PROSPECTS FOR SULPHUR SUPPLY, DEMAND

AND TRADE WORLDWIDE

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The trend in sulphur production worldwide has been for by-product elemental sulphur and sulphuric acid supply to grow faster than the overall market. The result has been displacement of mined elemental sulphur and pyrite.

Since 1980, mined sulphur production has fallen by nearly 15 million t.p.a. The use of pyrite outside of China has fallen by 6 million t.p.a. sulphur-equivalent. The largest voluntary sulphur production that remains is the use of over 4 million t.p.a. sulphur-equivalent of pyrite in China.

China has recently begun large-scale importation of elemental sulphur to substitute domestic pyrite. Use of elemental sulphur reduces the burden of transporting low-grade pyrite and has less adverse impact on the environment. Imports of elemental sulphur by China are heading for over 3 million tonnes in 2000 – up from just 0.8 million tonnes in 1997.

This paper examines trends in elemental sulphur supply/demand in an attempt to forecast whether there is sufficient sulphur available for China to increase elemental sulphur imports further.

WORLD SULPHUR PRODUCTION

World production of elemental sulphur will be around 42 million tonnes in 2000. Of this, 95% or nearly 40 million tonnes will arise as a by-product mainly from the processing of sour natural gas and sour crude oils. By-product sulphur is known collectively as 'recovered sulphur'. The balance of 5% of current production comes from the mining of naturally-occurring sulphur deposits and is known as mined sulphur. Recovered sulphur production has been growing faster than the overall market causing mined sulphur production to be cut back.

WORLD ELEMENTAL SULPHUR PRODUCTION
(million tonnes)

	1980	**1985**	**1990**	**1995**	**2000**
Mined	17.0	15.3	13.6	5.8	2.2
Recovered	19.2	20.9	25.5	31.0	39.6
- gas	12.7	13.9	14.9	17.9	22.5
- oil	5.6	6.1	9.5	11.9	16.0
- other	0.9	0.9	1.1	1.3	1.2
TOTAL	**36.2**	**36.1**	**39.1**	**36.9**	**41.9**

There are massive reserves of sulphur associated with hydrocarbon deposits worldwide, but particularly in western Canada, the Caspian basin and the Middle East. Rapid growth in demand for oil and gas, including imports of liquefied natural gas (LNG), is encouraging investment. Projects or trends can be identified that will add 15 million t.p.a. to recovered sulphur production over the next ten years. There is also potential for higher mined sulphur production, though this will be dictated by the marketplace. Longer-term production is more difficult to forecast. Projects have a relatively short lead-time between resources being identified and production commencing. Nevertheless, a forecast of likely trends beyond 2010 would include further strong growth.

The forecast below shows sulphur production growing at an average annual rate of over 3% up until 2010.

WORLD ELEMENTAL SULPHUR PRODUCTION FORECAST
(million tonnes)

	2000	**2005**	**2010**	**2015**	**2020**
Mined	2.2	2.3	2.3	2.3	2.0
Recovered	39.6	48.0	54.6	61.5	70.5
- gas	22.5	26.3	30.9	35.0	40.0
- oil	16.0	18.5	20.0	22.0	24.5
- other	1.2	3.2	3.7	4.5	6.0
TOTAL	**41.9**	**50.3**	**57.0**	**63.8**	**72.5**

The main assumptions in the forecast are as follows :

Mined sulphur

There are now only two locations left in the World where sulphur is mined on a commercial scale, but two other deposits could be of significance to the future. Both current commercial operations are in Poland. Two mines in Poland provide over 1 million t.p.a.. A mine with a 2 million t.p.a. rated capacity in the United States suspended production in September 2000, but will be kept on stand-by and would be able to restart if required. The other country with a significant mined sulphur production potential is Iraq. Iraq is currently isolated from the international community. When allowed to trade normally, Iraq could produce up to 2 million t.p.a. Of the three, only Iraq would be competitive in the China market. Iraq's costs are well below current Middle East export price levels.

Gas-recovered sulphur

Growth in gas-recovered sulphur production is forecast to come primarily from two areas, the Middle East and the Caspian Basin. In the Middle East, the projects that will add significantly to supply in the current decade are in Abu Dhabi, Iran, Saudi Arabia and, to a lesser extent, Qatar. The Caspian Basin developments include current operations at Astrakhan and Orenburg, in Russia, and Tengiz, in Kazakhstan ; a project underway at Karachaganak in Kazakhstan ; and potential new projects based on recent oil discoveries in the north Caspian Sea. New production in the Middle East would be readily accessible to the China market. The Caspian Basin is currently too remote to serve export markets.

In ***Abu Dhabi***, ADNOC has five stages of development of onshore gas at Habshan planned. Stage 1 came on stream at the end of 1997 with a production of 0.6 million t.p.a. Stage 2 is due at the end of this year with an additional 0.45 million t.p.a. Stage 3 is planned for 2003 with 0.8 million t.p.a. sulphur output. The next two stages, scheduled for 2005 and 2007, add progressively more sulphur as the gas exploited becomes sourer. Stage 4 would add 1.3 million t.p.a. sulphur production while stage 5 adds 1.5 million t.p.a. If further gas is required, the next level for exploitation would by itself give rise to 5 million t.p.a. of sulphur. At present, this is not expected due to the problem that disposing of the sulphur would create. A more likely option would be for Abu Dhabi to import gas from neighbouring Qatar.

Iran's three current sources of gas-recovered sulphur are all expecting to see production rise, but the main growth in the current decade will come from a new development at Assaluyeh. Gas from the offshore Soth Pars filed is being offered for exploitation in 25 separate stages each producing 1,000 million ft^3/day of gas and 200 t.p.d. of sulphur. The first three stages are under construction. Another five have been awarded. The next three are being prepared for tender. The initial gas is being developed for domestic use and export by pipeline to Turkey. Later stages will depend largely on the growing market for LNG. With China set to become a major importer of LNG, sulphur production will be encouraged.

Saudi Arabia currently produces 1.5 million t.p.a. of gas-recovered sulphur from three plants. Debottlenecking of these plants should enable production to reach 2 million t.p.a. while two new plants are now under construction or subject to contract negotiations for construction. Gas-recovered sulphur production in Saudi Arabia can increase by 1 million t.p.a. before the end of the current decade.

Elsewhere in the Middle East, there are smaller developments in ***Qatar*** and ***Kuwait***, while more sour gas sulphur production can be expected from ***Iraq*** when the economy returns to normal. The smaller producers can add around 0.5 million t.p.a. by 2010.

The recent entry of ***Russia*** to the sulphur market results from the growth in production at the sour-gas processing plant at Astrakhan. Astrakhan produced 3.4 million tonnes in 1999, easily the highest production from a single operation. Two more lines are planned to give a total of eight, with production set to rise in the coming years to 4.5 million t.p.a.

In ***Kazakhstan***, Tengizchevroil has been producing sulphur from sour associated gas at Tengiz since 1991. Output reached 1.07 million tonnes in 1999 and is set to reach 1.4 million tonnes next year. Thereafter, there should be a steady progression with reserves sufficient to support an operation that would give rise to 3.5 million t.p.a. by 2015. North of Tengiz, a consortium led by British Gas is developing a sour-gas processing plant at Karachaganak with an initial output of 0.4 million t.p.a. starting in 2002 and a second stage raising production to 1.2 million t.p.a. soon after. The biggest development in the Caspian Basin may come elsewhere, however. Results of drilling in the north Caspian Sea have yet to be released, but some rumours have been circulating suggesting reserves at least three times as large as those at Tengiz. The geological conditions would suggest that the reserves in the north Caspian would also be as sour as Tengiz.

Oil-recovered sulphur

Much of the World's production of crude oil is contaminated with compounds of sulphur. Because of the smell of the sulphur compounds, crude oil that contains sulphur is termed 'sour'. Some of the sulphur is released as gaseous H_2S when oil is distilled in a refinery. More is released in refinery processes, such as cracking, that aim to break down the heavier fractions to produce more light fractions. The sulphur that is not released as H_2S remains in the distillates, mostly in the heavier fractions such as fuel oils and residual asphalt and coke. Increasingly, refineries are required to remove sulphur from combustibles, such as diesel, to prevent urban pollution. Processes to remove sulphur, such as hydro-desulphurisation, further add to the sulphur released during refining. It is now general practice for refineries throughout the World to recover sulphur from the H_2S emissions rather than release it to the atmosphere as SO_2. There are still refinery products which contain sulphur and which do not pose a threat to the environment. The sulphur contained in petroleum coke used by the aluminium industry is a benefit. There is no problem with sulphur in asphalt. As yet, there are no restrictions on the sulphur-content of bunker fuels, used to power ships at sea. Some high-sulphur petroleum coke is used for power generation where SO_2 is removed as gypsum.

The amount of sulphur produced from oil depends on the amount of crude used, its sulphur-content, and the proportion recovered. Growth in oil consumption has been only modest in recent years and is expected to remain modest. The average sulphur-content of crudes used is increasing only slowly. The main growth in sulphur production is resulting from the increasing need to remove sulphur from refinery products. The amount of sulphur present in the crude used that is recovered at the refinery has now reached around 70% in the United States and Japan. West Europe is not far behind. Emerging markets, including South Korea and Thailand, now legislate limits on diesel that are close to those in more advanced countries. India is now showing the strongest growth in oil-recovered sulphur production following new limits imposed at the end of 1999.

There are now few countries left that allow significant amounts of sulphur to be emitted at refineries or to be moved out of refineries in products for combustion.

Other recovered sulphur

Apart from conventional refining of crude oil, there are two locations where extra-heavy oil or tar deposits are exploited or will be exploited. In both cases, significant sulphur production results. This source of sulphur is considered separately from oil-recovered sulphur as it is project-specific.

In Northern Alberta, ***Canada***, two companies mine tar which is upgraded near to the source to produce a crude that can be moved to the market by pipeline. Both producers have expansions underway. A third project has been given the go-ahead. In the third project, the tar is first dissolved in lighter fractions in order to be able to move it by pipeline to a conventional refinery. The solvent is separated at the refinery for returning to the source of the tar. Current production from tar in Canada is 0.7 million t.p.a. This is forecast to reach 2.6 million t.p.a. by 2010.

A similar heavy crude is found in the Orinoco Basin of ***Venezuela***. A number of projects are underway to bring this crude to the market. In Venezuela, the crude will be diluted with solvent before piping to upgrading facilities on the coast. The complex that will treat the crude will give rise to 0.6-0.7 million t.p.a. sulphur.

WORLD SULPHUR CONSUMPTION

The world market for elemental sulphur in 2000 is expected to be between 40 and 41 million tonnes. The main use, accounting for 89% of consumption is for the production of sulphuric acid. The main use of sulphuric acid is in the manufacture of phosphate fertilizers.

Historically, changes in elemental sulphur consumption roughly equated to changes in the sulphur requirement of the fertilizer industry. Growth in non-fertilizer sulphuric acid consumption was offset by growth in smelter acid production. The growth in the use of pyrite by the fertilizer sector in China was offset by displacement of pyrite by elemental sulphur elsewhere in the World.

WORLD ELEMENTAL SULPHUR CONSUMPTION (million tonnes H_2SO_4/S)					
	1980	**1985**	**1990**	**1995**	**2000**
H_2SO_4 demand	145.3	150.8	159.0	148.4	166.1
- fertilizer	87.9	93.7	99.0	89.5	92.3
- non-fertilizer	57.4	57.0	60.0	58.9	73.8
H_2SO_4 supply	145.7	150.6	156.1	143.8	161.0
- elemental	92.2	93.9	101.8	92.7	104.6
- pyrite	25.2	24.6	24.9	20.2	14.6
- other	28.4	32.1	29.4	30.9	41.8
elemental consumption					
- acid	31.8	32.7	35.0	31.5	36.0
- non acid	5.7	5.3	4.4	4.1	4.6
ELEMENTAL SULPHUR CONSUMPTION	**37.4**	**38.0**	**39.4**	**35.6**	**40.6**
P_2O_5 CONSUMPTION	**33.6**	**34.2**	**37.4**	**32.8**	**33.9**

The market since 1997 has been different in two important respects. First, non-fertilizer sulphuric acid consumption is growing faster than smelter acid production due to changes in the processes used by the copper and nickel industries. Second, China is no longer increasing pyrite consumption. Instead, there is a rapid displacement of China's pyrite consumption by imported elemental sulphur.

There is one other factor to address in the longer-term forecast and that is plant-nutrient-sulphur.

Trends in phosphate fertilizer consumption and production

Phosphate fertilizer consumption is forecast to grow at around 2.6% per year up until 2005, 2.3% between 2005 and 2010 and 2.0% thereafter. Growth is expected to exceed population growth as farming becomes more intensive and diets improve. It can be roughly assumed that all growth will come from products based on phosphoric acid, requiring on average 0.9 tonnes of sulphur per tonne of P_20_5. From a consumption of 34 million tonnes P_20_5 in 2000, the additional sulphur requirement by 2010 would be very close to 10 million tonnes.

Trends in non-fertilizer sulphur and sulphuric acid consumption, excluding ore leaching

There have been very few new sulphur-burning sulphuric acid plants built in recent years to supply sulphuric acid for chemicals, pigments, fibres and other general industrial uses.

Those that have been seen, for example in Brazil, Thailand and Malaysia, are of comparable size to plants closed in recent years in North America and West Europe. Non-acid uses, excluding fertilizer sulphur, are showing no growth. It would be surprising if general industrial uses of sulphur and sulphuric acid grow by 1 million tonnes sulphur-equivalent over the next twenty years.

Ore leaching

The only non-fertilizer use that could significantly affect the sulphur balance is ore-leaching and, particularly, leaching nickel-laterite ores. Until 1999, the only exploitation of laterite ores using acid-leaching took place in Cuba, where around 0.8 million tonnes of sulphuric acid is consumed. Three projects were completed in Western Australia in 1999 with a combined capacity to use 2 million t.p.a. of sulphuric acid. Although all three encountered severe problems with the equipment and materials used in their construction, the process has essentially been proved and nickel is being produced from laterite ores at significant cost advantages compared to conventional smelting of sulphide ores. Several of the World's major mining investment companies have moved into projects to develop nickel-laterite deposits as have most of the current major producers of nickel. On average, around 10 tonnes of sulphur are consumed in the manufacture of one tonne of nickel from nickel-laterite leaching. The current nickel market is around 1.2 million t.p.a. If half of the market was supplied from nickel-laterite, a market for around 6 million t.p.a. of sulphur would develop. There are sufficient projects to suggest that that amount of sulphur consumption can be reached, though the timing is difficult to predict. It is assumed that 3 million t.p.a. of sulphur is being used by the nickel industry in 2010 reaching 6 million t.p.a. by 2020.

Copper-leaching is an important and growing use for sulphuric acid, but mainly based on smelter acid. Although there have been projects investigated for the construction of sulphur-burning sulphuric acid plants in Chile and the Western United States, use of elemental sulphur for leaching copper ores remains very limited. Growth in elemental sulphur consumption for copper ore-leaching is not expected to be significant.

Prospects for further displacement of pyrite

After the closure of Fertiberia's 1 million t.p.a. pyrite sulphuric acid capacity at the start of 2000, the only remaining significant opportunity for displacement of pyrite is in China. China's production of sulphuric acid from pyrite peaked in 1997 at around 5 million t.p.a. sulphur-equivalent. A significant part of this has already been displaced by elemental sulphur. The process of change has not ended, but the remaining users are less vulnerable to competition from imported elemental sulphur. It is assumed that 2 million t.p.a. sulphur-equivalent of pyrite consumption will remain in China in 2010 requiring another 1.5 million t.p.a. growth in elemental sulphur consumption for pyrite substitution. Another 0.5 million t.p.a. of pyrite use can be taken out from consumption outside of China by 2010. Pyrite use is unlikely to be significant in 2020.

Plant-nutrient-sulphur

While the need for sulphur as a fertilizer is becoming widely accepted, the alternatives, such as adding gypsum or by-product ammonium sulphate to a fertilizer formulation, have limited the market for elemental sulphur. There is probably around 1.0 million t.p.a. of sulphur used as elemental sulphur, synthetic ammonium sulphate, ammonium thiosulphate, etc., where elemental sulphur is consumed to provide plant-nutrient-sulphur. The market is growing strongly, but it would take an 8% per year growth to add another 1 million t.p.a. by 2010. This is seen as the maximum. The forecast for 2020 is put in at 4 million t.p.a.

WORLD ELEMENTAL SULPHUR CONSUMPTION FORECAST
(million tonnes)

	2000	**2005**	**2010**	**2015**	**2020**
Phosphate fertilizers	25.6	29.8	34.1	38.3	42.8
Nickel	0.2	1.5	3.0	4.5	6.0
Pyrite substitution	0.0	1.5	2.0	3.0	4.0
Plant-nutrient-sulphur	1.0	1.5	2.2	3.2	4.7
Other	13.8	14.0	14.3	14.5	14.7
TOTAL	**40.6**	**48.3**	**55.6**	**63.5**	**72.2**

TOTAL	**41.9**	**50.3**	**57.0**	**63.8**	**72.5**

SUPPLY/DEMAND BALANCE

WORLD ELEMENTAL SULPHUR BALANCE
(million tonnes)

	2000	**2005**	**2010**	**2015**	**2020**
supply	41.9	50.3	57.0	63.8	72.5
demand	40.6	48.3	55.6	63.5	72.2
BALANCE	**1.3**	**2.0**	**1.4**	**0.5**	**0.3**

The balance between supply and demand shows a surplus throughout the forecast though the surplus is less than the production at the Syncrude tar-sands plant in Northern Alberta and at the Tengizchevroil sour-gas processing plant in Kazakhstan. Neither Syncrude nor Tengizchevroil currently market their output due to their remote locations. In order to meet the requirements of China and the rest of the World market, the remote production will have to be brought to the market.

In the first instance, supply can also come from inventory. Inventory in Canada currently exceeds 12 million tonnes. Of this, 9 million tonnes is at plants which currently export. There is also significant inventory in France, Russia, Kazakhstan and Iraq. In total, over 10 million tonnes can be added to World supply over the next 20 years through programmes to reduce producer inventory.

The cost of accessing inventory or remote production is higher than the cost of supply from current export sources. The main concern, however, for the remote producers is that adding their production to the World market would result in prices falling to the point where selling is no longer economic. There is a significant cost involved in establishing infrastructure for exports from Syncrude and Tengiz.

If China wants to ensure adequate future supply of sulphur at affordable prices, it would be a good idea to establish a means to offer long-term contracts to marginal supply sources to ensure that their production becomes a regular component of the World market.