



High grade Mn ore:
Can it influence the cost of future EMM
production in China?

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Presentation Layout

- Context
- Factors to consider in the use of high grade Mn ore in the EMM industry
 - Ore price, availability and grade
 - Process changes
 - Material/waste disposal practices
- Scenario planning and comparison
- Take home points

Context

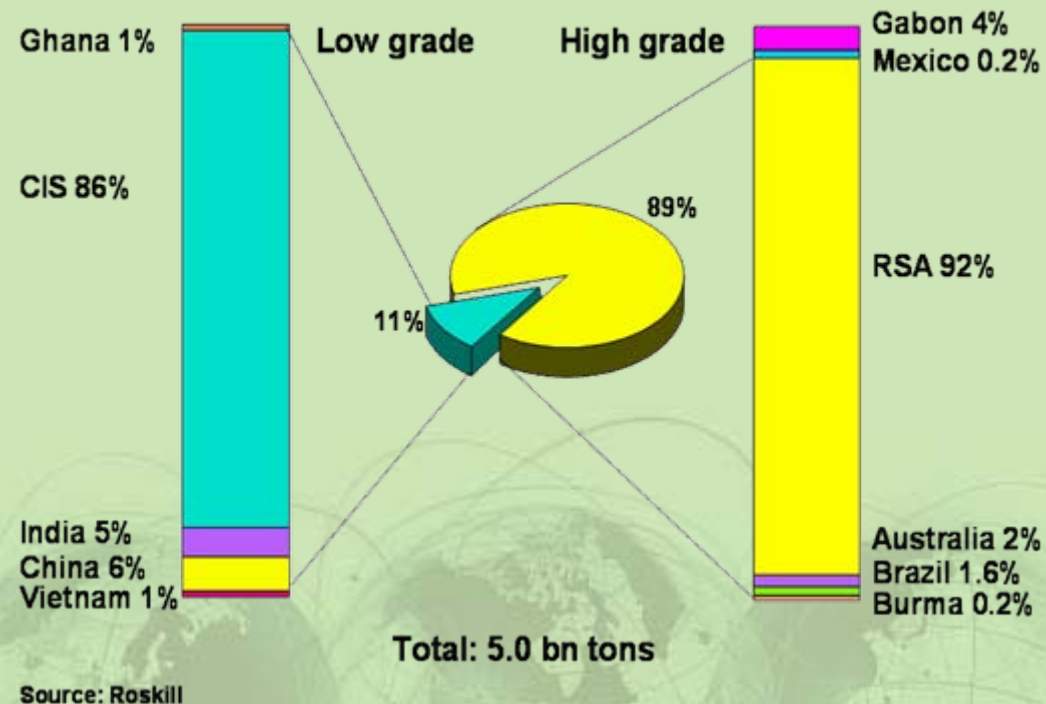
High grade Mn ore - RSA:

- 44% to 48% Mn content
- At 85% recovery require 2.6 to 2.8 ton ore per ton EMM
- Typically oxide mineralogy
- Requires reduction before leaching
- Needs 0.2t acid per ton EMM

Low grade Mn ore - China:

- 14% to 18% Mn content
- At 75% recovery require 6.9 to 8.9 ton ore per ton EMM
- Typically carbonate mineralogy
- Needs no reduction before leaching
- Needs 2.2t acid per ton EMM

World Mn Reserves (Roskill, The Economics of Manganese, 2000)



Factors to Consider

- Local ore availability, price and grade
- Process advantages and disadvantages
- Material and waste handling and disposal practices

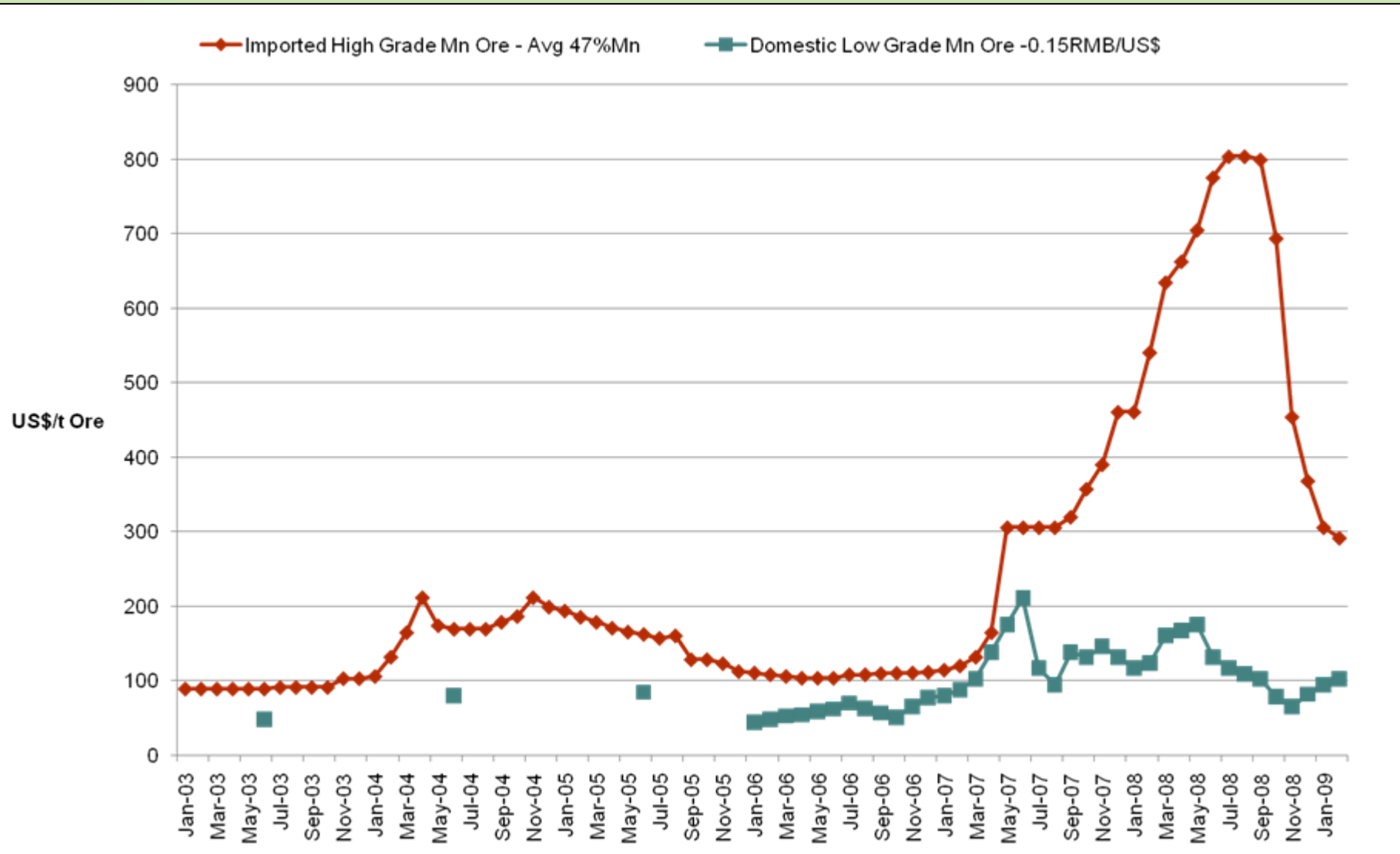
Ore Availability

- Although South Africa has the majority of high grade Mn ore reserves, Australia is currently the largest producer of high grade Mn ore
- China is the largest importer of seaborne high grade Mn ore in the world and imported 7.6Mt wet ore in 2008 for mostly the ferro-alloy industry, average grade 44% (China Customs, 2008)
- China local ore is predominantly low grade MnCO_3 ore. Produced 18.8Mt in 2008, average grade 20%, of which 67% was carbonate low grade ore and 33% MnO_2 (IMnI Market Research)

Ore Availability

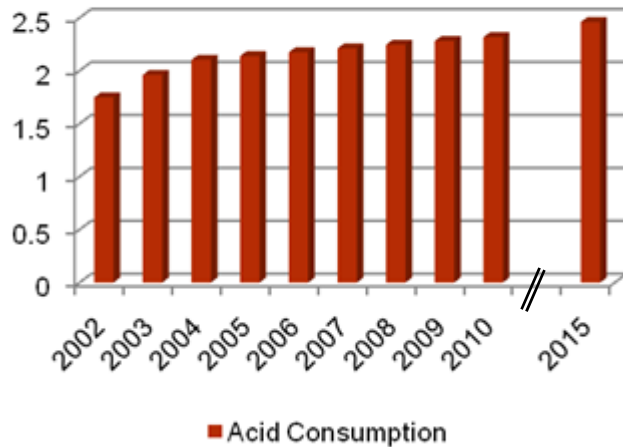
- Chinese EMM industry is the main consumer of domestic ore (balance used in ferro-alloy) and plants are typically situated close to Mn ore reserves (Mn Triangle)
- Total China Mn ore reserve around 421Mt ore (CISRI)
- Depending on production rate, local MnCO_3 ore reserves can deplete in specific areas in the next 10-15 years (Hunan, Shanxi and Chongqing traditional EMM production areas) - CISRI

Mn Ore Price



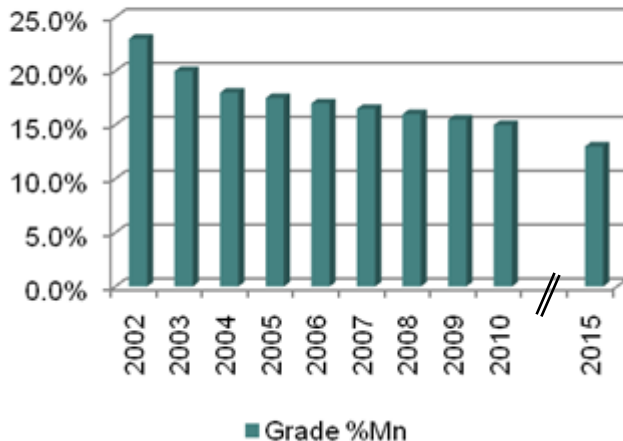
China's domestic Mn-ore grade is declining

Acid Consumption



- Currently consuming 7-8 t ore/t EMM due to 30% decrease in grade since 2002
- Rate of decrease is in the order of 0.5% Mn per year
- Currently in the order of 16% Mn
- Acid consumption could increase by similar rate as grade decreases
- Transport and milling cost will also increase as will the requirement for waste disposal space

Grade %Mn



High grade Mn ore -Process Aspects

- Advantages:
 - Lower acid consumption (price of acid volatile)
 - Higher Mn recovery can be achieved (up to 87% in RSA)
 - Lower waste production/handling – lower capital for filter banks
- Disadvantages:
 - Require ore reduction
 - Additional process step and associated CAPEX and OPEX

Waste Disposal Practice Comparison

- Comparison - USA, Chinese and RSA:
 - Permitting
 - Waste Classification
 - Landfill Design Requirements
 - Groundwater Monitoring and Standards
 - Closure Requirements
- Examples of liner systems
- Disposal rates and costs
 - Capex
 - Opex

Permitting

USA	China	RSA
<p>Resource Conservation and Recovery Act of 1976</p> <p>Subtitle C: Hazardous Waste Management</p>	<p>Standard for Pollution Control at General Industrial Solid Waste Disposal and Storage Sites. (CB 18599-2001)</p>	<p>Section 20 of the Environmental Conservation Act requires a waste disposal permit</p>
<p>Detailed Regulations by EPA, Title 40 of the Code of Federal Regulations</p>	<p>Identification standard for dangerous wastes (CB5085.1-5085.2-1996)</p>	<p>Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste, Department of Water Affairs, Second Addition 1998</p>
<p>Require detailed site assessment and EIA</p>	<p>Integrated standard of wastewater discharge (CB8978-1996) Integrated standard of air pollution emission (CB16298-1996)</p>	<p>SABS 0228 Identification and Classification of Dangerous Substances and Goods</p>
	<p>Integrated standard of air pollution emission (CB16298-1996)</p>	
	<p>Quality standard for groundwater (CB/T14848-93)</p>	
	<p>Test method for leaching toxicity of solid waste (CB5086.1 50862.2 1997)</p>	

Waste Classification

USA	China	RSA
<p>Must be a solid waste by definition</p> <p>Waste can be excluded</p> <p>There are listed wastes</p>	<p>Waste that is not listed in the National Catalogue of Dangerous Waste nor has hazardous characteristics as identified by leach tests, has to be subjected to waste characterisation tests and classification</p>	<p>Waste sources are categorised based on SABS0228, the Basel Convention and the DWAF Minimum Requirements.</p>
<p>All solid waste not excluded to undergo testing for:</p> <ul style="list-style-type: none"> •Ignitability •Corrosivity •Reactivity •Toxicity (TCLP) 	<p>Waste characterisation based on pH and leachable elements</p> <p>Waste Classified as Type I and II wastes.</p> <p>Waste disposal requirements based on waste class</p>	<p>All waste not already included in above list, undergoes Hazard Rating based on various test work including leaching characteristics.</p> <p>Hazard Rating is based on corrosivity, ignitability, toxicity, radioactivity, reactivity and involve the calculation of:</p>
<p>There are TCLP regulated substances of which Mn is not regulated (human health risk based)</p> <p>Can delist the waste based on pre-treatment</p>		<ul style="list-style-type: none"> • Estimated Environmental Concentration and comparison to ARL (require LC and LD50 values for substance) • Max loading/disposal rate • Max Total Load • Can delist the waste to a lower Hazard Rating using treatment and disposal rate. • ARL for Mn is 0.3mg/L

Landfill Design Requirements

USA	China	RSA
Follow a precautionary/prescribed approach with the option to follow a site specific Risk Based approach	Only mention prescribed approach	Follow a precautionary/prescribed approach with the option to follow a site specific Risk Based approach
Require: <ul style="list-style-type: none"> •Double liner (bottom geocomposite) •Double leachate collection and removal •Leak detection •Storm water control (25 year storm) •Air quality control •Construction quality assurance 	Require: <ul style="list-style-type: none"> •Leachate collection and discharge facilities •Storm water control •Type II require a prepared base with permeability of less than 1×10^{-7}cm/s and thickness of 1.5m •Type II require leachate treatment facilities 	Require: <ul style="list-style-type: none"> •Double liner (upper geocomposite) •Double leachate collection and removal •Leak detection •Storm water control (1:100 year storm event) •Air quality control •Construction quality assurance •Clay liners must have a lower outflow rate than 1×10^{-7}cm/s

Groundwater Monitoring and Standards

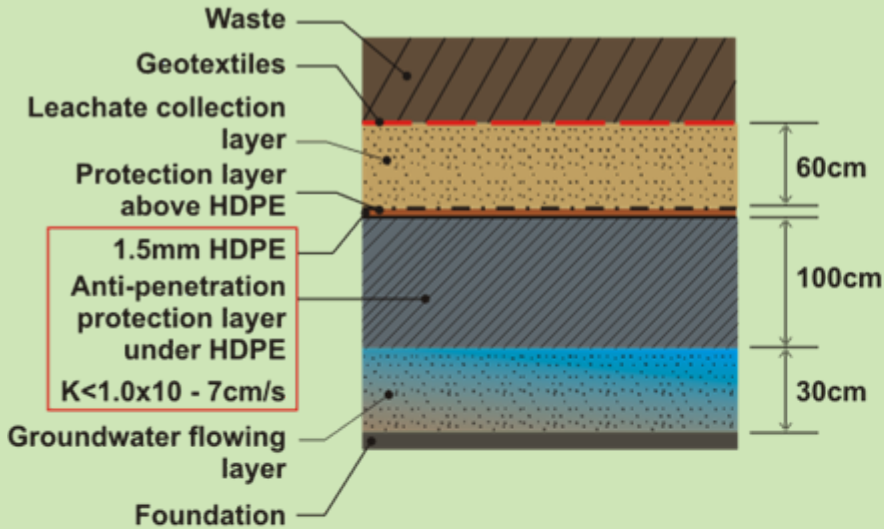
USA	China	RSA
<p>Comprehensive groundwater monitoring for the following purposes:</p> <ul style="list-style-type: none"> • Detection monitoring (require at least 1 upstream and 3 downstream) • Compliance monitoring • Corrective action • Need to establish site specific Groundwater Protection Standard • Compliance point no more than 150m away from landfill or at extent of operator property 	<p>More than 3 monitoring boreholes required, one upstream, one downstream and one in diffuse pathway</p>	<p>Comprehensive groundwater monitoring, including:</p> <ul style="list-style-type: none"> • 5-10 monitoring holes • 10-200m away from facility • Frequency and location to be determined by impact study
<p>Washington State groundwater quality 0.05mg Mn/L</p>	<p>Class 1&2 2mg Mn/L and Class 3 is 5mg Mn/L</p>	<p>Acceptable Risk Level 0.3mg Mn/L</p>

Closure Requirements

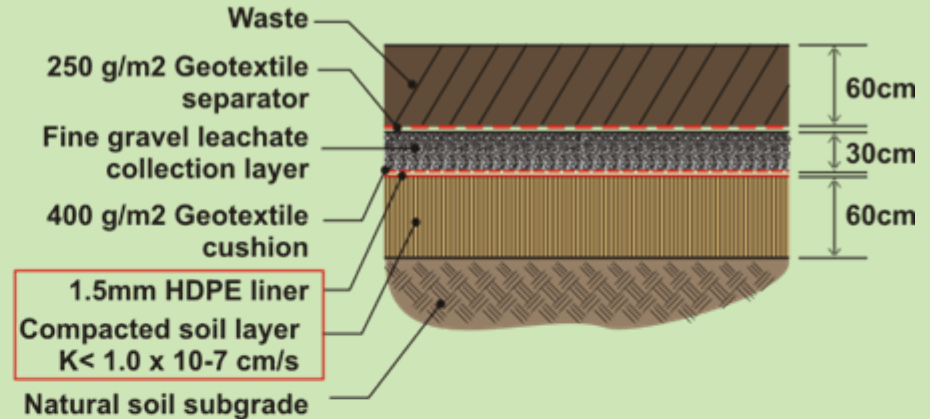
USA	China	RSA
Require a closure Plan	Require a Closure Plan	Require a Closure Plan
Cover to have a permeability equal or lower than bottom liner	<p>Type I facility cover – soil with vegetation specific specification of thickness</p> <p>Type II facility cover – two layers, one compacted clay of 20-45cm thickness and covered by natural soil layer with vegetation specific specification of thickness</p>	Cover system prescribed to include: <ul style="list-style-type: none"> •200mm soil layer •450mm clay layer •150mm base and gas drainage layer
30 year post closure maintenance and monitoring	Care and maintenance until water quality has stabilised in the groundwater system.	30 year post closure maintenance and monitoring
Require financial assurance		

Liner Design Examples

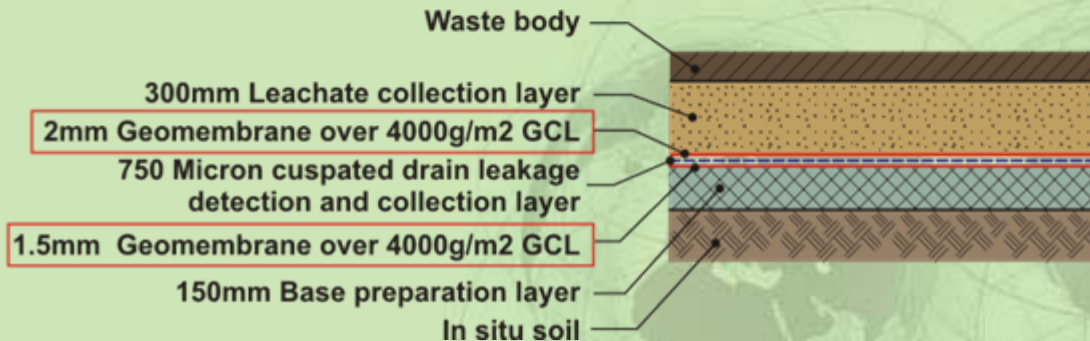
China Composite Liner



USA Composite Liner



RSA - Dual Composite Liner



Rates and Costs

Landfill	Opex (US\$/t)	Capex (US\$/m ²)
RSA, Nelspruit	18-22	4.80-6.00
USA, Washington State	?	?
China example	?	?

Assuming a 10 000t/a EMM Factory

Mn Ore Grade	Waste (t/a)	Landfill Space (m ² /a)
Low Grade – China	76 806 (1)	4 500 (3)
High Grade - RSA	16 738 (2)	990 (3)

1. Assume 16%Mn ore and factory efficiency of 72%
2. Assume 44%Mn ore and factory efficiency of 85%
3. Assume 10m high Mn waste disposal facility

How much landfill space is available?
At 900 000t/a require 405 000m²/a (40.5 ha/a)
waste disposal footprint growth

Scenario Evaluation

Scenario descriptions (low vs high grade ore as a function of EMM production cost)

- All things equal, current case
- All things equal, change in ore grade
- All things equal, change in ore grade and stricter waste disposal enforcement
- Scenario comparison (Table and results)

Key Inputs to EMM production:

- Mn ore
- Sulphuric acid
- Ammonia
- SeO_2 or SO_2
- Electricity
- Materials (e.g. cathodes)
- Labour

Base or Current Case

Source of price from Huacheng Electronic Exchange website. Price basis is for ore that has been milled to powder already, delivered to the EMM factory, ready for leaching

Generally accepted industry average for low grade pore in China EMM

Mass balance and stoichiometry based estimate

Source of price from Huacheng Electronic Exchange website. Price basis is for 98% acid, delivered

Estimate based on limited waste handling (short distance mechanical)

Example for EMM industry	Low grade ore	High grade ore	Unit
Mn content	16	44	%
Ore price (powder, DEL)	550	2690	RMB/t ore
Overall factory efficiency	72	85	%
Ore consumption	8.68	2.67	t/t EMM
Ore reduction cost	0	360	RMB/t ore
Acid consumption	2.32	0.25	t/t EMM
Acid price	450	450	RMB/t acid
Waste generation (dry basis)	7.68	1.67	t/t EMM
Cost to dispose waste	50	50	RMB/t waste
Cost of ore	4,774	8,155	RMB/t EMM
Cost of acid	1,044	113	RMB/t EMM
Cost of disposal of waste	384	84	RMB/t EMM
Total cost of above	6,202	8,351	RMB/t EMM
For 10,000tpa EMM factory:			
Volume of waste to landfill	76,806	16,738	t waste
<i>Cost saving to the EMM factory when using low grade:</i>			26%
<i>Difference in waste mass to landfill:</i>			359%

Imported ore price inside ports China in RMB/mtu as per website such as Asian Metal, times Mn content %, plus transport in RMB/t across average distance from east coast to Mn-Triangle in south-west China, plus milling cost as claimed by various producers.

General accepted industry average for high grade ore in South Africa

Estimated cost of operating a reduction kiln, electricity and reductant (coal or oil) cost in South Africa

General accepted industry average for high grade ore in South Africa



Decreasing Grade

Example for EMM industry	Low grade ore	Low grade ore	Low grade ore	High grade ore	Unit
Mn content	20	15	10	44%	
Ore price (powder, DEL)	550	550	550	2690	RMB/t ore
Overall factory efficiency	72	72	72	85%	
Ore consumption	6.94	9.26	13.89	2.67	t/t EMM
Ore reduction cost	0	0	0	360	RMB/t ore
Acid consumption	1.96	2.32	2.67	0.25	t/t EMM
Acid price	450	450	450	450	RMB/t acid
Waste generation (dry basis)	5.94	8.26	12.89	1.67	t/t EMM
Cost to dispose waste	50	50	50	50	RMB/t waste
Cost of ore	3,819	5,093	7,639	8,155	RMB/t EMM
Cost of acid	882	1,044	1,202	113	RMB/t EMM
Cost of disposal of waste	297	413	644	84	RMB/t EMM
Total cost of above	4,999	6,550	9,485	8,351	RMB/t EMM
For 10,000tpa EMM factory:					
Volume of waste to landfill	59,444	82,593	128,889	16,738	t waste
<i>Cost saving to the EMM factory when using low grade:</i>	40%	22%	-14%		
<i>Difference in waste to landfill:</i>	255%	393%	670%		

Standard Waste Disposal Practices

Example for EMM industry	Low grade ore	Low grade ore	Low grade ore	High grade ore	Unit
Mn content	20	16	10	44%	
Ore price (powder, DEL)	550	550	550	2690	RMB/t ore
Overall factory efficiency	72	72	72	85%	
Ore consumption	6.94	8.68	13.89	2.67	t/t EMM
Ore reduction cost	0	0	0	360	RMB/t ore
Acid consumption	1.96	2.32	2.67	0.25	t/t EMM
Acid price	450	450	450	450	RMB/t acid
Waste generation (dry basis)	5.94	7.68	12.89	1.67	t/t EMM
Cost to dispose waste	150	150	150	150	RMB/t waste
Cost of ore	3,819	4,774	7,639	8,155	RMB/t EMM
Cost of acid	882	1,044	1,202	113	RMB/t EMM
Cost of disposal of waste	892	1,152	1,933	251	RMB/t EMM
Total cost of above	5,593	6,970	10,774	8,519	RMB/t EMM
For 10,000tpa EMM factory:					
Volume of waste to landfill	59,444	76,806	128,889	16,738	t waste
<i>Cost saving to the EMM factory when using low grade:</i>	34%	18%	-26%		
<i>Difference in waste to landfill:</i>	255%	359%	670%		

High grade Mn ore: Can it influence the cost of future EMM production?

- Grade in local MnCO_3 ore can decrease to levels where high grade ore is more economical to use (all things equal)
- Use of high grade ore has lower waste volumes to handle and dispose
- Waste disposal practices in China will likely require higher future compliance to China standards with resultant increase in future waste disposal costs



Thank You for your Attention!
Questions?

