SOCIO-ECONOMIC ANALYSIS

Legal name of applicant(s):	BolidenMineral AB
Submitted by:	Boliden Mineral AB
Substance:	Sodium dichromate, EC 234-190-3, CAS 7789-12-0 and 10588-01-9
Use title:	The use of sodium dichromate in copper/lead separation in concentrators handling complex sulphide ores.
Use number:	1

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DECLARATION

We, Boliden Mineral AB, request that the information blanked out in the "public version" of the Socio-Economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today (2015-05-13) the information is not publicly available, and in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature:

Staffan Sandström, Director Technology

Date, Place:

2015-05-13

Boliden

1. SUMMARY OF SOCIO-ECONOMIC ANALYSIS

This report examines whether the socio-economic benefits of the continued use of sodium dichromate by Boliden outweigh the associated risks to human health and the environment. Boliden uses sodium dichromate in copper/lead separation in the Boliden Area and Garpenberg concentrators. Sodium dichromate is used to suppress lead when treating the sulphide ore containing both copper and lead. There is no sodium dichromate left in the products that the concentrators sell downstream to the smelters.

If the concentrators could no longer use sodium dichromate, they would switch to using the substance dextrin in the copper/lead separation step. The process change-over at the concentrators would lead to poorer separation capacity, resulting in lower-quality concentrates. The lower-quality concentrates would mean less income for the Boliden Area and Garpenberg concentrators. There would be economic losses to the Rönnskär smelter as well, due to the higher copper content in the lead concentrates produced by Garpenberg. In addition, there would be increased production disruption risk to Rönnskär due to uncertainty in the future sourcing arrangements. The total economic impact to the three units would be [redacted] which is equivalent to between [redacted] [redacted] However, this cost only represents those economic impacts that are easily quantifiable. The increased business uncertainty from the changing sourcing arrangements has not been monetised but should be considered as a significant business risk.

The main benefit of the non-use scenario is the reduced exposure to a carcinogenic substance. The health impacts on workers and the general population related to the carcinogenicity due to the use of sodium dichromate by Boliden ranged from [redacted].

By comparing the human health impact with the socio-economic impacts, the report finds that the net benefit of Boliden's continued use of sodium dichromate is between [redacted] which is equivalent to between [redacted] This conclusion is further supported by a comprehensive sensitivity analysis.

The report concludes that the benefits of Boliden's continued use of sodium dichromate are substantial and considerably outweigh the associated risks. Based on the best available current knowledge and the company's own R&D efforts over the last 30 years, it is highly unlikely that any new alternatives could be found and industrialised during the expected lifetime of the mines.

2. AIMS AND SCOPE OF SEA

2.1. Aims of SEA

Boliden uses sodium dichromate (EC 234-190-3; CAS 7789-12-0 and 10588-01-9) as a process chemical at the concentrator of the Boliden Area and the concentrator of Garpenberg in Sweden. Sodium dichromate is classified as carcinogenic (category 1B), mutagenic (1B) and toxic for reproduction (1B). It is not considered a threshold substance and, therefore, the adequate control of risks arising from the applied for use of the substance cannot be demonstrated in accordance with Annex I, section 6.4 of Regulation (EC) No 1907/2006.

The Analysis of Alternatives (AoA) has demonstrated that there are no suitable alternative substances or technologies for the applied for use. The aim of this report is to assess whether the socio-economic benefits of the continued use of sodium dichromate outweigh the risks to human health and the environment.

Background

Boliden is a Nordic metals company with core competencies in exploration, mining, smelting and metals recycling. With five mining areas and five smelters across Europe, Boliden is an active international player in the field of mining and selling metals. The map in Figure 1 shows Boliden's mining areas (dark grey), smelters (light grey) and offices (orange). The mines undertake exploration, mining, concentration and concentrate sales, while the smelters treat and refine the concentrates, produce metals and sell the metals and by-products. This application for authorisation covers the use of sodium dichromate in copper/lead separation of complex ores at the two mining areas of Boliden Area and Garpenberg:

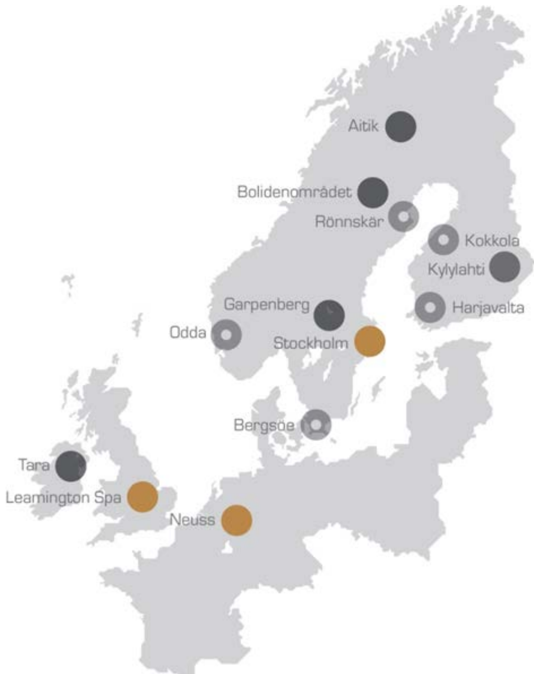


Figure 1. Map of Boliden's operations

a. The <u>Boliden Area</u> consists of a concentrator and five nearby mines.
b. <u>Garpenberg</u> consists of a concentrator and a mine.

The Boliden Area mines and concentrator, Garpenberg mine and concentrator and the Rönnskär smelter in Sweden belong to the same legal entity Boliden Mineral AB. In this report Boliden will be used when referring to the company.

Boliden Area's and Garpenberg's mines have complex ores, meaning that they contain several different metals that have to be separated before they can be smelted. The separation takes place at the concentrators located in close vicinity to the mines. In this process, the ore is crushed and grinded in several stages. After that, the metals are separated through a flotation method where process chemicals and air are injected to make different minerals float. Sodium dichromate is used to depress lead when treating the ore containing both copper and lead. There is no sodium dichromate left in products that the concentrators sell downstream to the smelters.

2.2. Scope of SEA

2.2.1 **Supply chain and geographical scope of SEA**

This section outlines Boliden supply chain in relation to sodium dichromate, lead concentrates and copper concentrates. It is an essential starting point for defining the geographical scope of the SEA and for analysing what impacts any changes to Boliden‘s availability of sodium dichromate will have on society.

Upstream supply chain

Ores: All ores processed at the Boliden Area and Garpenberg concentrators come from Boliden’s own mines.

Sodium dichromate: Boliden’s supplier of sodium dichromate is a big international chemical trading company with business operations worldwide. The socio-economic impact on it is therefore expected to be marginal in the non-use scenario.

Downstream supply chain

Copper concentrates: The copper concentrates from both Boliden Area (currently approximately 22,000 tonnes annually) and Garpenberg (approx. 4,000 tonnes annually) are delivered to Boliden’s smelter in Rönnskär in northern Sweden.

Lead concentrates: At the moment, Boliden Area sells its lead concentrate (currently approximately 8,000 tonnes annually) to an external buyer. There is a long-term agreement in place for this. Garpenberg sells its lead concentrate both to the Rönnskär smelter (approx. 40,000 tonnes annually) and to an external buyer (approx. 22,000 tonnes annually). Rönnskär’s lead smelting process is optimised specifically to treat concentrates of the qualities supplied by Garpenberg, containing low levels of copper.

Geographical scope

Boliden’s supply chain in relation to sodium dichromate, lead concentrates and copper concentrates is mapped out in Figure 2 below. The geographical scope of the socio-economic analysis is circled by the dashed blue line. As the non-use scenario will have no significant impacts upstream in the supply chain, the analysis in this report will focus on the impacts on the concentrators and the smelters that they sell the copper and lead concentrates to. As will be explained further in Chapter 2.5, Rönnskär is the only smelter that will be affected economically by the non-use scenario. The exposure to sodium dichromate is restricted to Boliden Area and Garpenberg concentrators.

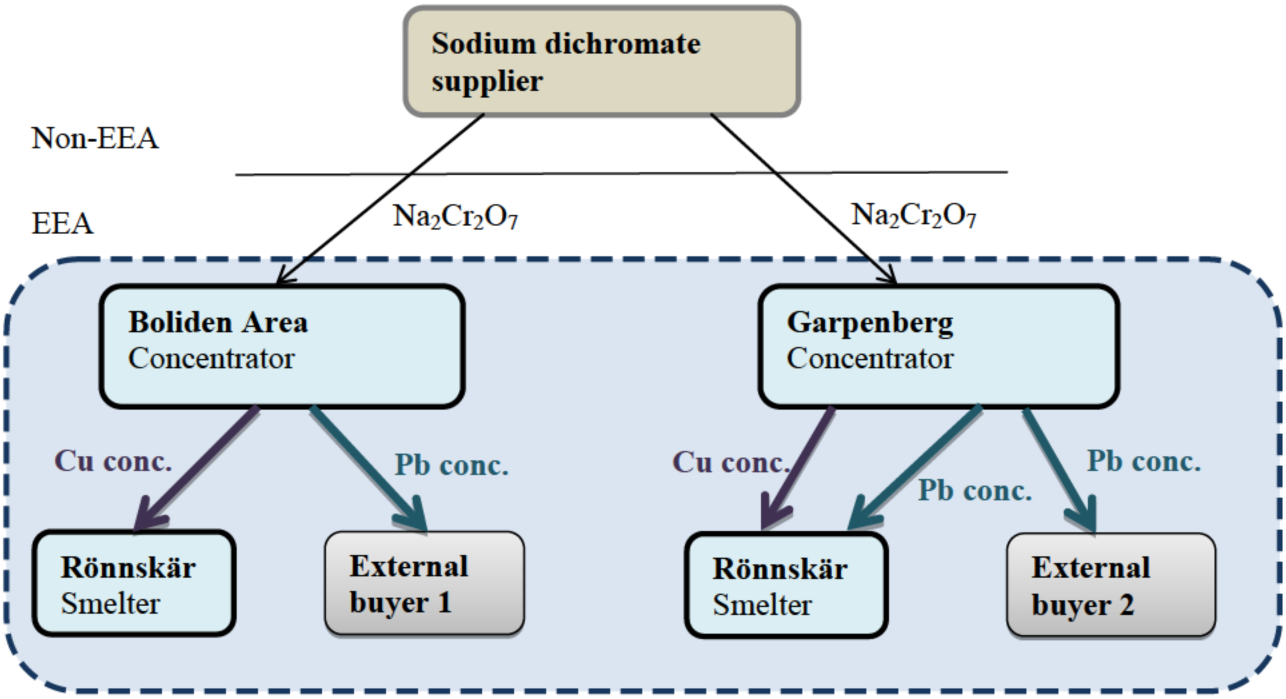


Figure 2. Boliden's supply chain for sodium dichromate ($Na_2Cr_2O_7$), copper concentrates (Cu conc.) and lead concentrates (Pb conc.) with the geographical scope circled by the dashed blue line

2.2.2 Temporal scope of SEA

The lifespan of the mines is an important temporal factor for the socio-economic impacts to be considered since the process of using sodium dichromate is optimised to the specific ore types extracted from these mines. When the mineral source is depleted, the use of sodium dichromate will naturally also cease in the baseline scenario. The estimated lifetimes (Table 1) are based on the size and geological type of known mineral deposits but they may most likely change as further exploration is undertaken in the area surrounding the mine. If other mineral resources are found to be technically, economically and legally feasible to extract, the lifetime of the mine may be extended. According to the current production plan, the Garpenberg mine's lifespan is expected to end in 2033. In Boliden Area, the expected lifespan of the Maurliden Västra mine is until the end of 2023, while that of the Kristineberg and Renström mines is until the end of 2027.

Table 1. End of mines' expected lifetime

Boliden Area			Garpenberg
Maurliden Västra mine	**Renström mine**	**Kristineberg mine**	**Garpenberg mine**
2023	2027	2027	2033

From an exposure point of view, it is important to keep in mind that the human health and environmental impacts may materialise long after the use of the substance has ceased. However, the majority of the Cr(VI) is converted to Cr(III) once in the environment. Furthermore, Cr(III) is not considered a carcinogenic, mutagenic and reproductive toxic oxidation stated of Cr metal. Therefore it can be assumed that the health and environment impacts will stop when the use of sodium dichromate ceases.

Accordingly, in order to consider relevant impacts during the remaining estimated lifetime of all the mines, the **time period of 2017 to 2033 has been chosen for the SEA**. The 17 year time period will run from the start of 2017 (when Boliden is expected to stop using sodium dichromate in preparation for the sunset date later in the year) until the end of 2033 (which is the final year that any of the relevant mines is expected to be operational).

2.3. Definition of "applied for use" scenario

This chapter provides background information about the two mining areas, describes their business model and discusses their market outlook.

2.3.1 The mines and related sodium dichromate usage

The Boliden Area consists of three underground mines and two open-pit mines with complex ore containing zinc, copper, lead, gold and silver. One of the underground mines contains tellurium, it has however no copper, zinc or lead. In 2012, the Boliden Area employed 483 people with approximately 100 of them working at the concentrator. Currently the three mines whose ores are treated with sodium dichromate at the concentrator account for an annual milled tonnage of approximately 1.2 Mtonnes of ore. The milled tonnage is expected to stay at a relatively stable level until the end of 2023, which is the end of the Maurliden mine's lifetime. After that, the milled tonnage will start decreasing until the end of the other two mines' lifetime in 2027.

The Garpenberg site has complex ore containing relatively high levels of zinc, silver and lead, with smaller amounts of copper and gold. The mine has continuously been increasing its production. The latest expansion project (launched in 2011), which includes new underground facilities, a new concentrator and new infrastructure, will increase the annual milled tonnage from 1.5 to 2.5 Mtonnes of ore by the end of 2015. In 2012, Garpenberg had 366 employees and further employed approximately 150 contractors.

For every mine there is a detailed production plan, which specifies the expected yearly production volumes and metal grades.

2.3.2 The business model

The metals market constitutes two supplementary markets: the concentrates market between mines and smelters, and the finished metals market between smelters and metal consumers. This application for authorisation concerns the concentrates market.

To the extent possible, Boliden Area's and Garpenberg's concentrates are sold to Boliden's own smelters. The contracts between Boliden's own mines and smelters are nevertheless made at market terms, with the base metal prices set at the London Metal Exchange (LME) and the precious metal prices set at the London Bullion Market Association (LBMA) used as a reference to price the payable metals in the concentrates. The LME and LBMA prices are determined by global supply and demand.

There are advantages in trading internally with other units within Boliden, for example in terms of aligning plans and investments as well as exchanging technical expertise and lowering transport costs. Most importantly, the internal purchasing also results in more reliable deliveries. As the mining industry is capital intensive, which processes and trades high volumes, the long-term planning and stability are key factors to control cost and risks. Since the prices are fixed at the international metal exchanges, effective cost control is the main way for Boliden to influence its own business success. The mining company's competitiveness is largely dependent on its capacity to extract metals from raw materials and on its cost efficiency.

The income model[i] for the concentrators and smelters

The price of a concentrate sold by the mine is calculated based on the main metal content and their prices being set at the LME and LBMA. The price of a concentrate is also affected by the content and qualities of impurities and subsidiary metals. From the metal prices a treatment and refining charge (TC/RC) is deducted for the benefit of the smelters. The TC/RC is a reflection of the global balance of mines' production and smelters' demand for raw materials. The TC/RC is also influenced by the composite of the concentrate in question, e.g. the more demanding it is to extract a metal, the higher the TC/RC.

One major income source of the smelters is the TC/RC. In addition, the commercial contract between a mine and a smelter defines the amount of contained metal in the concentrate the smelter needs to pay for. If the smelter is able to extract metal(s) above the payable quantity as specified in the agreement, they can sell them at the market price (so-called "free metals"). The smelter can also sell any by-products (the subsidiary metals contained in a concentrate) at the market price. The smelters sell the finished metal at the global LME and LBMA prices plus a regional metal premium. The regional metal premium is based on regional supply and demand, and is paid by customers on top of the LME and LBMA prices. The income model for mines and smelters is illustrated in Figure 3.

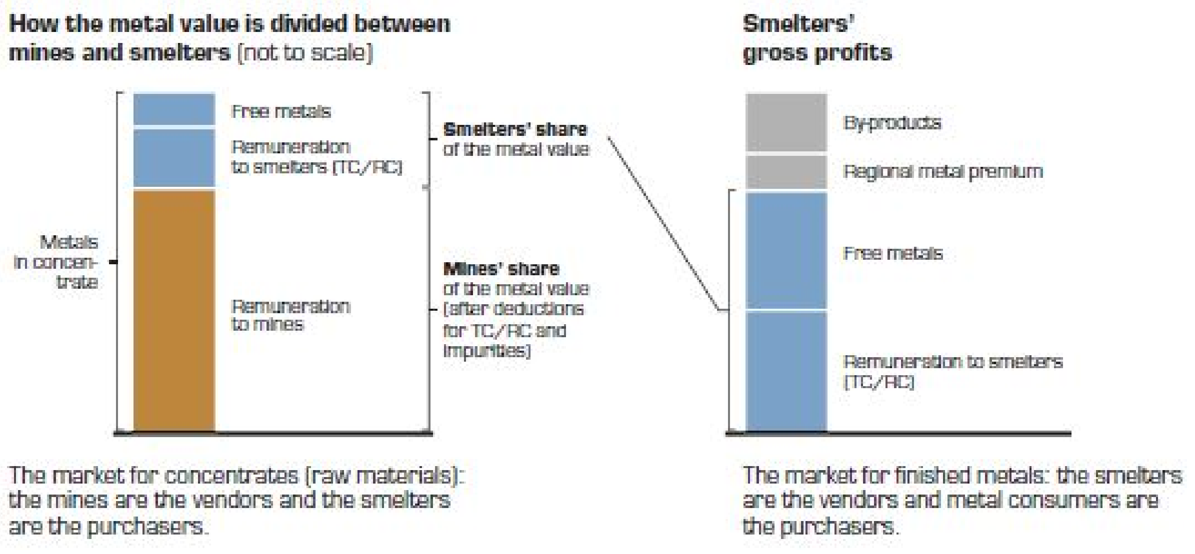


Figure 3. The income model for mines and smelters (source: Boliden[ii])

Normally mines bear the cost of delivering concentrates to the smelters. However, if a specific quality is in high demand, the mines can ask for a freight-compensation due to the higher freight cost compared to their alternative markets. In such cases transportation costs are paid by the smelters.

The contract between a mine and a smelter is usually negotiated using the settlement terms of the world's major miners and smelters as a benchmark. However, over the last years the global market has become more differentiated based on concentrate characteristics and smelter capabilities. The metals and impurities contained in the concentrates are valued as a package, and evaluated taking into account the capacity and ability of the smelters.

The concentrates' contracts are briefly described below. For more detailed information about the income model and the concentrates contracts, please see Annex 2 and Annex 3.

Copper concentrates

In terms of copper concentrates, the contracts between mines and smelters usually reflect the payment of the copper, gold and silver content of the concentrates. Other metals are usually not paid for, but may instead be penalised if they affect the recovery of copper or may cause problems during smelting and refining. For example, zinc, nickel, cobalt, alumina and tellurium may be penalised if they are present above a fairly low level in the concentrate. Elements that have health and safety risks, can damage equipment and/or have limited commercial value may also be penalised even if they can be recovered. Examples include lead, arsenic, antimony and mercury.[iii]

Lead concentrates

The lead concentrate contracts between mines and smelters normally reflect the payment of the lead, gold and silver content of the concentrates, as well as the quality of the concentrate determined by its chemical assay. The penalised elements of the lead concentrates would usually include antimony, arsenic, bismuth, mercury and zinc. The allowable quantities of these elements depend largely on the smelters' ability and willingness to handle high levels of impurities. The impurities all incur extra costs, either from required additional refining processes or from reduced recovery of lead and precious metals.[iv]

2.3.3 **Market forecasts for copper and lead**

Global demand for metals is driven by population growth, urbanisation and economic development. In particular, the rapid urbanisation in emerging economies requires increased investments in housing and infrastructure, which in turn leads to an increased demand for metals. There are signs indicating that the demand will continue rising, which means that the price is also expected to increase in the future.

Copper is one of the world's most important metals, as it is a good conductor of electricity and heat. It is a fundamental metal within construction, electronics, transportation and industrial applications, and its consumption therefore generally increases in parallel with economic growth.[v] Since 1900, world copper mine production has grown by 3.2% annually to 16.7 million tonnes in 2012 and it is expected to continue growing[vi]. The increased use of renewable energy and the development of modern communications and information systems demand significant quantities of copper.[vii] At the same time, the industry's discoveries of less high-grade deposits, fewer open pit mines, declining average grades and inadequate exploration funding are resulting in global copper supply challenges. Global production of refined copper is also not keeping up with the increasing global consumption.[viii]

Global lead consumption has been rising for the last decade, largely due to an increased global demand for lead-acid batteries used in vehicles.[ix] In 2013 global consumption of refined lead was 11.2 million tonnes, of which 5.4 million tonnes came from primary mine production while the remaining amount came through secondary production (i.e. recycling).[x] Lead consumption is forecasted to continue growing, although the increase will not be evenly distributed geographically. In Europe and the United States lead consumption is expected to stay quite stable, while in China it is expected to grow by 6.7% annually in the next few years.[xi]

Against the above mentioned megatrends, Boliden has expected high demand for its products and in the long run the metal prices could rise. Therefore the baseline scenario assumes that Boliden's operations run at full capacity and the socio-economic analysis will be based on the metal prices used by Boliden for its long-term planning purposes, which are marginally higher than the metal prices at the time of writing this report (autumn 2014). Potential changes to global output will be examined in the sensitivity analysis as changes in metal prices.

2.3.4 **Summary of applied for use-scenario**

The Table 2 below summaries the applied for use-scenario with a short description of each of the key supply chain actors.

Table 2. Applied for use-scenario

Actor	**Uses**	**Expected trends**
Needs authorisation		
Boliden Area mines and concentrator	At the moment, Boliden Area annually uses approx. 32 tonnes of sodium dichromate to produce approx. 20,000 tonnes of copper concentrates and 8,000 tonnes of lead concentrates.	The production volumes are expected to stay at a relatively stable level until the end of 2023, which is the end of the Maurliden mine's lifetime. After that, they will start decreasing until the end of the other two mines' lifetime in 2027. The sodium dichromate usage will reduce in parallel with the production volumes. There is expected to be strong demand for the copper and lead concentrates until the end of the mines' lifetime. Because of this, the metal prices are expected to increase in the future. The concentrator is expected to produce concentrates at full capacity.
Garpenberg mine and concentrator	At the moment, Garpenberg annually uses 13 tonnes of sodium dichromate to produce approximately 4,000 tonnes of copper concentrate and 62,000 tonnes of lead concentrate.	The production volumes are expected to stay at 2.5 Mtonnes until the end of 2020. There is expected to be strong demand for the copper and lead concentrates until the end of the mine's lifetime. Because of this, the metal prices are expected to increase in the future. The concentrator is expected to produce concentrates at full capacity.

Doesn't need authorisation		
Rönnskär smelter	The Rönnskär smelter annually refines a total of 24,400 tonnes of copper concentrates from both Boliden Area and Garpenberg, as well as 40,000 tonnes of lead concentrates from Garpenberg.	The sourcing of copper concentrates from Boliden Area and Garpenberg will decrease in parallel with the mines' reducing production volumes. The sourcing of lead concentrates from Garpenberg is expected to stay at Rönnskär's full refinery capacity of 40,000 tonnes annually until the end of 2033.
External buyer 1	Boliden Area currently sells approximately 8,000 tonnes of lead concentrates to external buyer 1.	The sales volumes to external buyer 1 are based on the production volumes of Boliden Area and will therefore stay relatively stable until 2023, after which they will start decreasing until the end of all the mines' lifetime in 2027.
External buyer 2	Garpenberg's currently sells approx. 22,000 tonnes of lead concentrates to external buyer 2.	The lead concentrates sold to external buyer 2 represent the remaining quantities once the Rönnskär smelter has been supplied. The volumes of lead concentrates produced by Garpenberg will start decreasing from 2020 onwards, which means that the volumes supplied to external buyer 2 will decrease in parallel.

2.4. Definition of "non-use" scenario

If Boliden could no longer use sodium dichromate for copper/lead separation, the two concentrators, Boliden Area and Garpenberg, would try to optimise their processes by using a worse alternative, dextrin, in the copper/lead separation step.

The process change-overs would not require any machinery investments at either concentrator and the operational costs would be slightly lower for both of them. However, the change-over would lead to poorer separation capacity, resulting in lower-quality concentrates. This would translate into financial losses to the concentrators. Since the lower quality concentrates have a lower economic value, the Boliden Area and Garpenberg concentrators would be paid significantly less for them. Furthermore, the lead content in Boliden Area's lead concentrate would decrease to such a low level that an additional TC need to be paid.

There would be economic loss to the Rönnskär smelter as well, as its lead smelting process is optimised for lead concentrate containing low levels of copper. The internal target set by Garpenberg is 0.5% copper in lead concentrates, and with sodium dichromate used in Garpenberg it is 0.31%. With dextrin the lead concentrates produced by Garpenberg would contain around 0.63% copper, causing a loss equivalent to [redacted] per tonne. Alternatively Rönnskär could and most likely would look for alternative suppliers of lead concentrate with low copper content. There are limited sources of such high-quality concentrates in the world and other smelters would be competing for them too. This would result in higher transportation cost for Rönnskär. More importantly, lack of a guaranteed long-term supply will mean increased uncertainty and business risk for Rönnskär. At the same time, if Rönnskär decides to buy from alternative suppliers, Garpenberg will need to sell its lead concentrate to other buyers, which will increase its transportation cost. Whether Rönnskär will continue to source exclusively, partly or not at all from Garpenberg is difficult for the company to answer at the moment, since it depends on a number of factors and will be highly speculative. Therefore the impacts related to Rönnskär's operation are expressed as the range of the cost related to the continued sourcing exclusively from Garpenberg and the sourcing completely from others.

The external buyers, as well as the Cu concentrate related business of Rönnskär, either have the capability to deal with the changes in the qualities of concentrates supplied to them in the non-use scenario, or they can choose changing suppliers. It will be a normal business decision. Therefore, there is no direct link between the non-use scenario and the impacts on the external buyers and Rönnskär's Cu concentrate related business.

The effects on Boliden Area, Garpenberg and Rönnskär are explained in more detail below.

2.4.1 **Effects on Boliden Area and Garpenberg mines**

A change-over from sodium dichromate to dextrin at Boliden Area and Garpenberg would result in changes to the copper, lead, silver and gold levels contained in the concentrates. The specific changes vary from mine to mine depending on their mineralogical differences. The direct effect on Boliden Area and Garpenberg of these changes will be reflected in the revenue they receive from selling the concentrates to the smelters.

The use of dextrin in Boliden Area results in copper concentrates containing lower copper levels, lower levels of precious metals and higher levels of lead, which is considered an impurity and is therefore penalised. All of these issues result in lower revenue for the mines. The lead concentrates produced with dextrin contain lower levels of lead and higher levels of copper, which is penalised. On the other hand, the concentrates also contain higher levels of precious metals, giving higher revenue for the mine. The change to dextrin will also affect the volumes of the produced concentrates. There will be a slight increase in the produced volume of copper concentrate and a slight decrease in the produced volume of lead concentrate. Overall the lead concentrate will generate less revenue for the mines. The impacts of the change-over on metal grades and revenues are outlined in Table 3. Boliden Area has mines with different grades and recoveries, therefore assumptions have been used for the metal grades and revenues.

Table 3. Boliden Area: The impact of dextrin on metal grades and revenue

		With sodium dichromate	**With dextrin**	**Impact on revenue**
Copper concentrates	Gold (g/tonne)	29	27	loss
	Silver (g/tonne)	2423	2153	loss
	Copper (%)	24.9	23.6	loss
	Lead (%)	8.5	10.4	loss
Lead concentrates	Gold (g/tonne)	3.6	5.4	benefit
	Silver (g/tonne)	1785	2231	benefit
	Copper (%)	3.9	4.9	loss
	Lead (%)	45	39	loss

Table 4. Garpenberg: The impact of dextrin on metal grades and revenue

		With sodium dichromate	With dextrin	Impact on revenue
Copper concentrates	*Gold (g/tonne)	104	104	-
	*Silver (g/tonne)	31360	31360	-
	Copper (%)	20.0	14.3	loss
	*Lead (%)	22.2	22.2	-
Lead concentrates	*Gold (g/tonne)	1.8	1.8	-
	*Silver (g/tonne)	2065	2065	-
	Copper (%)	0.31	0.63	loss
	*Lead (%)	70	70	-

* It is to be noticed that the new concentrator in Garpenberg has been in use for only less than a year and only one short operational test is available for the dextrin based separation process. The values are here as well as in Boliden Area assumptions based on tests and experience in several mines and years. The results are not sufficient to draw conclusions on all metal grades. Therefore the company has assumed that the gold, silver and lead yield will be the same as in sodium dichromate's case. This assumption is in favor of the dextrin results and the real situation is likely to be worse. Therefore the cost calculation undertaken in Chapter 3.2 in this aspect reflects a conservative scenario.

The change-over also has a small impact on the operational cost, which is for Boliden Area [redacted] and for Garpenberg [redacted] lower per tonne of ore than with sodium dichromate. The impact on the concentrators' operational cost will be considered as an economic benefit in the cost calculations undertaken in Chapter 3.2.

2.4.2 **Rönnskär smelter**

Rönnskär's lead smelting process is optimized for lead concentrates containing low level of copper. Garpenberg's lead concentration with the sodium dichromate process has 0.31% cooper on average. With dextrin the lead concentrates produced by Garpenberg would contain around 0.63% copper, causing an estimated loss equivalent to [redacted] per tonne for Rönnskär if they continue to source from Garpenberg.

Alternatively Rönnskär would look for alternative sup pliers for lead concentrate with low copper content. The smelter would need to negotiate a new sourcing agreement with external mines regarding 40,000 tonnes of high-quality lead concentrates. Suitable quality lead concentrates are currently supplied by [redacted] mines worldwide, one in [redacted]. Assuming that the sourcing can be arranged, the transport costs would increase. Since the external mines have alternative markets more closely located to them, Rönnskär would have to pay a freight compensation for the shipment of the concentrates to Sweden. The freight compensation would be around [redacted] per tonne of concentrate from [redacted] and [redacted] per tonne of concentrate from [redacted]. If Rönnskär manages to source all the concentrate needed from Bolivia with an additional transportation compensation of [redacted] it will be comparable with the cost related to the continued sourcing from Garpenberg.

At the same time, if Rönnskär decides to buy from alternative suppliers, Garpenberg will need to sell its lead concentrate to other buyers, which will increase its transportation cost. It is estimated that the transport costs will increase by [redacted] per tonne of concentrate supplied to external markets. So taking the cost to Rönnskär and related cost to Garpenberg into consideration, it means a total of at least [redacted] per tonne will incur with alternative suppliers.

Whether Rönnskär will continue to source exclusively, partly or not at all from Garpenberg is difficult for the company to answer, since it depends on a number of factors and will be highly speculative. The above mentioned cost related to transportation only is an oversimplification of the real situation. The price of a concentrate and its attractiveness to a particular smelter is always determined by what metals are there and their respective levels as a whole, and the concentrates from [redacted] will never be identical to the ones produced by Garpenberg. So there are many other considerations in choosing an alternative supplier. In addition, Rönnskär and Garpenberg are responsible for their own financial performances, and Rönnskär is not going to consider Garpenberg's cost when making its supply decisions. Therefore the following scenarios are as likely as each other; continue to source exclusively from Garpenberg or source completely from others or any combination of the two scenarios. The impacts related to Rönnskär's operation are therefore expressed as the range of [redacted] per tonne for 40 000 tonnes (continue to source exclusively from Garpenberg) and [redacted] per tonne for 40 000 tonnes (source completely from others).

Rönnskär smelter operates in a cyclic and highly capital-intensive industry in which stable processes and financial stability are prerequisites for sustainable growth and value-creation. One of Rönnskär smelter's competitive advantages until now has been that it is guaranteed the right lead concentrates from the Boliden's own mines. This enables long-term planning and thereby better business security. If Rönnskär need to change suppliers, it will likely not be guaranteed long-term sourcing agreements due to the limited availability and high competition. The uncertainty will force Rönnskär to keep the lead production line on a year-to-year basis, according to the yearly availability and price of concentrate with an increased risk of production interruption.

This increased risk and instability is a significant business problem for Rönnskär although it is difficult to specify what the consequences will be. The worst-case scenario is that the future lead concentrate sourcing arrangements become so unreliable that Rönnskär is forced to close down its whole lead production line. In this case, profit generated by the lead operations will be lost and a 40-45 employees would lose their jobs. While this is a possible scenario, there is so much uncertainty surrounding it that it will only be analysed as a secondary consequence. Its potential impacts will be outlined but not included in the total cost of the non-use scenario.

Alternatively, there may be a possibility to develop a new process for copper/lead separation at the Rönnskär smelter in the long term. This would be a way for Rönnskär to ensure sourcing stability and to manage risks. However, as this has not been done before, there is significant uncertainty regarding whether it would actually be technically and financially feasible. Another consideration is that the development of a new process would be very expensive. As there is a lot of uncertainty surrounding the development of such a process, the impact it would have on the non-use scenario will be discussed but not included in the total cost of the non-use scenario.

2.4.3 **Summary of non-use scenario**

The non-use scenario is summarised in Table 5 and illustrated in Figure 4. The implications for the various players are marked in Table 5 with the following marks:

– (negative impact);

+ (positive impact);

? (secondary impact, which will be explained but not included in the total cost estimates due to the uncertainty surrounding them); and
• (neutral, no real costs or benefits).

Table 5. Summary of "non-use scenario" and implication of impacts

	The non-use	Implication in the impact analysis
1	Boliden Area concentrator would switch to using dextrin in copper/lead separation. It would still produce two concentrates, but with changes to their metal content and minor changes to the produced quantities.	– Reduced net revenue due to lower quality concentrates – Increased TC ([redacted] per tonne of lead concentrate) paid to smelter due to decreased lead content in lead concentrate + Lower operational cost associated with the use of dextrin [redacted] per tonne of ore) + Decreased human health risk from not having any sodium dichromate exposure
2	Garpenberg concentrator would switch to using dextrin in copper/lead separation. It would still produce two concentrates, but with changes to their metal content and minor changes to the produced quantities.	– Reduced revenue due to lower quality concentrates + Lower operational cost associated with the use of dextrin [redacted] per tonne of ore) + Decreased human health risk from not having any sodium dichromate exposure
3	The Rönnskär smelter will continue to source lead concentrate from Garpenberg or change suppliers. Either way there will be increase cost to Rönnskär and to Garpenberg if Rönnskär chooses to change suppliers.	– [redacted] per tonne for 40 000 tonnes due to lower quality concentrate or the need to change lead concentrate suppliers – Increased uncertainty and risk of production interruption, as the smelter cannot be guaranteed a long-term sourcing agreement ? Worst-case scenario: shut-down of the whole lead operation line, if the sourcing of high-quality concentrates becomes too unreliable. ? If feasible, the smelter will look into developing a new process for lead/copper separation in the long-term.
4	External buyer 1	• No impact
5	External buyer 2	• No impact

As metals are commodity products sold at prices determined by global supply and demand, there is little possibility for price differentiation and cost transferability. The key part of the mines' income comes from the concentrate's metal content, which the individual mines or smelters have limited possibility to affect. Therefore, Boliden will not be able to pass on the costs down the supply chain.

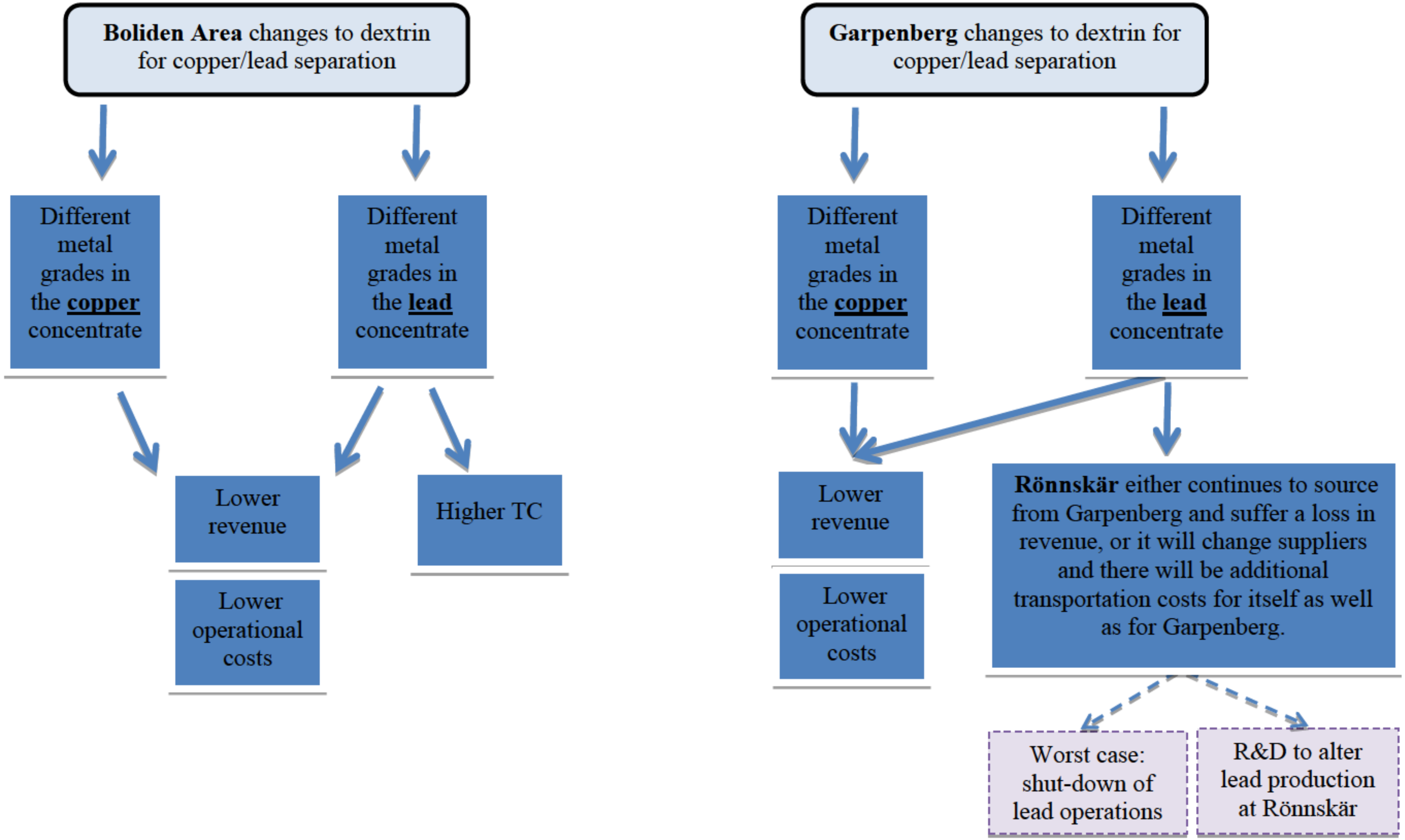


Figure 4. Non-use scenario (primary consequences marked in full lines, secondary ones in dashed lines)

3. ANALYSIS OF IMPACTS

The impacts presented in this chapter are the differences in costs and benefits when comparing the non-use scenario with the applied for use scenario. Monetised values are provided wherever available but when the impacts have not been possible to quantify, they have been described qualitatively instead. As the production volumes vary from year to year, all costs are presented in the actual year that they are expected to be incurred. The yearly values are generated from the company's internal program for long term planning. Although the exact calculation formula is not possible to describe, the principles of calculation have been described before and more information can be found in Annex II and III concerning the business model and commercial contracts.

The assumptions made in the impact analysis and cost calculations are outlined below and summarised in Table 6:

Production volumes: The impacts are analysed based on the mines' expected ore metal content and production volumes for each year. These have been taken from Boliden's long-term production plans.

Time period: The time period for the socio-economic analysis is 17 years, from the beginning of 2017 to the end of 2033. While there would be socio-economic impacts from Garpenberg during the full time period, the socio-economic impacts from Boliden Area would only be relevant until the end of the mines' lifetime in 2027. The human health impacts are also adjusted accordingly.

Metal prices: The metal prices used in the impact analysis are the prices used by Boliden for its long-term planning purposes. At the time of writing this report (autumn 2014), the actual prices were very close to Boliden's long-term planning prices. As the actual prices are expected to increase, the long-term planning prices can be considered conservative and should therefore not over-estimate the economic impacts.

Currency: Boliden is located in Sweden and thereby uses Swedish Crowns (SEK). At the same time, the metal prices are determined in U.S. Dollars (USD) at the London Metal Exchange and the London Bullion Market Association. The costs in this report will be presented in the real currency that they would be paid in. The USD costs to Boliden will be re-calculated to SEK, as that is the currency the company presents for financial reporting. The monetisation of human health impacts is based on Euro values, which will also be converted to SEK for comparison purposes. The impact of fluctuations in the exchange rates (both USD/SEK and EUR/SEK) will be assessed in the sensitivity analysis.

Treatment and refining charges (TC/RC): The TC and RC are paid to the smelters for treating the concentrates and refining the precious metals contained in the concentrates. The analysis will use Boliden's long term planning values. The TC and RC are different for each mining area and for each type of concentrates.

Discount rate: The discount rate used in the cost calculations is the 4% rate recommended in the European Commission's Impact Assessment Guidelines[xii]. Boliden's own Internal Rate of Return (IRR) is 10%, and this discount rate may also be relevant, particularly in relation to the company's own decision-making processes. As such, the costs will be re-calculated using Boliden's own IRR in the sensitivity analysis. The net present values are discounted to year 2014, when this application has been written.

Price level: All costs are expressed in the price level of 2014, when this report has been written. The values are rounded to MSEK and MEUR in the analysis when suitable.

Table 6. Key parameters for the impact analysis

Unit	Parameter	Comment
Copper price	6,600 USD/tonne	The metal prices and exchange rates are the planning figures of Boliden. These are used for Boliden's long-term planning and take into account expected future market trends. A sensitivity analysis will be undertaken at the end of the report to determine how changes to the metal prices and exchange rates affect the analysis.
Lead price	2,300 USD/tonne	
Gold price	1,200 USD/tr. oz.	
Silver price	20 USD/tr. oz.	
USD/SEK exchange rate	6.70	
EUR/SEK exchange rate	8.51	
Long term TC for Boliden Area copper concentrate	[redacted]	The TC and RC are the long term planning values used by Boliden. They may be different for each mining area and for each type of concentrate. The Long term TC/RC values will be tested in the sensitivity analysis.
Long term TC for Boliden Area lead concentrate	[redacted]	
Long term TC for Garpenberg copper concentrate	[redacted]	
Long term TC for Garpenberg lead concentrate	[redacted]	
Long term RC for Boliden Area copper concentrate	[redacted]	
Long term RC for Boliden Area lead concentrate	[redacted]	
Long term RC for Garpenberg copper concentrate	[redacted]	
Long term RC for Garpenberg lead concentrate	[redacted]	
Discount rate	4%	Used by the European Commission.
Price level	2014	The year when this report has been prepared.

3.1. Human health and environmental impacts

3.1.1 **Temporal scope**

Temporal scope for the health impacts will be the same as for the economic impacts, i.e. 11 years for the Boliden Area and 17 years for Garpenberg. This is due to the fact that the majority of Cr(VI) released to the environment will transform to a non-carcinogenic form of Cr(III) rather quickly. Therefore the exposure to Cr(VI) will cease when the use of the substance ceases.

3.1.2 **Remaining risk of the "applied for use" scenario**

Sodium dichromate is included in Annex XIV based on three intrinsic properties: Carcinogenic (category 1B), Mutagenic (category 1B) and Toxic for reproduction (category 1B). The NOAEL levels for fertility and development toxicity of Cr(VI) compounds has been observed at relatively high levels (at mg/kg/d level)[xiii]. As will be shown below the relevant exposure concentrations in the current exposure scenarios are at µg/kg bw/day level, which means that risks of the toxicity for fertility and reproduction are adequately controlled in the current use and the impacts negligible. In addition, Cr(VI) compounds are recognized as weakly mutagenic *in vivo* and its mutagenicity is thought to be a contributory factor in the carcinogenic process. In conclusion, the focus of the current health impacts assessment will be placed on the risks related to the carcinogenicity. Accordingly, the excess risk levels for the workers and general population (local) are estimated in the CSR and are summarized below in Table 7.

Table 7. Summary of excess risk levels and corresponding duration of exposure (Chapter 10 of CSR)

Exposed group	Excess lung cancer risk	Excess intestinal cancer risk	Duration of exposure
Worker WCS1	1.2×10^{-4}	0.6×10^{-5}	max 24 days/a
Worker WCS2	$\underline{< 1 \times 10^{-3}}$	$\underline{< 0.2 \times 10^{-4}}$	8 hr/d, ca.300 days/a
Worker WCS3	$<1.3\text{-}6.7 \times 10^{-4}$	$1.4\text{-}7.3 \times 10^{-5}$	max 10 days/a
General population	$\underline{1.4 \times 10^{-5}}$	$\underline{4.3 \times 10^{-6}}$	24 hr/day

For worst case scenario estimation, risk levels based on WCS2 can be chosen. The overall excess risk level is derived by adding the excess lung cancer risk level with the excess intestinal cancer risk level ($\underline{1 \times 10^{-3}}$ for worker, and $\underline{1.83 \times 10^{-5}}$ for the general population).

3.1.3 **Number of people exposed**

There are two categories of population that are exposed: the workers and the general population. The average numbers of workers in the corresponding tasks at each site are presented in Table 8.

Table 8. Average number of workers at the sites (Table 15 of CSR)

Site (time of the day)	Concentrator operators (at the concentrator) WCS 1 & 2	Maintenance workers (at the concentrator) WCS 3	Other workers on site (not at the concentrator premises)
Garpenberg (office hours)	15-20	0-10	310
Garpenberg (non-office hours)	8-10	0-10	195
Garpenberg (night time)	5-7	0-1	195
Garpenberg total	ca 35-40	1 (pers/a)	ca. 310
Boliden (office hours)	15-20	0-10	80
Boliden (non-office hours)	8-10	0-10	10
Boliden (night time)	5-7	0-1	10
Boliden total	ca 35-40	1 (pers/a)	ca. 80

The concentrator operators are considered the most relevant worker population because they work in the same operations hall and have access to the loading area. There are reported to be less than 40 operators per site, so a total of 80 workers are at risk.

There are only two sources of release of Cr(VI), the Boliden Area concentrator and the Garpenberg concentrator, and there is only one related exposure scenario. In addition, the exposure through the inhalation route is much more significant than the oral route. For these reasons, it is considered that for the general population the combined exposure at the regional level is less relevant than the local man *via* environment exposure.

To determine the right affected population, the concentration of Cr(VI) in local air at different distance from the points where it is emitted has been calculated by using Gaussian Plume Model “GPM tool” (Arche Consulting).

Table 9. Estimated Concentration of Ground-Level Cr(VI) ng/m^3

Wind speed (m/s)	0.1 km	0.5 km	0.8 km	1.5 km	3 km	5 km
1	155	42	20	7	3	1
3	59	14	7	2	1	0
5	36	8	4	1	1	0

From Table 9 it can be seen that the concentration of air-borne Cr(VI) is close to zero at 5 km from the concentrators. Also, taking into consideration that Cr(VI) is not the stable form in the environment, the regional exposure estimation is not applicable here. From Annex 4 of CSR (Aerial views for the sites), it can be seen that the inhabitants of Boliden town and Garpenberg town are exposed. In addition, since the nearest neighbourhoods are located tens of kilometres away, the excess cancer risk due to the use of sodium dichromate applies only to the most immediate inhabitants, in this case those in Boliden town and Garpenberg town. The population of Boliden is 1,566 (2010) while the population of Garpenberg is 518 (2010), with the combined population of 2,084.

3.1.4 **Monetised damage of human health and environmental impacts**

The excess cancer risks can be monetised as:

$$\textbf{Monetised excess cancer impact} = \textbf{Excess risk level} \times \textbf{Population} \times V_{mortal}$$

(V_{mortal}: Monetary value of one fatal cancer case)

Monetary values of fatal cancer cases are presented in Table 10 and 11 below.

Table 10. Monetary values for fatal cancer cases, based on the ECHA Guidance

	Fatal cancer **Central value of statistical life based on the median value**	**Fatal cancer (mortality)** **Sensitivity value of statistical life based on the statistical mean value**
2003 WTP value based on NewExt (2004) – starting value in ECHA Guidance (EUR)	EUR 1,052,000 (2003)	EUR 2,258,000 (2003)
Adjusting the 2003 values to the value of 2014* (EUR)	[redacted] (2014)	[redacted] (2014)

*Based on the Eurostat initial index of 94.75 for 2003 and end index of 117.63 for 2014 (multiplier of 1.2415) (Inflation calculator).

Table 11. Health impacts based on estimated excess fatal cancer incidences for Boliden Area

Health impact value (EUR)	**Based on central value**	**Based on sensitive value**
Excess risk level (worker)	1×10^{-3}	1×10^{-3}
Population (worker)	40	40
Excess risk level (general population)	1.83×10^{-5}	1.83×10^{-5}
Population (general population)	1,566	1,566
Monetised value of one fatal cancer (EUR)	[redacted]	[redacted]
Total (EUR)	[redacted]	[redacted]

The worst case for the health impacts of the continued use of sodium dichromate will be from [redacted] as shown in Table 11. However, one needs to take into consideration that the risk levels are derived based on the assumption of the continued exposure of 40 year working life (8h/day, 5 days/week) for workers, and an exposure for 70 years (24h/day, every day) for the general population. The temporal scope of the current use for the non-use scenario is 11 years for Boliden Area concentrator, so an exposure time based correction shall be applied (11/40 for workers and 11/70 for the general population). The corrected value of the worst case health impacts of the continued use will be from [redacted].

Table 12. Health impacts based on estimated excess fatal cancer incidences for Garpenberg

Health impact value (EUR)	Based on central value	Based on sensitive value
Excess risk level (worker)	1×10^{-3}	1×10^{-3}
Population (worker)	40	40
Excess risk level (general population)	1.83×10^{-5}	1.83×10^{-5}
Population (general population)	518	518
Monetised value of one fatal cancer (EUR)	[redacted]	[redacted]
Total (EUR)	[redacted]	[redacted]

The worst case of the health impacts of the continued use of sodium chromate will be from [redacted] as shown in Table 12. However, one needs to take into consideration that the risk levels are derived based on the assumption of the continued exposure of 40 year working life (8h/day, 5 days/week) for workers, and an exposure for 70 years (24h/day, every day) for the general population. The temporal scope of the current use for the non-use scenario is only 17 years for Garpenberg concentrator, so an exposure time based correction shall be applied (17/40 for workers and 17/70 for the general population). The corrected value of the worst case health impacts of the continued use will be from [redacted].

3.1.5 **Conclusion**

The health impacts on workers and the general population related to the estimated excess cancer cases due to the use of sodium dichromate in the Boliden Area concentrator ranged [redacted], and in the Garpenberg concentrator ranged from [redacted]. The total impacts are therefore between [redacted]. This equals to [redacted]

3.2. Economic impacts

The economic impacts on each of the main actors is analysed below. The economic impacts are presented on a yearly basis to take into account differences in production volumes and metal grades, as explained before. The revenue losses refer to net revenue losses before interest and taxes, meaning that they represent the total revenue loss once both the revenue increases and revenue reductions have been considered. All costs are presented in the currency that they would be incurred in and converted to SEK.

3.2.1 **Boliden Area**

The change-over to using dextrin in copper/lead separation in Boliden Area will result in three main economic impacts for the concentrator in comparison with the continued use of sodium dichromate:

1. There will be a net revenue reduction from the metals contained in the lead and copper concentrates, as a result of changes to both the payable metal and the penalised metals in the concentrates. The value of this net revenue reduction will vary from year to year and it is derived from Boliden's own programme, which calculates the net revenue based on the yearly production plan.
2. There will be a cost associated with an increase of the TC paid to the smelter for the lead concentrates by [redacted] per tonne (equivalent to [redacted] per tonne).
3. There will be a benefit associated with the lower operational costs of using dextrin. The operational cost will be [redacted] lower per milled tonne of ore, and the annual cost will therefore also vary from year to year depending on the milled tonnage.

The changes are outlined in Table 13 with the costs expressed in MSEK. The net present value of the cost to Boliden Area over the full temporal scope is [redacted]

3.2.2 **Garpenberg**

The change-over to using dextrin in copper/lead separation in Garpenberg will also result in two main economic impacts for the concentrator in comparison with the continued use of sodium dichromate:

1. There will be a net revenue reduction from the metals contained in the lead and copper concentrates, as a result of changes to both the payable metal and the penalised metals in the concentrates. The value of this net revenue reduction will vary from year to year and it is derived from Boliden's own programme, which calculates the net revenue based on the yearly production plan.
2. There will be a benefit associated with the lower operational costs of using dextrin. The operational cost will be [redacted] lower per milled tonne of ore, and the annual cost will therefore also vary from year to year depending on the milled tonnage.

The changes are outlined in Table 14 with the costs expressed in MSEK. The net present value of the cost to Garpenberg over the full temporal scope is [redacted].

3.2.3 **Rönnskär**

As mentioned previously, Rönnskär may have two scenarios:

1. Rönnskär will continue to source from Garpenberg, but will suffer a loss in revenue of [redacted] per tonne for 40,000 tonnes. This equals to [redacted] per year, which is equivalent to [redacted] per year.

2. If Rönnskär source externally, freight compensation costs for the 40,000 tonnes of lead concentrates purchased from external mines every year will be at [redacted] per tonne. In addition, Garpenberg needs to sell its lead concentrate to others and need to bear the freight compensation cost of [redacted] per tonne for 40,000 tonnes. The additional cost per year will therefore be [redacted], which is equivalent to [redacted] per year.

The changes are outlined in Table 15 with the costs expressed in MSEK. The net present value of the cost to the Rönnskär smelter over the full temporal scope is from [redacted].

In addition to the net present value above, there are several consequences for Rönnskär that are not so easy to monetise but nevertheless will have a significant economic impact. As explained in Chapter 2, the smelter could no longer be guaranteed a stable supply suitable lead concentrates in the non-use scenario. The importance of long-term sourcing agreements in the metals processing industry cannot be under-stated. The large and high-value volumes being processed means that stability, future planning and risk management are essential for business success.

In the non-use scenario, Rönnskär would keep up the lead production line on a year-to-year basis, according to the yearly availability and price of concentrate. The lead operations of Rönnskär would be economically analysed on an annual basis, with an increased risk of production interruption. It is difficult to specify what the actual impacts of this uncertainty will be. The worst case scenario is that the sourcing of suitable concentrates becomes so unreliable that Rönnskär is not able to continue operating the lead smelting line. If the lead operation was closed, Rönnskär would lose the operational profit of the lead production line and 40-45 of its workers will lose their jobs. Furthermore, local companies providing services to the smelter would lose a significant amount of business opportunities if the lead operations line was shut down. This worst-case scenario is not likely in the short-term, as suitable concentrates are currently available for short-term sourcing arrangements. In the long-term, it is a possible scenario but since there is a lot of uncertainty, no net present value will be provided.

As mentioned previously, the possibility exists that the Rönnskär smelter could develop a more efficient process for separation of copper and lead from concentrates. No studies have been performed and there is therefore a lot of uncertainty regarding whether it would actually be technically and financially feasible. Nevertheless, it would be a way for Rönnskär to ensure sourcing stability and to manage risks. Rönnskär estimates that if it was possible to develop such a process, the earliest it would be ready by for implementation is 2022. The best guess at the moment is that the investment would cost at least [redacted] ([redacted], distributed evenly between 2017 and 2022) and the operational costs would increase by [redacted] ([redacted] per year. If the new process was implemented, Garpenberg could again start selling its lead concentrates to Rönnskär from 2022 onwards without detrimental consequences.

It can be seen from Table 16 that the total cost of this non-use scenario is from [redacted] and falls between Rönnskär's two scenarios described above.

Table 13. Economic impact on Boliden Area (MSEK)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	3031	2032	2033
Change in net revenue	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
Change in treatment charge	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
Change in operational cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
TOTAL	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
NPV (2014)	[redacted]																

Table 14. Economic impact on Garpenberg (MSEK)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	3031	2032	2033
Change in net revenue	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Change in operational cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
TOTAL	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
NPV (2014)	[redacted]																

Table 15. Economic impact on Rönnskär (MSEK)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	3031	2032	2033
Loss due to poorer quality lead concentrate sourced from Garpenberg	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
NPV (2014)	[redacted]																
Freight compensation cost due to change of suppliers (both Rönnskär and Garpenberg)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
NPV (2014)	[redacted]																

Table 16. Scenario with the R&D development of an alternative process in Rönnskär (MSEK)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	3031	2032	2033
Loss due to poorer quality	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]												
R&D	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
TOTAL	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
NPV (2014)	[redacted]																
Freight cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]												
R&D	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
TOTAL	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
NPV (2014)	[redacted]																

3.3. Social impacts

The change to a worse alternative at the Boliden Area and Garpenberg concentrators would not have any direct social impacts. The alternative processes would require the same number of workers as with the current sodium dichromate process. There would therefore be no certain unemployment or any other direct social impacts.

There are also secondary impacts of the non-use scenario in that it would result in increased uncertainty and production disruption risk for Rönnskär. The worst scenario is that the sourcing of suitable lead concentrates becomes so unreliable that the whole lead operation line would have to shut down. If this was to happen, a total of 40-45 people working at Rönnskär's production, maintenance and administration would lose their jobs. However, these redundancies are only treated as secondary impacts and will not be included in the total costs of the non-use scenario.

As the people that would be primarily affected by this "worst-case secondary scenario" are all assumed to be located in the vicinity of the Rönnskär smelter, the local employment conditions will be examined next. The Rönnskär smelter is located in Skelleftehamn, which is situated in Skellefteå Municipality, Västerbotten County, on the North-Eastern coast of Sweden. The town of Skelleftehamn has been constructed around the port and the Rönnskär smelter. In December 2013, the town had 3,211 inhabitants while the wider municipality had 71,988[xiv].

Skellefteå is an industrial municipality largely due to its minerals, hydro power and forestry. While the industry has a strong position in the local economy, it is also relatively sensitive to market changes. A large part of the municipality's companies are easily affected by external markets and global developments.[xv] Boliden is the largest private employer in Skellefteå with the Rönnskär smelter and the Boliden Area mines employing a total of 1,349 people. The largest public employer is Skellefteå Municipality, with a total of 8,575 employees. Every fifth person has a university-level degree, compared to every fourth person in Sweden overall.[xvi]

In December 2013, the unemployment rate of Skellefteå was 8.8% compared to 8.5% in the rest of the country[xvii]. Looking at the Västerbotten County more widely, the unemployment rate was 8.0%[xviii] in the second quarter of 2014, compared to 8.7%[xix] in the rest of the country during the same time. Consequently, the people losing their jobs at the smelter would have better chances of finding re-employment if they are willing to work outside the municipality of Skellefteå.

3.4. Wider economic impacts

The mining industry relies on efficiency, stable processes, financial strength and sustainability in order to achieve long-term growth and profitability. Metals are essential resources for economic development and the demand for them will only increase as global population and consumption levels grow. Demand for metals has increased significantly over the last decade and the trend is expected to continue. At the same time, fewer high-grade deposits have been discovered, the average grades are declining and exploration efforts are receiving less funding[xx]. It is therefore increasingly important to extract mineral resources as efficiently as possible and to optimise the metal processing to get as much value out of the concentrates as possible. Mining companies' competitiveness is largely dependent on their capacity to extract metals from raw materials and on their cost-effectiveness. The current process with sodium dichromate is more resource efficient and cost effective than the dextrin process. In a highly competitive environment, even small difference in financial performance may have profound implications for the sustainable growth and long-term value creation necessary for a company like Boliden. In other words, the non-use scenario will have negative impacts to the competitiveness of the company.

4. COMBINED ASSESSMENT OF IMPACTS

4.1. Comparison of impacts

Below is a table summarising the qualitative and quantitative impacts or risks of the non-use scenario, in comparison to the baseline scenario. Impacts have been monetised where possible but since not all impacts can be quantified, the table also lists the qualitative impacts as losses or benefits. The non-use scenario's combined quantitative costs and benefits give a NPV (2014) of between [redacted] which is equivalent to between [redacted]

Table 17. List of quantitative and qualitative impacts related to the non-use scenario, as compared to the baseline scenario

Impacts	Difference between the non-use scenario and the baseline scenario	Values	Net present value in 2014
Human health impacts	The carcinogenic property of sodium dichromate is the main human health factor in the analysis.	The central value of statistical life based on the median value is [redacted] while the sensitivity value of statistical life based on the statistical mean value is [redacted] (2014 values).	[redacted]
Environmental impacts	The current risk to the environment is considered under control and therefore no impact is expected.		
Economic impacts	The net cost to the Boliden Area mines relates to reduced net revenue for metals, increased TC for the lead concentrates and reduced operational costs.	Vary from year to year depending on production volumes and assays	[redacted]
	The net cost to the Garpenberg mine relates to reduced net revenue for metals and reduced operational costs.	Vary from year to year depending on production volumes and assays	[redacted]
	The costs due to the impacts on the Rönnskär smelter is expressed as a range of two extreme scenarios: a) Rönnskär continues to source from Garpenberg and suffer a loss in revenue; b) Rönnskär will change suppliers and there will be additional transportation costs for itself as well as for	For scenario a) [redacted] annually and b) [redacted] annually	[redacted]

	Garpenberg.		
	Secondary impacts: The Rönnskär smelter will also experience increased uncertainty and production disruption due to the instability in future sourcing arrangements, leading to further financial losses. The worst-case scenario is that Rönnskär's sourcing arrangements with external mines become so unreliable that it is forced to shut down the whole lead operation line. Due to the uncertainty surrounding this, it is only mentioned as a potential secondary impact and not included in the total cost calculations.	Loss	
Social impacts	There are no direct social impacts from the non-use scenario.	-	
	In the worst-case scenario, the close-down of Rönnskär's whole lead operations would result in 40-45 people (production, maintenance, administration) losing their jobs. Furthermore, local companies providing services to the smelter would lose a significant amount of business opportunities if the lead operations line was shut down.	Loss	
Wider economic impacts	Decreased resource extraction efficiency and reduced potential for sustainable growth.	Loss	
Net present value			**The net present value is** [redacted] The total benefit/risk ratio is between 572 and 1969 [redacted]
Qualitative summary		**All qualitative impacts are negative**	

4.2. Distributional impacts

To support the socio-economic analysis, an assessment of the distributional impacts of the continued use of sodium dichromate compared to the non-use scenario is presented below.

Table 18. Distributional impacts

Distributional analysis	**Benefit of continued use**	**Cost of continued use**	**Comment**
Supplier – process chemicals	0	0	The importer and manufacturer are big international chemicals trading companies with business operations around the world. The socio-economic impact on them is therefore expected to be marginal in the non-use scenario.
Boliden	[redacted]	0	The [redacted] benefit to Boliden comprises the benefits of the Boliden Area mines, the Garpenberg mine and the Rönnskär smelter together.
Customers – external smelters	0	0	The external smelters are both able to deal with the reduced quality of the concentrates supplied to them. Or they may decide to change suppliers. No significant impact is expected.
Public	0	[redacted]	The continued use of sodium dichromate is a cost to the local population from a human health perspective. The estimated excess cases of cancer would pose a cost of between [redacted]
Secondary impacts: the Rönnskär smelter's staff and companies operating in the local business community	++	0	If Rönnskär can continue operating its lead smelting line as currently, the 40-45 people working in the lead operations line will be able to continue their work. Furthermore, the local business community will be able to continue providing its services to the smelter to the same extent as currently.
Conclusion	**Significant loss in non-use scenario**		

4.3. Uncertainty analysis

The purpose of the sensitivity analysis is to identify the key variables that have contributed most to the uncertainty, and to estimate how sensitive the overall results are to variations in each variable. As part of its business forecasts, Boliden itself tests how its results would be affected by 10%

changes to metal prices, exchange rates and TC. This is done to ensure that the Board of Directors and management team are aware of financial risks associated with market changes. The same values will therefore be tested in this sensitivity analysis. In addition, the effects of applying a higher discount rate will also be tested. The values used in the main analysis and the sensitivity analysis are outlined in Table 19.

Table 19. Values use in the main analysis and sensitivity analysis

	Main calculations	Sensitivity analysis	
		+ 10 %	-10 %
Copper price (USD/dmt)	6,600	7,260	5,940
Lead price (USD/dmt)	2,300	2,530	2,070
Gold price (USD/tr. oz.)	1,200	1,320	1,080
Silver price (USD/tr. oz.)	20	22	18
USD/SEK exchange rate	6.70	7.37	6.03
EUR/SEK exchange rate	8.51	9.361	7.659
Long term TC for Boliden Area copper concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Long term TC for Boliden Area lead concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Long term TC for Garpenberg copper concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Long term TC for Garpenberg lead concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Long term RC for Boliden Area copper concentrate (USD/mt)	[redacted]	[redacted]	[redacted]
Long term RC for Boliden Area lead concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Long term RC for Garpenberg copper concentrate (USD/mt)	[redacted]	[redacted]	[redacted]
Long term RC for Garpenberg lead concentrate (USD/dmt)	[redacted]	[redacted]	[redacted]
Discount rate	4%	10%	

4.3.1 **Metal prices**

The prices of metals are determined by global supply and demand. The prices used in the main analysis of this report are those used by Boliden for its long-term planning purposes. For the sensitivity analysis, the results are re-calculated with 10% higher and 10% lower prices. It should be noted that the sensitivity analysis assumes that the prices of all the relevant metals will increase and decrease by 10% simultaneously. The impact on the total prices will therefore be higher than if the metal prices were all assessed separately. The values used in the sensitivity analysis are outlined in Table 19.

The metal price affects the net revenue reduction of both Boliden Area and Garpenberg in the non-use scenario. The human health impacts and the economic impacts on the Rönnskär smelter remain the same as in the main analysis. The effects of +/-10% changes in metal prices on the costs to each concentrator, as well as the whole non-use scenario, are outlined in Table 20.

Table 20. Changes in revenue with different metal prices (MSEK)

	Main	+10%	-10%
Human Health benefit	[redacted]	[redacted]	[redacted]
Boliden Area	[redacted]	[redacted]	[redacted]
Garpenberg	[redacted]	[redacted]	[redacted]
Rönnskär	[redacted]	[redacted]	[redacted]
Total non-use scenario	[redacted]	[redacted]	[redacted]

4.3.2 **Exchange rate**

Similarly to the metal prices, the exchange rate is also based on global factors. The exchange rates used in the main analysis of this report are those that are used by Boliden for its long-term planning purposes. For the sensitivity analysis, the results are re-calculated with a 10% higher and 10% lower exchange rate.

The key exchange rate used in the analysis is the USD/SEK rate, as Boliden’s products are largely priced in USD, while the company mainly operates with and presents its result in SEK. The USD/SEK exchange rate affects the net revenue reduction of each concentrator. The only cost item which is expressed in EUR in the analysis is the human health impact, as its monetisation is based on literature using EUR. The human health impact is therefore tested for its EUR/SEK exchange rate. The results of changes to the exchange rates are outlined in Table 21.

In Garpenberg, when the USD/SEK rate increases 10%, they will be paid more for the concentrate but the amount paid to the smelter is increasing even faster. The change in USD/SEK rate affects the formulas and therefore the total revenue is negatively affected.

Table 21. Changes in revenue with different exchange rates (MSEK)

	Main	+10%	-10%
Human health benefit	[redacted]	[redacted]	[redacted]
Boliden Area	[redacted]	[redacted]	[redacted]
Garpenberg	[redacted]	[redacted]	[redacted]
Rönnskär	[redacted]	[redacted]	[redacted]
Total non-use scenario	[redacted]	[redacted]	[redacted]

4.3.3 **Treatment charge (TC) and refining charge (RC)**

Changes to the Long term TC/RC values affect the net revenue reductions of both Boliden Area and Garpenberg. Additionally, the non-use scenario assumes that the TC paid by Boliden Area to the smelter would increase by [redacted] per tonne of lead concentrates. The sensitivity analysis has therefore also assumed that this additional TC would be affected by +/-10% (i.e. to [redacted] and [redacted] . The results of the sensitivity analysis of the Long term TC/RC values are outlined in Table 22.

Similarly as with the change in USD/SEK rates, in Garpenberg the 10% increase in the Long term TC/RC values means that the penalties for the concentrate also increase, which affects the revenue negatively. Decrease in the TC/RC value causes lower penalties and lower amount paid to the smelter, which gives higher revenue for the Garpenberg concentrator.

Table 22. Changes in revenue with different Long term TC/RC values (MSEK)

	Main	+10%	-10%
Human Health benefit	[redacted]	[redacted]	[redacted]
Boliden Area	[redacted]	[redacted]	[redacted]
Garpenberg	[redacted]	[redacted]	[redacted]
Rönnskär	[redacted]	[redacted]	[redacted]
Total non-use scenario	[redacted]	[redacted]	[redacted]

4.3.4 **Discount rate**

The sensitivity analysis for the discount rate variable is different to that of the other variables, as it affects almost every item in the cost calculations. It is therefore presented separately from the other variables. Boliden's Internal Rate of Return is 10% and the sensitivity analysis outlined in Table 23 has therefore tested how the calculations are affected by applying this rate instead of the 4% discount rate used by the European Commission.

Table 23. Changes in revenue with 10% discount rate (MSEK)

	Main	10% discount rate
Human Health benefit	[redacted]	[redacted]
Boliden Area	[redacted]	[redacted]
Garpenberg	[redacted]	[redacted]
Rönnskär	[redacted]	[redacted]
Total non-use scenario	[redacted]	[redacted]

4.3.5 **Conclusions of the uncertainty analysis**

Out of all the variables tested, the sensitivity analysis shows that the total cost of the non-use scenario is most affected by applying Boliden's own IRR as the discount rate. The other variables all give much lower deviations from the main analysis. After all, it can be concluded that the socio-economic benefits of the continued use of sodium dichromate by Boliden by far outweigh the risks to human health and the environment on a wide range of variables.

5. CONCLUSIONS

This report has analysed whether the socio-economic benefits of the continued use of sodium dichromate at the Boliden Area and Garpenberg concentrators outweigh the risks to human health and the environment. If the concentrators could no longer use sodium dichromate for copper/lead separation, both Boliden Area and Garpenberg would try to optimise their processes by switching to a worse alternative depressant, dextrin, in copper/lead separation.

When comparing the human health risks of Boliden's continued use of sodium dichromate with the associated socio-economic benefits, it is clear that the benefits outweigh the risks considerably. By subtracting the monetised health risk from the monetised socio-economic benefits, the monetised value of Boliden's continued use of sodium dichromate is [redacted].

A comprehensive sensitivity analysis has been undertaken to evaluate how sensitive the above conclusions are to uncertainties. The NPV of the non-use scenario's costs derived by examining the different uncertainties were from [redacted] at the lowest end, when Boliden's own IRR was applied as the discount rate.

At the highest end, the NPV was [redacted] when applying a 10% higher metal price.

To compare the costs and benefits of the continued use of sodium dichromate the total benefit/risk ratio is calculated. The total benefit/risk ratio for Boliden is between 572 [redacted] to 1969 [redacted] This shows the robustness of the analysis and it can be concluded that the benefit of the continued use of sodium dichromate by Boliden outweighs the risk.

In addition, there is reason to believe that the non-use scenario would have economic impacts beyond the above mentioned figures and the competitiveness of Boliden would be hampered. There could also be social impacts in the form of unemployment.

5.1. Information for the length of the review period

The analysis in this report has shown that the benefits of Boliden's continued use of sodium dichromate clearly outweigh the risks to human health and the environment. The Chemical Safety Report has demonstrated that risks are minimised to a level of low concern, while the Analysis of Alternatives has outlined the substantial effort that the company has gone through in its own search for alternatives, but no suitable alternative is available before the sunset date.

Boliden have engaged in R&D activities for several decades in order to elucidate an alternative depressant, or technique, for copper/lead separation. The company has researched all currently known industrial alternatives in the separation and concluded that they are not suitable for the separation of the minerals from the ores that supply their concentrators.

The research on dextrin has been conducted over the course of 30 years. Extensive investigations into modification of conditions and other reagents have been undertaken with this alternative, but to no avail, i.e. they did not produce viable concentrates. Given the experience of dextrin, an alternative will most likely require significant development over several years. If dextrin is taken as a baseline, then a 30 year cycle of development would be required. It is therefore highly unlikely that any new alternatives could be found and industrialised during the expected lifetime of the Boliden Area and Garpenberg mines. While a review period of 17 years corresponding to Garpenberg mine's lifetime is preferred, the company finds it more realistic to request a standard long review period since the lifetime of Boliden Area mines is only 11 years.

To conclude, the socio-economic benefits of Boliden Area's and Garpenberg's continued use of sodium dichromate are substantial and it is highly unlikely that any new alternatives could be found and industrialised during the expected lifetime of the mines. Based on the best available current knowledge and the company's own R&D efforts over the last 30 years, a long review period of 12 years is both appropriate and justifiable for Boliden.

ANNEX 1 – JUSTIFICATIONS FOR CONFIDENTIALITY CLAIMS

Page number(s)	***Justification for blanking***
5 *15* *17* *23-25* *27* *32-34* *36-38*	**Demonstration of Commercial Interest** Boliden wishes to keep the figures regarding the annual and the total economic impact confidential. This since Boliden is a public listed company (the Boliden share is listed on the NASDAQ OMX Stockholm Exchange). **Demonstration of Potential Harm** The potential economic impact is significant and details on this economic impact could be regarded as share price sensitive information which must be disclosed to the market in accordance with certain rules and principles [this applies in particular to the blanked figures in section 1, section 3.2, section 4 and section 5 in the SEA]. If ECHA plans to make these details public, Boliden would like to be informed in advance. **Limitation to Validity of Claim** The claim for confidentiality on the information in this justification is 10 years.
13 *17* *20* *25* *35* *37*	**Demonstration of Commercial Interest** For commercial reasons, Boliden wishes to keep confidential the details regarding: 1. Boliden´s Long term TC and RC´s for Copper and Lead concentrates 2. Information on other suitable lead concentrates from competitive mining companies for Rönnskär 3. TC or RC loss due to downgraded qualities of Copper and Lead concentrates 4. Additional transport costs related to sourcing other lead concentrates and selling Garpenberg lead concentrates externally 5. Economic impact on Rönnskär, Boliden Area and Garpenberg split per year Boliden never publishes these kinds of internal long term conditions and transport costs or key suppliers officially. Revealing this information to our suppliers of concentrates will be beneficial for the supplier and it would put Boliden in a worse negotiation position. **Demonstration of Potential Harm** Revealing the information claimed confidential in this justification will put Boliden in a worse negotiation position in case Boliden would negotiate the commercial terms with the suppliers of external lead concentrates suitable for Rönnskär. There are limited qualities suitable for Rönnskär and the owners of these qualities will be in a good negotiation position in case they know that Rönnskär and in the end Boliden is dependent on them.

	Limitation to Validity of Claim The claim for confidentiality on the information in this justification is indefinitely.
15-17 *26* *28-29* *32* *36-38*	**Demonstration of Commercial Interest** Justification for confidential material regarding Rönnskär. For commercial reasons, Boliden wishes to keep confidential the details regarding Rönnskär's potential alternative sources of lead concentrate and the costs and losses that Rönnskär could suffer from processing concentrates of lower quality. Operating costs on this level is never presented in annual reports or published officially. Revealing this information to our suppliers of concentrates will be beneficial for the supplier and it would put Boliden in a worse negotiation position. Publish this kind of information officially can lead to lowered revenues to the smelter and in the end closing of business. **Demonstration of Potential Harm** Rönnskär's ability to achieve reasonable terms in a negotiation will be significantly impaired if it becomes known who the potential suppliers of high quality concentrates are and what cost increases Rönnskär suffers from processing concentrates of lower quality. In the concentrate market, knowledge of impurity capacity is sometimes used to produce blends filling up impurities just to the limit where penalties start to apply. This affects the revenue of the smelter. **Limitation to Validity of Claim** The claim for confidentiality on the information in this justification is indefinitely.

Income model

The metals market comprises two subsidiary markets, namely the market for concentrates (raw materials), where mines and smelters are the market players, and the market for finished metals, where smelters and metal consumers are the market players. Boliden operates in both of these markets.

Sales between Boliden's mines and smelters are made on market terms. There are a number of synergies between Boliden's mines and smelters when it comes to metallurgy and marketing, e.g. improvements to the ways in which plans and investments are adapted in line with future market trends and with natural changes in the mines' metal mixes. There are numerous similarities between concentration and smelting processes and the cooperation between smelters and mines helps develop Boliden's technical expertise.

Supplying the company's own smelters with the company's own raw materials also offers advantages in the form of lower transport costs, more reliable deliveries and revenues, and a reduced need for stockpiling.

The mines' income

The bases for the mines' income are the metal concentrates sold to the smelters in a global market. The mines' remuneration is based on the base metal prices that are set daily on the London Metal Exchange (LME) and the precious metal prices that are set by the London Bullion Market Association (LBMA). These prices are governed by the global supply of and demand for base and precious metals at the time.

Mines' income is also affected by other factors: concentrates with a higher payable metal content and only smaller amounts of impurities yield higher income.

A high valuable subsidiary metal content is another factor that has a positive impact on the mine's income and competitiveness. Boliden's primary subsidiary metals are gold, silver and lead.

The mines' price to the smelters comprises the metal value less treatment charges and deductions for impurities on agreed terms. Treatment and refining charges (TC/RC) consequently affect the mine's income. Lower TC/RC mean an increase in the mine's income and a decrease in the smelter's income.

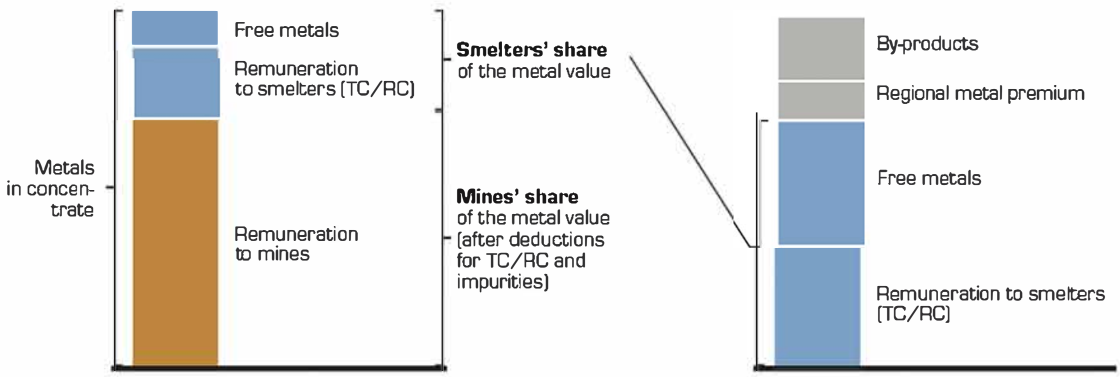
The smelters' income

The smelters sell the finished metal at the LME price plus a regional metal premium. The concentrate cost comprises, as noted above, the LME price and other terms. The zinc smelters' income is also affected by price sharing clauses whereby changes in the metals' market prices are shared by the mines and smelters. TC/RC and price sharing clauses are determined by the global balance between mined production and the smelters' demand for raw materials.

The regional metal premium is a surcharge on the LME price paid by customers. The premium is determined by regional supply and demand and includes such factors as localisation and transport aspects and compensation for payment terms other than

How the metal value is divided between mines and smelters (not to scale)

Smelters' gross profits



The market for concentrates (raw materials): the mines are the vendors and the smelters are the purchasers.

The market for finished metals: the smelters are the vendors and metal consumers are the purchasers.

those obtaining on the LME. The end-user may also pay for a special metal format, special alloys and technical service. Boliden almost exclusively sells its metals directly to industrial customers at a premium under contracts negotiated on an annual basis. These customer relationships are important to Boliden because they not only ensure more reliable demand, but help establish a stable cash flow.

The smelters' income is also, in addition to TC/RC and price sharing terms, affected by the volume of free metals produced, which is determined by the smelter's ability to extract quantities of metal over and above that assumed in the concentrate agreements. The free metals are sold at market price.

Smelters also earn money from the sale of by-products. The biggest by-product is sulphuric acid, but aluminium fluoride, sulphur dioxide, copper sulphate, nickel sulphate, cadmium and selenium are other important by-products.

The base metals market's income components

Income components	
LME price, USD/tonne	A
The concentrate's metal grade, %	B
The concentrate's payable metal content, %	C
Fees for any impurities present in the metal concentrate, USD/tonne of metal concentrate	D
Percentage of metal content that individual smelters are able to refine, %	E
Treatment charge (TC), USD/tonne of metal concentrate	F
Refining charge (RC), USD/tonne of payable metal content	G
Effects of any price escalators, USD/tonne of metal concentrate	H
Income from any subsidiary metals and other by-products in the metal concentrate, USD/tonne of metal concentrate	I
Income from extraction of any subsidiary metals and other by-products in the smelting concentrate, USD/tonne of metal concentrate	J
Metal premiums, USD/tonne of sold metal	K
Transport cost for metal delivery from smelter to customer, USD/tonne of metal concentrate	L

Mines' income	
Metal concentrate (per tonne dry weight)	A* B* C – (D+F+G) +/– H + I

Smelters' income	
Metal concentrate (per tonne dry weight)	
Treatment and refining charges	F + G +/– H + D
Free metals	A*B*(E–C)
Extraction of subsidiary metals and by-products	J
Value of metal premiums	B* E* (K – L)

The metals market's cyclic pattern

The balance between the supply of concentrates from the world's mines and the global demand for smelters' products is the primary factor controlling the metals market's price cycle.

This balance affects the price level on the London Metal Exchange (LME), where base metals are traded, as well as the treatment and refining charges (TC/RC) levied by the smelters for processing the mines' raw materials into a finished metal product.

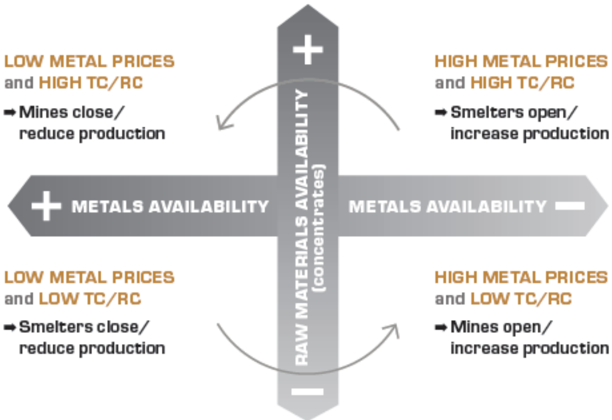
Prices that compensate for exploration activities, risks associated with growth investments, and production costs are key to the mines' willingness to invest in future production. When metal prices fall, mines' investments in growth also fall, which, in turn, results in a reduction in supply a few years later.

This results in declining availability of raw materials for the smelters. TC/RC fall and this, in turn, puts pressure on the smelters' profitability, leading to production cutbacks or the closure of smelters and ultimately a reduction in the availability of refined metals.

Reduced smelter capacity leads, in the long-term, to rising market prices for metals while TC/RC remain low until the pricing scenario has adjusted in line with supply and demand.

This means metal prices rise once more, as do TC/RC, provided that the demand for refined metals is good. New decisions are taken on the expansion of mine capacity in response to the increase in prices.

The metals market's cyclic pattern



Appendix E
Contractual arrangements

1. Introduction

A copper concentrate contract is in essence an agreement between a copper mine and a smelter/refinery covering the purchase of a specified tonnage of copper concentrates over a certain time frame. The terms and agreements contained in the contract will cover payment to the mine for the metal content of the ore, but will also include a number of deductions to account for the costs of treatment and refining of the ore by the smelter. The contract will also contain a quotational period specifying the time period during which payable metal contents will be priced. A number of standard commercial contract clauses covering the logistics of delivery, taxes and duties, insurance, assaying, and force majeure conditions are also normally included, but these are not discussed in this report.

2. Contract Clauses

2.1 Payments

In most concentrate contracts payments made to the mine reflect the copper, gold and silver content of the concentrate. Normally no payment is made for other metals though some are penalised (see **Deductions**). Payments are usually for less than 100% of the metal content of the concentrate in order to allow for handling and process losses.

For copper, typically 96.5-96.75% of the copper content is paid for, subject to a minimum deduction of 1 unit. However this might vary from contract to contract and some contracts now specify a sliding scale, so that the higher the copper content the higher the percentage paid for.

For concentrates grading 29% or more, the percentage payable formula applies. For concentrates grading less than 29% the 1 unit deduction applies.

For silver and gold, the payment terms in Europe are different from those in the Far East.

In the Far East, a sliding scale is applied for gold payables. A typical scale is as follows, but these will vary from contract to contract.

0-1g/t; no payment
1-3g/t: pay 90%
3-5g/t; pay 94 %
7-10g/t; pay 95 %
10-20g/t; pay 97 %
20-50 g/t; pay 97.5 %
>50g/t; pay 98.25 %

In Europe, one of two formulae may be used; either deduct 1g and pay for 100% of the remainder; or pay for 95% of the full content subject to a minimum deduction of 1g. For certain gold contents these will effectively be the same. For concentrates containing less than 20g/t of gold, making a deduction of 1g and paying for 100% of the remainder will be equivalent to paying for 95% of the content subject to a minimum deduction of 1g/t. For higher gold contents, the second formula will be more favourable.

In some contracts only 90% may be paid for subject to a minimum deduction of 1g/t.

Refining charges also apply. These vary from contract to contract but are typically $3.5-6/oz of payable gold. Refining charges usually vary with the gold content of the concentrates. Higher charges apply for concentrates with lower gold contents.

For silver, Far Eastern again have a sliding scale. For concentrates with less than 30g/t, no payment is made. If the content is less than 300g/t but more than 30g/t then 90% is paid for, if it is more than 300g but less than 1,500g 94% is paid for and if the content is more than 1,500g/t then 95% is paid for.

In Europe there are again two formulae that may be used: either deduct 30g and pay for 100% of the remainder; or pay for 95% subject to a minimum deduction of 30g/t.

Refining charges for silver vary from 30¢ to 50¢ per oz of payable silver.

2.2 Quotational Period

The quotational period (QP) is the time period during which payable metal contents are priced. QPs are usually related to a set period of time following shipment from the mine, or arrival at the smelter. For example, pricing the copper content of a concentrate under a typical QP might involve using the average LME cash settlement price (Comex #1 position price on domestic US business) in the third whole month following delivery. An early QP might be one where payment is specified over a period of time close to the original shipment date from the mine. Under a late QP payment is usually assessed over a period several months after delivery.

The QP is expressed either in relation to the month of shipment (M) or the month of arrival (MA). For example the QP might be specified as 3 months after month of shipment, or M+3. Alternatively it might be specified as 2 months after month of arrival, or 2MAMA. Generally the shipping period is assumed to be one month, so M+3 is roughly equivalent to 2MAMA.

In deals between mines and traders an option to nominate in advance an early or late QP is often included and the trader will usually pay for this right. The length of the QP can become particularly important in a market where the copper price is in backwardation (see **Concentrate Trading During a Backwardation**, below).

2.3 Deductions/Penalties

There are a number of elements that routinely qualify for penalties if they are present above a fairly low level in copper concentrates. These elements include arsenic, bismuth, antimony, mercury, lead, fluorine and chlorine. They are materials that are very noxious from a health and safety point of view, may be deleterious to plant and equipment, and have increasingly limited commercial value, even if they can be recovered from the smelting and refining process.

Other elements may also incur penalties, though only at higher concentrations. They include zinc, nickel, cobalt, alumina and tellurium. If present in significant quantities they may affect the recovery of copper or cause problems during smelting and refining.

Moisture in excessive amounts can cause problems in the transport of concentrates and incur additional costs for the smelter if the concentrate has to be extensively dried.

Concentrate contracts normally stipulate both the amount of a penalisable element that can be present in the concentrates before a penalty is imposed, and the scale of charges that then applies once the threshold is exceeded.

There is usually a fairly consistent trade off between the free level applied for a particular element and the penalties that it incurs above the threshold. Generally the lower the threshold, the lower the penalty rate, since a higher proportion will incur the penalty.

The overriding principle is the need to value the concentrate deal as a package. A smelter that specialises in handling noxious materials and is keen to obtain high precious metal material, for example, may specify a favourable penalty clause provided that it obtains the precious metals on favourable terms. A smelter that has scope for blending and is short of material may also offer attractive terms for a small parcel of concentrates that is high in deleterious elements.

Typical penalty clauses are summarised below. Arsenic, antimony and bismuth tend to attract rather similar levels of penalty, although arsenic is allowed the largest latitude in terms of free limits. Lead and zinc also attract similar penalties, both in terms of free limits and penalty rates.

Mercury has low levels of tolerance for a variety of reasons, one of which is that it can pass into the acid by-product and then into fertiliser products and potentially into the food chain. Fluorine and chlorine are tolerated at relatively low levels, not least because of their highly corrosive properties.

Arsenic may have a free level from 0.1% to 0.3% of the assay, but a common threshold is 0.2%. Above this level penalties are relatively standard at $2-2.50 per dry metric tonne (dmt) for each 0.1% present. A higher penalty may be applied for levels above 0.5%.

Bismuth has free levels ranging from 0.03% to 0.05%, with penalties from $3-10/dmt for each 0.1% above the threshold.

Antimony is free up to levels ranging from 0.08% to 0.3%, with penalties ranging from $1 to $1.5 for each 0.01% above the threshold.

Mercury tolerance is normally very low, with penalties normally starting at 10ppm, although the threshold may be as high as 40ppm. Penalties tend to be $0.2/dmt for each 1 ppm above the threshold.

Lead and **zinc** can be present free of charge up to 3% individually, or jointly up to 5%, then incur penalties of $1-3/dmt for each 1%.

Fluorine and **chlorine** tend to attract similar terms, with a limit of 100-350 ppm and penalties of 1¢/ppm above this level.

Tellurium may be penalised above 0.04%, with penalty rates of $3/dmt for each additional 0.01%.

Alumina may have a free level of up to 3%, with a penalty of $3/dmt for each 1% above this.

Moisture can attract penalties at levels starting from 11-14%. A common penalty would be $1-2/dmt for every 1% above the threshold.

The main deductions made from the payable metal contents are the treatment charge (TC), expressed in US$/dmt of concentrates, a refining charge (RC) for each of the payable metal contents expressed as US¢/lb payable copper, US$/oz payable gold and US¢/oz payable silver. Additional deductions or penalties, may be made for excessive levels of impurities in the concentrate and for moisture content above a certain level.

2.4 Price Participation

Until 2007, long term contracts also included a price participation clause (PP), which allowed for an additional payment to be made to the smelter as the copper price increased above (or fell below) a base level.

Typically PP was 10% of the difference between the actual price and the basis price of 90¢/lb. However there have been some variations around this, and in the 2006 mid-years the miners were successful in raising the basis price to $1.20/lb. In the 2007 calendar year agreements the PP was removed. However this may not be permanent and PP could be re-introduced in the future.

3. Combined TC/RC

The TC/RC has two components. The TC, expressed in $/t of concentrates, and the RC, expressed in ¢/lb of payable copper. This is normally converted into a combined TC/RC expressed in terms of ¢/lb of payable copper. This can then be compared with smelter costs and revenues, also expressed in ¢/lb of copper. The calculation is carried out as follows:

Assuming a 30% copper concentrate

The payable copper content is 29%, giving 639lb of payable copper per tonne of concentrate.

The TC per tonne of concentrate is thus divided by 639 to arrive at the TC per lb of payable copper. This is then added to the RC, to arrive at the combined charge in ¢/lb.

For example. The TC/RC is $45/4.5¢

TC per lb of payable copper	= $45 ÷ 639
	= 7.04¢
RC per lb of payable copper	= 4.5¢
Combined TC/RC	**= 11.54¢/lb**

4. Term and Spot Contracts

Most copper concentrate is traded on the basis of term contracts. Usually these will run for one to five years, although many long-term contracts are treated as evergreen arrangements which continue indefinitely with periodic renegotiation of key terms and conditions. Typically a term contract is a frame agreement under which a specified tonnage of material is shipped from mine to smelter, with charges negotiated afresh at regular intervals, normally annual or biannual. If an agreement over terms cannot be reached, or the mine or smelter needs to reduce the tonnage shipped or treated in any one year, the contracts may be temporarily suspended for a year or more with the intention of resurrecting them when conditions are appropriate. Instances where holidays have been taken in the recent past include Freeport/Japanese smelters, Highland Valley Copper/Atlantic Copper and Hudson Bay M&S/North American suppliers.

Spot contracts are normally one-off arrangements for the sale of concentrates and frequently involve a merchant. The material is paid for in much the same way as a concentrate shipped under a term contract. Merchant business primarily involves single consignments of concentrates and one-off contracts with smelters, but occasionally merchants may sign contracts for business with mines and smelters on a longer term basis.

5. Concentrate Trading During a Backwardation

The copper market was in backwardation (i.e. copper prices for forward months trading at a discount to the nearby months, due to tight supply of nearby metal) for long spells in the 1990s, and returned to backwardation in the wake of the price rally of late 2003/early 2004. Industry inventories have fallen to low levels, and we believe that the backwardation will remain in place for some time to come.

The existence of a backwardation has important implications for concentrate trading and in particular the timing of QPs, where merchants are involved in buying concentrate from a mine and selling it on to a smelter. In this section we work through two examples that illustrate how a merchant can adjust the timing of QP's and his hedging strategy in both contango and backwardation markets so as to be able to offer more attractive terms to the mine (i.e. low TC/RCs) when negotiating concentrate purchases.

6. Trading in the Copper Concentrates Market

In a normal contango copper market, where future quotations for metal are higher than the spot price, merchants can bid for concentrates and hedge the copper content in the usual way through a forward sale on the LME. The merchant's aim will be to get a QP (quotation period - ie the LME monthly average price at which the copper content of the concentrate is valued) from the mine as early as possible, while getting a QP from his smelter customer as late as possible.

The QPs matter because the merchant must try to get his hedge position to match as nearly as possible his physical (purchase and sale of concentrate), and the bigger the contango he can earn from his hedge (by selling further forward), the bigger his margin. Hence the keener the terms he can offer the mine in competing for concentrates; ie the bigger the contango the lower the TC/RC he can offer. But to get that bigger contango the merchant must press for the longest QP on his sale and/or the earliest QP on his purchase that he can get.

In backwardation market, the position is reversed. The merchant will want to sell on as early a QP as possible and to buy on as late a QP as possible. Again the hedge must match the physical position as nearly as possible. This time the aim is to maximise hedging earnings from the backwardation by a `lending' operation on the LME - ie selling nearby dates and buying longer dated contracts. The further out the QP of purchase can be pushed, and the nearer the QP of sale can be brought, the bigger the hedge earnings and the lower the TC/RC that the merchant can offer the miner.

7. Example of concentrates trading with a contango

All figures quoted in the examples below are entirely fictional for illustrative purposes. A trader contracts to buy 5,000 tonnes of copper in concentrate from a mine, with the shipment to be made in April and the trader's purchase to be priced at the average LME spot/cash settlement price for March (ie the QP for the trader's purchase is March). The trader's sale to a smelter is to be priced at the average LME settlement for June (ie the QP for the trader's sale is June).

Assume LME averages are March $2500/t and June $2800, and that there is a $100 spot:3-month contango in March. The transactions for the trader would be:

March:	Sell 5000t of copper forward on the LME at 3-month (June) price of $2600/t.
April:	Pay mine for 5000t of copper in concs at March average of $2500/t.
June:	Receive payment from smelter for 5000t of copper in concs priced at June average of $2800/t.
	Buy back 5000t of copper on the LME at June average spot price of $2800/t.

The proceeds of these transactions, from the trader's point of view, are as follows:

Physical:	expenditure:	5000 x $25000 =	$12,500,000
	receipts:	5000 x $28000 =	$14,000,000
	profit:		$1,500,000

LME:	expenditure:	5000 x $2800 =	$14,000,000
	receipts:	5000 x $2600 =	$13,000,000
	loss:		$1,000,000

Net receipts = $1,500,000-$1,000,000 = $500,000.

The profit from these combined transactions is $100/t, which represents the contango ruling in the month of March. The contango profit gives the trader his margin with which to offer more attractive terms to the mine when negotiating the original purchase.

8. Example of concentrates trading with a backwardation

A merchant contracts in March to buy 5000t of copper in concentrates. He agrees with the mine (ie for his purchase) a QP of September, and with the smelter (ie for his sale) a QP of June.

Assume averages for LME spot prices are March $2500, June $2800/t, and September $3000, and that the backwardation (for spot:3 months) is $100 per 3 month period throughout.

The transactions for the trader would be:

March	Sell 5000t on the LME at June forward price of $2400
	Buy 5000t on the LME at September forward price of $2300
June	Receive payment from smelter for 5000t at $2800
	Buy back 5000t on the LME at spot price of $2800
Sept	Sell back 5000t on the LME at spot price of $3000
	Pay mine at spot price of $3000

The proceeds are as follows:

Physical	Receipts:	5000 x $2800 =	$14,000,000
	Payments:	5000 x $3000 =	$15,000,000
	Loss on Physical:		$1,000,000
LME:	Receipts:	5000 x $2400 =	$12,000,000
		5000 x $3000 =	$15,000,000
Total:			$27,000,000
Payments:		5000 x $2300 =	$11,500,000
		5000 x $2800 =	$14,000,000
Total:			$25,500,000
Gain on LME:			$1,500,000

Overall gain = $500,000, or $100/t, which is the size of the spot:3 month backwardation. The larger this is the better the terms - ie the lower the TC/RC - that the merchant can offer the miner.

Treatment charges

Lead concentrate treatment contract

A contract for the sale of concentrate will contain a number of clauses setting out the contractual agreement between the seller (mine or trading company) and the buyer (smelter or trading company). Typically these will cover practical matters such as the duration of the contract (one or more years), the quality of the concentrate determined by its chemical assay, the quantity of the concentrate to be delivered as per a shipping schedule and the delivery conditions e.g. CIF, FOB, title and risk, weighing and sampling, the timing of payments, taxes and duties, force majeure, arbitration and special clauses. Further clauses will address the issues of metal payments, treatment charges, penalties and quotational periods.

The two key economic elements of the contract are:

Payment by the smelter to the mine for 95% of the lead contained in the concentrate or, if the concentrate grade is less than 60% Pb, a deduction of 3 units (i.e. 3% Pb) from the grade of lead in the concentrate. The paid lead is valued at the LME price averaged over an agreed quotational period.

Payment by the seller to the buyer of a treatment charge. Typically this will comprise a *base* TC and a *price participation* clause. For example, *the base treatment charge of $300/t concentrate shall be increased by $0.1/t (10%) for each one dollar (or part thereof) the quotational lead price is above or below the basis lead price of $1500/t.* The price participation clause will sometimes be expressed in terms relative to each US cent/lb movement in the lead price. For example, *the base treatment charge of $300/t concentrate shall be increased by $2.2/t concentrate for each one cent (or part thereof) the quotational lead price is above or below the basis lead price of 68c/lb*

Typical payment terms for lead concentrate

Pb	Payment for 95% of the contained metal or a minimum deduction of 3 units
Ag	Deduct 50g/t and pay for 95% of the remainder or for higher grade concentrate (say >1000g/t Ag) payment for 95% of the contained metal or a minimum deduction of 100g/t. In all cases deduct a silver refining charge of at least $0.35/oz.
Au	Deduct 1g/t (sometimes 1.5g/t) and pay 95% of the remainder. In all cases deduct a gold refining charge of $5 to $10/oz.

Source: Brook Hunt – A Wood Mackenzie Company

The TC contract may be agreed over 12 months in advance of the actual sale, when the future lead price on which the value of the concentrate will be based is not known. The escalation clause provides a mechanism whereby the buyer can share in the benefit of lead price increases. Since 2002 it has become common practice to include treatment charge de-escalation clauses, which were traditionally more common for zinc concentrate.

Common penalty terms for lead concentrate

The principal penalty elements present in lead concentrates are antimony, arsenic, bismuth, mercury and, to a lesser extent, zinc. The presence of any of these in any significant quantity over a set limit, as well as resulting in higher treatment charges and penalty payments, may also result in a reduced range of smelters willing, or able, to treat the concentrate in question. In particular, bismuth content is critical and there is a differential in penalty charges made between smelters that have the ability to recover and produce refined bismuth and those that do not. For smelters able to handle high levels of deleterious elements, the additional revenue from higher treatment charges and penalties can be very significant. While some deleterious elements may interfere with the smelting/refining process, all require removal to below certain limits in order to produce four-nines or higher grade lead, incurring extra costs, either directly in the form of additional refining processes, or indirectly in the form of reduced recovery of lead and precious metals.

Antimony traditionally was not considered to be a major problem in lead smelting/refining, since antimonial lead was universally used in battery manufacture. In traditional lead refining, antimony ends up in the slag from the softening furnace and this slag (around 25% Sb and 60% Pb) was widely used to produce antimonial lead. With the advent of maintenance-free SLI batteries, the use of antimonial lead in battery manufacture fell dramatically, with lead-calcium alloys used instead. Antimony removal from lead bullion, therefore, results in a net loss of lead units. In the Harris softening process antimonial lead is not formed, reducing the loss of lead units, but additional costs are incurred in the recovery of the antimony to a marketable form. Antimony penalties are generally charged at $2-3 per 0.1% above 0.3%.

Arsenic can cause additional speiss phases in smelting, which can reduce precious metals and lead recovery. It is removed from lead bullion in the softening process, ahead of desilverisation, where its presence would inhibit silver recovery. Recovery to high-purity arsenic, arsenic trioxide, etc incurs additional costs. Penalty levels start at around 0.3% and are typically charged at $2-3 per 0.1%.

In pyrometallurgical refineries**, bismuth** removal requires an additional (Kroll-Betterton) refining stage and not all lead refineries are equipped with such facilities. Some smelters are not able, therefore, to take concentrates or feed containing elevated bismuth levels. Penalties for bismuth also reflect the high cost of the Kroll-Betterton calcium-magnesium process. In electrolytic refineries, bismuth ends up in the tankhouse slimes, necessitating further recovery. Penalties are usually charged at levels above 0.1%, but may be triggered at levels as low as 0.01%, where the smelter is unable to recover bismuth. In the latter case, penalty payments may come in at bismuth levels above 0.01% at $2 per 0.01%. Where bismuth is recovered, typical penalties are charged $2-3 per 0.1% above 0.1%.

Mercury is penalised since, without removal facilities, it degrades the sulphuric acid produced from the sinter plant off-gases, making it unsuitable for use in fertiliser production. Penalties are charged at levels above 30-50ppm.

Zinc is only rarely subject to actual imposition of penalty charges. The presence of zinc sulphides in the furnace (and small amounts of both lead and zinc sulphides will be contained in the furnace charge after sintering) greatly increases furnace accretions. In addition, with higher zinc sulphide levels in the furnace, it requires the reduction phase to be less intensive (to prevent the fuming of the zinc sulphides), which leads to more lead ending up in the slag. Penalties for zinc, when charged, generally kick in above 5%, but for mines, better overall treatment terms will almost certainly be available from plants that are able to recover zinc units, usually ISFs, but also metallurgical complexes such as Port Pirie, Onsan, and Trail.

Typical penalty terms for lead concentrate

Mercury (Hg)	Above 50ppm pay $5 each 50ppm Hg. The free limit can be as high as 100ppm. The penalty charge can be as high as $10 each 50ppm Hg
Arsenic (As)	Above 0.2% pay $2 each 0.1% As. The free limit can be as high as 0.4% As. The penalty charge can be as high as $3.5 each 0.1% As
Bismuth (Bi)	Above 0.1% pay $2 each 0.1% Bi. Where bismuth is not refined the penalty can be more punitive at $1 each 0.01% Bi
Antimony (Sb)	Above 0.2% pay $1.5 each 0.1% Sb. The free limit can be as high as 0.3%. The penalty charge can be as high as $2.5 each 0.1% Sb

Source: Brook Hunt – A Wood Mackenzie Company

Historical treatment charges

Contracts are negotiated annually with the settlement terms established by a number of major miners and smelters being used as a general benchmark by the rest of the market. In recent years it has become more difficult to determine if any consensus has been achieved on a benchmark, with the market becoming more differentiated according to concentrate characteristics and smelter capabilities. There is no standard lead concentrate for the market to focus on as mine specifications vary widely. There are also only a few large mine producers selling into the custom market which might establish a benchmark.

The term TC contract is agreed in advance of the actual sale. The TC negotiations for the annual contract traditionally start in October of the previous year. Since the future availability of concentrate (the market balance) and the future lead price are not known, TCs are agreed based on an *expectation* of the following year's metal and concentrate market conditions. Needless to say, these expectations do not always turn out to be correct.

A properly functioning market should deliver a price that reflects the laws of supply and demand. As the availability of concentrate increases and the market moves to over supply so the base TC should increase, and as concentrate stocks fall and the market moves to deficit so the TC should fall. The charts below show the more general relationship between the base TC, the annual concentrate stock change and overall stocks, and display a reasonable, but not exact, correlation between the direction of overall stocks and the base TC. The correlation between the direction of stocks and the realised TC can also be seen in the charts that follow.

6. GLOSSARY

Annex XIV	Chemicals requiring authorisation under REACH
AoA	Analysis of Alternatives
bw	Body weight
CSR	Chemicals Safety Report
Cu	Copper
ECHA	European Chemicals Agency
EEA	European Economic Area
ES	Exposure Scenario
EUSES	European Union System for the Evaluation of Substances
IRR	Internal rate of return
LBMA	London Bullion Market Association
LME	London Metal Exchange
NOEAL	No observed adverse effect level
NPV	Net present value
OC	Operating conditions
Pb	Lead
PROC	Process categories
RC	Refining charge
REACH	Registration, evaluation, authorisation (and restriction) of chemicals
SEA	Socio-economic Analysis
SVHC	Substances of Very High Concern
TC	Treatment charge
WTP	Willingness To Pay

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