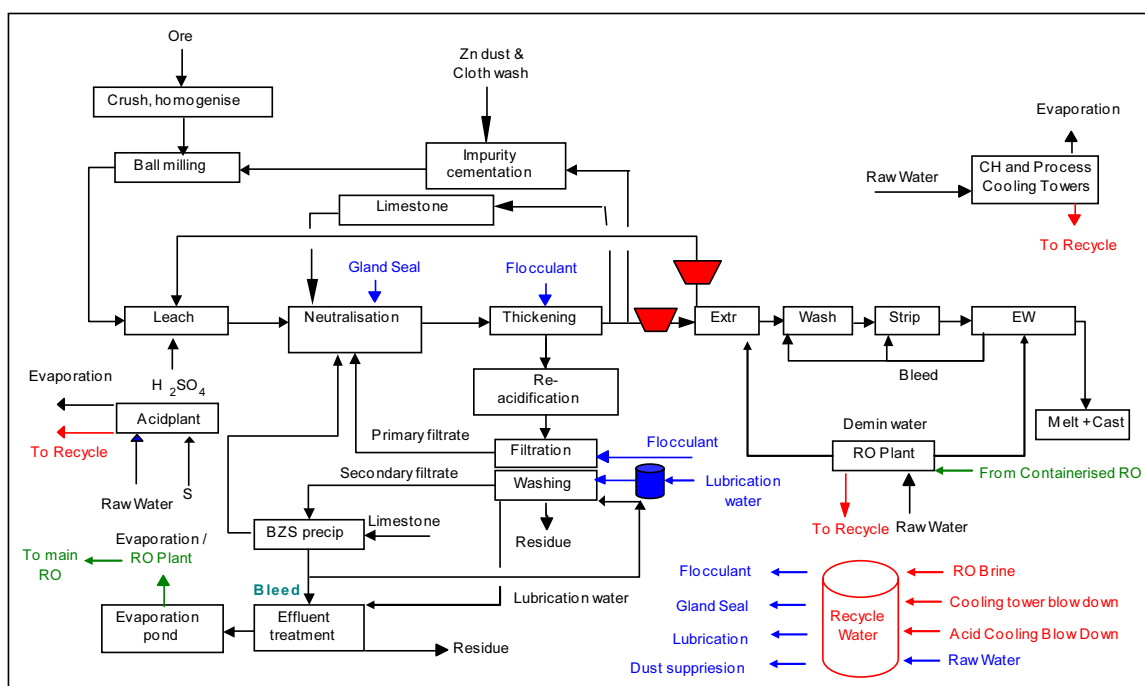


Figure 5.1: Modifications to water intake

#### 5.1 Process solution overflow due to excessive raw water intake.

The Basic Zinc Sulphate (BZS) treatment plant is operated at maximum design capacity. It is costly to increase the capacity of this plant to handle additional bleed. Even if the capacity was increased, it will not alleviate overflows from the evaporation ponds. Focus was therefore applied to address the root cause of high water inputs.

Gland seal water was operated above design due to poor maintenance and lack of attention. Actions were put in place to ensure gland packing on slurry pumps are replaced and pulled up regularly. This enabled a reduction in gland seal water from 960m<sup>3</sup>/day to 720m<sup>3</sup>/day (25% improvement).

Optimisation on flocculent addition to the thickeners and Residue Belt Filters and optimisation on the operation of these units reduced the flocculent consumption. This had a reduction in raw water intake via flocculant into the leach circuit.

Impurity transfer through the Solvent Extraction circuit was the root cause for high bleeds from Electrowinning to SX and the high amount of demineralised water required for washing in SX. Presently, very little opportunity exists to reduce this water intake until impurity transfer is reduced. Maintenance on the electrolyte circuit was improved to prevent loss of electrolyte due to tank failures and draining of electrolyte to the leach circuit.

Washing of equipment with raw water was strictly controlled to reduce unwanted raw water intake into the circuit.

A further management intervention implemented was blanking off un-used raw water lines to ensure that water was not used irresponsibly. Flow meters were installed where design did not provide for metering to ensure all water off-takes are measured. This enabled management to have accurate and on time water usage records to manage water consumption. Water consumption measurement did not only raise awareness, but allowed managers and engineers to identify and address deviations immediately. Approximately N\$ 1.0 million was spent to install additional flow meters.

## **5.2 Excess lubrication water.**

A root cause analysis indicated that the high lubrication water consumption was due to high fluctuations of pressure in the raw water ring main. The lubrication water supplying the Residue Belt Filters, ties off from the water ring main supply. Water pressure in the ring main drops intermittently due to other users on the ring-main drawing high flows of water. During times at low pressure, insufficient lubrication water reaches wear belts, causing damage to wear belts. This created a culture where operating and maintenance personnel, increases the lubrication water flow high above the design to ensure sufficient supply during low pressure scenarios.

The lubrication water supply was isolated from the raw water ring-main and a dedicated supply tank and pump was installed to feed the lubrication water system. A pressure control system was installed to ensure a constant water supply pressure. This enabled operating and maintenance personnel to run at designed lubrication water flows. The cost of this change was N\$ 3 million. This significantly reduces raw water consumption by ~700m<sup>3</sup>/day.

## **5.3 Process solution overflows due to solution management challenges**

As part of a runtime and de-coupling exercise at Skorpion Zinc, PLS and Raffinate ponds were installed, each with capacity of ~20 000m<sup>3</sup>. This efficiently decoupled the SX and Leach circuits, improving on runtime of the refinery. The additional buffer capacity was sufficient to take up all upsets when the Ore Mill and/or Limestone Mill was off line, as explained in paragraph 4.3. Process solution can now be contained, preventing contamination of evaporation pond solution.

#### **5.4 Reduction in water consumption**

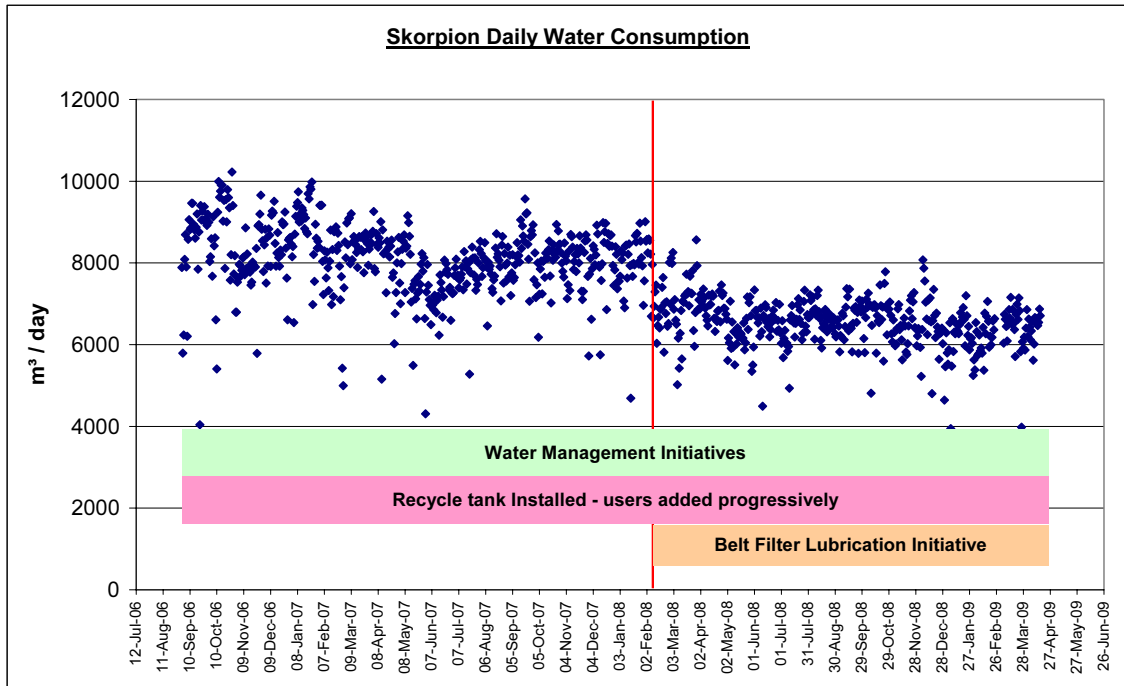
To further optimise and reduce water consumption, opportunities to recycle water were pursued. The cooling tower blow downs and Reverse Osmoses (RO) plant brine is of relatively good quality. It contains very little suspended solid matter and is low in salts. The major contaminant in these water streams are Chlorides. This water source was found suitable for flocculent make-up, RBF Lubrication water, dust suppression and was marginal for gland seal water. The high amount of chlorides will increase corrosion rates of the cast iron pumps in the refinery. To reduce the impact of the high chlorides, the recycle water is blended on a 50 / 50 % ratio with raw water before fed to the flocculent make-up plant, gland seal distribution tank and the Belt Filter Lubrication water tank as illustrated in Figure 5.1.

Approximately N\$ 4.5 million was spent to add a recycle water tank to accommodate surges and to blend the water to the various users. This change resulted in a saving of ~400m<sup>3</sup>/day of raw water.

A further opportunity to re-use the treated water from the ETP circuit was exploited. In the Effluent Treatment Plant (ETP), pH is increased to 9.5 with addition of lime, to precipitate all metals including Mn and Mg. The slurry is then filtered, and the filtrate containing chlorides, is sent to the evaporation ponds. It is of lower quality than raw water. A decision was made to install a containerised RO plant at a cost of N\$ 3 million to treat this solution, sufficient to supplement raw water intake to the main RO plant. As the quality of this treated solution is slightly better than that of raw water, this solution is best utilised at the main RO plant, reducing the load on the RO membranes. This will reduce raw water consumption by 300m<sup>3</sup>/day when implemented. The containerised RO plant is being commissioned at present and the benefit has not yet been realised.

#### **6 Conclusion**

All changes implemented to improve solution balance in the refinery, reduce raw water consumption and to recycle water had a significant impact on the water consumption of Skorpion Zinc. Figure 6.1 illustrates the 20% reduction in water consumption over the past 2.5 years, whilst production output of 150 ktpa of SHG zinc was maintained. The potential savings from the containerised RO plant is not yet included in this number.



**Figure 6.1: Skorpion Zinc water consumption**

The improvements allowed Skorpion Zinc to operate without any discharge of solution to the earth dams below the Evaporation Ponds. The rehabilitation of the earth dams is presented in Figure 6.2. The N\$ 11.5 million spent and results achieved confirm Skorpion Zinc and Anglo American's commitment to produce Zinc sustainable, considering of the environment and conserving the scarce resource – water – most needed by human life.



**Figure 6.2: Dry evaporation ponds**



**Figure 6.3: Rehabilitation of earth dams in progress**

The investment in the water reduction was primarily environmentally driven. A saving of N\$2.2 million per annum is achieved with the reduction in raw water consumption. This is giving ~ 5.5 years payback on the N\$11.5 million investment, or an Internal Rate of Return (IRR) of ~ 14% (over a 10 year investment period) - indicating that the improvement is paying for itself.

The lessons learnt by Skorpion Zinc are shared with the industry to apply and reduce the impact on the environment and lower the consumption of a most needed shared resource. A summary of lessons to be considered during the complete project life cycle are:

- Management of solutions and raw water is critical to most hydrometallurgical operations. In order to manage this effectively, accurate and relevant data is required, as you can't manage what you don't measure. Correct decisions can only be made when accurate information is available. Wastage can only be addressed if information is available pointing out deviations on time. Design engineers often overlook the importance of sufficient metering to assist Operation Management.
- Interaction and decoupling between plant sections must be well thought through – care must be taken to address the solution management and storage capacity between units of operation.
- Cognisance must be given to small water consuming equipment – example the impact of Gland Seal Water is significant in a hydrometallurgical plant where the water outlet from the process is restricted.

- When designing the raw water supply ring-main, care must be taken to understand the fluctuating pressure on downstream equipment. The impact of equipment, consuming large volumes over a short period on water supply pressure must be well understood. Where required, additional storage / separate supply must be considered.
- There is a clear advantage and opportunity in recycling of cooling tower blow down. Re-use of this water can be considered upfront in the design and construction phase of the project.
- Some effluent streams are costly to clean up and requires specialized processes like Reverse Osmoses. In isolated places where the cost of raw water is high, additional capital for this equipment may pay back by reduction in raw water intake.

### **The Author**



**Jacques Kruger, *Project Manager*, Skorpion Zinc**

- 10yrs operational experience in various production plants (heavy mineral sands, diamonds & zinc)
- Valuable process commissioning experience with:
  - Namakwa Sands' Mineral Separation Plant in 1994
  - De Beers Marine's Production Vessels in 1997 & 2000
  - Skorpion Zinc's Refinery in 2003
- 3yrs project manager experience, responsible for a number of successful process improvement projects at Skorpion Zinc.