

# **Manganese Market Research Report**

---

Date: June, 2023

Author: Brendan Jephcott

Prepared by:

**GOLDEN DRAGON CAPITAL**

# GOLDEN DRAGON CAPITAL

## Table of Contents

Executive Summary .....	2
1.0 Introduction .....	30
1.1 Definition and Properties .....	30
1.2 History.....	30
1.3 Industry Value Chain .....	31
2.0 Geology and Mineral Reserves .....	32
2.1 Modes of Occurrence .....	32
2.1.1 Sedimentary Deposits.....	33
2.1.2 Residual Deposits.....	36
2.1.3 Hydrothermal Deposits .....	37
2.1.4 Volcanogenic Sedimentary Deposits.....	37
2.1.5 Ocean Floor Nodules.....	37
2.2 Distribution of Manganese Deposits in Geological Time .....	38
2.3 Global Reserves.....	41
2.3 Global Production.....	42
2.4 Major Global Manganese Ore Production Companies .....	43
2.4.1 South Africa.....	43
2.4.2 Gabon .....	44
2.4.3 Australia .....	44
2.4.4 Ghana .....	44
2.4.5 Ukraine.....	44
2.4.6 India .....	44
2.5 Global Imports.....	44
3.0 Mining and Beneficiation .....	45
3.1 Ore Product Specifications .....	45
3.2 Mining .....	46
3.2.1 Groote Eylandt.....	47
3.2.2 Wessels.....	50
3.3 Beneficiation.....	54
3.3.1 Groote Eylandt.....	54
3.3.2 Mammatwan Sinter Plant.....	59
3.3.3 Moanda Industrial Complex .....	61
4.0 Manganese Alloys.....	61
4.1 Manganese Alloy Specifications .....	61
4.2 Manganese Alloy Production Process .....	63
4.2.1 High-Carbon Ferromanganese Production.....	63
4.2.2 Medium-Carbon Ferromanganese Production .....	65
4.2.3 Low-Carbon Ferromanganese Production .....	65
4.2.3 Silicomanganese Production.....	66
4.2.4 Low-Carbon Silicomanganese Production .....	67
4.3 Manganese Alloy Raw Material Properties .....	69

---

GOLDEN DRAGON CAPITAL LIMITED

Address: The Richmond, 18/A, Room A, 62c Robinson Road, Mid-Levels, Hong Kong, China

Telephone: +852 4647 0122

All correspondance to Email: [brendan@goldendragoncapital.com](mailto:brendan@goldendragoncapital.com)

Website: [www.goldendragoncapital.com](http://www.goldendragoncapital.com)

# GOLDEN DRAGON CAPITAL

4.4	Manganese Ferroalloy Market .....	70
5.0	Electrolytic Manganese Metal.....	74
5.1	Electrolytic Manganese Metal Specifications .....	74
5.2	Electrolytic Manganese Metal Production Process .....	76
5.2.1	EMM Production Process in Chongqing City, China.....	76
5.2.2	Manganese Metal Company (Pty) Ltd Selenium Free Process .....	78
5.3	Electrolytic Manganese Metal Raw Material Properties .....	80
5.4	Electrolytic Manganese Metal Market .....	81
6.0	Electrolytic Manganese Dioxide.....	87
6.1	Electrolytic Manganese Dioxide Specifications .....	87
6.2	Electrolytic Manganese Dioxide Production Process .....	90
6.3	Electrolytic Manganese Dioxide Raw Material Properties .....	97
6.4	Electrolytic Manganese Dioxide Market .....	97
7.0	Trimanganese Tetraoxide .....	100
7.1	Trimanganese Tetraoxide Specifications .....	100
7.2	Trimanganese Tetraoxide Production Process .....	101
7.3	Trimanganese Tetraoxide Raw Material Properties .....	102
7.4	Trimanganese Tetraoxide Market .....	102
8.0	Manganese Sulphate Monohydrate.....	104
8.1	Manganese Sulphate Monohydrate Specifications .....	104
8.2	Manganese Sulphate Monohydrate Production Process.....	106
8.2.1	Production Processes.....	106
8.2.2	Impurity Removal Processes .....	113
8.3	Manganese Sulphate Monohydrate Raw Material Properties.....	115
8.4	Manganese Sulphate Monohydrate Market .....	115
9.0	Market Outlook.....	117
10.0	Manganese Pricing .....	121
10.1	Manganese Ore .....	121
10.2	Manganese Alloy.....	122
10.3	Electrolytic Manganese .....	124
10.4	Trimanganese Tetraoxide.....	126
10.5	Manganese Sulphate Monohydrate .....	126
	References .....	128
	Disclaimer.....	134

---

GOLDEN DRAGON CAPITAL LIMITED

Address: The Richmond, 18/A, Room A, 62c Robinson Road, Mid-Levels, Hong Kong, China  
Telephone: +852 4647 0122  
All correspondance to Email: [brendan@goldendragoncapital.com](mailto:brendan@goldendragoncapital.com)  
Website: [www.goldendragoncapital.com](http://www.goldendragoncapital.com)

# GOLDEN DRAGON CAPITAL

## Table of Figures

Figure 1: Manganese industry value chain.....	31
Figure 2: Manganese downstream products .....	32
Figure 3: Kalahari Manganese Field – regional geology (left) and mine locations (right) .....	33
Figure 4: Cross section through the Nikopol manganese deposit .....	34
Figure 5: Groote Eylandt simplified geological setting.....	35
Figure 6: Moanda manganese mineralisation .....	36
Figure 7: Manganese nodules on the seabed off the south-eastern USA.....	37
Figure 8: Manganese nodules from the South Pacific Ocean .....	38
Figure 9: Distribution of Manganese Deposits in Geological Time .....	38
Figure 10: World map showing location of major land-based manganese deposits (USGS, 2017) .....	40
Figure 11: Distribution of Global Manganese Mineral Reserves 2021 .....	41
Figure 12: Global Manganese Mineral Reserves 2010 to 2021 .....	41
Figure 13 : Global manganese production (2011-2021).....	42
Figure 14: Global manganese production by country 1994-2020 (thousand tonnes).....	43
Figure 15: Top 10 Manganese Ore Importing Countries in 2021 .....	44
Figure 16: Global manganese ore production by Mn grade specification 2015-2021.....	45
Figure 17: GEMCO project layout .....	48
Figure 18: GEMCO open cut mining operations schematic .....	49
Figure 19: GEMCO mining activities at D Quarry .....	50
Figure 20: East-west section through Wessels Mine showing mine access.....	51
Figure 21: Bord and pillar mining method .....	52
Figure 22: Wessels Mine Headframe .....	52
Figure 23: Wessels Mine underground hydraulic twin boom drilling machines .....	53
Figure 24: Wessels Mine underground rubber wheeled loaders .....	53
Figure 25: GEMCO processing plant .....	55
Figure 26: GEMCO processing plant layout .....	56
Figure 27: GEMCO concentrator process flow diagram.....	57
Figure 28: GEMCO SBP process flowsheet diagram.....	58
Figure 29: Aerial view of Mamatwan Mine — Sinter plant right foreground.....	59
Figure 30: Mamatwan Mine process flowsheet diagram .....	60
Figure 31: Aerial view of Moanda Industrial Complex .....	61
Figure 32: Schematic of submerged arc furnace used in ferroalloy production.....	64
Figure 33: Overview of the main reactions in the HC FeMn process .....	64
Figure 34: Eramet Sauda Ferromanganese Plant, Norway .....	66
Figure 35: Eramet Sauda Ferromanganese Plant flow chart of production process .....	66
Figure 36: COMILOG SiMn production process, Gabon .....	67
Figure 37: Eramet Kvinesdal Silicomanganese Plant, Norway .....	68
Figure 38: Eramet Kvinesdal Silicomanganese Plant flow chart of production process .....	68
Figure 39: Global crude steel production (million tonnes) 2017-2021 .....	70
Figure 40: Global ferroalloy production (thousand tonnes) 2017-2021 .....	71
Figure 41: Top 10 HC FeMn producing countries in 2021 .....	72
Figure 42: Top 10 HC FeMn importing countries in 2021.....	72
Figure 43: Top 10 Ref FeMn producing countries in 2021 .....	73
Figure 44: Top 10 Ref FeMn importing countries in 2021 .....	73
Figure 45: Top 10 SiMn producing countries in 2021 .....	74
Figure 46: Top 10 SiMn importing countries in 2021 .....	74
Figure 47: Electrolytic manganese metal flakes .....	75
Figure 48: Electrolytic manganese metal production process in Chongqing City, China.....	76
Figure 49: Manganese Metal Company selenium-free electrolytic manganese metal production process .....	79
Figure 50: Electrolytic manganese industry application fields .....	81
Figure 51: Distribution of Electrolytic Manganese Consumption .....	81
Figure 52: Global stainless steel meltshop production (2012-2021).....	82
Figure 53: Stainless meltshop production (slab/ingot equivalent) by grade (2009-2019).....	82
Figure 54: Electronic manganese metal production in China vs rest of the world 2015-2021 .....	83

GOLDEN DRAGON CAPITAL LIMITED

Address: The Richmond, 18/A, Room A, 62c Robinson Road, Mid-Levels, Hong Kong, China

Telephone: +852 4647 0122

All correspondance to Email: [brendan@goldendragoncapital.com](mailto:brendan@goldendragoncapital.com)

Website: [www.goldendragoncapital.com](http://www.goldendragoncapital.com)

# GOLDEN DRAGON CAPITAL

Figure 55: China electronic manganese metal production capacity (2012-2021).....	83
Figure 56: China electronic manganese metal market supply and demand (Mt) 2016-2021 .....	84
Figure 57: Major Chinese Electrolytic Manganese Metal Company Production Capacity (x10,000) .....	85
Figure 58: Ningxia Tianyuan Manganese Industry Group Co., Ltd No. 2 Manganese Metal Plant .....	85
Figure 59: Major Chinese electrolytic manganese metal company production 2019 to 2021 (x10,000).....	86
Figure 60: Top 10 EMM importing countries in 2021.....	87
Figure 61: Electronic manganese dioxide powder.....	88
Figure 62: Manganese ore processing steps to EMD (Galaxy Resources Limited proposed EMD 40,000tpa Project at Jiangsu, China in 2010). .....	91
Figure 63: Guizhou Hongxing Development Dalong Manganese Industry Co., Ltd Aerial view Production Facilities .....	92
Figure 64: Guizhou Hongxing Development Dalong Manganese Industry Co., Ltd EMD flowsheet .....	95
Figure 65: Global electrolytic manganese dioxide production capacity (2018).....	97
Figure 66: China Electrolytic Manganese Dioxide Production (2012-2018) .....	98
Figure 67: China electrolytic manganese dioxide production by product (2012-2018).....	98
Figure 68: Top 10 EMD exporting countries in 2021 .....	99
Figure 69: Top 10 EMD Importing Countries in 2021 .....	99
Figure 70: Trimanganese Tetroxide high purity grade powder .....	100
Figure 71: Trimanganese Tetroxide battery grade powder .....	100
Figure 72: Trimanganese Tetroxide production in China 2019 to 2021.....	102
Figure 73: Sinosteel Tianyuan Co., Ltd Trimanganese Tetroxide production and sales 2017 to 2021.....	103
Figure 74: LMO EMD price (CNY blue) vs battery grade trimanganese tetroxide price (CNY red) 2021 to 2022	104
Figure 75: Manganese sulphate monohydrate powder .....	105
Figure 76: Guizhou Dalong Huicheng New Materials Co., Ltd Aerial view Production Facilities .....	109
Figure 77: Guizhou Dalong Huicheng New Materials Co., Ltd high-purity manganese sulfate and manganese tetroxide flowsheet .....	112
Figure 78: Top 5 manganese sulphate producers (2021) .....	115
Figure 79: Global crude steel production .....	117
Figure 80: Global manganese ore production by country 1994-2020 (thousand tonnes).....	117
Figure 81: Global battery demand to 2035 by cathode material type .....	118
Figure 82: Major China ternary cathode material company market share (2021) .....	119
Figure 83: Manganese downstream industrial products and ore demand share .....	120
Figure 84: Manganese ore price 44% Mn & 37% Mn CIF Tianjin (Apr 2016 to Apr 2022) .....	121
Figure 85: Manganese Ore Price 44% Mn CIF China & 37% Mn FOB Port Elizabeth May 14 to Nov 17 .....	122
Figure 86: Price of manganese alloys in Europe 2016 to 2021 .....	123
Figure 87: Price of silicomanganese in China 2014 to 2022 (1 USD = 7 CNY).....	123
Figure 88: Correlation between manganese alloy and manganese ore 2013 to 2021 .....	124
Figure 89: EMM price in China from 2009 to 2021 (1 USD = 7 CNY) .....	124
Figure 90: EMM price in Europe from January 2017 to September 2021 .....	125
Figure 91: EMM price in China from August 2021 to August 2022 (1 USD = 7 CNY) .....	125
Figure 92: Battery grade trimanganese tetroxide price (CNY red) 2021 to 2022 .....	126
Figure 93: Agricultural Manganese Sulphate price in China from January 2021 to May 2022 (1 USD = 7 CNY)	126
Figure 94: HPMSM price in China from January 2017 to October 2022 (1 USD = 7 CNY) .....	127
Figure 95: HPMSM price in China from July 2019 to January 2023 (1 USD = 7 CNY) .....	127

# GOLDEN DRAGON CAPITAL

## List of Tables

Table 1: Manganese Properties and Characteristics.....	30
Table 2: Principal manganese minerals .....	32
Table 3: Composition of ocean-floor manganese nodules by ocean (%) .....	37
Table 4: Identified resources estimated for major land-based manganese deposits of the world .....	39
Table 5: Global Manganese Ore Production by Country 2021 .....	42
Table 6: Kalahari Manganese Field chemical composition of manganese ore .....	46
Table 7: Nikopol chemical composition of manganese ore .....	46
Table 8: Groote Eylandt chemical composition of manganese ore .....	46
Table 9: Moanda chemical composition of manganese ore .....	46
Table 10: GEMCO size fractions of ore and tailings.....	54
Table 11: Manganese alloy specifications.....	62
Table 12: ASTM specification for ferromanganese, ASTM A99-03(2014).....	62
Table 13: ASTM specification for silicomanganese, ASTM A483M-10(2010).....	62
Table 14: Concentration of impurity elements in manganese ferroalloys .....	62
Table 15: Breakdown of Global Manganese Alloy Production by Product Type .....	71
Table 16: Major Global Manganese Alloy Producers by Country (ex-China & India*).....	71
Table 17: Electrolytic metal manganese product China standard YB/T051-2015 .....	75
Table 18: Manganese Metal Company HPEMM battery grade specifications.....	80
Table 19: Nsuta Manganese Mine, Ghana carbonate ore chemical analysis.....	80
Table 20: Nsuta Manganese Mine, Ghana carbonate ore mineralogical analysis.....	80
Table 21: Metal element content of major stainless steel products .....	81
Table 22: Major Chinese electrolytic manganese metal company production capacity.....	84
Table 23: Major Chinese Electrolytic Manganese Metal Company Production Output (2021) .....	86
Table 24: Xiangtan Electrochemical Technology Co., Ltd zinc-carbon battery EMD specifications .....	88
Table 25: Xiangtan Electrochemical Technology Co., Ltd mercury-free alkaline battery EMD specifications .....	89
Table 26: Xiangtan Electrochemical Technology Co., Ltd primary lithium manganese battery EMD specifications .....	89
Table 27: Xiangtan Electrochemical Technology Co., Ltd lithium manganese oxide battery EMD specifications .	90
Table 28: Xiangtan Electrochemical Technology Co., Ltd high performance battery EMD specifications .....	90
Table 29: Hongxing Development EMD two-mine one-step 6,000t/a Raw Material Requirements.....	95
Table 30: Hongxing Development EMD two-mine one-step Manganese Raw Material Specifications .....	95
Table 31: Guizhou Hongxing Development Dalong Manganese Industry Co., Ltd EMD two-mine one-step Pyrite Raw Material Specifications .....	96
Table 32: Guizhou Hongxing Development Dalong Manganese Industry Co., Ltd EMD Product Quality Specification.....	96
Table 33: Major China EMD Production by Company 2020 .....	99
Table 34: Manganous manganic oxide for soft magnetic ferrites China standard GB/T 21836-2008.....	100
Table 35: Sinosteel Tianyuan Technology Co., Ltd Timanganese Tetroxide index for lithium manganate .....	101
Table 36: Comparison of Trimanganese Tetroxide production methods.....	101
Table 37: Comparison of electrolytic manganese dioxide and trimanganese tetroxide indicators .....	103
Table 38: Manganese sulphate monohydrate agricultural grade China standard NY/Y 1111-2006.....	105
Table 39: Manganese sulphate monohydrate industrial grade China standard HG/T 2962-2010.....	105
Table 40: Manganese sulphate monohydrate high purity specifications .....	106
Table 41: Manganese sulphate monohydrate production methods from manganese ore .....	107
Table 42: Guizhou Dalong Huicheng New Materials Co., Ltd 30,000t/a HPMSM and 6,000t/a Mn <sub>3</sub> O <sub>4</sub> Raw Material Requirements.....	112
Table 43: Guizhou Dalong Huicheng New Materials Co., Ltd HPMSM Final Product Specifications .....	113
Table 44: Guizhou Dalong Huicheng New Materials Co., Ltd Mn <sub>3</sub> O <sub>4</sub> Final Product Specifications .....	113
Table 45: Major China HPMSM High-purity manganese sulfate current production capacity and planned expansion.....	116
Table 46: Major China ternary cathode material companies (2021).....	118
Table 47: Major China LMFP cathode material companies (2021) .....	119