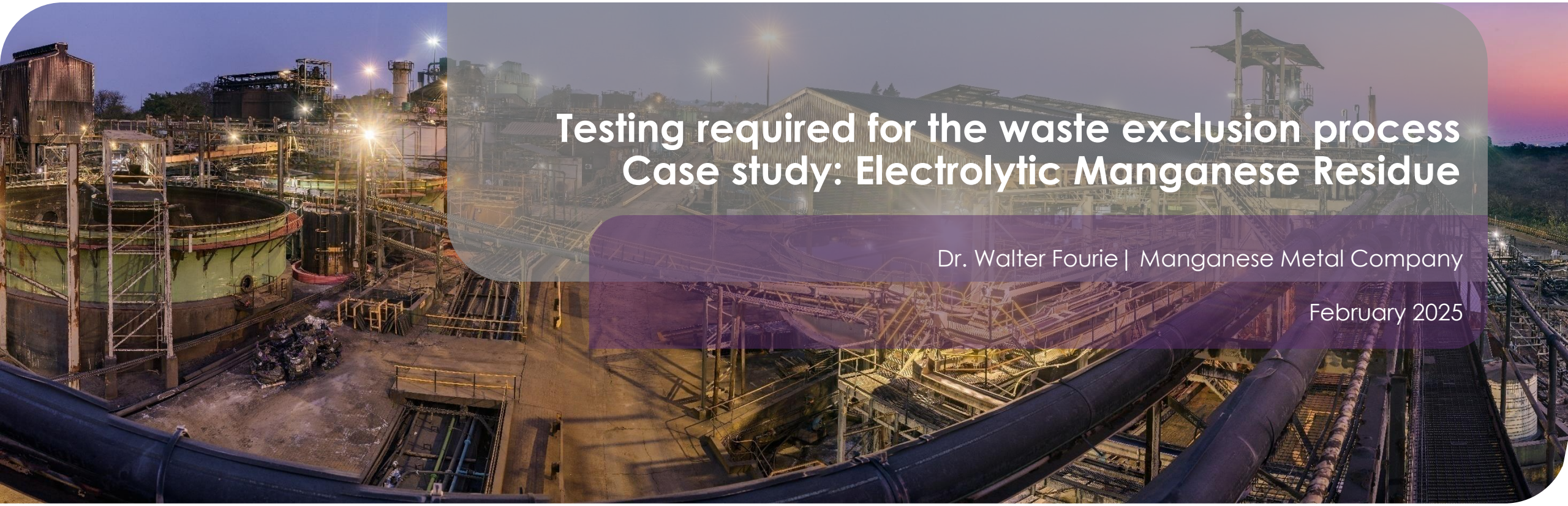
Manganese Metal Co



Testing required for the waste exclusion process Case study: Electrolytic Manganese Residue

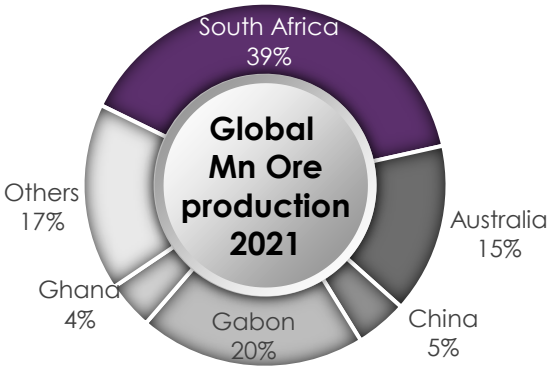
Dr. Walter Fourie | Manganese Metal Company

February 2025

Creating strength.

Location: South Africa, Mpumalanga, Mbombela

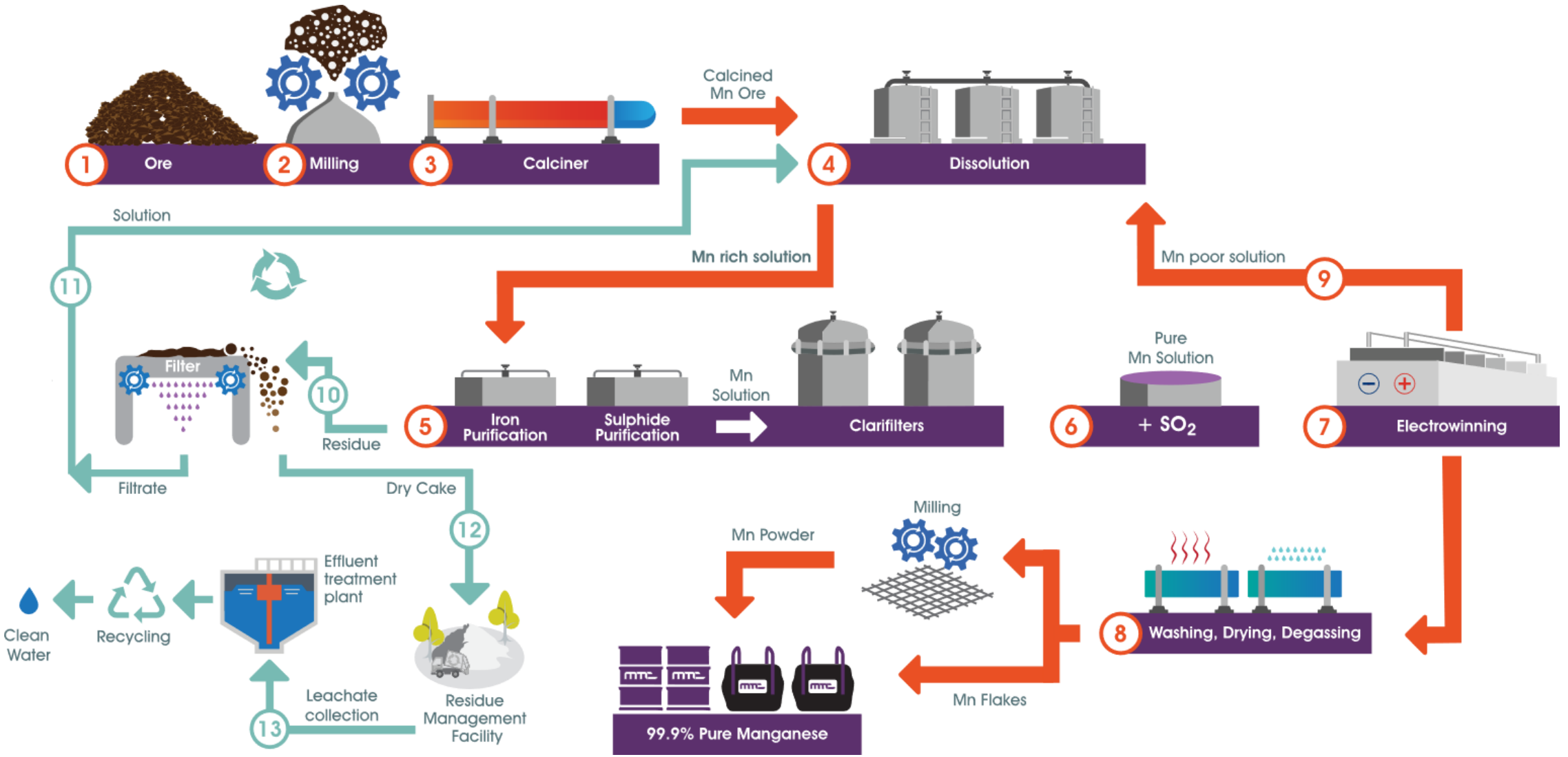
Manganese Metal Co



Limpopo
Kruger National Park
Polokwane
MOZAMBIQUE
MMC
Mbombela (Nelspruit)
Pretoria
Mafikeng
North West
Johannesburg
Gauteng
Mpumalanga
SWAZI-LAND
Maputo
Hotazel
Mn mines, Hotazel region 930km from Mbombela
Kwazulu-Natal
Free State
Kimberly
Bloemfontein
Northern Cape
Pietermaritzburg
Durban
Main ports used: Durban & Maputo
SOUTH AFRICA
Eastern Cape
Bisho
Saldanha
Western Cape
Cape Town
Port Elizabeth

Production Process

- Ore from Hotazel in the Northern Cape is beneficiated to Manganese Metal
- Also produce a dry manganese residue (filter cake) which is currently being landfilled



Annual EMM Sales by MMC

Manganese metal sales are increasingly being dominated by demand in the Green Electric Vehicle industry

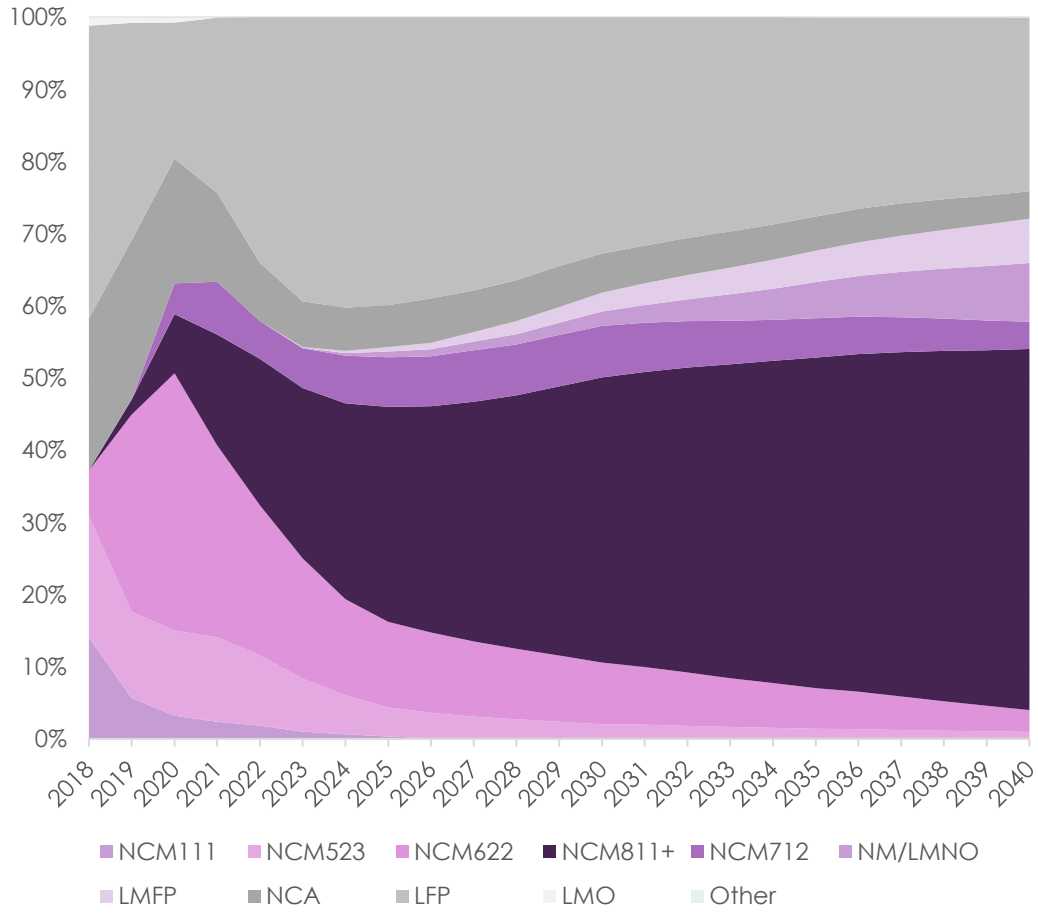
Far-east	41%
North America	40%
Europe	10%
Africa	6%
Other	2%

- First world countries
- High ESG requirements

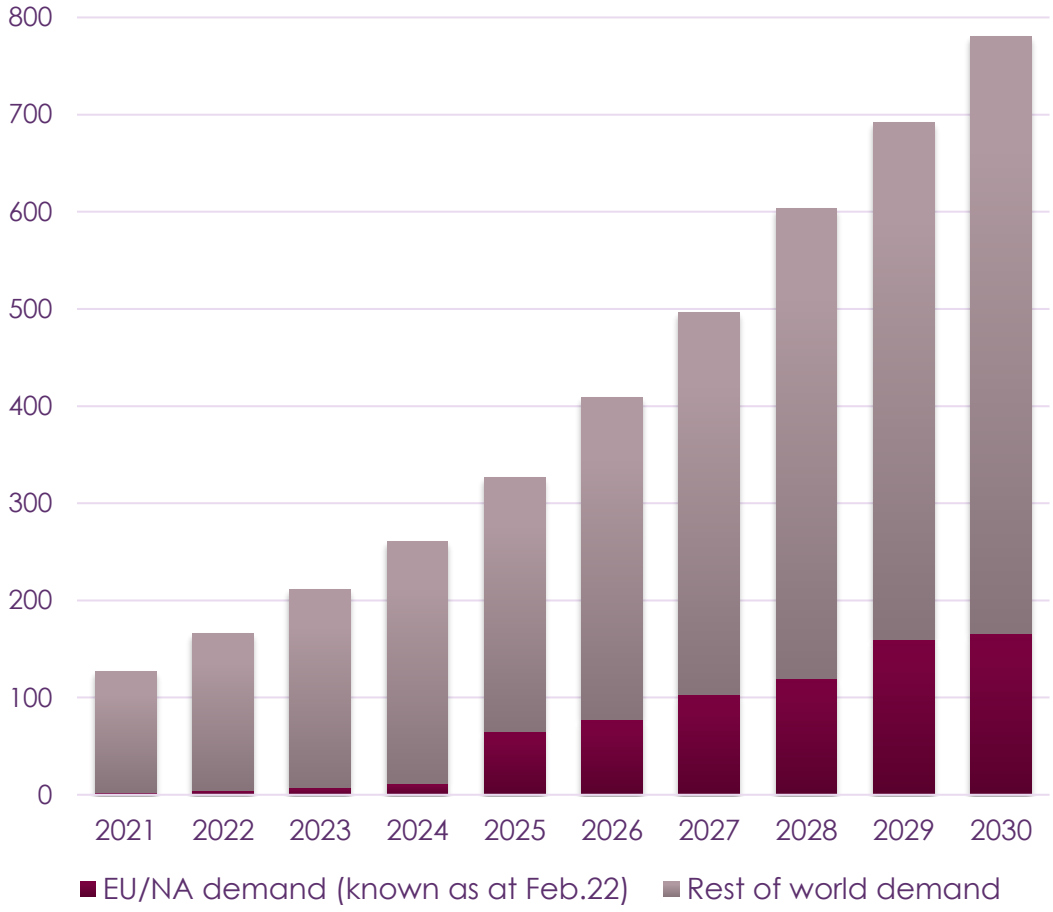
Significant demand growth for high purity Manganese in the LIB segment

EV battery chemistry & high purity Mn-sulphate demand

Cathode chemistry forecast



High purity $MnSO_4.H_2O$ demand in kt sulphate

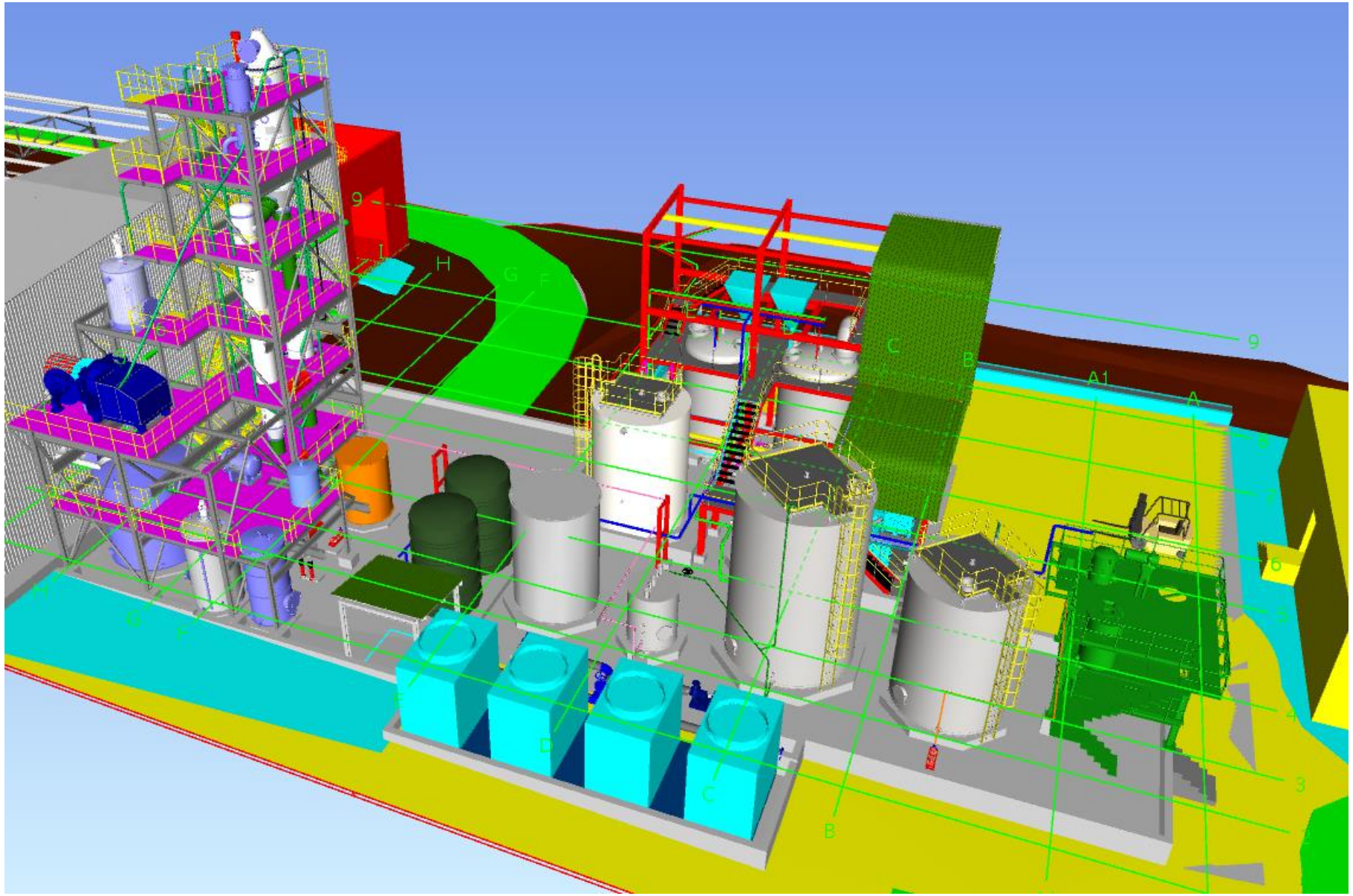


Green customers want full life cycle accountability, including energy and landfilling

Source: RhoMotion Q4 2022 for CAM chemistry. Global $MnSO_4$ demand taken as the average of 4 different analyst groups (CRU, Roskill WM, Benchmark, Cairn Energy Research), updated Dec.2021. EU/NA portion as per MMC Feb.2022 estimates per each EU/NA-based pCAM maker/integrated battery maker with announced plans/intentions. EU/NA demand on this graph excludes Asian battery makers operating within EU/NA but consuming pCAMs made in Asia, e.g. LC Chem, CATL.

Construction of a 6000tpa Manganese Sulphate Plant in Mbombela

Purpose-built for the Electric Vehicle market, coming online Q2 2026



Residue Management Facility – Kingston Vale

Taken into operation in 2006, and operated under an ECA H:H permit, and a S74 Exemption

Phase 2A :
In use from 2017

Phase 2B :
In use from 2019

Phase 1:
Interim Capping

Final Phase:
In use from 2023

Phase 2C :
In use from 2021

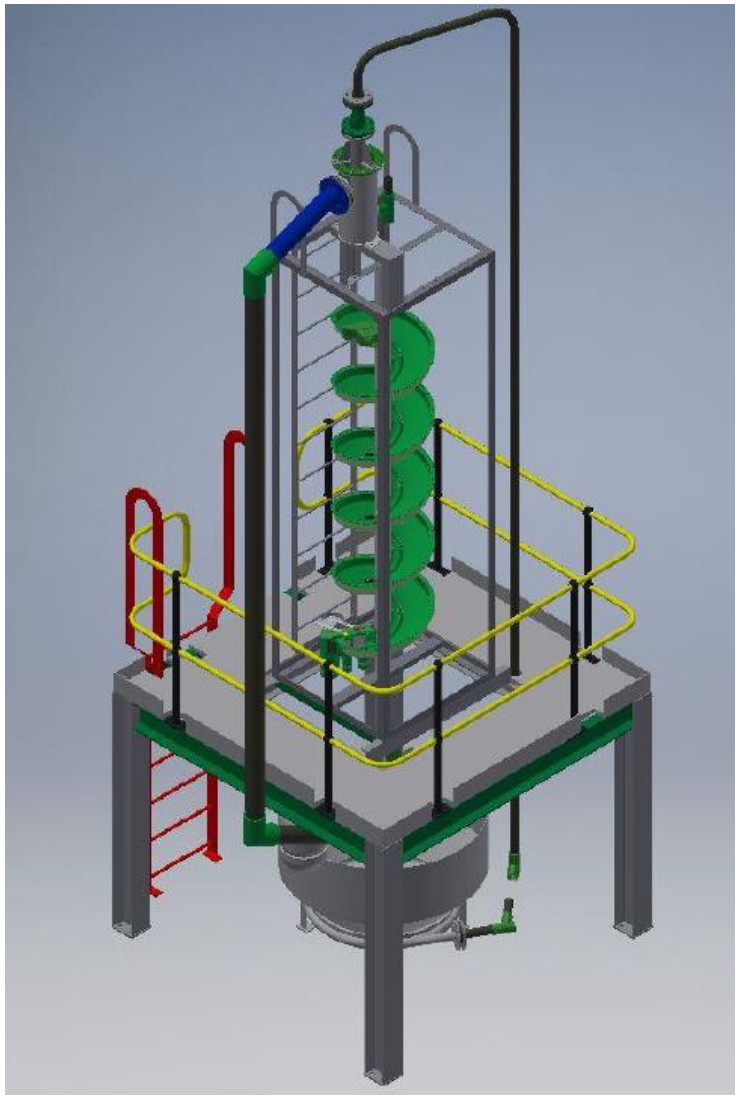
Rain water trench
to dam

Leachate collection dam
Contaminated & storm water

Zero Landfilling Future

MMC is actively seeking an alternative to landfilling of process residue:

- Gravity/Magnetic separation to produce a Mn-concentrate
  - Gravity separation was able to produce high concentrates, but yields were low
  - Magnetic separation tests still ongoing
- Chemically inerted fill material for construction / road building
  - High cost
- Roasting of residue to produce a general construction fill material plus sulphuric acid
  - Good results on the roasting, the residue becomes inert. But at a high cost?
  - Sulphuric acid production still pending
- Production of cement bricks
  - Great technical results! Commercials somewhat challenging.
- Production of clay bricks
  - Great technical results! Commercially more attractive.



Brick making methods

Cement Bricks

- Made from cement, sand and crushed aggregate
- Most important physical parameter is compressive strength (and friability)
- Most important chemical parameter is leachability
- Several variations tested varying the ratio's sand, cement and residue

- Waste Exclusion is viable mechanism
- But what testing is required for the rubber stamp?

Clay Bricks

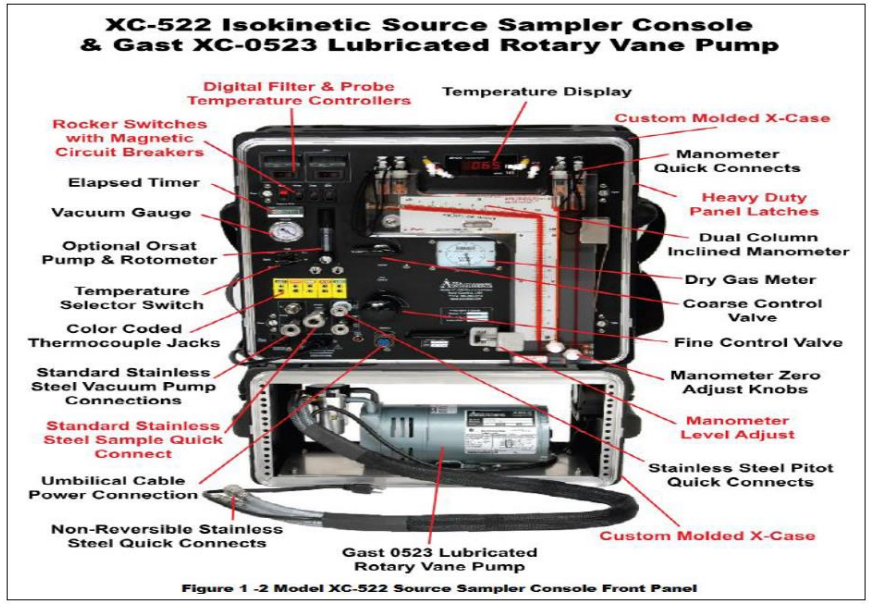
- Made from clay, gravel and a small amount of coal
- Can be either open field kiln, or in a temperature controlled oven
- Most important physical parameter is compressive strength, but it has a SANS standard that governs other parameters
- Most important chemical parameter is leachability
- Clay brick "recipes" differ between the type of clay. So depending on the manufacturer, the amount of residue and firing temperature were varied

Atmospheric Emissions

According to individual and/or national legislation

SO_2 limits for field kilns and temperature controlled kilns

Radiello tubes positioned around a field kiln



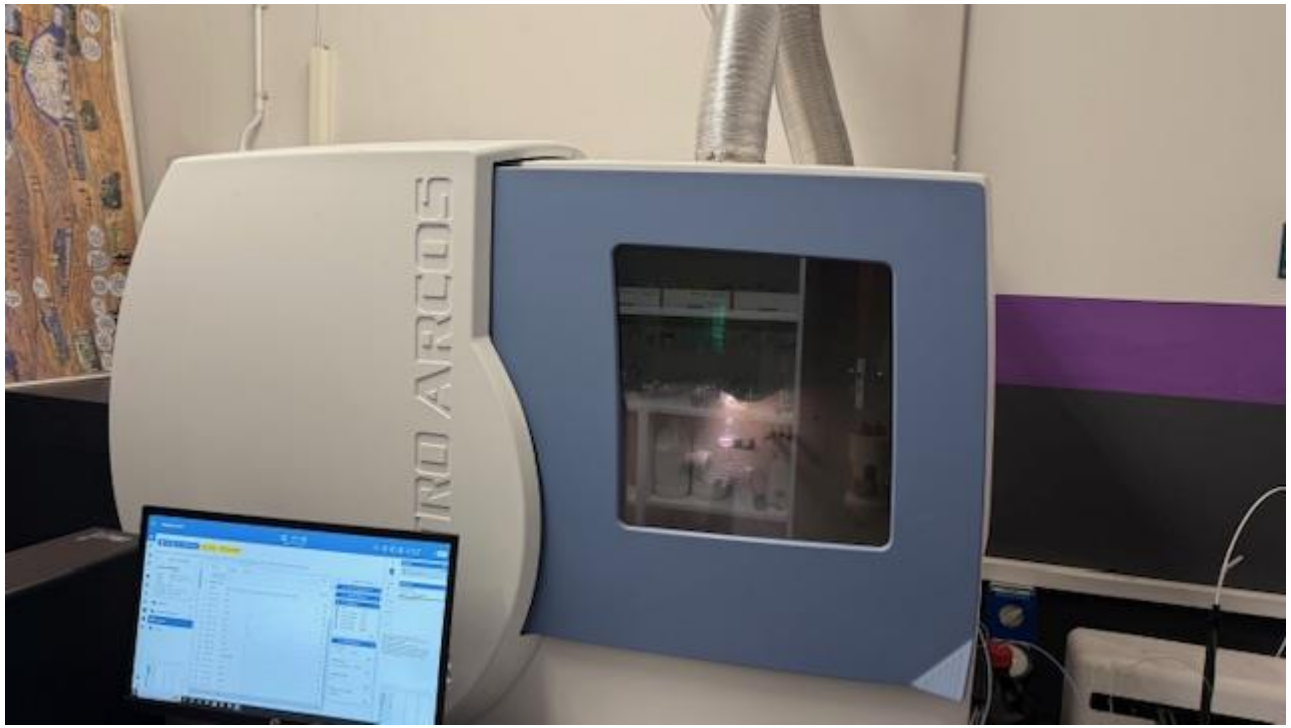
Isokinetic sampling for T controlled kilns

Leachability

AS 4439.3-1997 Wastes sediments and contaminated soils - Preparation of leachates - Bottle leaching procedure

- Aggressive method to determine if nasties will leach out of a solid if in contact with an acidified water
- Based on landfill operations, so there is 1 in 20 dilution
- Send the sample to an external laboratory, or…

Buy an Inductively Coupled Plasma Optical Emissions Spectrometer (ICP-OES)



SANS 227: 2007

Burnt clay masonry units

- Shape
- Appearance
- Texture and colour
- Dimensions
- Warpage
- Compressive strength
- Efflorescence
- Soundness
- Water absorption

ISBN 978-0-626-19745-2

SANS 227:2007

Edition 4.4

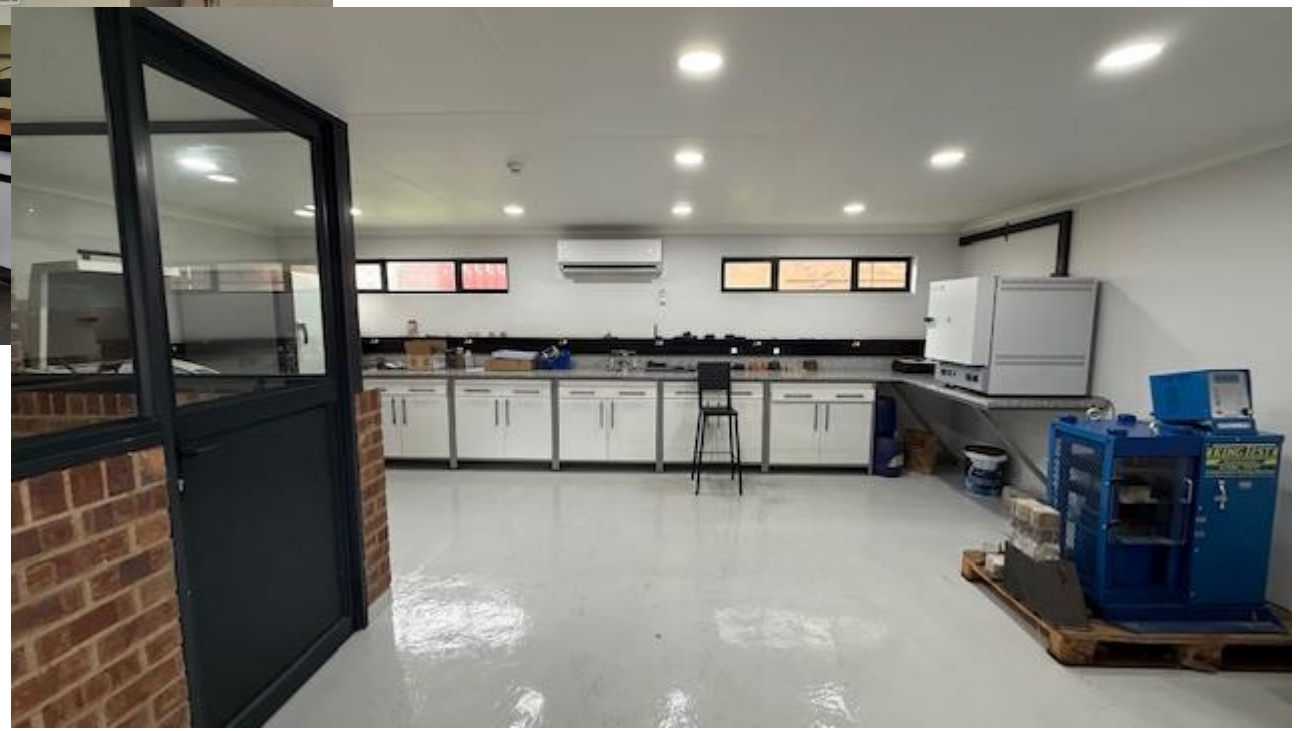
Any reference to SABS 227 is deemed
to be a reference to this standard
(Government Notice No. 1373 of 8 November 2002)

SOUTH AFRICAN NATIONAL STANDARD

Burnt clay masonry units

SANS 227: 2007

Burnt clay masonry units



First you need to revamp your facilities…

SANS 227: 2007

Burnt clay masonry units

Get the basic equipment to make test samples

Mixer

Extruder

High temperature oven

Manganese Metal Co

Shape, Appearance, Texture and colour

Burnt clay masonry units

- Shape
  - No cavities, perforations etc.
- Appearance
  - Well burnt, no cracking etc.
- Texture and colour
  - Texture and colour should be uniform

Epic fail

Much nicer!

SANS 227: 2007

Burnt clay masonry units

- Dimensions
  - Tolerances specified in the standard
- Warpage
  - Limits for individual units and average of the set

1	2	3	4	5	6	7
Class	Individual units mm			Average dimensions of 32 units mm		
	Length	Width	Height	Length	Width	Height
FBS	± 7	± 4	± 4	± 3,5	± 2	± 2
FBX	± 5	± 3	± 3	± 2,5	± 1,5	± 1,5
FBA	No requirement*			No requirement*		
NFP	No requirement			± 3,5	± 2	± 2
NFX	No requirement			± 3,5	± 2	± 2

* See appendix D for maximum and minimum usage rates per square metre of walling.

Another epic fail

SANS 227: 2007

Burnt clay masonry units

Compressive strength

SANS 227: 2007

Burnt clay masonry units

Efflorescence

Just a tray with water – and time

Efflorescence is not unusual in bricks

SANS 227: 2007

Burnt clay masonry units

Soundness

"Steam cooker" and lime paint

And then you check for pop-outs

SANS 227: 2007

Burnt clay masonry units

Water absorption, water soluble salts and moisture expansion

Crush and mix with DI water

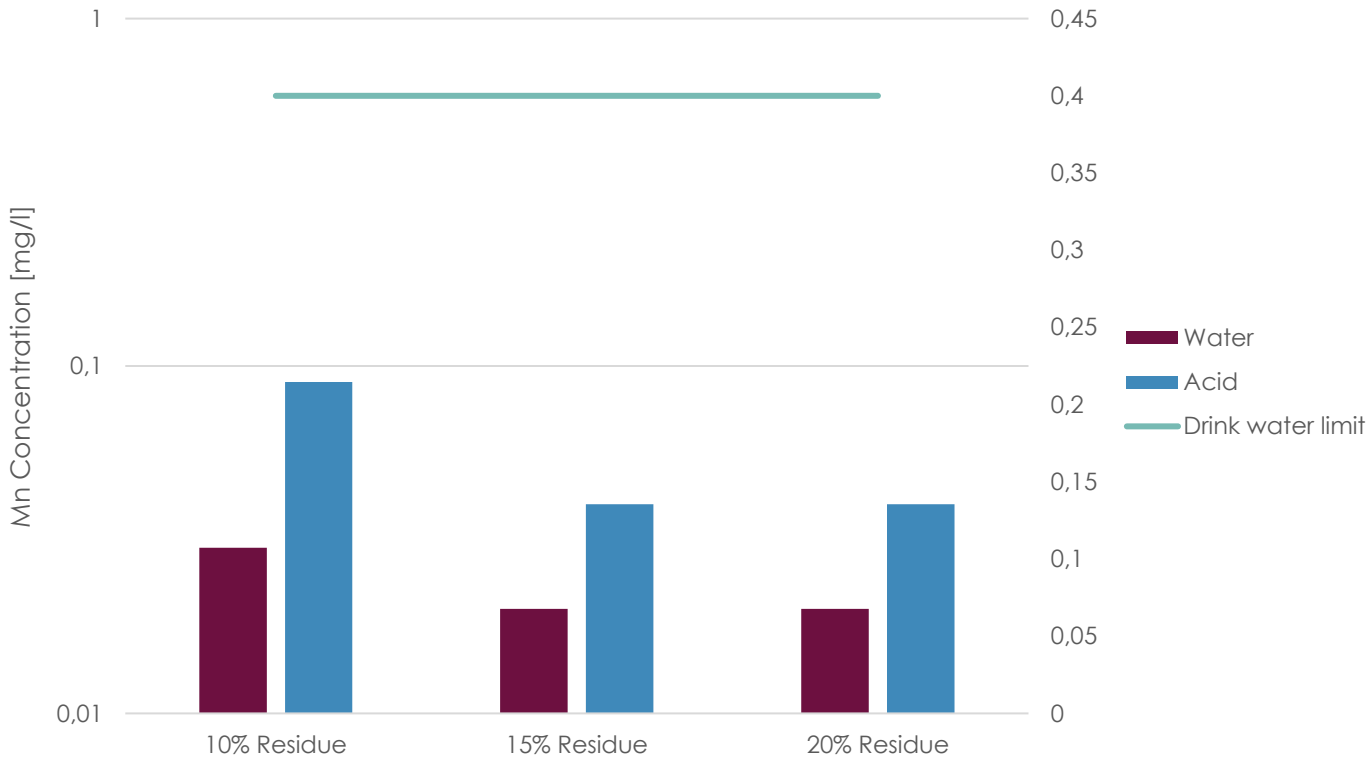
Cook it down and measure what is left

Moisture expansion

Manganese Metal Co

Results

Leachability



Leachates from bricks made in a temperature controlled kiln

Results

SANS 227:2007

Start testing: small amount of waste, and remember the **control!**

				Control Mix (0%)		5% Larox Mix	
Test	Passing Criteria	Tests Conducted Per Mix	**Pass Rate [%]**	Average	Standard Deviation	Average	Standard Deviation
Dimensions (mm)	L ± 3.5; W ± 2; H ± 2 (Tolerance between 32 units)	32	**100**	L=105; W=46; H=24	L=0,768; W=0,274; H=0,328	L=105; W=46; H=23	L=2,152; W=0,540; H=0,473
Warpage (mm)	< 5	32	**100**	2.055	0.689	1.984	0.566
Compressive Strength (MPa)	NFP brick > 7; NFX brick > 14	12	**100**	17.215	2.124	34.696	6.284
Efflorescence (units)	10 units exhibiting slight efflorescence &10 units with moderate efflorescence.	20	**100**	0	N/A	2 (slight)	N/A
Soundness (pop outs)	Maximum 2 pop outs in 2/6 units	6	**100**	0	0	0	0
Water absorption (%)	8 – 20 (Cold)	6	**100**	14.584	0.542	10.919	0.498
Water-soluble salts (%)	< 0,1	6	**100**	-0.013	0.009	-0.051	0.054
Moisture expansion (%)	< 0,2	9	**100**	0.05	0.037	0.02	0.012

Results

SANS 227:2007

Start testing: Larger amount of waste – all still good!

				Control Mix (0%)		10% Larox Mix	
Test	Passing Criteria	Tests Conducted Per Mix	**Pass Rate [%]**	Average	Standard Deviation	Average	Standard Deviation
Dimensions (mm)	L ± 3.5; W ± 2; H ± 2 (Tolerance between 32 units)	32	**100**	L=105; W=46; H=24	L=0,768; W=0,274; H=0,328	L=105; W=46; H=23	L=1,570; W=0,180; H=0,228
Warpage (mm)	< 5	32	**100**	2.055	0.689	0.613	0.283
Compressive Strength (MPa)	NFP brick > 7; NFX brick > 14	12	**100**	17.215	2.124	15.738	1.251
Efflorescence (units)	10 units exhibiting slight efflorescence &10 units with moderate efflorescence.	20	**100**	0	N/A	4 (Slight)	N/A
Soundness (pop outs)	Maximum 2 pop outs in 2/6 units	6	**100**	0	0	0	0
Water absorption (%)	8 – 20 (Cold)	6	**100**	14.584	0.542	11.876	0.376
Water-soluble salts (%)	< 0,1	6	**100**	-0.013	0.009	-0.016	0.019
Moisture expansion (%)	< 0,2	9	**100**	0.05	0.037	0.04	0.033

Results

SANS 227:2007

Continue testing: Keep the waste the same, but change the location

				Control Mix (0%)		10% Larox Mix	
Test	Passing Criteria	Tests Conducted Per Mix	**Pass Rate [%]**	Average	Standard Deviation	Average	Standard Deviation
Dimensions (mm)	L ± 3.5; W ± 2; H ± 2 (Tolerance between 32 units)	32	**100**	L=113; W=42; H=21	L=1,250; W=0,491; H=0,174	L=113; W=42; H=21	L=1,023; W=0; H=0
Warpage (mm)	< 5	32	**100**	0.477	0.13	0.531	0.232
Compressive Strength (MPa)	FBS/FBX Brick > 24	12	**100**	84.303	7.695	86.571	9.072
Efflorescence (units)	At most, 10 units exhibiting slight efflorescence and 10 units with moderate efflorescence	20	**100**	12 (slight)	N/A	14 (slight)	N/A
Soundness (pop outs)	Maximum, 2 pop-outs in 2/6 units	6	**100**	0	0	0	0
Water absorption (%)	8 – 20 (Cold)	6	**100**	9.519	0.111	10.875	0.189
Water-soluble salts (%)	< 0,1	6	**100**	-0.008	0.005	-0.006	0.005
Moisture expansion (%)	< 0,2	9	**100**	0.01	0.009	0.04	0.02

Results

SANS 227:2007

Continue testing: Keep the waste the same, but change the clay mix

				Control Mix (0%)		10% Larox Mix	
Test	Passing Criteria	Tests Conducted Per Mix	**Pass Rate [%]**	Average	Standard Deviation	Average	Standard Deviation
Dimensions (mm)	L ± 3.5; W ± 2; H ± 2 (Tolerance between 32 units)	32	**100**	L=110; W=41; H=21	L=2,297; W=0; H=0	L=112; W=42; H=21	L=0,755; W=0; H=0
Warpage (mm)	< 5	32	**100**	0.484	0.124	0.469	0.083
Compressive Strength (MPa)	FBS/FBX Brick > 24	12	**100**	89.822	10.086	104.487	8.589
Efflorescence (units)	At most, 10 units exhibiting slight efflorescence and 10 units with moderate efflorescence	20	**100**	18 (slight)	N/A	8 (slight)	N/A
Soundness (pop outs)	Maximum, 2 pop-outs in 2/6 units	6	**100**	0	0	0	0
Water absorption (%)	8 – 20 (Cold)	6	**100**	11.239	0.215	10.631	0.112
Water-soluble salts (%)	< 0,1	6	**100**	-0.012	0.003	-0.006	0.003
Moisture expansion (%)	< 0,2	9	**100**	0.01	0.004	0.03	0.013

About 1000 tests later… all seems good!

Conclusions

Use of electrolytic manganese residue in clay bricks

- A waste exclusion provides a **potentially profitable** method of moving waste up the hierarchy, supported by **enabling legislation**
- From a company liability perspective (and from our very green clients!) **due diligence** is paramount
- So you have to test and develop the same **quality** procedures as with any of your normal products
- **Invest** in the right equipment and develop the skills necessary **internally**

Questions?